FLUENT 6.3 UDF Manual

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Contents

About This Document

User-defined functions (UDFs) allow you to customize FLUENT and can significantly enhance its capabilities. This UDF Manual presents detailed information on how to write, compile, and use UDFs in FLUENT. Examples have also been included, where available. General information about C programming basics is included in an appendix.

Information in this manual is presented in the following chapters:

This document provides some basic information about the C programming language (Appendix A) as it relates to user-defined functions in FLUENT, and assumes that you are an experienced programmer in C. If you are unfamiliar with C, please consult a C language reference guide (e.g., [2, 3]) before you begin the process of writing UDFs and using them in your FLUENT model.

This document does not imply responsibility on the part of Fluent Inc. for the accuracy or stability of solutions obtained using UDFs that are either user-generated or provided by Fluent Inc. Support for current license holders will be limited to guidance related to communication between a UDF and the FLUENT solver. Other aspects of the UDF development process that include conceptual function design, implementation (writing C code), compilation and debugging of C source code, execution of the UDF, and function design verification will remain the responsibility of the UDF author.

UDF compiled libraries are specific to the computer architecture being used and the version of the FLUENT executable being run and must be rebuilt any time FLUENT is upgraded, your operating system changes, or the job is run on a different type of computer. Note that UDFs may need to be updated with new versions of FLUENT.

Chapter 1. Overview

This chapter contains an overview of user-defined functions (UDFs) and their usage in FLUENT. Details about UDF functionality are described in the following sections:

- Section 1.1: What is a User-Defined Function (UDF)?
- Section 1.2: Why Use UDFs?
- Section 1.3: Limitations
- Section 1.4: Defining Your UDF Using `DEFINE` Macros
- Section 1.5: Interpreting and Compiling UDFs
- Section 1.6: Hooking UDFs to Your FLUENT Model
- Section 1.7: Grid Terminology
- Section 1.8: Data Types in FLUENT
- Section 1.9: UDF Calling Sequence in the Solution Process
- Section 1.10: Special Considerations for Multiphase UDFs

1.1 What is a User-Defined Function (UDF)?

A user-defined function, or UDF, is a function that you program that can be dynamically loaded with the FLUENT solver to enhance the standard features of the code. For example, you can use a UDF to define your own boundary conditions, material properties, and source terms for your flow regime, as well as specify customized model parameters (e.g., DPM, multiphase models), initialize a solution, or enhance post-processing. See Section 1.2: Why Use UDFs? for more examples.

UDFs are written in the C programming language using any text editor and the source code file is saved with a `.c` extension (e.g., `myudf.c`). One source file can contain a single UDF or multiple UDFs, and you can define multiple source files. See Appendix A for some basic information on C programming.

UDFs are defined using DEFINE macros provided by Fluent Inc (see Chapter 2: DEFINE Macros). They are coded using additional macros and functions also supplied by Fluent Inc. that acccess FLUENT solver data and perform other tasks. See Chapter 3: Additional Macros for Writing UDFs for details.

Every UDF must contain the udf.h file inclusion directive (#include "udf.h") at the beginning of the source code file, which allows definitions of DEFINE macros and other Fluent-provided macros and functions to be included during the compilation process. See Section 1.4.1: Including the udf.h Header File in Your Source File for details. Note that values that are passed to a solver by a UDF or returned by the solver to a UDF are specified in SI units.

Source files containing UDFs can be either interpreted or compiled in FLUENT. For interpreted UDFs, source files are interpreted and loaded directly at *runtime*, in a single-step process. For compiled UDFs, the process involves two separate steps. A shared object code library is first built and then it is loaded into FLUENT. See Chapter 4: Interpreting UDFs and Chapter 5: Compiling UDFs. Once interpreted or compiled, UDFs will become visible and selectable in FLUENT graphics panels, and can be hooked to a solver by choosing the function name in the appropriate panel. This process is described in Chapter 6: Hooking UDFs to FLUENT.

In summary, UDFs:

- are written in the C programming language. (Appendix A)
- must have an include statement for the udf.h file. (Section 1.4.1: Including the udf.h Header File in Your Source File)
- must be defined using DEFINE macros supplied by Fluent Inc. (Chapter 2: DEFINE Macros)
- utilize predfined macros and functions supplied by Fluent Inc. to acccess FLUENT solver data and perform other tasks. (Chapter 3: Additional Macros for Writing UDFs)
- are executed as interpreted or compiled functions. (Chapter 4: Interpreting UDFs and Chapter 5: Compiling UDFs)
- are hooked to a FLUENT solver using a graphical user interface panel. (Chapter 6: Hooking UDFs to FLUENT)
- use and return values specified in SI units.

1.2 Why Use UDFs?

UDFs allow you to customize FLUENT to fit your particular modeling needs. UDFs can be used for a variety of applications, some examples of which are listed below.

- Customization of boundary conditions, material property definitions, surface and volume reaction rates, source terms in FLUENT transport equations, source terms in user-defined scalar (UDS) transport equations, diffusivity functions, etc.
- Adjustment of computed values on a once-per-iteration basis.
- Initialization of a solution.
- Asynchronous (on demand) execution of a UDF
- Execution at the end of an iteration, upon exit from FLUENT, or upon loading of a compiled UDF library.
- Post-processing enhancement.
- Enhancement of existing FLUENT models (e.g., discrete phase model, multiphase mixture model, discrete ordinates radiation model).

Simple examples of UDFs that demonstrate usage are provided with most DEFINE macro descriptions in Chapter 2: DEFINE Macros). In addition, a step-by-step example (mini-tutorial) and detailed examples can be found in Chapter 8: Examples.

1.3 Limitations

Although the UDF capability in FLUENT can address a wide range of applications, it is not possible to address every application using UDFs. Not all solution variables or FLUENT models can be accessed by UDFs. Specific heat values, for example, cannot be modified; this would require additional solver capabilities. If you are unsure whether a particular problem can be handled using a UDF, you can contact your technical support engineer for assistance.

> i Note that you may need to update your UDF when using a new version of FLUENT.

1.4 Defining Your UDF Using `DEFINE` Macros

UDFs are defined using Fluent-supplied function declarations. These function declarations are implemented in the code as macros, and are referred to in this document as `DEFINE` (all capitals) macros. Definitions for `DEFINE` macros are contained in the `udf.h` header file (see Appendix B for a listing). For a complete description of each `DEFINE` macro and an example of its usage, refer to Chapter 2: `DEFINE` Macros.

The general format of a `DEFINE` macro is

```
DEFINE_MACRONAME(udf_name, passed-in variables)
```

where the first argument in the parentheses is the name of the UDF that you supply. Name arguments are case-sensitive and *must* be specified in lowercase. The name that you choose for your UDF will become visible and selectable in drop-down lists in graphical user-interface panels in FLUENT, once the function has been interpreted or compiled. The second set of input arguments to the `DEFINE` macro are variables that are passed into your function from the FLUENT solver.

For example, the macro

```
DEFINE_PROFILE(inlet_x_velocity, thread, index)
```

defines a boundary profile function named `inlet_x_velocity` with two variables, `thread` and `index`, that are passed into the function from FLUENT. These passed-in variables are the boundary condition zone ID (as a pointer to the `thread`) and the `index` identifying the variable that is to be stored. Once the UDF has been interpreted or compiled, its name (e.g., `inlet_x_velocity`) will become visible and selectable in drop-down lists in the appropriate boundary condition panel (e.g., Velocity Inlet) in FLUENT.

> *i* Note that all of the arguments to a `DEFINE` macro need to be placed on the same line in your source code. Splitting the `DEFINE` statement onto several lines will result in a compilation error.

> *i* Do not include a `DEFINE` macro statement (e.g., `DEFINE_PROFILE`) within a comment in your source code. This will cause a compilation error.

1.4.1 Including the udf.h Header File in Your Source File

The udf.h header file contains definitions for DEFINE macros as well as #include compiler directives for C library function header files. It also includes header files (e.g., mem.h) for other Fluent-supplied macros and functions. You must, therefore, include the udf.h file at the beginning of *every* UDF source code file using the #include compiler directive:

```
#include "udf.h"
```

For example, when udf.h is included in the source file containing the DEFINE statement from the previous section,

```
#include "udf.h"

DEFINE_PROFILE(inlet_x_velocity, thread, index)
```

upon compilation, the macro will expand to

```
void inlet_x_velocity(Thread *thread, int index)
```

i You won't need to put a copy of udf.h in your local directory when you compile your UDF. The FLUENT solver automatically reads the udf.h file from the Fluent.Inc/ fluent6.x/src/ directory once your UDF is compiled.

1.5 Interpreting and Compiling UDFs

Source code files containing UDFs can be either interpreted or compiled in FLUENT. In both cases the functions are compiled, but the way in which the source code is compiled, and the code that results from the compilation process is different for the two methods. These differences are explained below.

Compiled UDFs

Compiled UDFs are built in the same way that the FLUENT executable itself is built. A script called `Makefile` is used to invoke the system C compiler to build an object code library. You initiate this action in the Compiled UDFs panel by clicking on the Build pushbutton. The object code library contains the native machine language translation of your higher-level C source code. The shared library must then loaded into FLUENT at runtime by a process called "dynamic loading." You initiate this action in the Compiled UDFs panel by clicking on the Load pushbutton. The object libraries are specific to the computer architecture being used, as well as to the particular version of the FLUENT executable being run. The libraries must, therefore, be rebuilt any time FLUENT is upgraded, when the computer's operating system level changes, or when the job is run on a different type of computer.

In summary, compiled UDFs are compiled from source files using the graphical user interface, in a two-step process. The process involves a visit to the Compiled UDFs panel where you first Build shared library object file(s) from a source file, and then Load the shared library that was just built into FLUENT.

Interpreted UDFs

Interpreted UDFs are interpreted from source files using the graphical user interface, but in a single-step process. The process, which occurs at *runtime*, involves a visit to the Interpreted UDFs panel where you Interpret a source file.

Inside FLUENT, the source code is compiled into an intermediate, architecture-independent machine code using a C preprocessor. This machine code then executes on an internal emulator, or interpreter, when the UDF is invoked. This extra layer of code incurs a performance penalty, but allows an interpreted UDF to be shared effortlessly between different architectures, operating systems, and FLUENT versions. If execution speed does become an issue, an interpreted UDF can always be run in compiled mode without modification.

The interpreter that is used for interpreted UDFs does not have all of the capabilities of a standard C compiler (which is used for compiled UDFs). Specifically interpreted UDFs *cannot* contain any of the following C programming language elements:

- goto statements
- non ANSI-C prototypes for syntax
- direct data structure references
- declarations of local structures
- unions
- pointers to functions
- arrays of functions
- multi-dimensional arrays

1.5.1 Differences Between Interpreted and Compiled UDFs

The major difference between interpreted and compiled UDFs is that interpreted UDFs cannot access FLUENT solver data using direct structure references; they can only indirectly access data through the use of Fluent-supplied macros. This can be significant if, for example, you want to introduce new data structures in your UDF.

A summary of the differences between interpreted and compiled UDFs is presented below. See Chapters 4 and 5 for details on interpreting and compiling UDFs, respectively, in FLUENT.

- Interpreted UDFs
  - are portable to other platforms.
  - can all be run as compiled UDFs.
  - do not require a C compiler.
  - are slower than compiled UDFs.
  - are restricted in the use of the C programming language.
  - cannot be linked to compiled system or user libraries.
  - can access data stored in a FLUENT structure *only* using a predefined macro (see Chapters 3).

- Compiled UDFs
  - execute faster than interpreted UDFs.
  - are *not* restricted in the use of the C programming language.
  - can call functions written in other languages (specifics are system- and compiler-dependent).
  - cannot necessarily be run as interpreted UDFs if they contain certain elements of the C language that the interpreter cannot handle.

In summary, when deciding which type of UDF to use for your FLUENT model

- use interpreted UDFs for small, straightforward functions.
- use compiled UDFs for complex functions that
  - have a significant CPU requirement (e.g., a property UDF that is called on a per-cell basis every iteration).
  - require access to a shared library.

1.6 Hooking UDFs to Your FLUENT Model

Once your UDF source file is interpreted or compiled, the function(s) contained in the interpreted code or shared library will appear in drop-down lists in graphical interface panels, ready for you to activate or "hook" to your CFD model. See Chapter 6: Hooking UDFs to FLUENT for details on how to hook a UDF to FLUENT.

1.7 Grid Terminology

Most user-defined functions access data from a FLUENT solver. Since solver data is defined in terms of grid components, you will need to learn some basic grid terminology before you can write a UDF.

A mesh is broken up into control volumes, or cells. Each cell is defined by a set of grid points (or nodes), a cell center, and the faces that bound the cell (Figure 1.7.1). FLUENT uses internal data structures to define the domain(s) of the mesh, to assign an order to cells, cell faces, and grid points in a mesh, and to establish connectivity between adjacent cells.

A thread is a data structure in FLUENT that is used to store information about a boundary or cell zone. Cell threads are groupings of cells, and face threads are groupings of faces. Pointers to thread data structures are often passed to functions and manipulated in FLUENT to access the information about the boundary or cell zones represented by each thread. Each boundary or cell zone that you define in your FLUENT model in a boundary conditions panel has an integer Zone ID that is associated with the data contained within the zone. You won't see the term "thread" in a graphics panel in FLUENT so you can think of a 'zone' as being the same as a 'thread' data structure when programming UDFs.

Cells and cell faces are grouped into zones that typically define the physical components of the model (e.g., inlets, outlets, walls, fluid regions). A face will bound either one or two cells depending on whether it is a boundary face or an interior face. A domain is a data structure in FLUENT that is used to store information about a collection of node, face threads, and cell threads in a mesh.

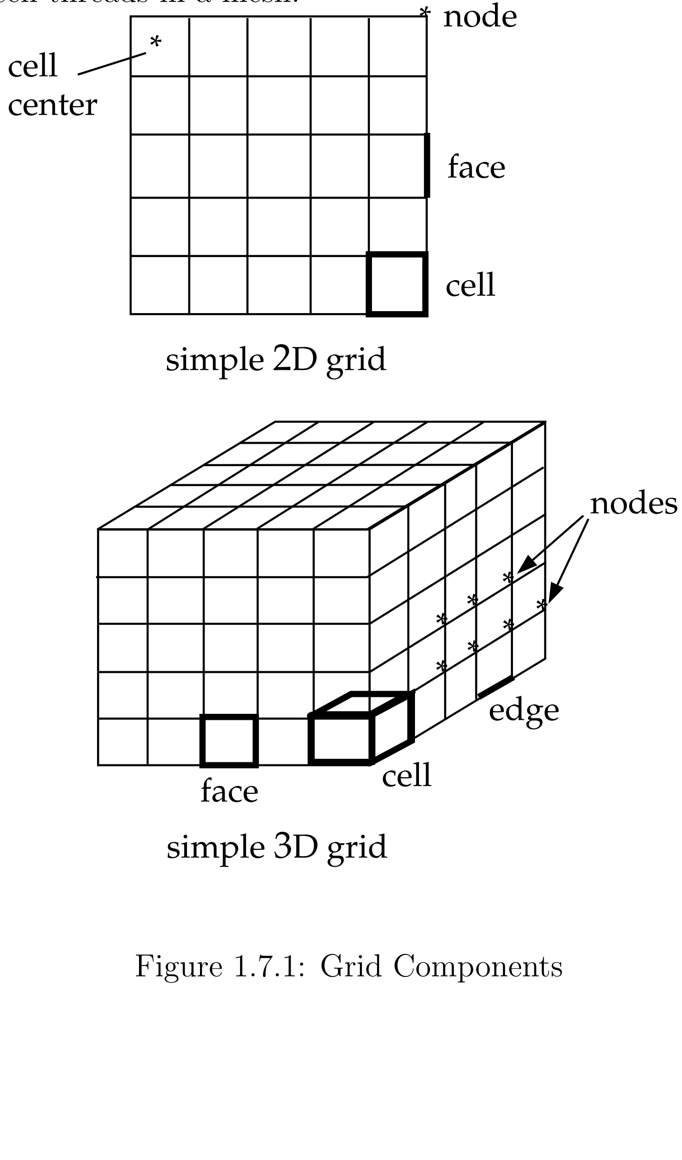


Figure 1.7.1: Grid Components

node	grid point
node thread	grouping of nodes
edge	boundary of a face (3D)
face	boundary of a cell (2D or 3D)
face thread	grouping of faces
cell	control volume into which domain is broken up
cell center	location where cell data is stored
cell thread	grouping of cells
domain	a grouping of node, face, and cell threads

1.8 Data Types in FLUENT

In addition to standard C language data types such as `real`, `int`, etc. that can be used to define data in your UDF, there are FLUENT-specific data types that are associated with solver data. These data types represent the computational units for a grid (Figure 1.7.1). Variables that are defined using these data types are typically supplied as arguments to `DEFINE` macros as well as to other special functions that access FLUENT solver data.

Some of the more commonly-used FLUENT data types are:

```
Node
face_t
cell_t
Thread
Domain
```

`Node` is a structure data type that stores data associated with a grid point.

`face_t` is an integer data type that identifies a particular face within a face thread.

`cell_t` is an integer data type that identifies a particular cell within a cell thread.

`Thread` is a structure data type that stores data that is common to the group of cells or faces that it represents. For multiphase applications, there is a thread structure for each phase, as well as for the mixture. See Section 1.10.1: Multiphase-specific Data Types for details.

`Domain` is a structure data type that stores data associated with a collection of node, face, and cell threads in a mesh. For single-phase applications, there is only a single domain structure. For multiphase applications, there are domain structures for each phase, the interaction between phases, as well as for the mixture. The mixture-level domain is the highest-level structure for a multiphase model. See Section 1.10.1: Multiphase-specific Data Types for details.

> ℹ Note that all of the FLUENT data types are case-sensitive.

When you use a UDF in FLUENT, your function can access solution variables at individual cells or cell faces in the fluid and boundary zones. UDFs need to be passed appropriate arguments such as a thread reference (i.e., pointer to a particular thread) and the cell or face ID in order to allow individual cells or faces to be accessed. Note that a face ID or cell ID, alone, does not uniquely identify the face or cell. A thread pointer is always required along with the ID to identify which thread the face (or cell) belongs to.

Some UDFs are passed the cell index variable (c) as an argument such as in DEFINE_PROPERTY(my_function,c,t), or the face index variable (f) such as in DEFINE_UDS_FLUX(my_function,f,t,i). If the cell or face index variable(e.g., cell_t c, cell_t f) isn't passed as an argument and is needed in the UDF, the variable is always available to be used by the function once it has been declared locally. See Section 2.7.3: DEFINE_UDS_FLUX for an example.

The data structures that are passed to your UDF (as pointers) depend on the DEFINE macro you are using and the property or term you are trying to modify. For example, DEFINE_ADJUST UDFs are general-purpose functions that are passed a domain pointer (d) such as in DEFINE_ADJUST(my_function, d). DEFINE_PROFILE UDFs are passed a thread pointer (t) to the boundary zone that the function is hooked to, such as in DEFINE_PROFILE(my_function, thread, i).

Some UDFs, such as DEFINE_ON_DEMAND functions, aren't passed any pointers to data structures while others aren't passed the pointer the UDF needs. If your UDF needs to access a thread or domain pointer that is not *directly* passed by the solver through an argument, then you will need to use a special Fluent-supplied macro to obtain the pointer in your UDF. For example, DEFINE_ADJUST is passed only the domain pointer so if your UDF needs a thread pointer, it will have to declare the variable locally and then obtain it using the special macro Lookup_Thread. An exception to this is if your UDF needs a thread pointer to loop over all of the cell threads or all the face threads in a domain (using thread_c_loop(c,t) or thread_f_loop(f,t), respectively) and the DEFINE macro isn't passed it. Since the UDF will be looping over all threads in the domain, you won't need to use Lookup_Thread to get the thread pointer to pass it to the looping macro; you'll just need to declare the thread pointer (and cell or face ID) locally before calling the loop. See Section 2.2.1: DEFINE_ADJUST for an example.

As another example, if you are using DEFINE_ON_DEMAND (which isn't passed any pointer argument) to execute an asynchronous UDF and your UDF needs a domain pointer, then the function will need to declare the domain variable locally and obtain it using Get_Domain. See Section 2.2.8: DEFINE_ON_DEMAND for an example. Refer to Section 3.2.6: Special Macros for details.

1.9 UDF Calling Sequence in the Solution Process

UDFs are called at predetermined times in the FLUENT solution process. However, they can also be executed asynchronously (or "on demand") using a DEFINE_ON_DEMAND UDF. If a DEFINE_EXECUTE_AT_END UDF is utilized, then FLUENT calls the function at the end of an iteration. A DEFINE_EXECUTE_AT_EXIT is called at the end of a FLUENT session while a DEFINE_EXECUTE_ON_LOADING is called whenever a UDF compiled library is loaded. Understanding the context in which UDFs are called within FLUENT's solution process may be important when you begin the process of writing UDF code, depending on the type of UDF you are writing. The solver contains call-outs that are linked to user-defined functions that you write. Knowing the sequencing of function calls within an iteration in the FLUENT solution process can help you determine which data are current and available at any given time.

Pressure-Based Segregated Solver

The solution process for the pressure-based segregated solver (Figure 1.9.1) begins with a two-step initialization sequence that is executed outside the solution iteration loop. This sequence begins by initializing equations to user-entered (or default) values taken from the FLUENT user interface. Next, PROFILE UDFs are called followed by a call to INIT UDFs. Initialization UDFs overwrite initialization values that were previously set.

The solution iteration loop begins with the execution of ADJUST UDFs. Next, momentum equations for u, v, and w velocities are solved sequentially, followed by mass continuity and velocity updates. Subsequently, the energy and species equations are solved followed by turbulence and other scalar transport equations, as required. Note that PROFILE and SOURCE UDFs are called by each "Solve" routine for the variable currently under consideration (e.g., species, velocity).

After the conservation equations, properties are updated including PROPERTY UDFs. Thus, if your model involves the gas law, for example, the density will be updated at this time using the updated temperature (and pressure and/or species mass fractions). A check for either convergence or additional requested iterations is done, and the loop either continues or stops.

Pressure-Based Coupled Solver

The solution process for the pressure-based coupled solver (Figure 1.9.2) begins with a two-step initialization sequence that is executed outside the solution iteration loop. This sequence begins by initializing equations to user-entered (or default) values taken from the FLUENT user interface. Next, PROFILE UDFs are called followed by a call to INIT UDFs. Initialization UDFs overwrite initialization values that were previously set.

The solution iteration loop begins with the execution of ADJUST UDFs. Next, FLUENT solves the governing equations of continuity and momentum in a coupled fashion, which is simultaneously as a set, or vector, of equations. Energy, species tranpsort, turbulence, and other transport equations as required are subsequently solved sequentially, and the remaining process is the same as the pressure-based segregated solver.

Density-Based Solver

As is the case for the other solvers, the solution process for the density-based solver (Figure 1.9.3) begins with a two-step initialization sequence that is executed outside the solution iteration loop. This sequence begins by initializing equations to user-entered (or default) values taken from the FLUENT user interface. Next, PROFILE UDFs are called followed by a call to INIT UDFs. Initialization UDFs overwrite initialization values that were previously set.

The solution iteration loop begins with the execution of ADJUST UDFs. Next, FLUENT solves the governing equations of continuity and momentum, energy, and species transport in a coupled fashion, which is simultaneously as a set, or vector, of equations. Turbulence and other transport equations as required are subsequently solved sequentially, and the remaining process is the same as the pressure-based segregated solver.

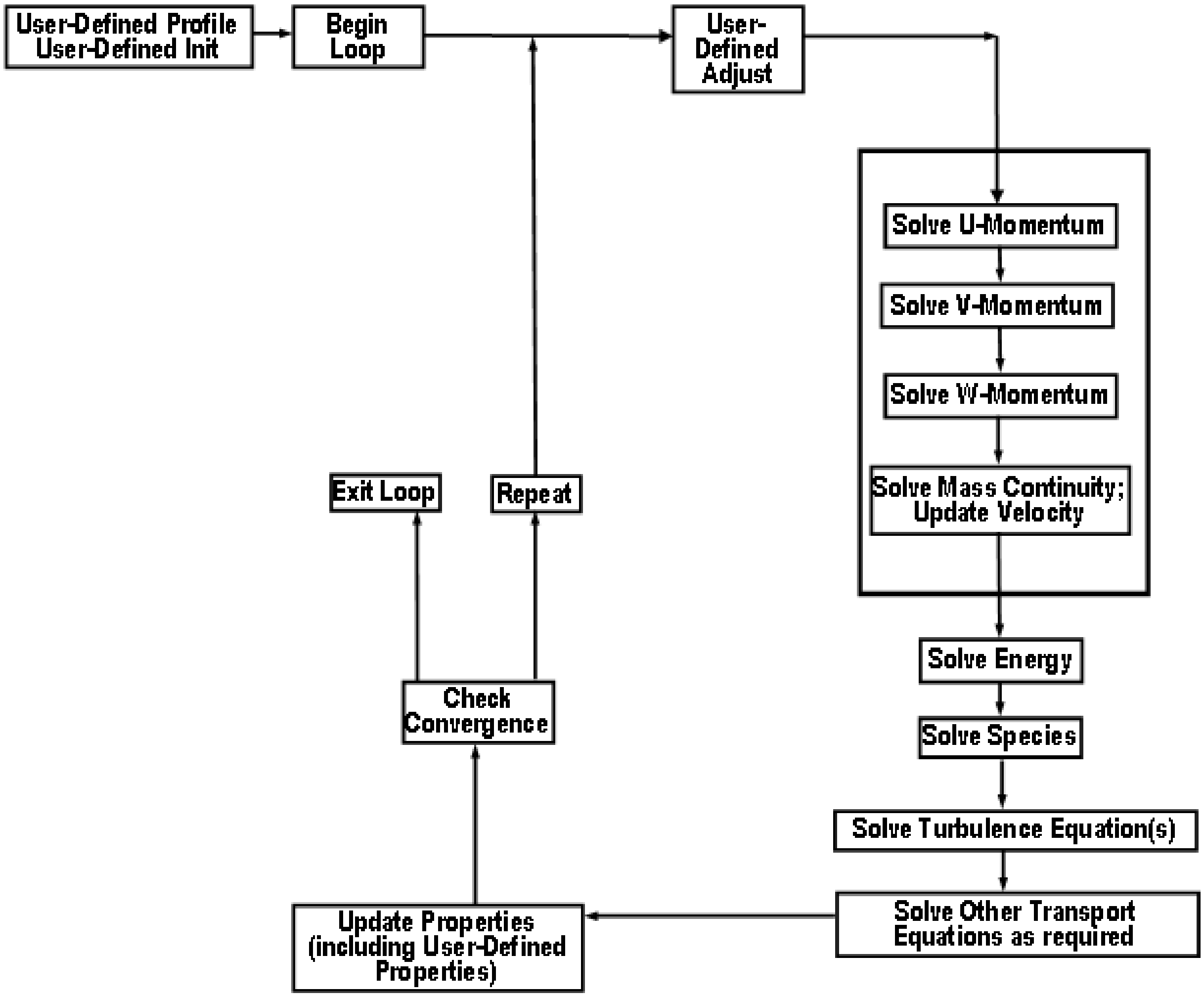


Figure 1.9.1: Solution Procedure for the Pressure-Based Segregated Solver

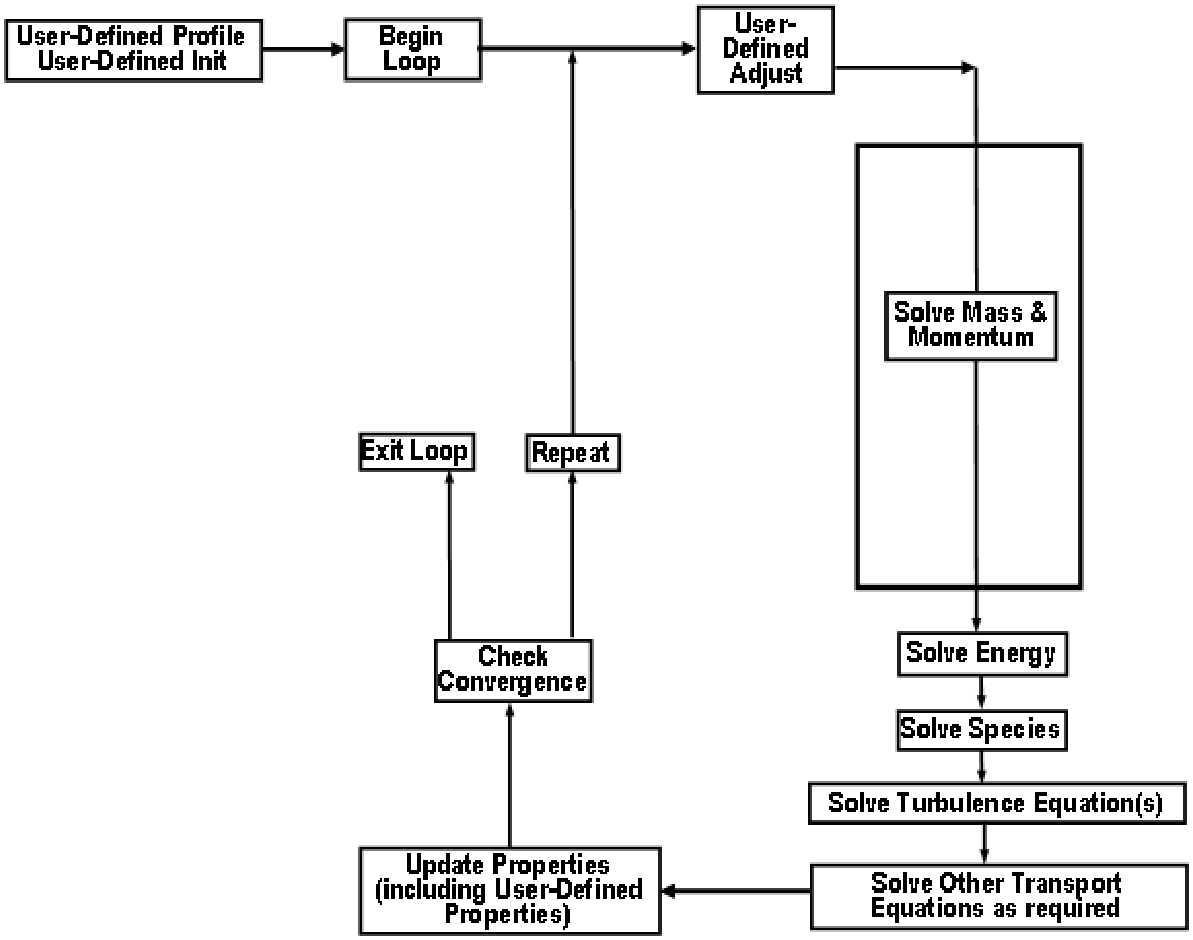


Figure 1.9.2: Solution Procedure for the Pressure-Based Coupled Solver

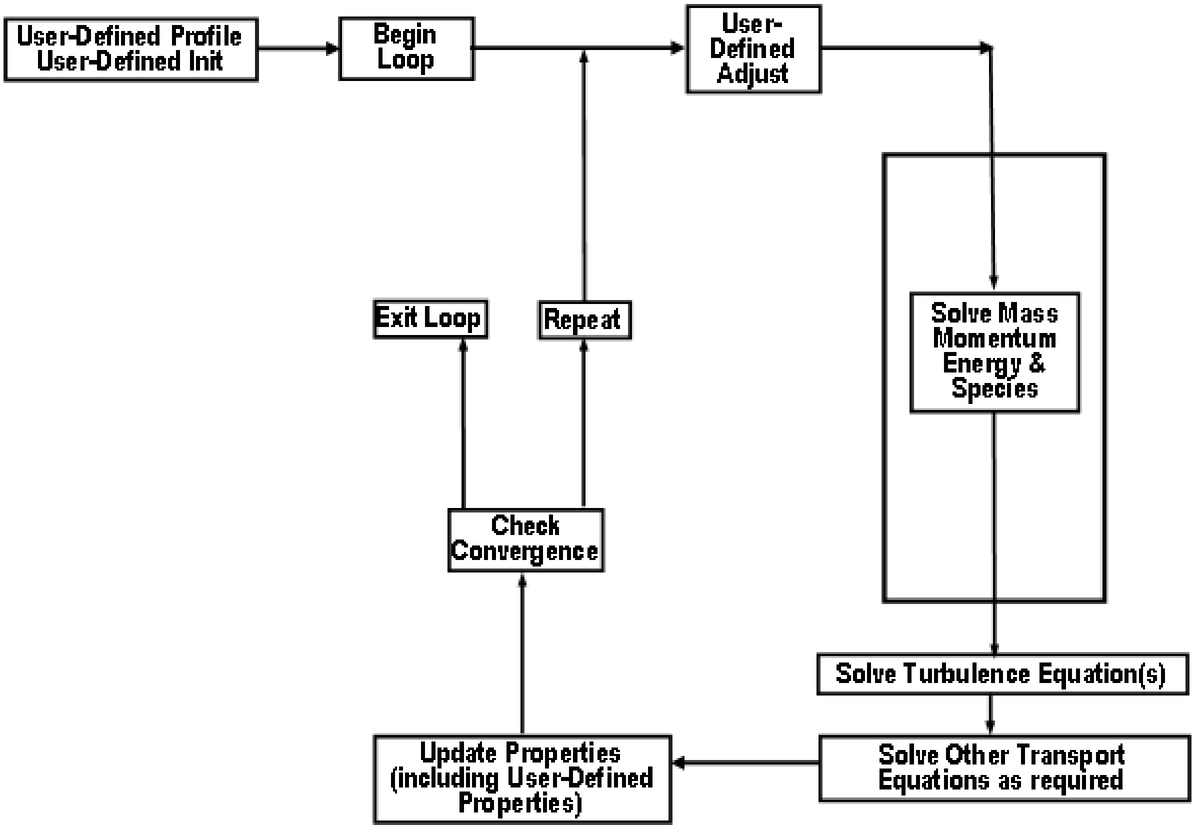

User-Defined Profile
User-Defined Init
Begin Loop
User-Defined Adjust
Solve Mass Momentum Energy & Species
Solve Turbulence Equation(s)
Solve Other Transport Equations as required
Update Properties (including User-Defined Properties)
Check Convergence
Exit Loop
Repeat

Figure 1.9.3: Solution Procedure for the Density-Based Solver

1.10 Special Considerations for Multiphase UDFs

In many cases, the UDF source code that you will write for a single-phase flow will be the same as for a multiphase flow. For example, there will be no differences between the C code for a single-phase boundary profile (defined using DEFINE_PROFILE) and the code for a multiphase profile, assuming that the function is accessing data *only* from the phase-level domain that it is hooked to in the graphical user interface. If your UDF is *not* explicitly passed a pointer to the thread or domain structure that it requires, you will need to use a special multiphase-specific macro (e.g., THREAD_SUB_THREAD) to retrieve it. This is discussed in Chapter 3: Additional Macros for Writing UDFs.

See Appendix B for a complete list of general-purpose DEFINE macros and multiphase-specific DEFINE macros that can be used to define UDFs for multiphase model cases.

1.10.1 Multiphase-specific Data Types

In addition to the FLUENT-specific data types presented in Section 1.8: Data Types in FLUENT, there are special thread and domain data structures that are specific to multiphase UDFs. These data types are used to store properties and variables for the mixture of all of the phases, as well as for each individual phase when a multiphase model (i.e., Mixture, VOF, Eulerian) is used.

In a multiphase application, the top-level domain is referred to as the 'superdomain'. Each phase occupies a domain referred to as a 'subdomain'. A third domain type, the 'interaction' domain, is introduced to allow for the definition of phase interaction mechanisms. When mixture properties and variables are needed (a sum over phases), the superdomain is used for those quantities while the subdomain carries the information for individual phases. In single-phase, the concept of a mixture is used to represent the sum over all the species (components) while in multiphase it represents the sum over all the phases. This distinction is important since FLUENT has the capability of handling multiphase multi-components, where, for example, a phase can consist of a mixture of species.

Since solver information is stored in thread data structures, threads must be associated with the superdomain as well as with each of the subdomains. In other words, for each cell or face thread defined in the superdomain, there is a corresponding cell or face thread defined for each subdomain. Some of the information defined in one thread of the superdomain is shared with the corresponding threads of each of the subdomains. Threads associated with the superdomain are referred to as 'superthreads', while threads associated with the subdomain are referred to as phase-level threads, or 'subthreads'. The domain and thread hierarchy are summarized in Figure 1.10.1.

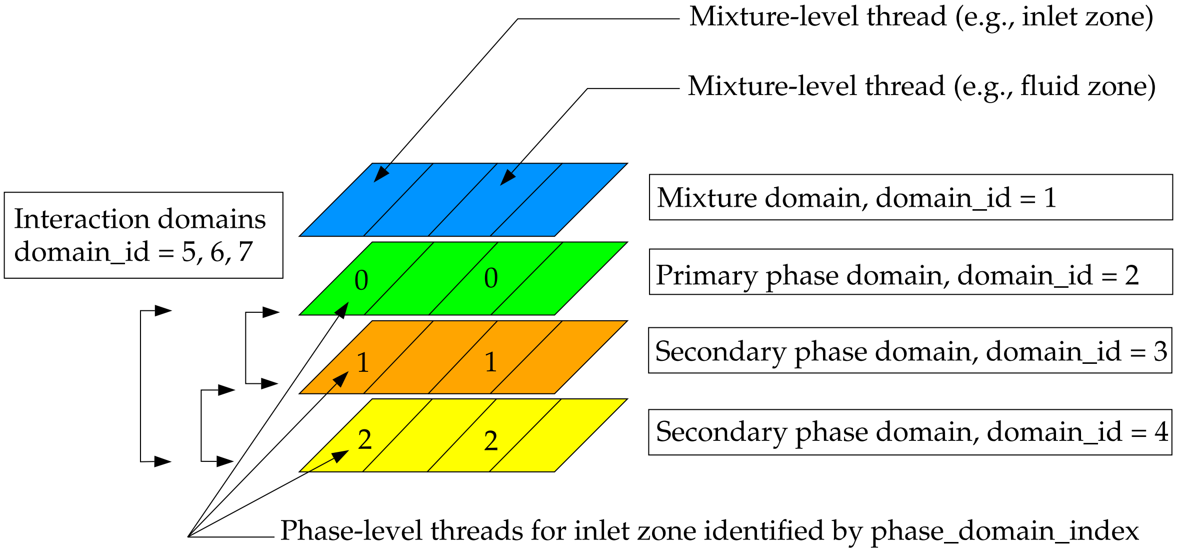

Mixture-level thread (e.g., inlet zone)
Mixture-level thread (e.g., fluid zone)
Interaction domains
domain_id = 5, 6, 7
Mixture domain, domain_id = 1
Primary phase domain, domain_id = 2
Secondary phase domain, domain_id = 3
Secondary phase domain, domain_id = 4
0
0
1
1
2
2
Phase-level threads for inlet zone identified by phase_domain_index

Figure 1.10.1: Domain and Thread Structure Hierarchy

Figure 1.10.1 introduces the concept of the `domain_id` and `phase_domain_index`. The `domain_id` can be used in UDFs to distinguish the superdomain from the primary and secondary phase-level domains. The superdomain (mixture domain) `domain_id` is always assigned the value of 1. Interaction domains are also identified with the `domain_id`. The `domain_id`s are not necessarily ordered sequentially as shown in Figure 1.10.1.

The `phase_domain_index` can be used in UDFs to distinguish between the primary and secondary phase-level threads. `phase_domain_index` is always assigned the value of 0 for the primary phase-level thread.

The data structures that are passed to a UDF depend on the multiphase model that is enabled, the property or term that is being modified, the `DEFINE` macro that is used, and the domain that is to be affected (mixture or phase). To better understand this, consider the differences between the Mixture and Eulerian multiphase models. In the Mixture model, a single momentum equation is solved for a mixture whose properties are determined from the sum of its phases. In the Eulerian model, a momentum equation is solved for each phase. FLUENT allows you to directly specify a momentum source for the mixture of phases (using `DEFINE_SOURCE`) when the mixture model is used, but not for the Eulerian model. For the latter case, you can specify momentum sources for the individual phases. Hence, the multiphase model, as well as the term being modified by the UDF, determines which domain or thread is required.

UDFs that are hooked to the mixture of phases are passed superdomain (or mixture-level) structures, while functions that are hooked to a particular phase are passed subdomain (or phase-level) structures. `DEFINE_ADJUST` and `DEFINE_INIT` UDFs are hardwired to the mixture-level domain. Other types of UDFs are hooked to different phase domains. For your convenience, Appendix B contains a list of multiphase models in FLUENT and the phase on which UDFs are specified for the given variables. From this information, you can infer which domain structure is passed from the solver to the UDF.

Chapter 2. DEFINE Macros

This chapter contains descriptions of predefined `DEFINE` macros that you will use to define your UDF.

The chapter is organized in the following sections:

2.1 Introduction

`DEFINE` macros are predefined macros provided by Fluent Inc. that must be used to define your UDF. A listing and discussion of each `DEFINE` macros is presented below. (Refer to Section 1.4: Defining Your UDF Using `DEFINE` Macros for general information about `DEFINE` macros.) Definitions for `DEFINE` macros are contained within the `udf.h` file. For your convenience, they are provided in Appendix B.

For each of the `DEFINE` macros listed in this chapter, a source code example of a UDF that utilizes it is provided, where available. Many of the examples make extensive use of other macros presented in Chapter 3: Additional Macros for Writing UDFs. Note that not all of the examples in the chapter are complete functions that can be executed as stand-alone UDFs in `FLUENT`. Examples are intended to demonstrate `DEFINE` macro usage only.

Special care must be taken for some serial UDFs that will be run in parallel `FLUENT`. See Chapter 7: Parallel Considerations for details.

i Note that all of the arguments to a `DEFINE` macro need to be placed on the same line in your source code. Splitting the `DEFINE` statement onto several lines will result in a compilation error.

2.2 General Purpose DEFINE Macros

The DEFINE macros presented in this section implement general solver functions that are independent of the model(s) you are using in FLUENT. Table 2.2.1 provides a quick reference guide to these DEFINE macros, the functions they are used to define, and the panels where they are activated or "hooked" to FLUENT. Definitions of each DEFINE macro are contained in udf.h can be found in Appendix B.

- Section 2.2.1: DEFINE_ADJUST
- Section 2.2.2: DEFINE_DELTAT
- Section 2.2.3: DEFINE_EXECUTE_AT_END
- Section 2.2.4: DEFINE_EXECUTE_AT_EXIT
- Section 2.2.5: DEFINE_EXECUTE_FROM_GUI
- Section 2.2.6: DEFINE_EXECUTE_ON_LOADING
- Section 2.2.7: DEFINE_INIT
- Section 2.2.8: DEFINE_ON_DEMAND
- Section 2.2.9: DEFINE_RW_FILE

Table 2.2.1: Quick Reference Guide for General Purpose DEFINE Macros

Function	DEFINE Macro	Panel Activated In
manipulates variables	DEFINE_ADJUST	User-Defined Function Hooks
time step size (for time dependent solutions)	DEFINE_DELTAT	Iterate
executes at end of iteration	DEFINE_EXECUTE_AT_END	User-Defined Function Hooks
executes at end of a FLUENT session	DEFINE_EXECUTE_AT_EXIT	N/A
executes from a user-defined Scheme routine	DEFINE_EXECUTE_FROM_GUI	N/A
executes when a UDF library is loaded	DEFINE_EXECUTE_ON_LOADING	N/A
initializes variables	DEFINE_INIT	User-Defined Function Hooks
executes asynchronously	DEFINE_ON_DEMAND	Execute On Demand
reads/writes variables to case and data files	DEFINE_RW_FILE	User-Defined Function Hooks

2.2.1 DEFINE_ADJUST

Description

DEFINE_ADJUST is a general-purpose macro that can be used to adjust or modify FLUENT variables that are *not* passed as arguments. For example, you can use DEFINE_ADJUST to modify flow variables (e.g., velocities, pressure) and compute integrals. You can also use it to integrate a scalar quantity over a domain and adjust a boundary condition based on the result. A function that is defined using DEFINE_ADJUST executes at every iteration and is called at the beginning of every iteration before transport equations are solved. For an overview of the FLUENT solution process which shows when a DEFINE_ADJUST UDF is called, refer to Figures 1.9.1, 1.9.2, and 1.9.3.

Usage

```
DEFINE_ADJUST(name,d)
```

Argument Type	**Description**
`symbol name`	UDF name.
`Domain *d`	Pointer to the domain over which the adjust function is to be applied. The domain argument provides access to all cell and face threads in the mesh. For multiphase flows, the pointer that is passed to the function by the solver is the mixture-level domain.

Function returns
`void`

There are two arguments to DEFINE_ADJUST: `name` and `d`. You supply `name`, the name of the UDF. `d` is passed by the FLUENT solver to your UDF.

Example 1

The following UDF, named my_adjust, integrates the turbulent dissipation over the entire domain using DEFINE_ADJUST. This value is then printed to the console window. The UDF is called once every iteration. It can be executed as an interpreted or compiled UDF in FLUENT.

```
/********************************************************************
   UDF for integrating turbulent dissipation and printing it to
   console window
*********************************************************************/

#include "udf.h"

DEFINE_ADJUST(my_adjust,d)
{
  Thread *t;
  /* Integrate dissipation. */
  real sum_diss=0.;
  cell_t c;

  thread_loop_c(t,d)
  {
   begin_c_loop(c,t)
       sum_diss += C_D(c,t)*
       C_VOLUME(c,t);
   end_c_loop(c,t)
  }

  printf("Volume integral of turbulent dissipation: %g\n", sum_diss);
}
```

Example 2

The following UDF, named adjust_fcn, specifies a user-defined scalar as a function of the gradient of another user-defined scalar, using DEFINE_ADJUST. The function is called once every iteration. It is executed as a compiled UDF in FLUENT.

```
/********************************************************************
   UDF for defining user-defined scalars and their gradients
 ********************************************************************/

#include "udf.h"

DEFINE_ADJUST(adjust_fcn,d)
{
  Thread *t;
  cell_t c;
  real K_EL = 1.0;

  /* Do nothing if gradient isn't allocated yet. */
  if (! Data_Valid_P())
    return;

  thread_loop_c(t,d)
    {
    if (FLUID_THREAD_P(t))
       {
        begin_c_loop_all(c,t)
            {
             C_UDSI(c,t,1) +=
                          K_EL*NV_MAG2(C_UDSI_G(c,t,0))*C_VOLUME(c,t);
            }
        end_c_loop_all(c,t)
       }
    }
}
```

Hooking an Adjust UDF to FLUENT

After the UDF that you have defined using DEFINE_ADJUST is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., adjust_fcn) will become visible and selectable in the User-Defined Function Hooks panel in FLUENT. Note that you can hook multiple adjust functions to your model. See Section 6.1.1: Hooking DEFINE_ADJUST UDFs for details.

2.2.2 DEFINE_DELTAT

Description

DEFINE_DELTAT is a general-purpose macro that you can use to control the size of the time step during the solution of a time-dependent problem. Note that this macro can be used only if the adaptive time-stepping method option has been activated in the Iterate panel in FLUENT.

Usage

```
DEFINE_DELTAT(name,d)
```

Argument Type	**Description**
symbol name	UDF name.
Domain *d	Pointer to domain over which the time stepping control function is to be applied. The domain argument provides access to all cell and face threads in the mesh. For multiphase flows, the pointer that is passed to the function by the solver is the mixture-level domain.

Function returns

real

There are two arguments to DEFINE_DELTAT: name and domain. You supply name, the name of the UDF. domain is passed by the FLUENT solver to your UDF. Your UDF will need to compute the real value of the physical time step and return it to the solver.

Example

The following UDF, named mydeltat, is a simple function that shows how you can use DEFINE_DELTAT to change the value of the time step in a simulation. First, CURRENT_TIME is used to get the value of the current simulation time (which is assigned to the variable flow_time). Then, for the first 0.5 seconds of the calculation, a time step of 0.1 is set. A time step of 0.2 is set for the remainder of the simulation. The time step variable is then returned to the solver. See Section 3.5: Time-Dependent Macros for details on CURRENT_TIME.

```
/*********************************************************************
   UDF that changes the time step value for a time-dependent solution
 **********************************************************************/
#include "udf.h"

DEFINE_DELTAT(mydeltat,d)
{
   real time_step;
   real flow_time = CURRENT_TIME;
   if (flow_time < 0.5)
      time_step = 0.1;
   else
      time_step = 0.2;
   return time_step;
}
```

Hooking an Adaptive Time Step UDF to FLUENT

After the UDF that you have defined using DEFINE_DELTAT is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g,. mydeltat) will become visible and selectable in the Iterate panel in FLUENT. See Section 6.1.2: Hooking DEFINE_DELTAT UDFs for details.

2.2.3 DEFINE_EXECUTE_AT_END

Description

DEFINE_EXECUTE_AT_END is a general-purpose macro that is executed at the end of an iteration in a steady state run, or at the end of a time step in a transient run. You can use DEFINE_EXECUTE_AT_END when you want to calculate flow quantities at these particular times. Note that you do not have to specify whether your execute-at-end UDF gets executed at the end of a time step or the end of an iteration. This is done automatically when you select the steady or unsteady time method in your FLUENT model.

Usage

```
DEFINE_EXECUTE_AT_END(name)
```

Argument Type	Description
symbol name	UDF name.

Function returns
void

There is only one argument to DEFINE_EXECUTE_AT_END: name. You supply name, the name of the UDF. Unlike DEFINE_ADJUST, DEFINE_EXECUTE_AT_END is not passed a domain pointer. Therefore, if your function requires access to a domain pointer, then you will need to use the utility Get_Domain(ID) to explicitly obtain it (see Section 3.2.6: Domain Pointer (Get_Domain) and the example below). If your UDF requires access to a phase domain pointer in a multiphase solution, then it will need to pass the appropriate phase ID to Get_Domain in order to obtain it.

Example

The following UDF, named execute_at_end, integrates the turbulent dissipation over the entire domain using DEFINE_EXECUTE_AT_END and prints it to the console window at the end of the current iteration or time step. It can be executed as an interpreted or compiled UDF in FLUENT.

```
/*********************************************************************
   UDF for integrating turbulent dissipation and printing it to
   console window at the end of the current iteration or time step
*********************************************************************/

#include "udf.h"

DEFINE_EXECUTE_AT_END(execute_at_end)
{

  Domain *d;
  Thread *t;
  /* Integrate dissipation. */
  real sum_diss=0.;
  cell_t c;
  d = Get_Domain(1);   /* mixture domain if multiphase */

 thread_loop_c(t,d)
    {
     if (FLUID_THREAD_P(t))
       {
        begin_c_loop(c,t)
             sum_diss += C_D(c,t) * C_VOLUME(c,t);
        end_c_loop(c,t)
       }
    }

  printf("Volume integral of turbulent dissipation: %g\n", sum_diss);
  fflush(stdout);
}
```

Hooking an Execute-at-End UDF to FLUENT

After the UDF that you have defined using DEFINE_EXECUTE_AT_END is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g. execute_at_end) will become visible and selectable in the User-Defined Function Hooks panel in FLUENT. Note that you can hook multiple end-iteration functions to your model. See Section 6.1.3: Hooking DEFINE_EXECUTE_AT_END UDFs for details.

2.2.4 DEFINE_EXECUTE_AT_EXIT

Description

DEFINE_EXECUTE_AT_EXIT is a general-purpose macro that can be used to execute a function at the end of a FLUENT session.

Usage

```
DEFINE_EXECUTE_AT_EXIT(name)
```

Argument Type	Description
symbol name	UDF name.

Function returns

void

There is only one argument to DEFINE_EXECUTE_AT_EXIT: name. You supply name, the name of the UDF.

Hooking an Execute-at-Exit UDF to FLUENT

After the UDF that you have defined using DEFINE_EXECUTE_AT_EXIT is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible and selectable in the User-Defined Function Hooks panel in FLUENT. Note that you can hook multiple at-exit UDFs to your model. See Section 6.1.4: Hooking DEFINE_EXECUTE_AT_EXIT UDFs for details.

2.2.5 DEFINE_EXECUTE_FROM_GUI

Description

DEFINE_EXECUTE_FROM_GUI is a general-purpose macro that you can use to define a UDF which is to be executed from a user-defined graphical user interface (GUI). For example, a C function that is defined using DEFINE_EXECUTE_FROM_GUI can be executed whenever a button is clicked in a user-defined GUI. Custom GUI components (panels, buttons, etc.) are defined in FLUENT using the Scheme language.

Usage

DEFINE_EXECUTE_FROM_GUI(name,libname,mode)

Argument Type	**Description**
symbol name	UDF name.
char *libname	name of the UDF library that has been loaded in FLUENT
int mode	an integer passed from the Scheme program that defines the user-defined GUI.

Function returns
void

There are three arguments to DEFINE_EXECUTE_FROM_GUI: name, libname, and mode. You supply name, the name of the UDF. The variables libname and mode are passed by the FLUENT solver to your UDF. The integer variable mode is passed from the Scheme program which defines the user-defined GUI, and represent the possible user options available from the GUI panel. A different C function in UDF can be called for each option. For example, the user-defined GUI panel may have a number of buttons. Each button may be represented by different integers, which, when clicked, will execute a corresponding C function.

i DEFINE_EXECUTE_FROM_GUI UDFs must be implemented as compiled UDFs, and there can be only one function of this type in a UDF library.

Example

The following UDF, named reset_udm, resets all user-defined memory (UDM) values when a reset button on a user-defined GUI panel is clicked. The clicking of the button is represented by 0, which is passed to the UDF by the FLUENT solver.

```
/**********************************************************
   UDF called from a user-defined GUI panel to reset all
   all user-defined memory locations
**********************************************************/
#include "udf.h"

DEFINE_EXECUTE_FROM_GUI(reset_udm, myudflib, mode)
{
Domain *domain = Get_Domain(1); /* Get domain pointer */
Thread *t;
cell_t c;
int i;

/* Return if mode is not zero */
if (mode != 0) return;

/* Return if no User-Defined Memory is defined in FLUENT */
        if (n_udm == 0) return;

        /* Loop over all cell threads in domain */
thread_loop_c(t, domain)
        {
        /* Loop over all cells */
                begin_c_loop(c, t)
                      {
                        /* Set all UDMs to zero */
                        for (i = 0; i < n_udm; i++)
                               {
                                C_UDMI(c, t, i) = 0.0;
                               }
                       }
                end_c_loop(c, t);
        }
}
```

Hooking an Execute From GUI UDF to FLUENT

After the UDF that you have defined using DEFINE_EXECUTE_FROM_GUI is compiled (Chapter 5: Compiling UDFs), the function will *not* need to be hooked to FLUENT through any graphics panels. Instead, the function will be searched automatically by the FLUENT solver when the execution of the UDF is requested (i.e., when a call is made from a user-defined Scheme program to execute a C function).

2.2.6 DEFINE_EXECUTE_ON_LOADING

Description

DEFINE_EXECUTE_ON_LOADING is a general-purpose macro that can be used to specify a function that executes as soon as a compiled UDF library is loaded in FLUENT. This is useful when you want to initialize or setup UDF models when a UDF library is loaded. (Alternatively, if you save your case file when a shared library is loaded, then the UDF will execute whenever the case file is subsequently read.)

Compiled UDF libraries are loaded using either the Compiled UDFs or the UDF Library Manager panel (see Section 5.5: Load and Unload Libraries Using the UDF Library Manager Panel). An EXECUTE_ON_LOADING UDF is the best place to reserve user-defined scalar (UDS) and user-defined memory (UDM) for a particular library (Sections 3.2.8 and 3.2.9) as well as set UDS and UDM names (Sections 3.2.8 and 3.2.9).

i DEFINE_EXECUTE_ON_LOADING UDFs can be executed only as compiled UDFs.

Usage

DEFINE_EXECUTE_ON_LOADING(name,libname)

Argument Type	Description
symbol name	UDF name.
char *libname	compiled UDF library name.

Function returns
void

There are two arguments to DEFINE_EXECUTE_ON_LOADING: name and libname. You supply a name for the UDF which will be used by FLUENT when reporting that the EXECUTE_ON_LOADING UDF is being run. The libname is set by FLUENT to be the name of the library (e.g., libudf) that you have specified (by entering a name or keeping the default libudf). libname is passed so that you can use it in messages within your UDF.

Example 1

The following simple UDF named report_version, prints a message on the console that contains the version and release number of the library being loaded.

```
#include "udf.h"

static int version = 1;
static int release = 2;

DEFINE_EXECUTE_ON_LOADING(report_version, libname)
{
    Message("\nLoading %s version %d.%d\n",libname,version,release);
}
```

Example 2

The following source code contains two UDFs. The first UDF is an EXECUTE_ON_LOADING function that is used to reserve three UDMs (using Reserve_User_Memory_Vars) for a library and set unique names for the UDM locations (using Set_User_Memory_Name). The second UDF is an ON_DEMAND function that is used to set the values of the UDM locations after the solution has been initialized. The ON_DEMAND UDF sets the initial values of the UDM locations using udm_offset, which is defined in the on-loading UDF. Note that the on demand UDF must be executed *after* the solution is initialized to reset the initial values for the UDMs. See Sections 3.2.9 and 3.2.9 for more information on reserving and naming UDMs.

```
/**********************************************************************
udm_res1.c contains two UDFs: an execute on loading UDF that reserves
three UDMs for libudf and renames the UDMs to enhance postprocessing,
and an on-demand UDF that sets the initial value of the UDMs.
**********************************************************************/
#include "udf.h"

#define NUM_UDM 3
static int udm_offset = UDM_UNRESERVED;

DEFINE_EXECUTE_ON_LOADING(on_loading, libname)
{
  if (udm_offset == UDM_UNRESERVED) udm_offset =
            Reserve_User_Memory_Vars(NUM_UDM);

  if (udm_offset == UDM_UNRESERVED)
```

```
      Message("\nYou need to define up to %d extra UDMs in GUI and
      then reload current library %s\n", NUM_UDM, libname);
  else
        {
  Message("%d UDMs have been reserved by the current
          library %s\n",NUM_UDM, libname);

  Set_User_Memory_Name(udm_offset,"lib1-UDM-0");
  Set_User_Memory_Name(udm_offset+1,"lib1-UDM-1");
          Set_User_Memory_Name(udm_offset+2,"lib1-UDM-2");
}
  Message("\nUDM Offset for Current Loaded Library = %d",udm_offset);
}

DEFINE_ON_DEMAND(set_udms)
{
  Domain *d;
  Thread *ct;
  cell_t c;
  int i;

  d=Get_Domain(1);

  if(udm_offset != UDM_UNRESERVED)
        {
         Message("Setting UDMs\n");

         for (i=0;i<NUM_UDM;i++)
                 {
                  thread_loop_c(ct,d)
                        {
                         begin_c_loop(c,ct)
                            {
                             C_UDMI(c,ct,udm_offset+i)=3.0+i/10.0;
                             }
                         end_c_loop(c,ct)
                        }
                  }
        }
  else
     Message("UDMs have not yet been reserved for library 1\n");
}
```

Hooking an Execute On Loading UDF to FLUENT

After the UDF that you have defined using DEFINE_EXECUTE_ON_LOADING is compiled (Chapter 5: Compiling UDFs), the function will *not* need to be hooked to FLUENT through any graphics panels. Instead, FLUENT searches the newly-loaded library for any UDFs of the type EXECUTE_ON_LOADING, and will automatically execute them in the order they appear in the library.

2.2.7 DEFINE_INIT

Description

DEFINE_INIT is a general-purpose macro that you can use to specify a set of initial values for your solution. DEFINE_INIT accomplishes the same result as patching, but does it in a different way, by means of a UDF. A DEFINE_INIT function is executed once per initialization and is called immediately after the default initialization is performed by the solver. Since it is called after the flow field is initialized, it is typically used to set initial values of flow quantities. For an overview of the FLUENT solution process which shows when a DEFINE_INIT UDF is called, refer to Figures 1.9.1, 1.9.2, and 1.9.3.

Usage

```
DEFINE_INIT(name,d)
```

Argument Type	Description
symbol name	UDF name.
Domain *d	Pointer to the domain over which the initialization function is to be applied. The domain argument provides access to all cell and face threads in the mesh. For multiphase flows, the pointer that is passed to the function by the solver is the mixture-level domain.

Function returns
void

There are two arguments to DEFINE_INIT: name and d. You supply name, the name of the UDF. d is passed from the FLUENT solver to your UDF.

Example

The following UDF, named my_init_func, initializes flow field variables in a solution. It is executed once, at the beginning of the solution process. The function can be executed as an interpreted or compiled UDF in FLUENT.

```
/***********************************************************************
   UDF for initializing flow field variables
***********************************************************************/

#include "udf.h"

DEFINE_INIT(my_init_func,d)
```

```
{
  cell_t c;
  Thread *t;
  real xc[ND_ND];

  /* loop over all cell threads in the domain  */
  thread_loop_c(t,d)
    {

      /* loop over all cells  */
      begin_c_loop_all(c,t)
        {
          C_CENTROID(xc,c,t);
          if (sqrt(ND_SUM(pow(xc[0] - 0.5,2.),
                          pow(xc[1] - 0.5,2.),
                          pow(xc[2] - 0.5,2.))) < 0.25)
            C_T(c,t) = 400.;
          else
            C_T(c,t) = 300.;
        }
      end_c_loop_all(c,t)
    }
}
```

The macro ND_SUM(a,b,c) computes the sum of the first two arguments (2D) or all three arguments (3D). It is useful for writing functions involving vector operations so that the same function can be used for 2D and 3D. For a 2D case, the third argument is ignored. See Chapter 3: Additional Macros for Writing UDFs for a description of predefined macros such as C_CENTROID) and ND_SUM.

Hooking an Initialization UDF to FLUENT

After the UDF that you have defined using DEFINE_INIT is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., my_init_func) will become visible and selectable in the User-Defined Function Hooks panel in FLUENT. Note that you can hook multiple init functions to your model. See Section 6.1.5: Hooking DEFINE_INIT UDFs for details.

2.2.8 DEFINE_ON_DEMAND

Description

DEFINE_ON_DEMAND is a general-purpose macro that you can use to specify a UDF that is executed "on demand" in FLUENT, rather than having FLUENT call it automatically during the calculation. Your UDF will be executed immediately, once it is activated, but it is not accessible while the solver is iterating. Note that the domain pointer d is not explicitly passed as an argument to DEFINE_ON_DEMAND. Therefore, if you want to use the domain variable in your on-demand function, you will need to first retrieve it using the Get_Domain utility provided by Fluent (shown in the example below). See Section 3.2.6: Domain Pointer (Get_Domain) for details on Get_Domain.

Usage

```
DEFINE_ON_DEMAND(name)
```

Argument Type	Description
symbol name	UDF name.

Function returns
void

There is only one argument to DEFINE_ON_DEMAND: name. You supply name, the name of the UDF.

Example

The following UDF, named on_demand_calc, computes and prints the minimum, maximum, and average temperatures for the current data field. It then computes a temperature function

$$f(T) = \frac{T - T_{\rm min}}{T_{\rm max} - T_{\rm min}}$$

and stores it in user-defined memory location 0 (which is allocated as described in Section 3.2.3: Cell Macros). Once you hook the on-demand UDF (as described in Section 6.1.6: Hooking DEFINE_ON_DEMAND UDFs), the field values for $f(T)$ will be available in drop-down lists in post-processing panels in FLUENT. You can select this field by choosing User Memory 0 in the User Defined Memory... category. If you write a data file after executing the UDF, the user-defined memory field will be saved to the data file. This source code can be interpreted or compiled in FLUENT.

```
/**********************************************************************
   UDF to calculate temperature field function and store in
   user-defined memory. Also print min, max, avg temperatures.
***********************************************************************/
#include "udf.h"

DEFINE_ON_DEMAND(on_demand_calc)
{
   Domain *d; /* declare domain pointer since it is not passed as an
                 argument to the DEFINE macro  */
   real tavg = 0.;
   real tmax = 0.;
   real tmin = 0.;
   real temp,volume,vol_tot;
   Thread *t;
   cell_t c;
   d = Get_Domain(1);     /* Get the domain using Fluent utility */

   /* Loop over all cell threads in the domain */
   thread_loop_c(t,d)
     {

     /* Compute max, min, volume-averaged temperature */

     /* Loop over all cells  */
     begin_c_loop(c,t)
       {
         volume = C_VOLUME(c,t);   /* get cell volume */
         temp = C_T(c,t);          /* get cell temperature */

         if (temp < tmin || tmin == 0.) tmin = temp;
         if (temp > tmax || tmax == 0.) tmax = temp;

         vol_tot += volume;
         tavg += temp*volume;

       }
     end_c_loop(c,t)

     tavg /= vol_tot;

     printf("\n Tmin = %g   Tmax = %g   Tavg = %g\n",tmin,tmax,tavg);
```

```
    /* Compute temperature function and store in user-defined memory*/
    /*(location index 0)                                             */

    begin_c_loop(c,t)
      {
        temp = C_T(c,t);
        C_UDMI(c,t,0) = (temp-tmin)/(tmax-tmin);
      }
    end_c_loop(c,t)

    }
}
```

Get_Domain is a macro that retrieves the pointer to a domain. It is necessary to get the domain pointer using this macro since it is not explicitly passed as an argument to DEFINE_ON_DEMAND. The function, named on_demand_calc, does not take any explicit arguments. Within the function body, the variables that are to be used by the function are defined and initialized first. Following the variable declarations, a looping macro is used to loop over each cell thread in the domain. Within that loop another loop is used to loop over all the cells. Within the inner loop, the total volume and the minimum, maximum, and volume-averaged temperature are computed. These computed values are printed to the FLUENT console. Then a second loop over each cell is used to compute the function $f(T)$ and store it in user-defined memory location 0. Refer to Chapter 3: Additional Macros for Writing UDFs for a description of predefined macros such as C_T and begin_c_loop.

Hooking an On-Demand UDF to FLUENT

After the UDF that you have defined using DEFINE_ON_DEMAND is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., on_demand_calc) will become visible and selectable in the Execute On Demand panel in FLUENT. See Section 6.1.6: Hooking DEFINE_ON_DEMAND UDFs for details.

2.2.9 DEFINE_RW_FILE

Description

DEFINE_RW_FILE is a general-purpose macro that you can use to specify customized information that is to be written to a case or data file, or read from a case or data file. You can save and restore custom variables of any data type (e.g., integer, real, CXBoolean, structure) using DEFINE_RW_FILE. It is often useful to save dynamic information (e.g., number of occurrences in conditional sampling) while your solution is being calculated, which is another use of this function. Note that the read order and the write order must be the same when you use this function.

Usage

DEFINE_RW_FILE(name,fp)

Argument Type	**Description**
symbol name	UDF name.
FILE *fp	Pointer to the file you are reading or writing.

Function returns
void

There are two arguments to DEFINE_RW_FILE: name and fp. You supply name, the name of the UDF. fp is passed from the solver to the UDF.

i DEFINE_RW_FILE cannot be used in UDFs that are executed on Windows systems.

Example

The following C source code listing contains examples of functions that write information to a data file and read it back. These functions are concatenated into a single source file that can be interpreted or compiled in FLUENT.

```
/***********************************************************************
   UDFs that increment a variable, write it to a data file
   and read it back in
************************************************************************/
#include "udf.h"

int kount = 0;  /* define global variable kount */
```

```
DEFINE_ADJUST(demo_calc,d)
{
  kount++;
  printf("kount = %d\n",kount);
}
DEFINE_RW_FILE(writer,fp)
{
  printf("Writing UDF data to data file...\n");
  fprintf(fp,"%d",kount); /* write out kount to data file */
}
DEFINE_RW_FILE(reader,fp)
{
  printf("Reading UDF data from data file...\n");
  fscanf(fp,"%d",&kount); /* read kount from data file */
}
```

At the top of the listing, the integer kount is defined and initialized to zero. The first function (demo_calc) is an ADJUST function that increments the value of kount at each iteration, since the ADJUST function is called once per iteration. (See Section 2.2.1: DEFINE_ADJUST for more information about ADJUST functions.) The second function (writer) instructs FLUENT to write the current value of kount to the data file, when the data file is saved. The third function (reader) instructs FLUENT to read the value of kount from the data file, when the data file is read.

The functions work together as follows. If you run your calculation for, say, 10 iterations (kount has been incremented to a value of 10) and save the data file, then the current value of kount (10) will be written to your data file. If you read the data back into FLUENT and continue the calculation, kount will start at a value of 10 and will be incremented at each iteration. Note that you can save as many static variables as you want, but you must be sure to read them in the same order in which they are written.

Hooking a Read/Write Case or Data File UDF to FLUENT

After the UDF that you have defined using DEFINE_RW_FILE is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., writer) will become visible and selectable in the User-Defined Function Hooks panel in FLUENT. Note that you can hook multiple read/write functions to your model. See Section 6.1.7: Hooking DEFINE_RW_FILE UDFs for details.

2.3 Model-Specific DEFINE Macros

The DEFINE macros presented in this section are used to set parameters for a particular model in FLUENT. Table 2.3 provides a quick reference guide to the DEFINE macros, the functions they are used to define, and the panels where they are activated in FLUENT. Definitions of each DEFINE macro are listed in udf.h. For your convenience, they are listed in Appendix B.

- Section 2.3.1: DEFINE_CHEM_STEP
- Section 2.3.2: DEFINE_CPHI
- Section 2.3.3: DEFINE_DIFFUSIVITY
- Section 2.3.4: DEFINE_DOM_DIFFUSE_REFLECTIVITY
- Section 2.3.5: DEFINE_DOM_SOURCE
- Section 2.3.6: DEFINE_DOM_SPECULAR_REFLECTIVITY
- Section 2.3.7: DEFINE_GRAY_BAND_ABS_COEFF
- Section 2.3.8: DEFINE_HEAT_FLUX
- Section 2.3.9: DEFINE_NET_REACTION_RATE
- Section 2.3.10: DEFINE_NOX_RATE
- Section 2.3.11: DEFINE_PR_RATE
- Section 2.3.12: DEFINE_PRANDTL UDFs
- Section 2.3.13: DEFINE_PROFILE
- Section 2.3.14: DEFINE_PROPERTY UDFs
- Section 2.3.15: DEFINE_SCAT_PHASE_FUNC
- Section 2.3.16: DEFINE_SOLAR_INTENSITY
- Section 2.3.17: DEFINE_SOURCE
- Section 2.3.18: DEFINE_SOX_RATE
- Section 2.3.19: DEFINE_SR_RATE
- Section 2.3.20: DEFINE_TURB_PREMIX_SOURCE
- Section 2.3.21: DEFINE_TURBULENT_VISCOSITY
- Section 2.3.22: DEFINE_VR_RATE
- Section 2.3.23: DEFINE_WALL_FUNCTIONS

Table 2.3.1: Quick Reference Guide for Model-Specific DEFINE Functions

Function	DEFINE Macro	Panel Activated In
mixing constant	DEFINE_CPHI	User-Defined Function Hooks
homogeneous net mass reaction rate for all species, integrated over a time step	DEFINE_CHEM_STEP	User-Defined Function Hooks
species mass or UDS diffusivity	DEFINE_DIFFUSIVITY	Materials
diffusive reflectivity for discrete ordinates (DO) model	DEFINE_DOM_DIFFUSE_ REFLECTIVITY	User-Defined Function Hooks
source for DO model	DEFINE_DOM_SOURCE	User-Defined Function Hooks
specular reflectivity for DO model	DEFINE_DOM_SPECULAR_ REFLECTIVITY	User-Defined Function Hooks
gray band absorption coefficient for DO model	DEFINE_GRAY_BAND_ ABS_COEFF	Materials
wall heat flux	DEFINE_HEAT_FLUX	User-Defined Function Hooks
homogeneous net mass reaction rate for all species	DEFINE_NET_ REACTION_RATE	User-Defined Function Hooks
NO_x formation rates for Thermal NO, Prompt NO, Fuel NO, and N2O Pathways	DEFINE_NOX_RATE	NOx Model
particle surface reaction rate	DEFINE_PR_RATE	User-Defined Function Hooks
Prandtl numbers	DEFINE_PRANDTL	Viscous Model
species mass fraction	DEFINE_PROFILE	boundary condition (e.g., Velocity Inlet)

Table 2.3.2: Quick Reference Guide for Model-Specific DEFINE Functions Continued

Function	DEFINE Macro	Panel Activated In
velocity at a boundary	DEFINE_PROFILE	boundary condition (e.g., Velocity Inlet)
pressure at a boundary	DEFINE_PROFILE	boundary condition
temperature at a boundary	DEFINE_PROFILE	boundary condition
mass flux at a boundary	DEFINE_PROFILE	boundary condition
target mass flow rate for pressure outlet	DEFINE_PROFILE	Pressure Outlet
turbulence kinetic energy	DEFINE_PROFILE	boundary condition
turbulence dissipation rate	DEFINE_PROFILE	boundary condition
specific dissipation rate	DEFINE_PROFILE	boundary condition
porosity	DEFINE_PROFILE	boundary condition
viscous resistance	DEFINE_PROFILE	boundary condition
inertial resistance	DEFINE_PROFILE	boundary condition
porous resistance direction vector	DEFINE_PROFILE	boundary condition
user-defined scalar boundary value	DEFINE_PROFILE	boundary condition
internal emissivity	DEFINE_PROFILE	boundary condition
wall thermal conditions (heat flux, heat generation rate, temperature, heat transfer coefficient, external emissivity, external radiation and free stream temperature)	DEFINE_PROFILE	boundary condition
wall radiation (internal emissivity, irradiation)	DEFINE_PROFILE	boundary condition
wall momentum (shear stress x,y,z components swirl component, moving wall velocity components, roughness height, roughness constant)	DEFINE_PROFILE	boundary condition
wall species mass fractions	DEFINE_PROFILE	boundary condition
wall user-defined scalar boundary value	DEFINE_PROFILE	boundary condition
wall discrete phase boundary value	DEFINE_PROFILE	boundary condition
wall functions	DEFINE_WALL_FUNCTIONS	Wall

Table 2.3.3: Quick Reference Guide for Model-Specific DEFINE Functions - Continued

Function	DEFINE Macro	Panel Activated In
density (as function of temperature)	DEFINE_PROPERTY	Materials
density (as function of pressure for compressible liquids)	DEFINE_PROPERTY	Materials
viscosity	DEFINE_PROPERTY	Materials
mass diffusivity	DEFINE_PROPERTY	Materials
thermal conductivity	DEFINE_PROPERTY	Materials
thermal diffusion coefficient	DEFINE_PROPERTY	Materials
absorption coefficient	DEFINE_PROPERTY	Materials
scattering coefficient	DEFINE_PROPERTY	Materials
laminar flow speed	DEFINE_PROPERTY	Materials
rate of strain	DEFINE_PROPERTY	Materials
speed of sound function	DEFINE_PROPERTY	Materials
user-defined mixing law for mixture materials (density viscosity, thermal conductivity)	DEFINE_PROPERTY	Materials
scattering phase function	DEFINE_SCAT_PHASE_FUNC	Materials
solar intensity	DEFINE_SOLAR_INTENSITY	Radiation Model
mass source	DEFINE_SOURCE	boundary condition
momentum source	DEFINE_SOURCE	boundary condition
energy source	DEFINE_SOURCE	boundary condition
turbulence kinetic energy source	DEFINE_SOURCE	boundary condition
turbulence dissipation rate source	DEFINE_SOURCE	boundary condition
species mass fraction source	DEFINE_SOURCE	boundary condition
user-defined scalar source	DEFINE_SOURCE	boundary condition
P1 radiation model source	DEFINE_SOURCE	boundary condition
surface reaction rate	DEFINE_SR_RATE	User-Defined Function
SO_x formation rate	DEFINE_SOX_RATE	SOx Model
turbulent premixed source	DEFINE_TURB_PREMIX_SOURCE	User-Defined Function Hooks
turbulent viscosity	DEFINE_TURBULENT_VISCOSITY	Viscous Model
UDS flux function	DEFINE_UDS_FLUX	User-Defined Scalars
UDS unsteady function	DEFINE_UDS_UNSTEADY	User-Defined Scalars
wall function	DEFINE_WALL_FUNCTIONS	boundary condition
volume reaction rate	DEFINE_VR_RATE	User-Defined Function Hooks

Table 2.3.4: Quick Reference Guide for Model-Specific DEFINE Functions MULTIPHASE ONLY

Function	DEFINE Macro	Panel Activated In
volume fraction (all multiphase models)	DEFINE_PROFILE	boundary condition
contact angle (VOF)	DEFINE_PROFILE	Wall boundary condition
heat transfer coefficient (Eulerian)	DEFINE_PROPERTY	Phase Interaction
surface tension coefficient (VOF)	DEFINE_PROPERTY	Phase Interaction
cavitation surface tension coefficient (Mixture)	DEFINE_PROPERTY	Phase Interaction
cavitation vaporization pressure (Mixture)	DEFINE_PROPERTY	Phase Interaction
particle or droplet diameter (Mixture)	DEFINE_PROPERTY	Materials
temperature source (Eulerian, Mixture)	DEFINE_SOURCE	boundary condition
diameter (Eulerian, Mixture)	DEFINE_PROPERTY	Secondary Phase
solids pressure (Eulerian, Mixture)	DEFINE_PROPERTY	Secondary Phase
radial distribution (Eulerian, Mixture)	DEFINE_PROPERTY	Secondary Phase
elasticity modulus (Eulerian, Mixture)	DEFINE_PROPERTY	Secondary Phase
viscosity (Eulerian, Mixture)	DEFINE_PROPERTY	Secondary Phase
temperature (Eulerian, Mixture)	DEFINE_PROPERTY	Secondary Phase
bulk viscosity (Eulerian)	DEFINE_PROPERTY	Secondary Phase
frictional viscosity (Eulerian)	DEFINE_PROPERTY	Secondary Phase
frictional pressure (Eulerian)	DEFINE_PROPERTY	Secondary Phase
frictional modulus (Eulerian)	DEFINE_PROPERTY	Secondary Phase
granular viscosity (Eulerian)	DEFINE_PROPERTY	Secondary Phase
granular bulk viscosity (Eulerian)	DEFINE_PROPERTY	Secondary Phase
granular conductivity (Eulerian)	DEFINE_PROPERTY	Secondary Phase

2.3.1 DEFINE_CHEM_STEP

Description

You can use DEFINE_CHEM_STEP to compute the homogeneous net mass reaction rate of all species integrated over a time step:

$$Y_i^{\Delta t} = Y_i^0 + \int_0^{\Delta t} \frac{dY_i}{dt} dt \qquad (2.3\text{-}1)$$

where Y_i^0 is the initial mass fraction of species i, t is time, Δt is the given time step, and $\frac{dY_i}{dt}$ is the net mass reaction rate. $Y_i^{\Delta t}$ is ith species mass fraction at the end of the integration.

DEFINE_CHEM_STEP UDFs are used for the EDC and PDF Transport models.

Usage

```
DEFINE_CHEM_STEP(name,c,t,p,num_p,n_spe,dt,pres,
temp,yk)
```

Argument Type	**Description**
symbol name	UDF name.
cell_t c	Cell index of current particle.
Thread *t	Pointer to cell thread for particle.
Particle *p	Pointer to particle data structure that contains data related to the particle being tracked.
int num_p	Not Used.
int n_spec	Number of volumetric species.
double *dt	Time step.
double *pres	Pointer to pressure.
double *temp	Pointer to temperature.
double *yk	Pointer to array of initial species mass fractions.

Function returns
void

There are nine arguments to DEFINE_CHEM_STEP: name, c, p ,num_p, n_spe, dt, pres, temp, and yk. You supply name, the name of the UDF. c, p, n_spe, dt, pres, temp, and yk are variables that are passed by the FLUENT solver to your UDF. num_p is not used by the function and can be ignored. The output of the function is the array of mass fractions yk *after* the integration step. The initial mass fractions in array yk are overwritten.

Example

The following UDF, named user_chem_step, assumes that the net volumetric reaction rate is the expression,

$$\frac{dY_k}{dt} = 1/N_{spe} - Y_k \qquad (2.3\text{-}2)$$

where N_{spe} is the number of species.

An analytic solution exists for the integral of this ODE as,

$$Y_k^{\Delta t} = (Y_k^0 - 1/N_{spe})exp(-\Delta t) + 1/N_{spe} \qquad (2.3\text{-}3)$$

```
/***************************************************
   Example UDF that demonstrates DEFINE_CHEM_STEP
***************************************************/
#include "udf.h"

DEFINE_CHEM_STEP(user_chem_step,cell,thread,particle,nump,nspe,dt,pres,temp,yk)
{
   int i;
   double c = 1./(double)nspe;
   double decay = exp(-(*dt));
   for(i=0;i<n_spe;i++)
     yk[i] = (yk[i]-c)*decay + c;
}
```

Hooking a Chemistry Step UDF to FLUENT

After the UDF that you have defined using DEFINE_CHEM_STEP is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., user_chem_step) will become visible and selectable in the User-Defined Function Hooks panel in FLUENT. See Section 6.2.1: Hooking DEFINE_CHEM_STEP UDFs for details.

2.3.2 DEFINE_CPHI

Description

You can use DEFINE_CPHI to set the value of the mixing constant C_ϕ (see Equation 18.2-6 and Equation 18.2-8 in the the User's Guide for details.). It is useful for modeling flows where C_ϕ departs substantially from its default value of 2, which occurs at low Reynolds and/or high Schmidt numbers.

Usage

```
DEFINE_CPHI(name,c,t)
```

Argument Type	**Description**
symbol name	UDF name.
cell_t c	Cell index.
Thread *t	Pointer to cell thread.

Function returns
real

There are three arguments to DEFINE_CPHI: name, c, and t. You supply name, the name of the UDF. c and t are passed by the FLUENT solver to your UDF. Your UDF will need to compute the real value of the mixing constant (C_ϕ) and return it to the solver.

Hooking a Mixing Constant UDF to FLUENT

After the UDF that you have defined using DEFINE_CPHI is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible and selectable in the Users Defined Function Hooks panel in FLUENT whenever the Composition PDF Transport model is enabled. See Section 6.2.2: Hooking DEFINE_CPHI UDFs for details.

2.3.3 DEFINE_DIFFUSIVITY

Description

You can use DEFINE_DIFFUSIVITY to specify the diffusivity for the species transport equations (e.g., mass diffusivity) or for user-defined scalar (UDS) transport equations. See Section 8.6: User-Defined Scalar (UDS) Diffusivity in the User's Guide for details about UDS diffusivity.

Usage

```
DEFINE_DIFFUSIVITY(name,c,t,i)
```

Argument Type	Description
symbol name	UDF name.
cell_t c	Cell index.
Thread *t	Pointer to cell thread on which the diffusivity function is to be applied.
int i	Index that identifies the species or user-defined scalar.

Function returns
real

There are four arguments to DEFINE_DIFFUSIVITY: name, c, and t, and i. You supply name, the name of the UDF. c, t, and i are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to compute the diffusivity *only* for a single cell and return the real value to the solver.

Note that diffusivity UDFs are called by FLUENT from within a loop on cell threads. Consequently, your UDF will not need to loop over cells in a thread since FLUENT is doing it outside of the function call.

Example

The following UDF, named mean_age_diff, computes the diffusivity for the mean age of air using a user-defined scalar. Note that the mean age of air calculations do not require that energy, radiation, or species transport calculations have been performed. You will need to set uds-0 = 0.0 at all inlets and outlets in your model. This function can be executed as an interpreted or compiled UDF.

```
/***********************************************************************
   UDF that computes diffusivity for mean age using a user-defined
   scalar.
************************************************************************/

#include "udf.h"

DEFINE_DIFFUSIVITY(mean_age_diff,c,t,i)
{
     return C_R(c,t) * 2.88e-05 + C_MU_EFF(c,t) / 0.7;
}
```

Hooking a Diffusivity UDF to FLUENT

After the UDF that you have defined using DEFINE_DIFFUSIVITY is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name that you specified in the DEFINE macro argument (e.g., mean_age_diff) will become visible and selectable in the Materials panel in FLUENT. See Section 6.2.3: Hooking DEFINE_DIFFUSIVITY UDFs for details.

2.3.4 DEFINE_DOM_DIFFUSE_REFLECTIVITY

Description

You can use DEFINE_DOM_DIFFUSE_REFLECTIVITY to modify the inter-facial reflectivity computed by FLUENT at diffusely reflecting semi-transparent walls, based on the refractive index values. During execution, a DEFINE_DOM_DIFFUSE_REFLECTIVITY function is called by FLUENT for each semi-transparent wall and also for each band (in the case of a non-gray Discrete Ordinates Model). Therefore the function can be used to modify diffuse reflectivity and diffuse transmissivity values at the interface.

Usage

DEFINE_DOM_DIFFUSE_REFLECTIVITY(name,t,nb,n_a,n_b,diff_ref_a,diff_tran_a, diff_ref_b,diff_tran_b)

Note that all of the arguments to a DEFINE macro need to be placed on the same line in your source code. Splitting the DEFINE statement onto several lines will result in a compilation error.

Argument Type	**Description**
symbol name	UDF name.
Thread *t	Pointer to the thread on which the discrete ordinate diffusivity function is to be applied.
int nb	Band number (needed for the non-gray Discrete Ordinates Model).
real n_a	Refractive index of medium a.
real n_b	Refractive index of medium b.
real *diff_ref_a	Diffuse reflectivity at the interface facing medium a.
real *diff_tran_a	Diffuse transmissivity at the interface facing medium a.
real *diff_ref_b	Diffuse reflectivity at the interface facing medium b.
real *diff_tran_b	Diffuse transmissivity at the interface facing medium b.

Function returns
void

There are nine arguments to DEFINE_DOM_DIFFUSE_REFLECTIVITY: name, t, nb, n_a, n_b, diff_ref_a, diff_tran_a, diff_ref_b, and diff_tran_b. You supply name, the name of the UDF. t, nb, n_a, n_b, diff_ref_a, diff_tran_a, diff_ref_b, and diff_tran_b are variables that are passed by the FLUENT solver to your UDF.

Example

The following UDF, named user_dom_diff_refl, modifies diffuse reflectivity and transmissivity values on both the sides of the interface separating medium a and b. The UDF is called for all the semi-transparent walls and prints the value of the diffuse reflectivity and transmissivity values for side a and b.

```
/* UDF to print the diffuse reflectivity and transmissivity
at semi-transparent walls*/

#include "udf.h"

DEFINE_DOM_DIFFUSE_REFLECTIVITY(user_dom_diff_refl,t,nband,n_a,n_b,
diff_ref_a,diff_tran_a,diff_ref_b,diff_tran_b)
{
printf("diff_ref_a=%f  diff_tran_a=%f \n", *diff_ref_a, *diff_tran_a);
printf("diff_ref_b=%f  diff_tran_b=%f \n", *diff_ref_b, *diff_tran_b);
}
```

Hooking a Discrete Ordinates Model (DOM) Diffuse Reflectivity UDF to FLUENT

After the UDF that you have defined using DEFINE_DOM_DIFFUSE_REFLECTIVITY is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., user_dom_diff_refl) will become visible and selectable in the User-Defined Function Hooks panel in FLUENT. See Section 6.2.4: Hooking DEFINE_DOM_DIFFUSE_REFLECTIVITY UDFs for details.

2.3.5 DEFINE_DOM_SOURCE

Description

You can use DEFINE_DOM_SOURCE to modify the emission term (first term on the right hand side in Equation 13.3-37 or Equation 13.3-38 of the User's Guide) as well as the scattering term (second term on the right hand side of either equation) in the radiative transport equation for the Discrete Ordinates (DO) model.

Usage

```
DEFINE_DOM_SOURCE(name,c,t,ni,nb,emission,in_scattering,abs_coeff,scat_coeff)
```

Argument Type	Description
symbol name	UDF name.
cell_t c	Cell index.
Thread *t	Pointer to cell thread.
int ni	Direction represented by the solid angle.
int nb	Band number (needed for the non-gray Discrete Ordinates Model).
real *emission	Pointer to emission term in the radiative transport equation (Equation 13.3-37 to go to the User's Guide manual).
real *in_scattering	Pointer to scattering term in the radiative transport equation (Equation 13.3-38 to go to the User's Guide manual).
real *abs_coeff	Pointer to absorption coefficient.
real *scat_coeff	Pointer to scattering coefficient.

Function returns
void

There are nine arguments to DEFINE_DOM_SOURCE: name, c, ni, nb, emission, in_scattering, abs_coeff, and scat_coeff. You supply name, the name of the UDF. c, ni, nb, emission, in_scattering, abs_coeff, and scat_coeff are variables that are passed by the FLUENT solver to your UDF. DEFINE_DOM_SOURCE is called by FLUENT for each cell.

Example

In the following UDF, named user_dom_source, the emission term present in the radiative transport equation is modified. The UDF is called for all the cells and increases the emission term by 5%.

```
/* UDF to alter the emission source term in the DO model */

#include "udf.h"

DEFINE_DOM_SOURCE(user_dom_source,c,t,ni,nb,emission,in_scattering,
abs_coeff,scat_coeff)
{

   /* increased the emission by 5 %   */

   *emission  *= 1.05;

}
```

Note that all of the arguments to a DEFINE macro need to be placed on the same line in your source code. Splitting the DEFINE statement onto several lines will result in a compilation error.

Hooking a DOM Source UDF to FLUENT

After the UDF that you have defined using DEFINE_DOM_SOURCE is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., user_dom_source) will become visible and selectable in the User-Defined Function Hooks panel in FLUENT. Note that you can hook multiple discrete ordinate source term functions to your model. See Section 6.2.5: Hooking DEFINE_DOM_SOURCE UDFs for details.

2.3.6 DEFINE_DOM_SPECULAR_REFLECTIVITY

Description

You can use DEFINE_DOM_SPECULAR_REFLECTIVITY to modify the inter-facial reflectivity of specularly reflecting semi-transparent walls. You may wish to do this if the reflectivity is dependent on other conditions that the standard boundary condition doesn't allow for. (See Section 13.3.6: Specular Semi-Transparent Walls in the User's Guide for more information.) During FLUENT execution, the same UDF is called for all the faces of the semi-transparent wall, for each of the directions.

Usage

```
DEFINE_DOM_SPECULAR_REFLECTIVITY(name,f,t,nband,n_a,n_b,ray_direction,en,
internal_reflection,specular_reflectivity,specular_transmissivity)
```

Note that all of the arguments to a DEFINE macro need to be placed on the same line in your source code. Splitting the DEFINE statement onto several lines will result in a compilation error.

Argument Type	**Description**
symbol name	UDF name.
face_t f	Face index.
Thread *t	Pointer to face thread on which the specular reflectivity function is to be applied.
int nband	Band number (needed for non-gray Discrete Ordinates Model).
real n_a	Refractive index of medium a.
real n_b	Refractive index of medium b.
real ray_direction	Direction vector (s) defined in Equation 13.3-55 in the User's Guide
real en	Interface normal vector (n) defined in Equation 13.3-55 in the User's Guide
int internal_reflection	Variable used to flag the code that total internal reflection has occurred.
real *specular_reflectivity	Specular reflectivity for the given direction s.
real *specular_transmissivity	Specular transmissivity for the given direction s.

Function returns
void

There are eleven arguments to DEFINE_DOM_SPECULAR_REFLECTIVITY: name, f, t, nband, n_a, n_b, ray_direction, en, internal_reflection, specular_reflectivity, and specular_transmissivity. You supply name, the name of the UDF. f, t, nband, n_a, n_b, ray_direction, en, internal_reflection, specular_reflectivity, and specular_transmissivity are variables that are passed by the FLUENT solver to your UDF.

Example

In the following UDF, named user_dom_spec_refl, specular reflectivity and transmissivity values are altered for a given ray direction *s* at face f.

```
/*  UDF to alter the specular reflectivity and transmissivity, at
    semi-transparent walls, along direction s at face f */

#include "udf.h"

DEFINE_DOM_SPECULAR_REFLECTIVITY(user_dom_spec_refl,f,t, nband,n_a,n_b,
ray_direction,en,internal_reflection,specular_reflectivity,
specular_transmissivity)
{
   real angle, cos_theta;
   real PI = 3.141592;
   cos_theta = NV_DOT(ray_direction, en);
   angle = acos(cos_theta);
   if (angle >45   && angle < 60)
     {
       *specular_reflectivity = 0.3;
       *specular_transmissivity = 0.7;
     }
}
```

Hooking a Discrete Ordinate Model (DOM) Specular Reflectivity UDF to FLUENT

After the UDF that you have defined using DEFINE_DOM_SPECULAR_REFLECTIVITY is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., user_dom_spec_refl) will become visible and selectable in the User-Defined Function Hooks panel in FLUENT. See Section 6.2.6: Hooking DEFINE_DOM_SPECULAR_REFLECTIVITY UDFs for details.

2.3.7 DEFINE_GRAY_BAND_ABS_COEFF

Description

You can use DEFINE_GRAY_BAND_ABS_COEFF to specify a UDF for the gray band absorption coefficient as a function of temperature, that can be used with a non-gray discrete ordinate model.

Usage

DEFINE_GRAY_BAND_ABS_COEFF(name,c,t,nb)

Argument Type	Description
symbol name	UDF name.
cell_t c	Cell index.
Thread *t	Pointer to cell thread.
int nb	Band number associated with non-gray model.

Function returns
real

There are four arguments to DEFINE_GRAY_BAND_ABS_COEFF: name, c, t, and nb. You supply name, the name of the UDF. The variables c, t, and nb are passed by the FLUENT solver to your UDF. Your UDF will need to return the real value of the gray band coefficient to the solver.

Example

The following UDF, named user_gray_band_abs, specifies the gray-band absorption coefficient as a function of temperature that can be used for a non-gray Discrete Ordinate model.

```
#include  "udf.h"

DEFINE_GRAY_BAND_ABS_COEFF(user_gray_band_abs,c,t,nb)
{
   real abs_coeff = 0;
   real T = C_T(c,t);

  switch (nb)
  {
     case 0 :  abs_coeff = 1.3+0.001*T; break;
     case 1 :  abs_coeff =  2.7 + 0.005*T; break;
}

return abs_coeff;

}
```

Hooking a Gray Band Coefficient UDF to FLUENT

After the UDF that you have defined using DEFINE_GRAY_BAND_ABS_COEFF is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument
(e.g., user_gray_band_abs) will become visible and selectable in the Materials panel for the Absorption Coefficient. See Section 6.2.7: Hooking DEFINE_GRAY_BAND_ABS_COEFF UDFs for details.

2.3.8 DEFINE_HEAT_FLUX

Description

You can use DEFINE_HEAT_FLUX to modify the heat flux at a wall. Despite the name, a DEFINE_HEAT_FLUX UDF is *not* the means to specify the actual heat flux entering a domain from the outside. To specify this type of heat flux, you would simply use a DEFINE_PROFILE function in conjunction with a heat flux thermal boundary condition. In contrast, a DEFINE_HEAT_FLUX UDF allows you to modify the way in which the dependence between the flux entering the domain and the wall and cell temperatures is modeled.

i This function allows you to modify the heat flux at walls adjacent to a solid.Note, however, that for solids since only heat conduction is occurring, any extra heat flux that you add in a heat flux UDF can have a detrimental effect on the solution of the energy equation. These effects will likely show up in conjugate heat transfer problems. To avoid this, you will need to make sure that your heat flux UDF excludes the walls adjacent to solids, or includes only the necessary walls adjacent to fluid zones.

Usage

```
DEFINE_HEAT_FLUX(name,f,t,c0,t0,cid,cir)
```

Argument Type	Description
symbol name	UDF name.
face_t f	Index that identifies a wall face.
Thread *t	Pointer to wall face thread on which heat flux function is to be applied.
cell_t c0	Cell index that identifies the cell next to the wall.
Thread *t0	Pointer to the adjacent cell's thread.
real cid[]	Array of fluid-side diffusive heat transfer coefficients.
real cir[]	Array of radiative heat transfer coefficients.

Function returns

void

There are seven arguments to DEFINE_HEAT_FLUX: name, f, t, c0, t0, cid, and cir. You supply name, the name of the UDF. f, t, c0, and t0 are variables that are passed by the FLUENT solver to your UDF. Arrays cir[] and cid[] contain the linearizations of the radiative and diffusive heat fluxes, respectively, computed by FLUENT based on the activated models. These arrays allow you to modify the heat flux in any way that you choose. FLUENT computes the heat flux at the wall using these arrays *after* the call to DEFINE_HEAT_FLUX, so the total heat flux at the wall will be the currently computed heat flux (based on the activated models) with any modifications as defined by your UDF.

The diffusive heat flux (qid) and radiative heat flux (qir) are computed by FLUENT according to the following equations:

```
qid = cid[0] + cid[1]*C_T(c0,t0) - cid[2]*F_T(f,t) - cid[3]*pow(F_T(f,t),4)
qir = cir[0] + cir[1]*C_T(c0,t0) - cir[2]*F_T(f,t) - cir[3]*pow(F_T(f,t),4)
```

The sum of qid and qir defines the total heat flux from the fluid to the wall (this direction being positive flux), and, from an energy balance at the wall, equals the heat flux of the surroundings (exterior to the domain). Note that heat flux UDFs (defined using DEFINE_HEAT_FLUX) are called by FLUENT from within a loop over wall faces.

In order for the solver to compute C_T and F_T, the values you supply to cid[1] and cid[2] should never be zero.

Example

Section 8.2.5: Implementing FLUENT's P-1 Radiation Model Using User-Defined Scalars provides an example of the P-1 radiation model implementation through a user-defined scalar. An example of the usage of the DEFINE_HEAT_FLUX macro is included in that implementation.

Hooking a Heat Flux UDF to FLUENT

After the UDF that you have defined using DEFINE_HEAT_FLUX is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., heat_flux) will become visible and selectable in the User-Defined Function Hooks panel in FLUENT. See Section 6.2.8: Hooking DEFINE_HEAT_FLUX UDFs for details.

2.3.9 DEFINE_NET_REACTION_RATE

Description

You can use DEFINE_NET_REACTION_RATE to compute the homogeneous net molar reaction rates of all species. The net reaction rate of a species is the sum over all reactions of the volumetric reaction rates:

$$R_i = \sum_{r=1}^{N_R} \hat{R}_{i,r} \tag{2.3-4}$$

where R_i is the net reaction rate of species i and $\hat{R}_{i,r}$ is the Arrhenius molar rate of creation/destruction of species i in reaction r.

A DEFINE_NET_REACTION_RATE UDF may be used for the Laminar finite-rate, EDC, and PDF Transport models, as well as for the surface chemistry model. In contrast, the volumetric UDF function DEFINE_VR_RATE and surface UDF function DEFINE_SR_RATE return the molar rate per reaction ($\hat{R}_r$).

Usage

```
DEFINE_NET_REACTION_RATE(name,c,t,particle,pressure,temp,yi,rr,jac)
```

Argument Type	**Description**
symbol name	UDF name.
cell_t c	Cell index of current particle.
Thread *t	Pointer to cell thread for particle.
Particle *particle	Pointer to Particle data structure that contains data related to the particle being tracked.
double *pressure	Pointer to pressure variable.
double *temp	Pointer to temperature variable.
double *yi	Pointer to array containing species mass fractions.
double *rr	Pointer to array containing net mass reaction rates.
double *jac	Pointer to array of Jacobians.

Function returns
void

There are nine arguments to DEFINE_NET_REACTION_RATE: name, c, t, particle, pressure, temp, yi, rr, and jac. You supply name, the name of the UDF. The variables c, t, particle, pressure, temp, yi, rr, and jac are passed by the FLUENT solver to your UDF and have SI units. The outputs of the function are the array of net molar reaction rates, rr (with units $kgmol/m^3 - s$), and the Jacobian array jac. The Jacobian is only required for surface chemistry, and is the derivative of the surface net reaction rate with respect to the species concentration.

DEFINE_NET_REACTION_RATE is called for all fluid zones (volumetric reactions as well as surface reactions in porous media) and for all wall thread zones whenever the Reaction button is enabled in the Boundary Conditions panel and the UDF is hooked to FLUENT in the User-Defined Function Hooks panel.

> DEFINE_NET_REACTION_RATE functions can be executed only as compiled UDFs.

Example

The following UDF, named user_net_reaction_rate, assumes that the net volumetric reaction rate is the expression,

$$R_{net} = 1/N_{spe} - Y_i \tag{2.3-5}$$

where N_{spe} is the number of species.

```
/***********************************************************
    Net Reaction Rate Example UDF
***********************************************************/
#include "udf.h"

DEFINE_NET_REACTION_RATE(user_net_reaction_rate,c,t,particle,
                         pressure,temp,yi,rr,jac)
{
   int i;
   for(i=0;i<n_spe;i++)
     rr[i] = 1./(real)n_spe - yi[i];
}
```

Hooking a Net Mass Reaction Rate UDF to FLUENT

After the UDF that you have defined using DEFINE_NET_REACTION_RATE is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., user_net_reaction_rate) will become visible and selectable for the Net Reaction Rate function in the User-Defined Function Hooks panel in FLUENT. See Section 6.2.9: Hooking DEFINE_NET_REACTION_RATE UDFs for details.

2.3.10 DEFINE_NOX_RATE

Description

You can use the DEFINE_NOX_RATE to specify a custom NO_x rate for thermal NO, prompt NO, fuel NO and N2O intermediate pathways that can *either* replace the internally-calculated NO_x rate in the source term equation, or be added to the FLUENT rate. The default functionality is to add user-defined rates to the FLUENT-calculated rates. If the Replace with UDF Rate checkbox is checked for a given NO_x formation pathway in the NOx Model panel, then the FLUENT-calculated rate for that NO_x pathway will not be used and it will instead be replaced by the NO_x rate you have defined in your UDF. When you hook a NO_x rate UDF to the graphical interface without checking the Replace with UDF Rate box for a particular pathway, then the user NO_x rate will be added to the internally-calculated rate for the source term calculation.

> *i* Note that a single UDF is used to define the different rates for the four NO_x pathways: thermal NO, prompt NO, fuel NO and N2O intermediate pathway. That is, a NO_x rate UDF can contain up to four separate rate functions that are concatenated in a single source file which you hook to FLUENT.

Usage

```
DEFINE_NOX_RATE(name,c,t,Pollut,Pollut_Par,NOx)
```

Argument Type	**Description**
symbol name	UDF name.
cell_t c	Cell index.
Thread *t	Pointer to cell thread on which the NO_x rate is to be applied.
Pollut_Cell *Pollut	Pointer to the data structure that contains the common data at each cell
Pollut_Parameter *Pollut_Par	Pointer to the data structure that contains auxiliary data.
NOx_Parameter *NOx	Pointer to the data structure that contains data specific to the NO_x model.

Function returns

void

There are six arguments to DEFINE_NOX_RATE: name, c, t, Pollut, Pollut_Par, and NOx. You will supply name, the name of the UDF. c, t, Pollut, Pollut_Par, and NOx are variables that are passed by the FLUENT solver to your function. A DEFINE_NOX_RATE function does not output a value. The calculated NO rates (or other pollutant species rates) are returned through the Pollut structure as the forward rate Pollut->fwdrate and reverse rate Pollut->revrate, respectively.

> The data contained within the NO_x structure is specific *only* to the NO_x model. Alternatively, the Pollut structure contains data at each cell that are useful for all pollutant species (e.g., forward and reverse rates, gas phase temperature, density). The Pollut_Par structure contains auxiliary data common to all pollutant species (e.g., equation solved, universal gas constant, species molecular weights). Note that molecular weights extracted from the Pollut_Par structure (i.e., Pollut_Par->sp[IDX(i)].mw) has units of $kg/kg - mol$. The reverse rate calculated by user must be divided by the respective species mass fraction in order to be consistent with the FLUENT 6.3 implementation (prior versions of FLUENT used explicit division by species mass fraction internally).

Example

The following compiled UDF, named user_nox, exactly reproduces the default FLUENT NO_x rates for the prompt NO pathway. Note that this UDF will replace the FLUENT rate *only* if you select the Replace with UDF option for the prompt NO pathway in the NO_x Model panel.

See Section 3.2.7: NO_x Macros for details about NO_x macros (e.g., POLLUT_EQN, MOLECON, ARRH) that are used in pollutant rate calculations in this UDF.

```
/********************************************************************
   UDF example of User-Defined NOx Rate
   For FLUENT Versions 6.3 or above

   If used with the "Replace with UDF" radio buttons activated,
   this UDF will exactly reproduce the default fluent NOx
   rates for prompt NO pathway.

   The flag "Pollut_Par->pollut_io_pdf == IN_PDF" should always
   be used for rates other than that from char N, so that if
   requested, the contributions will be pdf-integrated. Any
   contribution from char must be included within a switch
   statement of the form "Pollut_Par->pollut_io_pdf == OUT_PDF".
   *
   * Arguments:
```

```
   *   char nox_func_name           - UDF name
   *   cell_t c                     - Cell index
   *   Thread *t                    - Pointer to cell thread on
   *                                  which the NOx rate is to be
   *                                  applied
   *   Pollut_Cell *Pollut          - Pointer to the data structure
   *                                  that contains common data at
   *                                  each cell.
   *                                  structure
   *   Pollut_Parameter *Pollut_Par - Pointer to the data structure
   *                                  that contains auxillary data.
   *   NOx_Parameter *NOx           - Pointer to the data structure
   *                                  that contains data specific
   *                                  to the NOx model.

**********************************************************************/

#include "udf.h"
DEFINE_NOX_RATE(user_nox, c, t, Pollut, Pollut_Par, NOx)
{

    Pollut->fluct.fwdrate = 0.0;
    Pollut->fluct.revrate = 0.0;

    switch (Pollut_Par->pollut_io_pdf) {
    case IN_PDF:
    /* Source terms other than those from char must be included here*/

       if (POLLUT_EQN(Pollut_Par) == EQ_NO) {

           /* Prompt NOx */
           if (NOx->prompt_nox && NOx->prompt_udf_replace) {
           int j;
           real f,rf;
           real xc_fuel=0.0;

           Rate_Const K_PM = {6.4e6,  0.0, 36483.49436};

           f = 4.75 + 0.0819*NOx->c_number
             - 23.2*NOx->equiv_ratio + 32.0*pow(NOx->equiv_ratio,2.)
             - 12.2*pow(NOx->equiv_ratio,3.);

           for (j=FUEL; j<FUEL+NOx->nfspe; j++) {
              xc_fuel += MOLECON(Pollut, j);
           }

           rf = ARRH(Pollut, K_PM);
           rf *= pow((Pollut_Par->uni_R*Pollut->temp_m/Pollut->press),
                 (1.+Pollut->oxy_order));
           rf *= pow(MOLECON(Pollut, O2), Pollut->oxy_order);
           rf *= MOLECON(Pollut, N2)*xc_fuel;

           Pollut->fluct.fwdrate += f*rf;
          }
       }

    case OUT_PDF:
    /* Char Contributions, that do not go into pdf loop must be
       included here */

       break;

    default:
       ;
    }

}
```

Hooking a NO_x Rate UDF to FLUENT

After the UDF that you have defined using DEFINE_NOX_RATE is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., user_nox) will become visible and selectable in the NOx Model panel in FLUENT. See Section 6.2.10: Hooking DEFINE_NOX_RATE UDFs for details.

2.3.11 DEFINE_PR_RATE

Description

You can use DEFINE_PR_RATE to specify a custom particle surface reaction for the multiple surface reactions particle model. During FLUENT execution, the same UDF is called sequentially for all particle surface reactions, so DEFINE_PR_RATE can be used to define custom reaction rates for a single reaction, or for multiple reactions. The volumetric and wall surface reactions are not affected by the definition of this macro and will follow the designated rates. Note that a DEFINE_PR_RATE UDF is *not* called with the coupled solution option, so you will need to disable the Coupled Heat Mass Solution option in the Discrete Phase Model panel when using it. The auxiliary function, zbrent_pr_rate, which is provided below, can be used when there is no analytical solution for the overall particle reaction rate.

Usage

```
DEFINE_PR_RATE(name,c,t,r,mw,ci,p,sf,dif_index,cat_index,rr)
```

Argument Type	**Description**
symbol name	UDF name.
cell_t c	Cell index of current particle.
Thread *t	Pointer to cell thread for particle.
Reaction *r	Pointer to data structure that represents the current reaction.
real *mw	Pointer to array containing gaseous and surface species molecular weights
real *ci	Pointer to array containing gas partial pressures.
Tracked_Particle *p	Pointer to Tracked_Particle data structure that contains data related to the particle being tracked.
real *sf	Pointer to array containing mass fractions of the solid species in the particle char mass at the current time step.
int dif_index	Diffusion controlled species as defined in the Reactions panel for the current reaction.
int cat_index	Catalyst species as defined in the Reactions panel for the current reaction.
real *rr	Pointer to array containing particle reaction rate (kg/s).

Function returns

void

There are eleven arguments to DEFINE_PR_RATE: name, c, t, r, mw, ci, p, sf, dif_index, cat_index, and rr. You supply name, the name of the UDF. c, t, r, mw, ci, p, sf, dif_index, cat_index, and rr are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to set the value referenced by the real pointer rr to the particle reaction rate in kg/s.

Note that p is an argument to many particle-specific macros defined in Section 3.2.7: DPM Macros and can be used to obtain information about particle properties. Also note that the order in which the solid species mass fractions are stored in array sf is the same as the order in which the species are defined in the Selected Solid Species list in the Materials panel, which is opened from the Edit Species names option for the Mixture Material.

DEFINE_PR_RATE is called by FLUENT every time step during the particle tracking calculation. The auxiliary function zbrent_pr_rate is used when there is no analytical solution for the overall particle reaction rate. It uses Brent's method to find the root of a function known to lie between $x1$ and $x2$. The root will be refined until its accuracy has reached tolerance tol. This is demonstrated in Example 2.

Auxiliary function

```
zbrent_pr_rate (real (*func),(real,real [],int [],cxboolean [],char *,) real
ruser[],int iuser[],
cxboolean buser[],char *cuser,real x1 real x2,real tol,cxboolean *ifail)
```

Auxiliary function returns: real

Example 1

The following UDF, named user_pr_rate, specifies a particle reaction rate given by Equation 14.3-9 of the User's Guide , where the effectiveness factor η_r is defined as

$$\eta_r = 1 - x$$

where x is the fractional conversion of the particle char mass. In this case, the UDF will be applied to all surface particle reactions defined in the FLUENT model.

```
/* UDF of specifying the surface reaction rate of a particle */

#include "udf.h"

#define A1  0.002
#define E1  7.9e7

DEFINE_PR_RATE(user_pr_rate,c,t,r,mw,pp,p,sf,dif_i,cat_i,rr)
{
/* Argument types
    cell_t c
    Thread *t
    Reaction *r (reaction structure)
    real *mw  (species molecular weight)
    real *pp  (gas partial pressures)
    Tracked_Particle *p (particle structure)
    real *sf   (current mass fractions of solid species in
                particle char mass)
    int dif_i  (index of diffusion controlled species)
    int cat_i  (index of catalyst species)
    real *rr   (rate of reaction kg/s)
*/

real ash_mass =
P_INIT_MASS(p)*(1.-DPM_CHAR_FRACTION(p)-DPM_VOLATILE_FRACTION(p));

real one_minus_conv =
MAX(0.,(P_MASS(p) -ash_mass) / P_INIT_MASS(p)/ DPM_CHAR_FRACTION(p));

real rate = A1*exp(-E1/UNIVERSAL_GAS_CONSTANT/P_T(p));

*rr=-rate*P_DIAM(p)*P_DIAM(p)*M_PI*sf[0]*one_minus_conv;
}
```

Example 2

The following compiled UDF, named user_rate, specifies a particle reaction rate given by Equation 14.3-4 to Equation 14.3-7 in the User's Guide . The reaction order on the kinetic rate is 0.9 and the effectiveness factor η_r is defined as

$$\eta_r = 1 - x$$

where x is the fractional conversion of the particle char mass. In this case it is necessary to obtain a numerical solution for the overall surface reaction rate.

This UDF is called only for reaction 2, which means that the default FLUENT solution will be used for the rest of the particle surface reactions defined.

```
/* UDF of specifying the surface reaction rate of a particle,
 using a numerical solution */

#include "udf.h"

#define c1  5e-12
#define A1  0.002
#define E1  7.9e7
#define tolerance 1e-4
#define order 0.9

real reaction_rate(real rate, real ruser[], int iuser[], cxboolean buser[],
 char *cuser)
{
    return (ruser[2]*pow(MAX(0.,(ruser[0]-rate/ruser[1])),order) -rate);
}

DEFINE_PR_RATE(user_rate,c,t,r,mw,pp,p,sf,dif_i,cat_i,rr)
{
if (!strcmp(r->name, "reaction-2"))
  {
  cxboolean ifail=FALSE;

  real ash_mass =
  P_INIT_MASS(p)*(1.-DPM_CHAR_FRACTION(p)-DPM_VOLATILE_FRACTION(p));

  real one_minus_conv =
  MAX(0.,(P_MASS(p) -ash_mass) / P_INIT_MASS(p)/ DPM_CHAR_FRACTION(p));
```

```
   real ruser[3];
   int iuser[1];
   cxboolean buser[1];
   char cuser[30];

   real ratemin, ratemax, root;

   ruser[0] = pp[dif_i];
   ruser[1] = MAX(1.E-15, (c1*pow(0.5*(P_T(p)+C_T(c,t)),0.75)/P_DIAM(p)));
   ruser[2] = A1*exp(-E1/UNIVERSAL_GAS_CONSTANT/P_T(p));
   strcpy(cuser, "reaction-2");

   ratemin=0;
   ratemax=ruser[1]*pp[dif_i];

   /* arguments for auxiliary function zbrent_pr_rate */

   root = zbrent_pr_rate(reaction_rate, ruser, iuser, buser, cuser,
                         ratemin, ratemax, tolerance, &ifail);

   if (ifail) root=MAX(1.E-15,ruser[1]);

   *rr=-root*P_DIAM(p)*P_DIAM(p)*M_PI*sf[0]*one_minus_conv;

   Message("Fail status %d\n", ifail);
   Message("Reaction rate for reaction %s : %g\n", cuser, *rr);

  }
 }
```

In this example, a real function named reaction_rate is defined at the top of the UDF. The arguments of reaction_rate are real rate, and the pointer arrays real ruser[], integer iuser[], cxboolean buser[], and char *cuser, which must be declared and defined in the main body of the DEFINE_PR_RATE function.

Typically, if the particle surface reaction rate is described by

```
        rate = f(ruser[],iuser[],rate)
```

then the real function (in this example reaction_rate) should return

```
        f(ruser[],iuser[],rate) - rate
```

The variables cxboolean buser[] and char *cuser can be used to control the flow of the program in cases of complicated rate definitions.

ratemin and ratemax, hold the minimum and maximum possible values of the variable rate, respectively. They define the search interval where the numerical algorithm will search for the root of the equation, as defined in the function reaction_rate. The value of reaction rate rr will be refined until an accuracy specified by the value of tolerance tol is reached.

The variable ifail will take the value TRUE if the root of the function has not been found.

Hooking a Particle Reaction Rate UDF to FLUENT

After the UDF that you have defined using DEFINE_PR_RATE is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., user_pr_rate) will become visible and selectable in the User-Defined Function Hooks panel in FLUENT. See Section 6.2.11: Hooking DEFINE_PR_RATE UDFs for details.

2.3.12 DEFINE_PRANDTL UDFs

The following DEFINE macros can be used to specify Prandtl numbers in FLUENT, for single-phase flows.

DEFINE_PRANDTL_D

Description

You can use DEFINE_PRANDTL_D to specify Prandtl numbers for turbulent dissipation (ϵ).

Usage

```
DEFINE_PRANDTL_D(name,c,t)
```

Argument Type	Description
symbol name	UDF name.
cell_t c	Index of cell on which the Prandtl number function is to be applied.
Thread *t	Pointer to cell thread.

Function returns
real

There are three arguments to DEFINE_PRANDTL_D: name, c, and t. You supply name, the name of the UDF. c and t are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to return the real value for the turbulent dissipation Prandtl number to the solver.

Example

An example of a Prandtl_D UDF is provided below in the source listing for DEFINE_PRANDTL_K.

Hooking a Prandtl Number UDF to FLUENT

After the UDF that you have defined using DEFINE_PRANDTL_D is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., user_pr_d) will become visible and selectable in the Viscous Model panel in FLUENT. See Section 6.2.12: Hooking DEFINE_PRANDTL UDFs for details.

DEFINE_PRANDTL_K

Description

You can use DEFINE_PRANDTL_K to specify Prandtl numbers for turbulence kinetic energy (k).

Usage

DEFINE_PRANDTL_K(name,c,t)

Argument Type	Description
symbol name	UDF name.
cell_t c	Index that identifies the cell on which the Prandtl number function is to be applied.
Thread *t	Pointer to cell thread.

Function returns
real

There are three arguments to DEFINE_PRANDTL_K: name, c, and t. You supply name, the name of the UDF. c and t are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to return the real value for the kinetic energy Prandtl number to the solver.

Example

The following UDF implements a high-Re version of the RNG model, using the k-ϵ option that is activated in FLUENT.

Three steps are required:

1. Set Cmu, C1eps, and C2eps as in the RNG model.
2. Calculate Prandtl numbers for k and ϵ using the UDF.
3. Add the -r source term in the ϵ equation.

In the RNG model, diffusion in k and ϵ equations appears as

$$(\mu + \mu_t) * \alpha$$

while in the standard k-ϵ model, it is given by

$$\mu + \frac{\mu_t}{Pr}$$

For the new implementation, a UDF is needed to define a Prandtl number Pr as

$$Pr = \frac{\mu_t}{[(\mu + \mu_t) * \alpha - \mu]}$$

in order to achieve the same implementation as the original RNG Model.

The following functions (which are concatenated into a single C source code file) demonstrate this usage. Note that the source code must be executed as a compiled UDF.

```
#include "udf.h"

DEFINE_PRANDTL_K(user_pr_k,c,t)
{
  real pr_k, alpha;
  real mu    = C_MU_L(c,t);
  real mu_t  = C_MU_T(c,t);

  alpha = rng_alpha(1., mu + mu_t, mu);

  pr_k = mu_t/((mu+mu_t)*alpha-mu);

  return pr_k;
}

DEFINE_PRANDTL_D(user_pr_d,c,t)
{
  real pr_d, alpha;
  real mu    = C_MU_L(c,t);
  real mu_t  = C_MU_T(c,t);

  alpha = rng_alpha(1., mu + mu_t, mu);

  pr_d = mu_t/((mu+mu_t)*alpha-mu);

  return pr_d;
}

DEFINE_SOURCE(eps_r_source,c,t,dS,eqn)
```

```
{
  real con, source;
  real mu    = C_MU_L(c,t);
  real mu_t  = C_MU_T(c,t);
  real k     = C_K(c,t);
  real d     = C_D(c,t);
  real prod  = C_PRODUCTION(c,t);

  real s =  sqrt(prod/(mu+ mu_t) ) ;
  real eta   = s*k/d;
  real eta_0 = 4.38;
  real term = mu_t*s*s*s/(1.0 + 0.012*eta*eta*eta);

  source = - term * (1. - eta/eta_0);
  dS[eqn] = - term/d;

  return source;
}
```

Hooking a Prandtl Number UDF to FLUENT

After the UDF that you have defined using DEFINE_PRANDTL_K is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., user_pr_k) will become visible and selectable in the Viscous Model panel in FLUENT. See Section 6.2.12: Hooking DEFINE_PRANDTL UDFs for details.

DEFINE_PRANDTL_O

Description

You can use DEFINE_PRANDTL_O to specify Prandtl numbers for specific dissipation (ω in the k-ω model).

Usage

DEFINE_PRANDTL_O(name,c,t)

Argument Type	Description
symbol name	UDF name.
cell_t c	Index that identifies the cell on which the Prandtl number function is to be applied.
Thread *t	Pointer to cell thread.

Function returns
real

There are three arguments to DEFINE_PRANDTL_O: name, c, and t. You supply name, the name of the UDF. c and t are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to return the real value for the specific dissipation Prandtl number to the solver.

Example

```
/* Specifying a Constant Specific Dissipation Prandtl Number */
#include "udf.h"

DEFINE_PRANDTL_O(user_pr_o,c,t)
{
  real pr_o;
  pr_o = 2.;
  return pr_o;
}
```

Hooking a Prandtl Number UDF to FLUENT

After the UDF that you have defined using DEFINE_PRANDTL_O is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., user_pr_o) will become visible and selectable in the Viscous Model panel in FLUENT. See Section 6.2.12: Hooking DEFINE_PRANDTL UDFs for details.

DEFINE_PRANDTL_T

Description

You can use DEFINE_PRANDTL_T to specify Prandtl numbers that appear in the temperature equation diffusion term.

Usage

```
DEFINE_PRANDTL_T(name,c,t)
```

Argument Type	**Description**
symbol name	UDF name.
cell_t c	Index that identifies the cell on which the Prandtl number function is to be applied.
Thread *t	Pointer to cell thread.

Function returns
real

There are three arguments to DEFINE_PRANDTL_T: name, c, and t. You supply name, the name of the UDF. c and t are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to return the real value for the temperature Prandtl number to the solver.

Example

```
/* Specifying a Constant Temperature Prandtl Number */
#include "udf.h"

DEFINE_PRANDTL_T(user_pr_t,c,t)
{
  real pr_t;
  pr_t = 0.85;
  return pr_t;
}
```

Hooking a Prandtl Number UDF to FLUENT

After the UDF that you have defined using DEFINE_PRANDTL_T is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., user_pr_t) will become visible and selectable in the Viscous Model panel in FLUENT. See Section 6.2.12: Hooking DEFINE_PRANDTL UDFs for details.

DEFINE_PRANDTL_T_WALL

Description

You can use DEFINE_PRANDTL_T_WALL to specify Prandtl numbers for thermal wall functions.

Usage

DEFINE_PRANDTL_T_WALL(name,c,t)

Argument Type	Description
symbol name	UDF name.
cell_t c	Index that identifies the cell on which the Prandtl number function is to be applied.
Thread *t	Pointer to cell thread.

Function returns
real

There are three arguments to DEFINE_PRANDTL_T_WALL: name, c, and t. You supply name, the name of the UDF. c and t are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to return the real value for the thermal wall function Prandtl number to the solver.

Example

```
/*************************************************************
  Specifying a constant thermal wall function Prandtl number
  ********************************************************* **/
#include "udf.h"

DEFINE_PRANDTL_T_WALL(user_pr_t_wall,c,t)
{
  real pr_t_wall;
  pr_t_wall = 0.85;
  return pr_t_wall;
}
```

Hooking a Prandtl Number UDF to FLUENT

After the UDF that you have defined using DEFINE_PRANDTL_T_WALL is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., user_pr_t_wall) will become visible and selectable in the Viscous Model panel in FLUENT. See Section 6.2.12: Hooking DEFINE_PRANDTL UDFs for details.

2.3.13 DEFINE_PROFILE

Description

You can use DEFINE_PROFILE to define a custom boundary profile that varies as a function of spatial coordinates or time. Some of the variables you can customize at a boundary are:

- velocity, pressure, temperature, turbulence kinetic energy, turbulence dissipation rate
- mass flux
- target mass flow rate as a function of physical flow time
- species mass fraction (species transport)
- volume fraction (multiphase models)
- wall thermal conditions (temperature, heat flux, heat generation rate, heat transfer coefficients, and external emissivity, etc.)
- wall roughness conditions
- wall shear and stress conditions
- porosity
- porous resistance direction vector
- wall adhesion contact angle (VOF multiphase model)

Note that DEFINE_PROFILE allows you to modify only a single value for wall heat flux. Single values are used in the explicit source term which FLUENT does not linearize. If you want to linearize your source term for wall heat flux and account for conductive and radiative heat transfer separately, you will need to use DEFINE_HEAT_FLUX to specify your UDF.

Some examples of boundary profile UDFs are provided below. For an overview of the FLUENT solution process which shows when a DEFINE_PROFILE UDF is called, refer to Figures 1.9.1, 1.9.2, and 1.9.3.

Usage

DEFINE_PROFILE(name,t,i)

Argument Type	Description
symbol name	UDF name.
Thread *t	Pointer to thread on which boundary condition is to be applied.
int i	Index that identifies the variable that is to be defined. i is set when you hook the UDF with a variable in a boundary condition panel through the graphical user interface. This index is subsequently passed to your UDF by the FLUENT solver so that your function knows which variable to operate on.

Function returns
void

There are three arguments to DEFINE_PROFILE: name, t, and i. You supply name, the name of the UDF. t and i are variables that are passed by the FLUENT solver to your UDF.

While DEFINE_PROFILE is usually used to specify a profile condition on a boundary face zone, it can also be used to specify, or fix, flow variables that are held constant during computation in a cell zone. (Click Section 7.27: Fixing the Values of Variables to go to the User's Guide for more information on fixing values in a cell zone boundary condition.) For these cases, the arguments of the macro will change accordingly.

Note that unlike source term and property UDFs, profile UDFs (defined using DEFINE_PROFILE) are *not* called by FLUENT from within a loop on threads in the boundary zone. The solver passes only the pointer to the thread associated with the boundary zone to the DEFINE_PROFILE macro. Your UDF will need to do the work of looping over all of the faces in the thread, computing the face value for the boundary variable, and then storing the value in memory. Fluent has provided you with a face looping macro to loop over all faces in a thread (begin_f_loop...). See Chapter 3: Additional Macros for Writing UDFs for details.

F_PROFILE is typically used along with DEFINE_PROFILE and is a predefined macro supplied by Fluent. F_PROFILE stores a boundary condition in memory for a given face and thread and is nested within the face loop as shown in the examples below. It is important to note that the index i that is an argument to DEFINE_PROFILE is the same argument to F_PROFILE. F_PROFILE uses the thread pointer t, face identifier f, and index i to set the appropriate boundary face value in memory. See Section 3.2.6: Set Boundary Condition Value (F_PROFILE) for a description of F_PROFILE. Note that in the case of porosity profiles, you can also utilize C_PROFILE to define those types of functions. See the example

UDFs provided below.

In multiphase cases a DEFINE_PROFILE UDF may be called more than once (particularly if the profile is used in a mixture domain thread). If this needs to be avoided, then add the prefix MP_ to the UDF name. The function will then be called only once even if it is used for more than one profile.

Example 1 - Pressure Profile

The following UDF, named pressure_profile, generates a parabolic pressure profile according to the equation

$$p(y) = 1.1 \times 10^5 - 0.1 \times 10^5 \left(\frac{y}{0.0745}\right)^2$$

Note that this UDF assumes that the grid is generated such that the origin is at the geometric center of the boundary zone to which the UDF is to be applied. y is 0.0 at the center of the inlet and extends to ±0.0745 at the top and bottom of the inlet. The source code can be interpreted or compiled in FLUENT.

```
/***********************************************************************
   UDF for specifying steady-state parabolic pressure profile boundary
   profile for a turbine vane
 ***********************************************************************/

#include "udf.h"

DEFINE_PROFILE(pressure_profile,t,i)
{
  real x[ND_ND];                /* this will hold the position vector */
  real y;
  face_t f;

  begin_f_loop(f,t)
    {
      F_CENTROID(x,f,t);
      y = x[1];
      F_PROFILE(f,t,i) = 1.1e5 - y*y/(.0745*.0745)*0.1e5;
    }
  end_f_loop(f,t)
}
```

The function named pressure_profile has two arguments: t and i. t is a pointer to the face's thread, and i is an integer that is a numerical label for the variable being set within each loop.

Within the function body variable f is declared as a face. A one-dimensional array x and variable y are declared as real data types. Following the variable declarations, a looping macro is used to loop over each face in the zone to create a profile, or an array of data. Within each loop, F_CENTROID returns the value of the face centroid (array x) for the face with index f that is on the thread pointed to by t. The y coordinate stored in x[1] is assigned to variable y, and is then used to calculate the pressure. This value is then assigned to F_PROFILE which uses the integer i (passed to it by the solver, based on your selection of the UDF as the boundary condition for pressure in the Pressure Inlet panel) to set the pressure face value in memory.

Example 2 - Velocity, Turbulent Kinetic Energy, and Turbulent Dissipation Rate Profiles

In the following example, DEFINE_PROFILE is used to generate profiles for the x velocity, turbulent kinetic energy, and dissipation rate, respectively, for a 2D fully-developed duct flow. Three separate UDFs named x_velocity, k_profile, and dissip_profile are defined. These functions are concatenated in a single C source file and can be interpreted or compiled in FLUENT.

The 1/7th power law is used to specify the x velocity component:

$$v_x = v_{x,\mathrm{free}} \left(\frac{y}{\delta}\right)^{1/7}$$

A fully-developed profile occurs when δ is one-half the duct height. In this example, the mean x velocity is prescribed and the peak (free-stream) velocity is determined by averaging across the channel.

The turbulent kinetic energy is assumed to vary linearly from a near-wall value of

$$k_{\mathrm{nw}} = \frac{u_\tau^2}{\sqrt{C_\mu}}$$

to a free-stream value of

$$k_{\mathrm{inf}} = 0.002 u_{\mathrm{free}}^2$$

The dissipation rate is given by

$$\epsilon = \frac{C_\mu^{3/4}(k^{3/2})}{\ell}$$

where the mixing length ℓ is the minimum of κy and 0.085δ. (κ is the von Karman constant = 0.41.)

The friction velocity and wall shear take the forms:

$$u_\tau = \sqrt{\tau_w/\rho}$$

$$\tau_w = \frac{f\rho u_{\rm free}^2}{2}$$

The friction factor is estimated from the Blasius equation:

$$f = 0.045\left(\frac{u_{\rm free}\delta}{\nu}\right)^{-1/4}$$

```
/***********************************************************************
     Concatenated UDFs for fully-developed turbulent inlet profiles
************************************************************************/

/*#include "udf.h"*/

#define YMIN 0.0                        /* constants  */
#define YMAX 0.4064
#define UMEAN 1.0
#define B 1./7.
#define DELOVRH 0.5
#define VISC 1.7894e-05
#define CMU 0.09
#define VKC 0.41


/*  profile for x-velocity    */


DEFINE_PROFILE(x_velocity,t,i)
{
  real y, del, h, x[ND_ND], ufree;      /* variable declarations */
  face_t f;

  h = YMAX - YMIN;
  del = DELOVRH*h;
  ufree = UMEAN*(B+1.);

  begin_f_loop(f,t)
```

```
    {
      F_CENTROID(x,f,t);
      y = x[1];

      if (y <= del)
         F_PROFILE(f,t,i) = ufree*pow(y/del,B);
      else
         F_PROFILE(f,t,i) = ufree*pow((h-y)/del,B);
    }
  end_f_loop(f,t)
}

/*  profile for kinetic energy  */

DEFINE_PROFILE(k_profile,t,i)
{
  real y, del, h, ufree, x[ND_ND];
  real ff, utau, knw, kinf;
  face_t f;

  h = YMAX - YMIN;
  del = DELOVRH*h;
  ufree = UMEAN*(B+1.);
  ff = 0.045/pow(ufree*del/VISC,0.25);
  utau=sqrt(ff*pow(ufree,2.)/2.0);
  knw=pow(utau,2.)/sqrt(CMU);
  kinf=0.002*pow(ufree,2.);

  begin_f_loop(f,t)
    {
      F_CENTROID(x,f,t);
      y=x[1];

      if (y <= del)
        F_PROFILE(f,t,i)=knw+y/del*(kinf-knw);
      else
        F_PROFILE(f,t,i)=knw+(h-y)/del*(kinf-knw);
    }
  end_f_loop(f,t)
}

/* profile for dissipation rate  */
```

```
DEFINE_PROFILE(dissip_profile,t,i)
{
  real y, x[ND_ND], del, h, ufree;
  real ff, utau, knw, kinf;
  real mix, kay;
  face_t f;

  h = YMAX - YMIN;
  del = DELOVRH*h;
  ufree = UMEAN*(B+1.);
  ff = 0.045/pow(ufree*del/VISC,0.25);
  utau=sqrt(ff*pow(ufree,2.)/2.0);
  knw=pow(utau,2.)/sqrt(CMU);
  kinf=0.002*pow(ufree,2.);

  begin_f_loop(f,t)
    {
      F_CENTROID(x,f,t);
      y=x[1];

      if (y <= del)
        kay=knw+y/del*(kinf-knw);
      else
        kay=knw+(h-y)/del*(kinf-knw);

      if (VKC*y < 0.085*del)
        mix = VKC*y;
      else
        mix = 0.085*del;

      F_PROFILE(f,t,i)=pow(CMU,0.75)*pow(kay,1.5)/mix;
    }
  end_f_loop(f,t)
}
```

Example 3 - Fixed Velocity UDF

In the following example DEFINE_PROFILE is used to fix flow variables that are held constant during computation in a cell zone. Three separate UDFs named fixed_u, fixed_v, and fixed_ke are defined in a single C source file. They specify fixed velocities that simulate the transient startup of an impeller in an impeller-driven mixing tank. The physical impeller is simulated by fixing the velocities and turbulence quantities using the fix option in FLUENT. Click Section 7.27: Fixing the Values of Variables to go to the User's Guide for more information on fixing variables.

```
/***********************************************************************
   Concatenated UDFs for simulating an impeller using fixed velocity
************************************************************************/

#include "udf.h"

#define FLUID_ID 1
#define ua1 -7.1357e-2
#define ua2 54.304
#define ua3 -3.1345e3
#define ua4 4.5578e4
#define ua5 -1.9664e5

#define va1 3.1131e-2
#define va2 -10.313
#define va3 9.5558e2
#define va4 -2.0051e4
#define va5 1.1856e5

#define ka1 2.2723e-2
#define ka2 6.7989
#define ka3 -424.18
#define ka4 9.4615e3
#define ka5 -7.7251e4
#define ka6 1.8410e5

#define da1 -6.5819e-2
#define da2 88.845
#define da3 -5.3731e3
#define da4 1.1643e5
#define da5 -9.1202e5
#define da6 1.9567e6
```

```
DEFINE_PROFILE(fixed_u,t,i)
{
  cell_t c;
  real x[ND_ND];
  real r;

  begin_c_loop(c,t)
    {
/* centroid is defined to specify position dependent profiles */

      C_CENTROID(x,c,t);
      r =x[1];
      F_PROFILE(c,t,i) =
ua1+(ua2*r)+(ua3*r*r)+(ua4*r*r*r)+(ua5*r*r*r*r);
}
  end_c_loop(c,t)
}


DEFINE_PROFILE(fixed_v,t,i)
{
  cell_t c;
  real x[ND_ND];
  real r;

  begin_c_loop(c,t)
    {
/* centroid is defined to specify position dependent profiles*/

      C_CENTROID(x,c,t);
      r =x[1];
      F_PROFILE(c,t,i) =
va1+(va2*r)+(va3*r*r)+(va4*r*r*r)+(va5*r*r*r*r);
}
  end_c_loop(c,t)
}

DEFINE_PROFILE(fixed_ke,t,i)
{
  cell_t c;
  real x[ND_ND];
  real r;

  begin_c_loop(c,t)
    {
/* centroid is defined to specify position dependent profiles*/
      C_CENTROID(x,c,t);
      r =x[1];
      F_PROFILE(c,t,i) =
ka1+(ka2*r)+(ka3*r*r)+(ka4*r*r*r)+(ka5*r*r*r*r)+(ka6*r*r*r*r*r);
    }
  end_c_loop(c,t)
}
```

Example 4 - Wall Heat Generation Rate Profile

The following UDF, named wallheatgenerate, generates a heat generation rate profile for a planar conduction wall. Once interpreted or compiled, you can activate this UDF in the Wall boundary condition panel in FLUENT.

```
/*  Wall Heat Generation Rate Profile UDF  */

#include "udf.h"

DEFINE_PROFILE(wallheatgenerate,thread,i)
{
  real source = 0.001;
  face_t f;

  begin_f_loop(f,thread)
    F_PROFILE(f,thread,i) = source;
  end_f_loop(f,thread)
}
```

Example 5 - Viscous Resistance Profile in a Porous Zone

You can either use F_PROFILE or C_PROFILE to define a viscous resistance profile in a porous zone. Below are two sample UDFs that demonstrate the usage of F_PROFILE and C_PROFILE, respectively. Note that porosity functions are hooked to FLUENT in the Porous Zone tab in the appropriate Fluid boundary conditions panel.

The following UDF, named vis_res, generates a viscous resistance profile in a porous zone. Once interpreted or compiled and loaded, you can activate this UDF in the Fluid boundary condition panel in FLUENT.

```
/*  Viscous Resistance Profile UDF in a Porous Zone  that utilizes F_PROFILE*/

#include "udf.h"

DEFINE_PROFILE(vis_res,t,i)
{
  real x[ND_ND];
  real a;
  cell_t c;

  begin_c_loop(c,t)
  {
    C_CENTROID(x,c,t);
    if( x[1] < (x[0]-0.01) )
      a = 1e9;
    else
      a = 1.0;
    F_PROFILE(c,t,i) = a;
  }
  end_c_loop(c,t)
}

/*  Viscous Resistance Profile UDF in a Porous Zone that utilizes C_PROFILE*/

#include "udf.h"

DEFINE_PROFILE{porosity_function, t, nv}
{
   cell_t c;
   begin_c_loop(c,t)
      C_PROFILE(c,t,nv) = USER INPUT  ;
   end_c_loop(c,t)
}
```

Example 6 - Porous Resistance Direction Vector

The following UDF contains profile functions for two porous resistance direction vectors that utilize C_PROFILE. These profiles can be hooked to corresponding direction vectors under Porous Zone in the Fluid boundary condition panel.

```
/*  Porous Resistance Direction Vector Profile that utilizes C_PROFILE*/

#include "udf.h"

DEFINE_PROFILE{dir1, t, nv}
{
   cell_t c;
   begin_c_loop(c,t)
      C_PROFILE(c,t,nv) = USER INPUT1  ;
   end_c_loop(c,t)
}

DEFINE_PROFILE{dir2, t, nv}
{
   cell_t c;
   begin_c_loop(c,t)
      C_PROFILE(c,t,nv) = USER INPUT2  ;
   end_c_loop(c,t)
}
```

Example 7 -Target Mass Flow Rate UDF as a Function of Physical Flow Time

For some unsteady problems, it is desirable that the target mass flow rate be a function of the physical flow time. This boundary condition can be applied using a DEFINE_PROFILE UDF. The following UDF, named tm_pout2, adjusts the mass flow rate from 1.00kg/s to 1.35kg/s when the physical time step is greater than 0.2 seconds. Once interpreted or compiled, you can activate this UDF in the Pressure Outlet boundary condition panel in FLUENT by selecting the Specify target mass-flow rate option, and then choosing the UDF name from the corresponding drop-down list.

Note that the mass flow rate profile is a function of time and only one constant value should be applied to all zone faces at a given time.

```
/* UDF for setting target mass flow rate in pressure-outlet          */
/* at t<0.2 sec the target mass flow rate set to 1.00 kg/s           */
/* when t>0.2 sec the target mass flow rate will change to 1.35 kg/s */
```

```
#include "udf.h"
DEFINE_PROFILE(tm_pout2, t, nv)
{
  face_t f ;

  real flow_time = RP_Get_Real("flow-time");

  if (flow_time < 0.2 )
    {
      printf("Time            = %f  sec. \n",flow_time);
      printf("Targeted mass-flow rate set at 1.0 kg/s \n");

      begin_f_loop(f,t)
       {
         F_PROFILE(f,t,nv) = 1.0 ;
       }
      end_f_loop(f,t)
     }
  else
    {
      printf("Time            = %f  sec. \n",flow_time);
      printf("Targeted mass-flow rate set at 1.35 kg/s \n") ;


      begin_f_loop(f,t)
        {
          F_PROFILE(f,t,nv) = 1.35 ;
        }
      end_f_loop(f,t)
     }
}
```

Hooking a Boundary Profile UDF to FLUENT

After the UDF that you have defined using DEFINE_PROFILE is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., vis_res) will become visible and selectable in the appropriate boundary condition panel (e.g., the Velocity Inlet panel) in FLUENT. See Section 6.2.13: Hooking DEFINE_PROFILE UDFs for details.

2.3.14 DEFINE_PROPERTY UDFs

Description

You can use DEFINE_PROPERTY to specify a custom material property in FLUENT for single-phase and multiphase flows. When you are writing a user-defined mixing law UDF for a mixture material, you will need to use special utilities to access species material properties. These are described below. If you want to define a custom mass diffusivity property when modeling species transport, you must use DEFINE_DIFFUSIVITY instead of DEFINE_PROPERTY. See Section 2.3.3: DEFINE_DIFFUSIVITY for details on DEFINE_DIFFUSIVITY UDFs. For an overview of the FLUENT solution process which shows when a DEFINE_PROPERTY UDF is called, refer to Figures 1.9.1, 1.9.2, and 1.9.3.

Some of the properties you can customize using DEFINE_PROPERTY are:

- density (as a function of temperature)
- viscosity
- thermal conductivity
- absorption and scattering coefficients
- laminar flow speed
- rate of strain
- user-defined mixing laws for density, viscosity, and thermal conductivity of mixture materials

i UDFs cannot be used to define specific heat properties; specific heat data can be accessed only and not modified in FLUENT.

i Note that when you specify a user-defined density function for a compressible liquid flow application, you must also include a speed of sound function in your model. Compressible liquid density UDFs can be used in the pressure-based solver and for single phase, multiphase mixture and cavitation models, only. See the example below for details.

For Multiphase Flows

- surface tension coefficient (VOF model)
- cavitation parameters including surface tension coefficient and vaporization pressure (Mixture, cavitation models)
- heat transfer coefficient (Mixture model)
- particle or droplet diameter (Mixture model)
- speed of sound function (Mixture, cavitation models)
- density (as a function of pressure) for compressible liquid flows only (Mixture, cavitation models)
- granular temperature and viscosity (Mixture, Eulerian models)
- granular bulk viscosity (Eulerian model)
- granular conductivity (Eulerian model)
- frictional pressure and viscosity (Eulerian model)
- frictional modulus (Eulerian model)
- elasticity modulus (Eulerian model)
- radial distribution (Eulerian model)
- solids pressure (Eulerian, Mixture models)
- diameter (Eulerian, Mixture models)

Usage

```
DEFINE_PROPERTY(name,c,t)
```

Argument Type	Description
`symbol name`	UDF name.
`cell_t c`	Cell index.
`Thread *t`	Pointer to cell thread on which the property function is to be applied.

Function returns

`real`

There are three arguments to DEFINE_PROPERTY: name, c, and t. You supply name, the name of the UDF. c and t are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to compute the real property *only* for a single cell and return it to the solver.

Note that like source term UDFs, property UDFs (defined using DEFINE_PROPERTY) are called by FLUENT from within a loop on cell threads. The solver passes all of the variables needed to allow a DEFINE_PROPERTY UDF to define a custom material, since properties are assigned on a cell basis. Consequently, your UDF will *not* need to loop over cells in a zone since FLUENT is already doing it.

Auxiliary Utilities

Some commonly-used auxiliary utilities for custom property UDFs are described below. They are generic_property, MATERIAL_PROPERTY, THREAD_MATERIAL, and mixture_species_loop.

generic_property is a general purpose function that returns the real value for the given property id for the given thread material. It is defined in prop.h and is used only for species properties.

The following Property_ID variables are available:

- PROP_rho, density
- PROP_mu, viscosity
- PROP_ktc, thermal conductivity

```
generic_property (name,c,t,prop,id,T)
```

Argument Type	**Description**
symbol name	Function name.
cell_t c	Cell index.
Thread *t	Pointer to cell thread on which property function is to be applied.
Property *prop	Pointer to property array for the thread material that can be obtained through the macro MATERIAL_PROPERTY(m) See below.
Property_ID id	Property ID of the required property you want to define a custom mixing law for (e.g., PROP_ktc for thermal conductivity). See below for list of variables.
real T	Temperature at which the property is to be evaluated (used only if a polynomial method is specified).

Function returns

real

MATERIAL_PROPERTY is defined in materials.h and returns a real pointer to the Property array prop for the given material pointer m.

```
MATERIAL_PROPERTY(m)
```

Argument Type	**Description**
Material *m	Material pointer.

Function returns
real

THREAD_MATERIAL is defined in threads.h and returns real pointer m to the Material that is associated with the given cell thread t.

> *i* Note that in previous versions of FLUENT, THREAD_MATERIAL took two arguments (t,i), but now only takes one (t).

```
THREAD_MATERIAL(t)
```

Argument Type	**Description**
Thread *t	Pointer to cell thread.

Function returns
real

mixture_species_loop is defined in materials.h and loops over all of the species for the given mixture material.

```
mixture_species_loop (m,sp,i)
```

Argument Type	**Description**
Material *m	Material pointer.
Material *sp	Species pointer.
int i	Species index.

Function returns
real

Example 1 - Temperature-dependent Viscosity Property

The following UDF, named cell_viscosity, generates a variable viscosity profile to simulate solidification. The function is called for every cell in the zone. The viscosity in the warm ($T > 288$ K) fluid has a molecular value for the liquid (5.5×10^{-3}kg/m-s), while the viscosity for the cooler region ($T < 286$ K) has a much larger value (1.0 kg/m-s). In the intermediate temperature range ($286 \text{ K} \leq T \leq 288 \text{ K}$), the viscosity follows a linear profile that extends between the two values given above:

$$\mu = 143.2135 - 0.49725T \qquad (2.3\text{-}6)$$

This model is based on the assumption that as the liquid cools and rapidly becomes more viscous, its velocity will decrease, thereby simulating solidification. Here, no correction is made for the energy field to include the latent heat of freezing. The source code can be interpreted or compiled in FLUENT.

```
/*********************************************************************
   UDF that simulates solidification by specifying a temperature-
   dependent viscosity property
 *********************************************************************/
#include "udf.h"

DEFINE_PROPERTY(cell_viscosity,c,t)
{
  real mu_lam;
  real temp = C_T(c,t);

  if (temp > 288.)
    mu_lam = 5.5e-3;
  else if (temp > 286.)
    mu_lam = 143.2135 - 0.49725 * temp;
  else
    mu_lam = 1.;

  return mu_lam;
}
```

The function cell_viscosity is defined on a cell. Two real variables are introduced: temp, the value of C_T(c,t), and mu_lam, the laminar viscosity computed by the function. The value of the temperature is checked, and based upon the range into which it falls, the appropriate value of mu_lam is computed. At the end of the function the computed value for the viscosity (mu_lam) is returned to the solver.

Example 2 - User-defined Mixing Law for Thermal Conductivity

You can use DEFINE_PROPERTY to define custom user-defined mixing laws for density, viscosity, and conductivity of mixture materials. In order to access species material properties your UDF will need to utilize auxiliary utilities that are described above.

The following UDF, named mass_wtd_k, is an example of a mass-fraction weighted conductivity function. The UDF utilizes the generic_property function to obtain properties of individual species. It also makes use of MATERIAL_PROPERTY and THREAD_MATERIAL.

```
/*******************************************************************
  UDF that specifies a custom mass-fraction weighted conductivity
*******************************************************************/
#include "udf.h"

DEFINE_PROPERTY(mass_wtd_k,c,t)
{
    real sum = 0.; int i;
    Material *sp;
    real ktc;
    Property *prop;
    mixture_species_loop(THREAD_MATERIAL(t),sp,i)
      {
        prop = (MATERIAL_PROPERTY(sp));
        ktc = generic_property(c,t,prop,PROP_ktc,C_T(c,t));
        sum += C_YI(c,t,i)*ktc;
      }
    return sum;
}
```

Example 3 - Surface Tension Coefficient UDF

DEFINE_PROPERTY can also be used to define a surface tension coefficient UDF for the multiphase VOF model. The following UDF specifies a surface tension coefficient as a quadratic function of temperature. The source code can be interpreted or compiled in FLUENT.

```
/***************************************************************
Surface Tension Coefficient UDF for the multiphase VOF Model
***************************************************************/

#include "udf.h"
DEFINE_PROPERTY(sfc,c,t)
{
    real T = C_T(c,t);
    return 1.35 - 0.004*T + 5.0e-6*T*T;
}
```

Note that surface tension UDFs for the VOF and Mixture multiphase models are both hooked to FLUENT in the Phase Interaction panel, but in different ways. For the VOF model, the function hook is located in the Surface Tension tab in the panel. For the Mixture model, however, the function hook is located in the Mass tab, and will become visible upon selecting the Cavitation option.

Example 4 - Density Function for Compressible Liquids

Liquid density is not a constant but is instead a function of the pressure field. In order to stabilize the pressure solution for compressible flows in FLUENT, an extra term related to the speed of sound is needed in the pressure correction equation. Consequently, when you want to define a custom density function for a compressible flow, your model must also include a speed of sound function. Although you can direct FLUENT to calculate a speed of sound function by choosing one of the available methods (e.g., piecewise-linear, polynomial) in the Materials panel, as a general guideline you should define a speed of sound function along with your density UDF using the formulation:

$$\sqrt{(\frac{\partial p}{\partial \rho})}$$

For simplicity, it is recommended that you concatenate the density and speed of sound functions into a single UDF source file.

The following UDF source code example contains two concatenated functions: a density function named superfluid_density that is defined in terms of pressure and a custom speed of sound function named sound_speed.

```
/********************************************************************
Density and speed of sound UDFs for compressible liquid flows.
For use with pressure-based solver, for single phase, multiphase mixture
or cavitation models only.
Note that for density function, dp is the difference between a cell
absolute pressure and reference pressure.
*********************************************************************/
#include "udf.h"

#define BMODULUS 2.2e9
#define rho_ref 1000.0
#define p_ref 101325

DEFINE_PROPERTY(superfluid_density, c, t)
{
    real rho;
    real p, dp;
    real p_operating;

    p_operating = RP_Get_Real ("operating-pressure");

    p = C_P(c,t) + p_operating;
    dp = p-p_ref;
    rho = rho_ref/(1.0-dp/BMODULUS);
    return rho;
}


DEFINE_PROPERTY(sound_speed, c,t)

{
    real a;
    real p, dp,p_operating;

    p_operating = RP_Get_Real ("operating-pressure");

    p = C_P(c,t) + p_operating;
    dp = p-p_ref;
    a = (1.-dp/BMODULUS)*sqrt(BMODULUS/rho_ref);
    return a;
}
```

Hooking a Property UDF to FLUENT

After the UDF that you have defined using DEFINE_PROPERTY is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., sound_speed) will become visible and selectable in graphics panels in FLUENT.
See Section 6.2.14: Hooking DEFINE_PROPERTY UDFs for details.

2.3.15 DEFINE_SCAT_PHASE_FUNC

Description

You can use DEFINE_SCAT_PHASE_FUNC to specify the radiation scattering phase function for the Discrete Ordinates (DO) model. The function computes two values: the fraction of radiation energy scattered from direction i to direction j, and the forward scattering factor.

Usage

DEFINE_SCAT_PHASE_FUNC(name,cosine,f)

Argument Type	**Description**
symbol name	UDF name.
real cosine	Cosine of the angle between directions i and j.
real *f	Pointer to the location in memory where the real forward scattering factor is stored.

Function returns
real

There are three arguments to DEFINE_SCAT_PHASE_FUNC: name, cosine, and f. You supply name, the name of the UDF. cosine and f are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to compute the real fraction of radiation energy scattered from direction i to direction j and return it to the solver. Note that the solver computes and stores a scattering matrix for each material by calling this function for each unique pair of discrete ordinates.

Example

In the following example, a number of UDFs are concatenated in a single C source file. These UDFs implement backward and forward scattering phase functions that are cited by Jendoubi et al. [1]. The source code can be interpreted or compiled in FLUENT.

```
/*******************************************************************
   UDFs that implement backward and forward scattering
   phase functions as cited by Jendoubi et. al.
********************************************************************/

#include "udf.h"

DEFINE_SCAT_PHASE_FUNC(ScatPhiB2,c,fsf)
```

```
{
  real phi=0;
  *fsf = 0;
  phi = 1.0 - 1.2*c + 0.25*(3*c*c-1);
  return (phi);
}

DEFINE_SCAT_PHASE_FUNC(ScatPhiB1,c,fsf)
{
  real phi=0;
  *fsf = 0;
  phi = 1.0 - 0.56524*c + 0.29783*0.5*(3*c*c-1) +
    0.08571*0.5*(5*c*c*c-3*c) + 0.01003/8*(35*c*c*c*c-30*c*c+3) +
    0.00063/8*(63*c*c*c*c*c-70*c*c*c+15*c);
  return (phi);
}

DEFINE_SCAT_PHASE_FUNC(ScatPhiF3,c,fsf)
{
  real phi=0;
  *fsf = 0;
  phi = 1.0 + 1.2*c + 0.25*(3*c*c-1);
  return (phi);
}

DEFINE_SCAT_PHASE_FUNC(ScatPhiF2,c,fsf)
{
  real phi=0;
  real coeffs[9]={1,2.00917,1.56339,0.67407,0.22215,0.04725,
                  0.00671,0.00068,0.00005};
  real P[9];
  int i;
  *fsf = 0;
  P[0] = 1;
  P[1] = c;
  phi = P[0]*coeffs[0] + P[1]*coeffs[1];
  for(i=1;i<7;i++)
    {
      P[i+1] = 1/(i+1.0)*((2*i+1)*c*P[i] - i*P[i-1]);
      phi += coeffs[i+1]*P[i+1];
    }
  return (phi);
}
```

```
DEFINE_SCAT_PHASE_FUNC(ScatIso,c,fsf)
{
  *fsf=0;
  return (1.0);
}
```

Hooking a Scattering Phase UDF to FLUENT

After the UDF that you have defined using DEFINE_SCAT_PHASE_FUNCTION is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name that you specified in the DEFINE macro argument (e.g., ScatPhiB) will become visible and selectable in the Materials panel in FLUENT.
See Section 6.2.15: Hooking DEFINE_SCAT_PHASE_FUNC UDFs for details.

2.3.16 DEFINE_SOLAR_INTENSITY

Description

You can use the DEFINE_SOLAR_INTENSITY macro to define direct solar intensity or diffuse solar intensity UDFs for the solar load model. See Chapter 13: Modeling Heat Transfer to go to the User's Guide for more information on the solar load model.

Note that solar intensity UDFs are used with the Solar Model, which is available only for the 3d geometries in FLUENT.

Usage

DEFINE_SOLAR_INTENSITY(name,sum_x,sun_y,sun_z,S_hour,S_minute)

Argument Type	Description
symbol name	UDF name.
real sun_x	x component of the sun direction vector.
real sun_y	y component of the sun direction vector.
real sun_z	z component of the sun direction vector.
real S_hour	Time in hours.
real S_minute	Time in minutes.

Function returns

real

There are six arguments to DEFINE_SOLAR_INTENSITY: name, sun_x, sun_y, sun_z, S_hour, and S_minute. You provide the name of your user-defined function. The variables sun_x, sun_y, sun_z, S_hour, and S_minute are passed by the FLUENT solver to your UDF. Your UDF will need to compute the direct or diffuse solar irradiation and return the real value (in w/m^2) to the solver.

Example

The following source code contains two UDFs: sol_direct_intensity computes the direct solar irradiation and returns it to the FLUENT solver, and sol_diffuse_intensity computes the diffuse solar irradiation.

```
#include "udf.h"

DEFINE_SOLAR_INTENSITY(sol_direct_intensity,sun_x,sun_y,sun_z,hour,minute)
{
  real intensity;
  intensity = 1019;
  printf("solar-time=%f intensity=%e\n", minute, intensity);
  return intensity;
}

DEFINE_SOLAR_INTENSITY(sol_diffuse_intensity,sun_x,sun_y,sun_z,hour,minute)
{
  real intensity;
  intensity = 275;
  printf("solar-time=%f intensity-diff=%e\n", minute, intensity);
  return intensity;
}
```

Hooking a Solar Intensity UDF to FLUENT

After the UDF that you have defined using DEFINE_SOLAR_INTENSITY is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name that you specified (e.g., sol_direct_intensity) in the DEFINE macro argument will become visible and selectable for Direct Solar Irradiation and Diffuse Solar Irradiation in the Radiation Model panel in FLUENT. Note that the solar load model must be enabled. See Section 6.2.16: Hooking DEFINE_SOLAR_INTENSITY UDFs for details.

2.3.17 DEFINE_SOURCE

Description

You can use DEFINE_SOURCE to specify custom source terms for the different types of solved transport equations in FLUENT (except the discrete ordinates radiation model) including:

- mass
- momentum
- k, ϵ
- energy (also for solid zones)
- species mass fractions
- P1 radiation model
- user-defined scalar (UDS) transport
- granular temperature (Eulerian, Mixture multiphase models)

Usage

DEFINE_SOURCE(name,c,t,dS,eqn)

Argument Type	**Description**
symbol name	UDF name.
cell_t c	Index that identifies cell on which the source term is to be applied.
Thread *t	Pointer to cell thread.
real dS[]	Array that contains the derivative of the source term with respect to the dependent variable of the transport equation.
int eqn	Equation number.

Function returns
real

There are five arguments to DEFINE_SOURCE: name, c, t, dS, and eqn. You supply name, the name of the UDF. c, t, dS, and eqn are variables that are passed by the FLUENT solver to your UDF. Note that the source term derivatives may be used to linearize the source term if they enhance the stability of the solver. To illustrate this, note that the source term can be expressed, in general, as Equation 2.3-7, where ϕ is the dependent variable, A is the explicit part of the source term, and $B\phi$ is the implicit part.

$$S_\phi = A + B\phi \tag{2.3-7}$$

Specifying a value for B in Equation 2.3-7 can enhance the stability of the solution and help convergence rates due to the increase in diagonal terms on the solution matrix. FLUENT automatically determines if the value of B that is given by the user will aid stability. If it does, then FLUENT will define A as $S^* - (\partial S/\partial\phi)^*\phi^*$, and B as $(\partial S/\partial\phi)^*$. If not, the source term is handled explicitly.

Your UDF will need to compute the `real` source term *only* for a single cell and return the value to the solver, but you have the choice of setting the implicit term `dS[eqn]` to $dS/d\phi$, or forcing the explicit solution of the source term by setting it equal to 0.0.

Note that like property UDFs, source term UDFs (defined using `DEFINE_SOURCE`) are called by FLUENT from within a loop on cell threads. The solver passes to the `DEFINE_SOURCE` term UDF all the necessary variables it needs to define a custom source term, since source terms are solved on a cell basis. Consequently, your UDF will *not* need to loop over cells in the thread since FLUENT is already doing it.

The units on all source terms are of the form generation-rate/volume. For example, a source term for the continuity equation would have units of kg/m^3-s.

Example

The following UDF, named `xmom_source`, is used to add source terms in FLUENT. The source code can be interpreted or compiled. The function generates an x-momentum source term that varies with y position as

$$\text{source} = -0.5 C_2 \rho y |v_x| v_x$$

Suppose

$$\text{source} = S = -A|v_x|v_x$$

where

$$A = 0.5 C_2 \rho y$$

Then

$$\frac{dS}{dv_x} = -A|v_x| - A v_x \frac{d}{dv_x}\left(|v_x|\right)$$

The source term returned is

$$\text{source} = -A|v_x|v_x$$

and the derivative of the source term with respect to v_x (true for both positive and negative values of v_x) is

$$\frac{dS}{dv_x} = -2A|v_x|$$

```
/*****************************************************************/
/* UDF for specifying an x-momentum source term in a spatially    */
/* dependent porous media                                         */
/*****************************************************************/

#include "udf.h"

#define C2 100.0

DEFINE_SOURCE(xmom_source,c,t,dS,eqn)
{
  real x[ND_ND];
  real con, source;

  C_CENTROID(x,c,t);
  con = C2*0.5*C_R(c,t)*x[1];

  source = -con*fabs(C_U(c, t))*C_U(c,t);
  dS[eqn] = -2.*con*fabs(C_U(c,t));

  return source;
}
```

Hooking a Source UDF to FLUENT

After the UDF that you have defined using DEFINE_SOURCE is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., xmom_source) will become visible and selectable in the Fluid or Solid boundary condition panel in FLUENT. See Section 6.2.17: Hooking DEFINE_SOURCE UDFs for details.

2.3.18 DEFINE_SOX_RATE

Description

You can use DEFINE_SOX_RATE to specify a custom SO_x rate that can either replace the internally calculated SOx rate in the source term equation, or be added to the FLUENT rate. The default functionality is to add user-defined rates to the FLUENT-calculated rates. If the Replace with UDF Rate checkbox is checked in the SOx Model panel, then the FLUENT-calculated rate will not be used and it will instead be replaced by the SO_x rate you have defined in your UDF. When you hook a SO_x rate UDF to the graphical interface without checking the Replace with UDF Rate box, then the user SO_x rate will be *added* to the internally calculated rate for the source term calculation.

Usage

```
DEFINE_SOX_RATE(name,c,t,Pollut,Pollut_Par, SOx)
```

Argument Type	Description
symbol name	UDF name.
cell_t c	Cell index.
Thread *t	Pointer to cell thread on which the SO_x rate is to be applied.
Pollut_Cell *Pollut	Pointer to the data structure that contains the common data at each cell.
Pollut_Parameter *Pollut_Par	Pointer to the data structure that contains auxilliary data.
SOx_Parameter *SOx	Pointer to the data structure that contains data specific to the SOx model.

Function returns
void

There are six arguments to DEFINE_SOX_RATE: name, c, t, Pollut, Pollut_Par and SOx. You will supply name, the name of the UDF. c, t, Pollut, Pollut_Par and SOx are variables that are passed by the FLUENT solver to your function. A DEFINE_SOX_RATE function does not output a value. The calculated SO2 rates (or other pollutant species rates) are returned through the Pollut structure as the forward rate Pollut->fluct.fwdrate and reverse rate Pollut->fluct.revrate, respectively.

The data contained within the SO_x structure is specific *only* to the SO_x model. Alternatively, the Pollut structure contains data at each cell that are useful for all pollutant species (e.g. forward and reverse rates, gas phase temperature, density). The Pollut_Par structure contains auxiliary data common for all pollutant species (e.g. equation solved, universal gas constant, species molecular weights). Note that molecular weights extracted from the Pollut_Par structure (i.e., Pollut_Par->sp[IDX(i)].mw for pollutant species and Pollut_Par->sp[i].mw for other species such as O2) has units of kg/kg-mol. The reverse rate calculated by user must be divided by the respective species mass fraction in order to be consistent with the FLUENT 6.3 implementation (prior versions of FLUENT used explicit division by species mass fraction internally).

Example

The following compiled UDF, named user_sox, computes the rates for SO_2 and SO_3 formation according to the reaction given in Equation 2.3-8. Note that this UDF will replace the FLUENT rate *only* if you select the Replace with UDF Rate option in the SOx Model panel.

It is assumed that the release of fuel sulphur from fuel is proportional to the rate of release of volatiles and all sulphur is in the form of SO2 when released to the gas phase. The reversible reaction for SO_2/SO_3 is given below:

$$SO_3 + O \longleftrightarrow SO_2 + O2 \tag{2.3-8}$$

with forward and reverse rates of reaction in the Arrhenius form

$k_f = 1.2e^6 e^{(-39765.575/RT)}$

$k_f = 1.0e^4 T^{-1} e^{(-10464.625/RT)}$

The O atom concentration in the gas phase is computed using the partial equilibrium assumption, which states

$o_{eq} = 36.64 T^{0.5} e^{(-27123.0/RT)} \sqrt{O_2}$

Here, all units are in m-gmol-J-sec.

The function so2_so3_rate is used to compute the forward and reverse rates for both SO_2 and SO_3.

The rate of release of SO_2 from volatiles is given by:

$$S_{SO_2,volatile} = \frac{r\_volatile * Ys\_volatile * fuels\_so2\_frac * 1000}{MW_S * V}$$

where $r\_volatile$ is the rate of release of volatiles, $Ys\_volatile$ is the mass fraction of sulphur species in volatiles and $fuels\_so2\_frac$ is the mass fraction of fuel S that converts to SO_2. MW_S is the molecular weight of sulphur and V is the cell volume.

Note that the reverse rate is divided by the respective species mass fraction. This practice is different from that used in prior versions of FLUENT where the actual reverse rate was stored without division by pollutant mass fraction.

See Section 3.2.7: SO_x Macros for details about Fluent-provided SO_x macros (e.g., POLLUT_EQN, MOLECON, ARRH) that are used in pollutant rate calculations in this UDF.

```
/***************************************************************************
   UDF example of User-Defined SOx Rate
   For FLUENT Versions 6.3 or above

   If used with the "replace with udf" radio button activated,
   this udf will replace the default fluent SOx rates.

   The flag "Pollut_Par->pollut_io_pdf == IN_PDF" should always
   be used for rates other than that from char S, so that if
   requested, the contributions will be pdf integrated. Any
   contribution from char must be included within a switch
   statement of the form "Pollut_Par->pollut_io_pdf == OUT_PDF".
   *
   * Arguments:
   *        char sox_func_name           - UDF name
   *        cell_t c                     - Cell index
   *        Thread *t                    - Pointer to cell thread on
   *                                       which the SOx rate is to be
   *                                       applied
   *        Pollut_Cell *Pollut          - Pointer to the data structure
   *                                       that contains common data
   *                                       at each cell
   *        Pollut_Parameter *Pollut_Par - Pointer to the data structure
   *                                       that contains auxiliary data
   *        SOx_Parameter *SOx           - Pointer to the data structure
   *                                       that contains data specific
   *                                       to the SOx model
***************************************************************************/

#include "udf.h"
void so2_so3_rate(cell_t c, Thread* t, Pollut_Cell *Pollut,
                  Pollut_Parameter *Pollut_Par, SOx_Parameter *SOx);

DEFINE_SOX_RATE(user_sox, c, t, Pollut, Pollut_Par, SOx)
{

    Pollut->fluct.fwdrate = 0.0;
    Pollut->fluct.revrate = 0.0;

    switch (Pollut_Par->pollut_io_pdf) {
    case IN_PDF:
    /* Source terms other than those from char must be included here */

       if (SOx->user_replace) {
       /* This rate replaces the default FLUENT rate */
          so2_so3_rate(c,t,Pollut,Pollut_Par,SOx);
       }
       else {
       /* This rate is added to the default FLUENT rate */
          so2_so3_rate(c,t,Pollut,Pollut_Par,SOx);
       }

       break;
    case OUT_PDF:
    /* Char Contributions that do not go into pdf loop must be included
       here */

       break;
    }

}

void so2_so3_rate(cell_t c, Thread* t, Pollut_Cell *Pollut,
                  Pollut_Parameter *Pollut_Par, SOx_Parameter *SOx)
{
   real kf,kr,rf=0,rr=0;
   real xc_o2, o_eq;
   real r_volatile,Ys_volatile,fuels_so2_frac;

   Rate_Const K_F = {1.2e6,  0.0, 39765.575};
   Rate_Const K_R = {1.0e4, -1.0, 10464.625};
   Rate_Const K_O = {36.64,  0.5, 27123.0};

   /* SO3 + O <-> SO2 + O2 */
   kf = ARRH(Pollut, K_F);
   kr = ARRH(Pollut, K_R);

   xc_o2 = MOLECON(Pollut, O2);
   o_eq  = ARRH(Pollut, K_O)*sqrt(MOLECON(Pollut, O2));

   if (POLLUT_EQN(Pollut_Par) == EQ_SO2) {
      r_volatile = Pollut->r_volatile;

      Ys_volatile = 1.e-04;
      fuels_so2_frac = 1.;

      rf = r_volatile*Ys_volatile*fuels_so2_frac*1000./
      (Pollut_Par->sp[S].mw*Pollut->cell_V);
      rf += kf*o_eq*MOLECON(Pollut, IDX(SO3));
      rr = -kr*MOLECON(Pollut, O2)*
            Pollut->den*1000./Pollut_Par->sp[IDX(SO2)].mw;
   }
   else if (POLLUT_EQN(Pollut_Par) == EQ_SO3) {
      rf = kr*MOLECON(Pollut, O2)*MOLECON(Pollut, IDX(SO2));
      rr = -kf*o_eq*
            Pollut->den*1000./Pollut_Par->sp[IDX(SO3)].mw;
   }

   Pollut->fluct.fwdrate += rf;
   Pollut->fluct.revrate += rr;
}
```

Hooking a SO$_x$ Rate UDF to FLUENT

After the UDF that you have defined using DEFINE_SOX_RATE is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., user_sox) will become visible and selectable in the SOx Model panel in FLUENT. See Section 6.2.18: Hooking DEFINE_SOX_RATE UDFs for details.

2.3.19 DEFINE_SR_RATE

Description

You can use DEFINE_SR_RATE to specify a custom surface reaction rate. A custom surface reaction rate function defined using this macro will overwrite the default reaction rate (e.g., finite-rate) that is specified in the Materials panel. An example of a reaction rate that depends upon gas species mass fractions is provided below. Also provided is a reaction rate UDF that takes into account site species.

Note that the three types of surface reaction species are internally numbered with an (integer) index i in order

Usage

DEFINE_SR_RATE(name,f,t,r,my,yi,rr)

Argument Type	Description
symbol name	UDF name.
face_t f	Index that identifies a face within the given thread (or cell in the case of surface reaction in a porous zone).
Thread *t	Pointer to face thread on which the surface rate reaction is to be applied.
Reaction *r	Pointer to data structure for the reaction.
real *mw	Pointer to array of species molecular weights.
real *yi	Pointer to array of mass fractions of gas species at the surface and the coverage of site species (or site fractions).
real *rr	Pointer to reaction rate.

Function returns
void

There are seven arguments to DEFINE_SR_RATE: name, f, t, r, my, yi, and rr. You supply name, the name of the UDF. Once your UDF is compiled and linked, the name that you have chosen for your function will become visible and selectable in the graphical user interface in FLUENT. f, t, r, my, and yi are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to set the reaction rate to the value referenced by the real pointer rr as shown in the examples below.

Example 1 - Surface Reaction Rate Using Species Mass Fractions

The following compiled UDF, named arrhenius, defines a custom surface reaction rate using species mass fractions in FLUENT.

```
/*******************************************************************
   Custom surface reaction rate UDF
*******************************************************************/
#include "udf.h"
/* ARRHENIUS CONSTANTS */
#define PRE_EXP 1e+15
#define ACTIVE 1e+08
#define BETA 0.0

real arrhenius_rate(real temp)
{
  return
  PRE_EXP*pow(temp,BETA)*exp(-ACTIVE/(UNIVERSAL_GAS_CONSTANT*temp));
}

/* Species numbers. Must match order in Fluent panel */
#define HF  0
#define WF6 1
#define H2O 2
#define NUM_SPECS 3

/* Reaction Exponents */
#define HF_EXP  2.0
#define WF6_EXP 0.0
#define H2O_EXP 0.0

#define MW_H2 2.0
#define STOIC_H2 3.0

/* Reaction Rate Routine */

real reaction_rate(cell_t c, Thread *cthread,real mw[],real yi[])

*/ Note that all arguments in the reaction_rate function
call in your .c source file MUST be on the same line or a
compilation error will occur */

{
  real concenHF = C_R(c,cthread)*yi[HF]/mw[HF];
  return arrhenius_rate(C_T(c,cthread))*pow(concenHF,HF_EXP);
}

DEFINE_SR_RATE(arrhenius,f,fthread,r,mw,yi,rr)
```

```
{
 *rr =
reaction_rate(F_C0(f,fthread),THREAD_T0(fthread),mw,yi);
}
```

Example 2 - Surface Reaction Rate Using Site Species

The following compiled UDF, named my_rate, defines a custom surface reaction rate that takes into account site species.

```
/*******************************************************************
   Custom surface reaction rate UDF
*******************************************************************/
/* #include "udf.h" */
DEFINE_SR_RATE(my_rate,f,t,r,mw,yi,rr)
{
 Thread *t0=t->t0;
 cell_t c0=F_C0(f,t);
 real sih4  = yi[0];   /* mass fraction of sih4 at the wall */
 real si2h6 = yi[1];
 real sih2  = yi[2];
 real h2    = yi[3];
 real ar    = yi[4];   /* mass fraction of ar at the wall */

 real rho_w = 1.0, site_rho = 1.0e-6, T_w = 300.0;

 real si_s  = yi[6];   /* site fraction of si_s*/
 real sih_s = yi[7];   /* site fraction of sih_s*/

 T_w = F_T(f,t);
 rho_w = C_R(c0,t0)*C_T(c0,t0)/T_w;

 sih4  *= rho_w/mw[0];  /* converting of mass fractions
to molar concentrations */
 si2h6 *= rho_w/mw[1];
 sih2  *= rho_w/mw[2];
 h2    *= rho_w/mw[3];
 ar    *= rho_w/mw[4];

 si_s   *= site_rho;   /* converting of site fractions to
 site concentrations */
 sih_s  *= site_rho;
 if (STREQ(r->name, "reaction-1"))
   *rr = 100.0*sih4;
 else if (STREQ(r->name, "reaction-2"))
   *rr = 0.1*sih_s;
 else if (STREQ(r->name, "reaction-3"))
   *rr = 100*si2h6*si_s;
 else if (STREQ(r->name, "reaction-4"))
   *rr = 1.0e10*sih2;

}
```

Hooking a Surface Reaction Rate UDF to FLUENT

After the UDF that you have defined using DEFINE_SR_RATE is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., my_rate) will become visible and selectable in the User-Defined Function Hooks panel in FLUENT. See Section 6.2.19: Hooking DEFINE_SR_RATE UDFs for details.

2.3.20 DEFINE_TURB_PREMIX_SOURCE

Description

You can use DEFINE_TURB_PREMIX_SOURCE to customize the turbulent flame speed and source term in the premixed combustion model (Chapter 16: Modeling Premixed Combustion in the User's Guide)) and the partially premixed combustion model (Chapter 17: Modeling Partially Premixed Combustion in the User's Guide).

Usage

```
DEFINE_TURB_PREMIX_SOURCE(name,c,t,turb_flame_speed,source)
```

Argument Type	**Description**
symbol name	UDF name.
cell_t c	Cell index.
Thread *t	Pointer to cell thread on which the turbulent premixed source term is to be applied.
real *turb_flame_speed	Pointer to the turbulent flame speed.
real *source	Pointer to the reaction progress source term.

Function returns
void

There are five arguments to DEFINE_TURB_PREMIX_SOURCE: name, c, t, turb_flame_speed, and source. You supply name, the name of the UDF. c, t, turb_flame_speed, and source are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to set the turbulent flame speed to the value referenced by the turb_flame_speed pointer. It will also need to set the source term to the value referenced by the source pointer.

Example

The following UDF, named turb_flame_src, specifies a custom turbulent flame speed and source term in the premixed combustion model. The source code must be executed as a compiled UDF in FLUENT.

In the standard premixed combustion model in FLUENT, the mean reaction rate of the progress variable (that is, the source term) is modeled as

$$\rho S_c = \rho_u U_t |\nabla c| \tag{2.3-9}$$

where c is the mean reaction progress variable, ρ is the density, and U_t is the turbulent flame speed.

In the UDF example, the turbulent flame speed is modeled as

$$U_t = U_l\sqrt{1 + (u'/U_l)^2} \tag{2.3-10}$$

where U_l is the laminar flame speed and u' is the turbulent fluctuation. Note that the partially premixed combustion model is assumed to be enabled (Click see Chapter 17: Modeling Partially Premixed Combustion to go to the User's Guide manual), so that the unburned density and laminar flame speed are available as polynomials. See Chapter 3: Additional Macros for Writing UDFs for details on the NULLP, THREAD_STORAGE, and SV_VARS macros.

```
/*******************************************************************
    UDF that specifies a custom turbulent flame speed and source
    for the premixed combustion model
********************************************************************/

#include "udf.h"
#include "sg_pdf.h" /* not included in udf.h so must include here  */

DEFINE_TURB_PREMIX_SOURCE(turb_flame_src,c,t,turb_flame_speed,source)
{
  real up = TRB_VEL_SCAL(c,t);
  real ut, ul, grad_c, rho_u, Xl, DV[ND_ND];

  ul = C_LAM_FLAME_SPEED(c,t);
  Calculate_unburnt_rho_and_Xl(t, &rho_u, &Xl);

  if( NNULLP(THREAD_STORAGE(t,SV_PREMIXC_G)) )
    {
      NV_V(DV, =, C_STORAGE_R_NV(c,t,SV_PREMIXC_G));
      grad_c = sqrt(NV_DOT(DV,DV) );
    }

  ut = ul*sqrt( 1. + SQR(up/ul) );

  *turb_flame_speed = ut;
  *source = rho_u*ut*grad_c;
}
```

Hooking a Turbulent Premixed Source UDF to FLUENT

After the UDF that you have defined using `DEFINE_TURB_PREMIX_SOURCE` is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first `DEFINE` macro argument (e.g., `turb_flame_src`) will become visible and selectable in the User-Defined Function Hooks panel in FLUENT. See Section 6.2.20: Hooking `DEFINE_TURB_PREMIX_SOURCE` UDFs for details.

2.3.21 DEFINE_TURBULENT_VISCOSITY

Description

You can use `DEFINE_TURBULENT_VISCOSITY` to specify a custom turbulent viscosity function for the Spalart-Allmaras, k-ϵ, and k-ω turbulence models for single-phase applications. In addition, for 3d versions of FLUENT you can specify a subgrid-scale turbulent viscosity UDF for the large eddy simulation model. For Eulerian multiphase flows, turbulent viscosity UDFs can be assigned on a per-phase basis, and/or to the mixture, depending on the turbulence model. See Table 2.3.5 for details.

Table 2.3.5: Eulerian Multiphase Model and `DEFINE_TURBULENT_VISCOSITY` UDF Usage

Turbulence Model	**Phase that Turbulent Viscosity UDF Is Specified On**
k-ϵ **Mixture**	mixture, primary and secondary phases
k-ϵ **Dispersed**	primary and secondary phases
k-ϵ **Per-Phase**	primary and secondary phases

Usage

```
DEFINE_TURBULENT_VISCOSITY(name,c,t)
```

Argument Type	**Description**
`symbol name`	UDF name.
`cell_t c`	Cell index.
`Thread *t`	Pointer to cell thread on which the turbulent viscosity is to be applied.

Function returns

`real`

There are three arguments to `DEFINE_TURBULENT_VISCOSITY`: `name`, `c`, and `t`. You supply `name`, the name of the UDF. `c` and `t` are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to return the `real` value of the turbulent viscosity to the solver.

Example 1 - Single Phase Turbulent Viscosity UDF

The following UDF, named `user_mu_t`, defines a custom turbulent viscosity for the standard k-ϵ turbulence model. Note that the value of `M_keCmu` in the example is defined through the graphical user interface, but made accessible to all UDFs. The source code can be interpreted or compiled in FLUENT.

```
/********************************************************************
    UDF that specifies a custom turbulent viscosity for standard
    k-epsilon formulation
*********************************************************************/

#include "udf.h"

DEFINE_TURBULENT_VISCOSITY(user_mu_t,c,t)
{
  real mu_t;
  real rho = C_R(c,t);
  real k   = C_K(c,t);
  real d   = C_D(c,t);

  mu_t = M_keCmu*rho*SQR(k)/d;

  return mu_t;
}
```

Example 2 - Multiphase Turbulent Viscosity UDF

```
/*******************************************************************
    Custom turbulent viscosity functions for each phase and the
    mixture in a two-phase multiphase flow
********************************************************************/
#include "udf.h"

DEFINE_TURBULENT_VISCOSITY(mu_t_ke_mixture, c, t)
{
  real mu_t;
  real rho = C_R(c,t);
  real k   = C_K(c,t);
  real d   = C_D(c,t);
  real cmu = M_keCmu;

  mu_t = rho*cmu*k*k/d;

  return mu_t;
}

DEFINE_TURBULENT_VISCOSITY(mu_t_ke_1, c, t)
{
  Thread *tm = lookup_thread_by_id(DOMAIN_SUPER_DOMAIN(THREAD_DOMAIN(t)),
                                        t->id);
  CACHE_T_SV_R (density,   t,   SV_DENSITY);
  CACHE_T_SV_R (mu_t,      t,   SV_MU_T);
  CACHE_T_SV_R (density_m, tm,  SV_DENSITY);
  CACHE_T_SV_R (mu_t_m,    tm,  SV_MU_T);

  return density[c]/density_m[c]*mu_t_m[c];
}

DEFINE_TURBULENT_VISCOSITY(mu_t_ke_2, c, t)
{
  Thread *tm = lookup_thread_by_id(DOMAIN_SUPER_DOMAIN(THREAD_DOMAIN(t)),
                                        t->id);
  CACHE_T_SV_R (density,   t,   SV_DENSITY);
  CACHE_T_SV_R (mu_t,      t,   SV_MU_T);
  CACHE_T_SV_R (density_m, tm,  SV_DENSITY);
  CACHE_T_SV_R (mu_t_m,    tm,  SV_MU_T);

  return density[c]/density_m[c]*mu_t_m[c];
}
```

Hooking a Turbulent Viscosity UDF to FLUENT

After the UDF that you have defined using DEFINE_TURBULENT_VISCOSITY is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the function name(s) that you specified in the DEFINE macro argument(s) (for example user_mu_t for single phase, or mu_t_ke_mixture, mu_t_ke_1, and mu_t_ke_2 for multiphase) will become visible and selectable in the Viscous Model panel in FLUENT. See Section 6.2.21: Hooking DEFINE_TURBULENT_VISCOSITY UDFs for details.

2.3.22 DEFINE_VR_RATE

Description

You can use DEFINE_VR_RATE to specify a custom volumetric reaction rate for a single reaction or for multiple reactions. During FLUENT execution, DEFINE_VR_RATE is called for every reaction in every single cell.

Usage

```
DEFINE_VR_RATE(name,c,t,r,mw,yi,rr,rr_t)
```

Argument Type	**Description**
symbol name	UDF name.
cell_t c	Cell index.
Thread *t	Pointer to cell thread on which the volumetric reaction rate is to be applied.
Reaction *r	Pointer to data structure that represents the current reaction.
real *mw	Pointer to array of species molecular weights.
real *yi	Pointer to array of the species mass fractions.
real *rr	Pointer to laminar reaction rate.
real *rr_t	Pointer to turbulent reaction rate.

Function returns
void

There are eight arguments to DEFINE_VR_RATE: name, c, t, r, mw, yi, rr, and rr_t. You supply name, the name of the UDF. c, t, r, mw, yi, rr, and rr_t are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to set the values referenced by the real pointers rr and rr_t to the laminar and turbulent reaction rates, respectively.

rr and rr_t (defined by the UDF) are computed and the lower of the two values is used when the finite-rate/eddy-dissipation chemical reaction mechanism used. Note that rr and rr_t are conversion rates in kgmol/m^3-s. These rates, when multiplied by the respective stoichiometric coefficients, yield the production/consumption rates of the individual chemical components.

Example 1

The following UDF, named vol_reac_rate, specifies a volume reaction rate. The function must be executed as a compiled UDF in FLUENT.

```
/*********************************************************************
   UDF for specifying a volume reaction rate
   The basics of Fluent's calculation of reaction rates:  only an
   Arrhenius ("finite rate") reaction rate is calculated
   from the inputs given by the user in the graphical user interface
**********************************************************************/

#include "udf.h"

DEFINE_VR_RATE(vol_reac_rate,c,t,r,wk,yk,rate,rr_t)
{
  real ci, prod;
  int i;

/* Calculate Arrhenius reaction rate  */

  prod = 1.;

  for(i = 0; i < r->n_reactants; i++)
    {
      ci     = C_R(c,t) * yk[r->reactant[i]] / wk[r->reactant[i]];
      prod  *= pow(ci, r->exp_reactant[i]);
    }
  *rate = r->A * exp( - r->E / (UNIVERSAL_GAS_CONSTANT * C_T(c,t))) *
                                        pow(C_T(c,t), r->b) * prod;

  *rr_t = *rate;

  /* No "return..;" value. */
}
```

Example 2

When multiple reactions are specified, a volume reaction rate UDF is called several times in each cell. Different values are assigned to the pointer `r`, depending on which reaction the UDF is being called for. Therefore, you will need to determine which reaction is being called, and return the correct rates for that reaction. Reactions can be identified by their name through the `r->name` statement. To test whether a given reaction has the name `reaction-1`, for example, you can use the following C construct:

```
if (!strcmp(r->name, "reaction-1"))
    {
      ....  /* r->name is identical to "reaction-1" ... */
    }
```

Note that `strcmp(r->name, ‘‘reaction-1")` returns 0 which is equal to FALSE when the two strings are identical.

It should be noted that `DEFINE_VR_RATE` defines only the reaction rate for a predefined stoichiometric equation (set in the Reactions panel) thus providing an alternative to the Arrhenius rate model. `DEFINE_VR_RATE` does not directly address the particular rate of species creation or depletion; this is done by the FLUENT solver using the reaction rate supplied by your UDF.

The following is a source code template that shows how to use `DEFINE_VR_RATE` in connection with more than one user-specified reaction. Note that FLUENT always calculates the `rr` and `rr_t` reaction rates before the UDF is called. Consequently, the values that are calculated are available only in the given variables when the UDF is called.

```
/*********************************************************************
   Multiple reaction UDF that specifies different reaction rates
   for different volumetric chemical reactions
**********************************************************************/
#include "udf.h"

DEFINE_VR_RATE(myrate,c,t,r,mw,yi,rr,rr_t)
{
 /*If more than one reaction is defined, it is necessary to distinguish
   between these using the names of the reactions.                    */

      if (!strcmp(r->name, "reaction-1"))
        {
          /* Reaction 1 */
        }
      else if (!strcmp(r->name, "reaction-2"))
        {
          /* Reaction 2 */
        }
      else
        {
/*        Message("Unknown Reaction\n"); */
        }
/*    Message("Actual Reaction: %s\n",r->name); */

}
```

Hooking a Volumetric Reaction Rate UDF to FLUENT

After the UDF that you have defined using DEFINE_VR_RATE is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., myrate) will become visible and selectable in the User-Defined Function Hooks panel in FLUENT. See Section 6.2.22: Hooking DEFINE_VR_RATE UDFs for details.

2.3.23 DEFINE_WALL_FUNCTIONS

Description

You can use DEFINE_WALL_FUNCTIONS to provide custom wall functions for applications when you want to replace the standard wall functions in FLUENT. Note that this is available only for use with the k-ϵ turbulence models.

Usage

DEFINE_WALL_FUNCTIONS(name,f,t,c0,t0,wf_ret,yPlus,Emod)

Argument Type	Description
symbol name	UDF name.
face_t f	face index.
Thread *t	pointer to cell thread
cell_t c0	cell index.
Thread *t0	pointer to face thread.
int wf_ret	wall function index
real yPlus	y+ value
real Emod	wall function E constant

Function returns
real

There are eight arguments to DEFINE_WALL_FUNCTIONS: name, f, t, c0, t0, wf_ret, yPlus, and Emod. You supply name, the name of the UDF. f, t, c0, t0, wf_ret, yPlus, and Emod are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to compute the real value of the wall functions U+, dU+, and dY+ for laminar and turbulent regions and return them to the solver.

Example

The following UDF, named user_log_law, computes U+ and dU+, and dY+ for laminar and turbulent regions using DEFINE_WALL_FUNCTIONS. The source code can be interpreted or compiled in FLUENT.

```
/******************************************************************
User-defined wall functions: separated into turbulent and
laminar regimes
/*****************************************************************/
#include "udf.h"

DEFINE_WALL_FUNCTIONS(user_log_law, f, t, c0, t0, wf_ret, yPlus, Emod)
{
  real wf_value;

  switch (wf_ret)
    {
    case UPLUS_LAM:
      wf_value = yPlus;
      break;
    case UPLUS_TRB:
      wf_value = log(Emod*yPlus)/KAPPA;
      break;
    case DUPLUS_LAM:
      wf_value = 1.0;
      break;
    case DUPLUS_TRB:
      wf_value = 1./(KAPPA*yPlus);
      break;
    case D2UPLUS_TRB:
      wf_value = -1./(KAPPA*yPlus*yPlus);
      break;
    default:
printf("Wall function return value unavailable\n");
    }
  return wf_value;
}
```

Hooking a Wall Function UDF to FLUENT

After the UDF that you have defined using DEFINE_WALL_FUNCTIONS is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., user_log_law) will become visible and selectable in the Viscous Model panel in FLUENT. See Section 6.2.23: Hooking DEFINE_WALL_FUNCTIONS UDFs for details.

2.4 Multiphase DEFINE Macros

The DEFINE macros presented in this section are used for multiphase applications, *only*.

Table 2.4.1 provides a quick reference guide to the multiphase-specific DEFINE macros, the functions they are used to define, and the panels where they are activated in FLUENT. Definitions of each DEFINE macro are listed in the udf.h header file (see Appendix C).

Appendix B contains a list of general purpose DEFINE macros that can also be used to define UDFs for multiphase cases. For example, the general purpose DEFINE_PROPERTY macro is used to define a surface tension coefficient UDF for the multiphase VOF model. See Section 2.3.14: DEFINE_PROPERTY UDFs for details.

- Section 2.4.1: DEFINE_CAVITATION_RATE
- Section 2.4.2: DEFINE_EXCHANGE_PROPERTY
- Section 2.4.3: DEFINE_HET_RXN_RATE
- Section 2.4.4: DEFINE_MASS_TRANSFER
- Section 2.4.5: DEFINE_VECTOR_EXCHANGE_PROPERTY

Table 2.4.1: Quick Reference Guide for Multiphase DEFINE Macros

Model	Function	DEFINE Macro	Panel Activated
VOF	mass transfer	DEFINE_MASS_TRANSFER	Phase Interaction
	heterogeneous reaction rate	DEFINE_HET_RXN_RATE	Phase Interaction
Mixture	mass transfer	DEFINE_MASS_TRANSFER	Phase Interaction
	drag coefficient	DEFINE_EXCHANGE_PROPERTY	Phase Interaction
	slip velocity	DEFINE_VECTOR_EXCHANGE_ _PROPERTY	Phase Interaction
	cavitation rate	DEFINE_CAVITATION_RATE	User-Defined Function Hooks
	heterogeneous reaction rate	DEFINE_HET_RXN_RATE	Phase Interaction
Eulerian	mass transfer	DEFINE_MASS_TRANSFER	Phase Interaction
	heat transfer	DEFINE_EXCHANGE_PROPERTY	Phase Interaction
	drag coefficient	DEFINE_EXCHANGE_PROPERTY	Phase Interaction
	lift coefficient	DEFINE_EXCHANGE_PROPERTY	Phase Interaction
	heterogeneous reaction rate	DEFINE_HET_RXN_RATE	Phase Interaction

2.4.1 DEFINE_CAVITATION_RATE

Description

You can use DEFINE_CAVITATION_RATE to model the cavitation source terms R_e and R_c in the vapor mass-fraction transport equation (Equation 23.7-12 in the User's Guide). Assuming m_{dot} denotes the mass-transfer rate between liquid and vapor phases, we have

$$R_e = MAX[m_{dot}, 0]f_1$$

$$R_c = MAX[-m_{dot}, 0]f_v$$

where f_1 and f_v are the mass-fraction of the liquid and vapor phase, respectively.

DEFINE_CAVITATION_RATE is used to calculate m_{dot} only. The values of R_e and R_c are computed by the solver, accordingly.

Usage

```
DEFINE_CAVITATION_RATE(name,c,t,p,rhoV,rhoL,mafV,p_v,cigma,f_gas,m_dot)
```

Argument Type	**Description**
symbol name	UDF name.
cell_t c	Cell index.
Thread *t	Pointer to the mixture-level thread.
real *p[c]	Pointer to shared pressure.
real *rhoV[c]	Pointer to vapor density.
real *rhoL[c]	Pointer to liquid density.
real *mafV[c]	Pointer to vapor mass fraction.
real *p_v	Pointer to vaporization pressure.
real *cigma	Pointer to liquid surface tension coefficient.
real *f_gas	Pointer to the prescribed mass fraction of non condensable gases.
real *m_dot	Pointer to cavitation mass transfer rate.

Function returns

void

There are eleven arguments to DEFINE_CAVITATION_RATE: name, c, t, p, rhoV, rhoL, mafV, p_v, cigma, f_gas, and m_dot. You supply name, the name of the UDF. c, t, p, rhoV, rhoL, mafV, p_v, cigma, f_gas, and m_dot are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to set the value referenced by the real pointer m_dot to the cavitation rate.

Example

The following UDF named user_cav_rate, is an example of a cavitation model for a multiphase mixture that is different from the default model in FLUENT. This cavitation model calculates the cavitation mass transfer rates between the liquid and vapor phase depending on fluid pressure (*p), turbulence kinetic energy (C_K(c,t)), and the liquid vaporization pressure (*p_v).

In general, the existence of turbulence enhances cavitation. In this example, the turbulence effect is taken into account by increasing the cavitation pressure by 0.195* C_R(c,t) * C_K(c,t). The pressure p_vapor that determines whether cavitation occurs increases from p_v to

```
p_v + 0.195 * C_R(c,t) * C_K(c,t)
```

When the absolute fluid pressure (ABS_P) is lower than p_vapor, then liquid evaporates to vapor (R_e). When it is greater than p_vapor, vapor condenses to liquid (R_c).

The evaporation rate is calculated by

```
  If ABS_P < p_vapor, then
    c_evap * rhoV[c] * sqrt(2.0/3.0*rhoL[c]) * ABS(p_vapor - ABS_P(p[c]))
```

The condensation rate is

```
  If ABS_P > p_vapor, then
    -c_con*rhoL[c] * sqrt(2.0/3.0*rhoL[c]) * ABS(p_vapor - ABS_P(p[c]))
```

where c_evap and c_con are model coefficients.

```
/***********************************************************************
   UDF that is an example of a cavitation model different from default.
   Can be interpreted or compiled.
************************************************************************/

#include "udf.h"

#define c_evap 1.0
#define c_con 0.1

DEFINE_CAVITATION_RATE(user_cav_rate, c, t, p, rhoV, rhoL, mafV, p_v,
                       cigma, f_gas, m_dot)
{
    real p_vapor = *p_v;
    real dp, dp0, source;
    p_vapor  += MIN(0.195*C_R(c,t)*C_K(c,t), 5.0*p_vapor);
    dp = p_vapor - ABS_P(p[c], op_pres);
    dp0 = MAX(0.1, ABS(dp));
    source = sqrt(2.0/3.0*rhoL[c])*dp0;

    if(dp > 0.0)
      *m_dot = c_evap*rhoV[c]*source;
    else
      *m_dot = -c_con*rhoL[c]*source;
}
```

Note that all of the arguments to a DEFINE macro need to be placed on the same line in your source code. Splitting the DEFINE statement onto several lines will result in a compilation error.

Hooking a Cavitation Rate UDF to FLUENT

After the UDF that you have defined using DEFINE_CAVITATION_RATE is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., user_cav_rate) will become visible and selectable in the User-Defined Function Hooks panel in FLUENT. See Section 6.3.1: Hooking DEFINE_CAVITATION_RATE UDFs for details.

2.4.2 DEFINE_EXCHANGE_PROPERTY

Description

You can use DEFINE_EXCHANGE_PROPERTY to specify UDFs for some phase interaction variables in multiphase models. These include net heat transfer rates between phases, and drag and lift coefficient functions. Below is a list of user-defined functions that can be specified using DEFINE_EXCHANGE_PROPERTY for the multiphase models in FLUENT. Note that there are some phase interaction variables such as vaporization pressure and surface tension coefficient (cavitation parameters) that are defined using DEFINE_PROPERTY. See Section 2.3.14: DEFINE_PROPERTY UDFs for details.

Table 2.4.2: DEFINE_EXCHANGE_PROPERTY Variables

Mixture Model	Eulerian Model
drag exchange coefficient	net heat transfer rate drag coefficient lift coefficient

Usage

```
DEFINE_EXCHANGE_PROPERTY(name,c,mixture_thread,second_column_phase_index,
first_column_phase_index)
```

Note that all of the arguments to a DEFINE macro must be placed on the same line in your source code. Splitting the DEFINE statement onto several lines will result in a compilation error.

Argument Type	Description
symbol name	UDF name.
cell_t c	Cell index.
Thread *mixture_thread	Pointer to the mixture-level thread.
int second_column_phase_index	Identifier that corresponds to the pair of phases in your multiphase flow that you are specifying a slip velocity for. The identifiers correspond to the phases you select in the Phase Interaction panel in the graphical user interface. An index of 0 corresponds to the primary phase, and is incremented by one for each secondary phase.
int first_column_phase_index	See int second_column_phase_index.

Function returns
real

There are five arguments to DEFINE_EXCHANGE_PROPERTY: name, c, mixture_thread, second_column_phase_index, and first_column_phase_index. You supply name, the name of the UDF. c, mixture_thread, second_column_phase_index, and first_column_phase_index are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to return the real value of the lift coefficient, drag exchange coefficient, heat or mass transfer to the solver.

Example 1 - Custom Drag Law

The following UDF, named custom_drag, can be used to customize the default Syamlal drag law in FLUENT. The default drag law uses 0.8 (for void <=0.85) and 2.65 (void >0.85) for bfac. This results in a minimum fluid velocity of 25 cm/s. The UDF modifies the drag law to result in a minimum fluid velocity of 8 cm/s, using 0.28 and 9.07 for the bfac parameters.

```
/******************************************************************
   UDF for customizing the default Syamlal drag law in Fluent
*******************************************************************/

#include "udf.h"

#define pi 4.*atan(1.)
#define diam2 3.e-4

DEFINE_EXCHANGE_PROPERTY(custom_drag,cell,mix_thread,s_col,f_col)
```

```
{
 Thread *thread_g, *thread_s;
 real x_vel_g, x_vel_s, y_vel_g, y_vel_s, abs_v, slip_x, slip_y,
      rho_g, rho_s, mu_g, reyp, afac,
      bfac, void_g, vfac, fdrgs, taup, k_g_s;

 /* find the threads for the gas (primary) */
 /* and solids (secondary phases)          */

 thread_g = THREAD_SUB_THREAD(mix_thread, s_col);/* gas phase  */
 thread_s = THREAD_SUB_THREAD(mix_thread, f_col);/* solid phase*/

 /* find phase velocities and properties*/

 x_vel_g = C_U(cell, thread_g);
 y_vel_g = C_V(cell, thread_g);

 x_vel_s = C_U(cell, thread_s);
 y_vel_s = C_V(cell, thread_s);

 slip_x = x_vel_g - x_vel_s;
 slip_y = y_vel_g - y_vel_s;

 rho_g = C_R(cell, thread_g);
 rho_s = C_R(cell, thread_s);

 mu_g = C_MU_L(cell, thread_g);

 /*compute slip*/
 abs_v = sqrt(slip_x*slip_x + slip_y*slip_y);

 /*compute Reynold's number*/

 reyp = rho_g*abs_v*diam2/mu_g;

 /* compute particle relaxation time */

 taup = rho_s*diam2*diam2/18./mu_g;

 void_g = C_VOF(cell, thread_g);/* gas vol frac*/

 /*compute drag and return drag coeff, k_g_s*/
 afac = pow(void_g,4.14);

 if(void_g<=0.85)
  bfac = 0.281632*pow(void_g, 1.28);
 else
  bfac = pow(void_g, 9.076960);

 vfac = 0.5*(afac-0.06*reyp+sqrt(0.0036*reyp*reyp+0.12*reyp*(2.*bfac-
              afac)+afac*afac));
 fdrgs = void_g*(pow((0.63*sqrt(reyp)/
                           vfac+4.8*sqrt(vfac)/vfac),2))/24.0;

 k_g_s = (1.-void_g)*rho_s*fdrgs/taup;

 return k_g_s;
}
```

Example 2 - Heat Transfer

The following UDF, named heat_udf, specifies a coefficient that when multiplied by the temperature difference between the dispersed and continuous phases, is equal to the net rate of heat transfer per unit volume.

```
#include "udf.h"

#define PR_NUMBER(cp,mu,k) ((cp)*(mu)/(k))
#define IP_HEAT_COEFF(vof,k,nu,d) ((vof)*6.*(k)*(Nu)/(d)/(d))

static real
heat_ranz_marshall(cell_t c, Thread *ti, Thread *tj)
{
 real h;
 real d = C_PHASE_DIAMETER(c,tj);
 real k = C_K_L(c,ti);
 real NV_VEC(v), vel, Re, Pr, Nu;

 NV_DD(v,=,C_U(c,tj),C_V(c,tj),C_W(c,tj),-,C_U(c,ti),C_V(c,ti),C_W(c,ti));
 vel = NV_MAG(v);

 Re = RE_NUMBER(C_R(c,ti),vel,d,C_MU_L(c,ti));
 Pr = PR_NUMBER (C_CP(c,ti),C_MU_L(c,ti),k);
 Nu = 2. + 0.6*sqrt(Re)*pow(Pr,1./3.);
 h = IP_HEAT_COEFF(C_VOF(c,tj),k,Nu,d);
return h;
}

DEFINE_EXCHANGE_PROPERTY(heat_udf, c, t, i, j)
{
  Thread *ti = THREAD_SUB_THREAD(t,i);
  Thread *tj = THREAD_SUB_THREAD(t,j);
  real val;

  val = heat_ranz_marshall(c,ti, tj);
  return val;
}
```

Hooking an Exchange Property UDF to FLUENT

After the UDF that you have defined using DEFINE_EXCHANGE_PROPERTY is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., heat_udf) will become visible and selectable in the Phase Interaction panel in FLUENT. See Section 6.3.2: Hooking DEFINE_EXCHANGE_PROPERTY UDFs for details.

2.4.3 DEFINE_HET_RXN_RATE

Description

You need to use DEFINE_HET_RXN_RATE to specify reaction rates for heterogeneous reactions. A heterogeneous reaction is one that involves reactants and products from more than one phase. Unlike DEFINE_VR_RATE, a DEFINE_HET_RXN_RATE UDF can be specified differently for different heterogeneous reactions.

During FLUENT execution, the DEFINE_HET_RXN_RATE UDF for each heterogeneous reaction that is defined is called in every fluid cell. FLUENT will use the reaction rate specified by the UDF to compute production/destruction of the species participating in the reaction, as well as heat and momentum transfer across phases due to the reaction.

A heterogeneous reaction is typically used to define reactions involving species of different phases. The bulk phase can participate in the reaction if the phase does not have any species (i.e. phase has fluid material instead of mixture material). Heterogeneous reactions are defined in the Phase Interaction panel.

Usage

DEFINE_HET_RXN_RATE(name,c,t,r,mw,yi,rr,rr_t)

Argument Type	Description
symbol name	UDF name.
cell_t c	Cell index.
Thread *t	Cell thread (mixture level) on which heterogeneous reaction rate is to be applied.
Hetero_Reaction *r	Pointer to data structure that represents the current heterogeneous reaction (see sg_mphase.h).
real mw[MAX_PHASES][MAX_SPE_EQNS]	Matrix of species molecular weights. mw[i][j] will give molecular weight of species with ID j in phase with index i. For phase which has fluid material, the molecular weight can be accessed as mw[i][0].
real yi[MAX_PHASES][MAX_SPE_EQNS]	Matrix of species mass fractions. yi[i][j] will give mass fraction of species with ID j in phase with index i. For phase which has fluid material, yi[i][0] will be 1.
real *rr	Pointer to laminar reaction rate.
real *rr_t	Currently not used. Provided for future use.

Function returns

void

There are eight arguments to DEFINE_HET_RXN_RATE: name, c, t, r, mw, yi, rr, and rr_t. You supply name, the name of the UDF. c, t, r, mw, yi, rr, and rr_t are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to set the values referenced by the real pointer rr. The values must be specified in $\frac{kmol\ m^3}{s}$ (where the volume is the cell volume).

Example

The following compiled UDF named user_evap_condens_react defines the reaction rate required to simulate evaporation or condensation on the surface of droplets. Such a reaction can be formally described by the following:

$$H_2O_{(\mathrm{liq})} \longleftrightarrow H_2O_{(\mathrm{gas})} \qquad (2.4\text{-}1)$$

Here, gas is a primary phase mixture of two species: $H_2O_{(gas)}$ and air. Droplets constitute the secondary phase and represent a mixture of one species - $H_2O_{(liq)}$. Single-species mixtures are allowed in multiphase models.

The forumlation for the reaction rate follows the model for particle evaporation that is defined in Section 22.9.2: Droplet Vaporization (Law 2) of the User's Guide

```
/*Constants used in psat_h2o to calculate saturation pressure*/

#define PSAT_A 0.01
#define PSAT_TP 338.15
#define C_LOOP 8
#define H2O_PC 22.089E6
#define H2O_TC 647.286

/*user inputs*/

#define MAX_SPE_EQNS_PRIM 2 /*total number of species in primary phase*/
#define  index_evap_primary 0  /*evaporating species index in primary phase*/
#define  prim_index 0  /*index of primary phase*/
#define  P_OPER 101325    /*operating pressure equal to GUI value*/

/*end of user inputs*/

/**************************************************************/
/* UDF for specifying an interfacial area density             */
/**************************************************************/
double psat_h2o(double tsat)                                  */
/*                                                            */
/* Computes saturation pressure of water vapor                */
/* as function of temperature                                 */
/* Equation is taken from THERMODYNAMIC PROPERTIES IN SI,     */
*/ by Reynolds, 1979                                          */
/* Returns pressure in PASCALS, given temperature in KELVIN  */
{
   int i;
   double var1,sum1,ans1,psat;
   double constants[8]={-7.4192420, 2.97221E-1, -1.155286E-1,
    8.68563E-3, 1.094098E-3, -4.39993E-3, 2.520658E-3, -5.218684E-4};

/* var1 is an expression that is used in the summation loop */
   var1 = PSAT_A*(tsat-PSAT_TP);

/* Compute summation loop */
   i = 0;
   sum1 = 0.0;
   while (i < C_LOOP){
      sum1+=constants[i]*pow(var1,i);
++i;
   }
ans1 = sum1*(H2O_TC/tsat-1.0);

/* compute exponential to determine result */
/* psat has units of Pascals               */

psat = H2O_PC*exp(ans1);
return psat;
}

DEFINE_HET_RXN_RATE(user_evap_condens_react, c, t, hr, mw,
                     yi, rr, rr_t)
{
    Thread **pt = THREAD_SUB_THREADS(t);
    Thread *tp = pt[0];
    Thread *ts = pt[1];
    int i;
    real concentration_evap_primary, accum = 0., mole_frac_evap_prim,
         concentration_sat ;
    real T_prim = C_T(c,tp); /*primary phase (gas) temperature*/
    real T_sec = C_T(c,ts);  /*secondary phase (droplet) temperature*/
    real diam = C_PHASE_DIAMETER(c,ts);  /*secondary phase diameter*/
    real D_evap_prim = C_DIFF_EFF(c,tp,index_evap_primary)
       - 0.7*C_MU_T(c,tp)/C_R(c,tp);
        /*primary phase species turbulent diffusivity*/
    real Re, Sc, Nu, urel, urelx,urely,urelz=0., mass_coeff, area_density,
        flux_evap ;

    if(Data_Valid_P())
    {
      urelx = C_U(c,tp) - C_U(c,ts);
      urely = C_V(c,tp) - C_V(c,ts);

      #if RP_3D
        urelz = C_W(c,tp) - C_W(c,ts);
      #endif

      urel = sqrt(urelx*urelx + urely*urely + urelz*urelz);
        /*relative velocity*/

       Re = urel * diam * C_R(c,tp) / C_MU_L(c,tp);

       Sc = C_MU_L(c,tp) / C_R(c,tp) / D_evap_prim ;

       Nu =  2. + 0.6 * pow(Re, 0.5)* pow(Sc, 0.333);

       mass_coeff = Nu * D_evap_prim / diam ;

       for (i=0; i < MAX_SPE_EQNS_PRIM ; i++)
         {
           accum = accum + C_YI(c,tp,i)/mw[i][prim_index];
         }

       mole_frac_evap_prim = C_YI(c,tp,index_evap_primary )
                   / mw[index_evap_primary][prim_index] / accum;

       concentration_evap_primary = mole_frac_evap_prim * P_OPER
                   / UNIVERSAL_GAS_CONSTANT / T_prim ;

       concentration_sat = psat_h2o(T_sec)/UNIVERSAL_GAS_CONSTANT/T_sec ;

       area_density = 6. * C_VOF(c,ts) / diam ;

       flux_evap = mass_coeff *
            (concentration_sat - concentration_evap_primary ) ;

       *rr = area_density * flux_evap ;
       }
}
```

Hooking a Heterogeneous Reaction Rate UDF to FLUENT

After the UDF that you have defined using DEFINE_HET_RXN_RATE is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., user_evap_condens_react) will become visible and selectable under Reaction Rate Function in the Reactions tab of the Phase Interaction panel. (Note you will first need to specify the Total Number of Reactions greater than 0.) See Section 6.3.3: Hooking DEFINE_HET_RXN_RATE UDFs for details.

2.4.4 DEFINE_MASS_TRANSFER

Description

You can use DEFINE_MASS_TRANSFER when you want to model mass transfer in a multiphase problem. The mass transfer rate specified using a DEFINE_MASS_TRANSFER UDF is used to compute mass, momentum, energy, and species sources for the phases involved in the mass transfer. For problems in which species transport is enabled, the mass transfer will be from one species in one phase, to another species in another phase. If one of the phases does not have a mixture material associated with it, then the mass transfer will be with the bulk fluid of that phase.

Usage

```
DEFINE_MASS_TRANSFER(name,c,mixture_thread,from_phase_index, from_species_index,
to_phase_index,to_species_index)
```

i Note that all of the arguments to a DEFINE macro need to be placed on the same line in your source code. Splitting the DEFINE statement onto several lines will result in a compilation error.

Argument Type	**Description**
symbol name	UDF name.
cell_t c	Index of cell on the thread pointed to by mixture_thread.
Thread *mixture_thread	Pointer to mixture-level thread.
int from_phase_index	Index of phase from which mass is transferred.
int from_species_index	ID of species from which mass is transferred (ID= -1 if phase does not have mixture material).
int to_phase_index	Index of phase to which mass is transferred.
int to_species_index	ID of species to which mass is transferred (ID= -1 if phase does not have mixture material).

Function returns: real

There are seven arguments to DEFINE_MASS_TRANSFER: name, c, mixture_thread, from_phase_index, from_species_index, to_phase_index, to_species_index. You supply name, the name of the UDF. The variables c, mixture_thread, from_phase_index, from_species_index, to_phase_index, and to_species_index are passed by the FLUENT solver to your UDF. Your UDF will need to return the real value of the mass transfer to the solver in the units of kg/m^3.

The arguments from_species_index and to_species_index are relevant for multiphase species transport problems only, and only if the respective phase has a mixture material associated with it.

Example

The following UDF, named liq_gas_source, specifies a simple mass transfer coefficient based on saturation temperature:

```
/* UDF to define a simple mass transfer based on Saturation
   Temperature. The "from" phase is the gas and the "to" phase is the
   liquid phase  */

#include "udf.h"

DEFINE_MASS_TRANSFER(liq_gas_source,cell,thread,from_index,
from_species_index, to_index, to_species_index)
{
   real m_lg;
   real T_SAT = 373.15;
   Thread *gas = THREAD_SUB_THREAD(thread, from_index);
   Thread *liq = THREAD_SUB_THREAD(thread, to_index);

   m_lg = 0.;
   if (C_T(cell, liq) >= T_SAT)
     {
       m_lg = -0.1*C_VOF(cell,liq)*C_R(cell,liq)*
               fabs(C_T(cell,liq)-T_SAT)/T_SAT;
     }
   if ((m_lg == 0. ) && (C_T(cell, gas) <= T_SAT))
     {
       m_lg = 0.1*C_VOF(cell,gas)*C_R(cell,gas)*
         fabs(T_SAT-C_T(cell,gas))/T_SAT;
     }

   return (m_lg);
}
```

Hooking a Mass Transfer UDF to FLUENT

After the UDF that you have defined using DEFINE_MASS_TRANSFER is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., liq_gas_source) will become visible and selectable under Mass Transfer when you select the Mass tab option in the Phase Interaction panel and specify the Number of Mass Transfer Functions. See Section 6.3.4: Hooking DEFINE_MASS_TRANSFER UDFs for details.

2.4.5 DEFINE_VECTOR_EXCHANGE_PROPERTY

Description

You can use DEFINE_VECTOR_EXCHANGE_PROPERTY to specify custom slip velocities for the multiphase Mixture model.

Usage

```
DEFINE_VECTOR_EXCHANGE_PROPERTY(name,c,mixture_thread,
second_column_phase_index,first_column_phase_index,vector_result)
```

i Note that all of the arguments to a DEFINE macro need to be placed on the same line in your source code. Splitting the DEFINE statement onto several lines will result in a compilation error.

Argument Type	Description
symbol name	UDF name.
cell_t c	Cell index.
Thread *mixture_thread	Pointer to cell thread of mixture domain.
int second_column_phase_index	Index of second phase in phase interaction.
int first_column_phase_index	Index of first phase in phase interaction.
real *vector_result	Pointer to slip velocity vector.

Function returns: void

There are six arguments to DEFINE_VECTOR_EXCHANGE_PROPERTY: name, c, mixture_thread, second_column_phase_index, first_column_phase_index, and vector_result. You supply name, the name of the UDF. c, mixture_thread, second_column_phase_index, first_column_phase_index, and vector_result are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to set the values referenced by the real pointer to the slip velocity vector (vector_result) to the components of the slip velocity vector (e.g., vector_result[0], vector_result[1] for a 2D problem).

Example

The following UDF, named custom_slip, specifies a custom slip velocity in a two-phase mixture problem.

```
/*****************************************************************
   UDF for a defining a custom slip velocity in a 2-phase
   mixture problem
******************************************************************/

#include "udf.h"

DEFINE_VECTOR_EXCHANGE_PROPERTY(custom_slip,c,mixture_thread,
second_column_phase_index,first_column_phase_index,vector_result)
{
 real grav[2] = {0., -9.81};
 real K = 5.e4;

 real pgrad_x, pgrad_y;

 Thread *pt, *st;/* thread pointers for primary and secondary phases*/

 pt = THREAD_SUB_THREAD(mixture_thread, second_column_phase_index);
 st = THREAD_SUB_THREAD(mixture_thread, first_column_phase_index);

 /* at this point the phase threads are known for primary (0) and
 secondary(1) phases */

 pgrad_x = C_DP(c,mixture_thread)[0];
 pgrad_y = C_DP(c,mixture_thread)[1];

 vector_result[0] =
 -(pgrad_x/K)
 +( ((C_R(c, st)-
 C_R(c, pt))/K)*
 grav[0]);

 vector_result[1] =
 -(pgrad_y/K)
 +( ((C_R(c, st)-
 C_R(c, pt))/K)*
 grav[1]);
}
```

i Note that the pressure gradient macro C_DP is now obsolete. A more current pressure gradient macro can be found in Table 3.2.4.

Hooking a Vector Exchange Property UDF to FLUENT

After the UDF that you have defined using DEFINE_VECTOR_EXCHANGE_PROPERTY is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., custom_slip) will become visible and selectable in the Phase Interaction panel in FLUENT. See Section 6.3.5: Hooking DEFINE_VECTOR_EXCHANGE_PROPERTY UDFs for details.

2.5 Discrete Phase Model (DPM) DEFINE Macros

This section contains descriptions of DEFINE macros for the discrete phase model (DPM). Table 2.5.1 provides a quick reference guide to the DPM DEFINE macros, the functions they define, and the panels where they are activated in FLUENT. Definitions of each DEFINE macro are contained in the udf.h header file. For your convenience, they are listed in Appendix B.

- Section 2.5.1: DEFINE_DPM_BC
- Section 2.5.2: DEFINE_DPM_BODY_FORCE
- Section 2.5.3: DEFINE_DPM_DRAG
- Section 2.5.4: DEFINE_DPM_EROSION
- Section 2.5.5: DEFINE_DPM_HEAT_MASS
- Section 2.5.6: DEFINE_DPM_INJECTION_INIT
- Section 2.5.7: DEFINE_DPM_LAW
- Section 2.5.8: DEFINE_DPM_OUTPUT
- Section 2.5.9: DEFINE_DPM_PROPERTY
- Section 2.5.10: DEFINE_DPM_SCALAR_UPDATE
- Section 2.5.11: DEFINE_DPM_SOURCE
- Section 2.5.12: DEFINE_DPM_SPRAY_COLLIDE
- Section 2.5.13: DEFINE_DPM_SWITCH
- Section 2.5.14: DEFINE_DPM_TIMESTEP
- Section 2.5.15: DEFINE_DPM_VP_EQUILIB

Table 2.5.1: Quick Reference Guide for DPM-Specific DEFINE Macros

Function	DEFINE Macro	Panel Activated In
particle state at boundaries	DEFINE_DPM_BC	boundary condition (e.g., Velocity Inlet)
body forces on particles	DEFINE_DPM_BODY_FORCE	Discrete Phase Model
drag coefficients between particles and fluid	DEFINE_DPM_DRAG	Discrete Phase Model
erosion and accretion rates	DEFINE_DPM_EROSION	Discrete Phase Model
heat and mass transfer of multicomponent particles to the gas phase	DEFINE_DPM_HEAT_MASS	Set Injection Properties
initializes injections	DEFINE_DPM_INJECTION_INIT	Set Injection Properties
custom laws for particles	DEFINE_DPM_LAW	Custom Laws
modifies what is written to the sampling plane output	DEFINE_DPM_OUTPUT	Sample Trajectories
material properties	DEFINE_DPM_PROPERTY	Materials
updates scalar every time a particle position is updated	DEFINE_DPM_SCALAR_UPDATE	Discrete Phase Model
particle source terms	DEFINE_DPM_SOURCE	Discrete Phase Model
particle collisions algorithm	DEFINE_DPM_SPRAY_COLLIDE	User-Defined Function Hooks
changes the criteria for switching between laws	DEFINE_DPM_SWITCH	Custom Laws
time step control for DPM simulation	DEFINE_DPM_TIMESTEP	Discrete Phase Model
equilibrium vapor pressure of vaporizing components of multicomponent particles	DEFINE_DPM_VP_EQUILIB	Materials

2.5.1 DEFINE_DPM_BC

Description

You can use DEFINE_DPM_BC to specify your own boundary conditions for particles. The function is executed every time a particle touches a boundary of the domain, except for symmetric or periodic boundaries. You can define a separate UDF (using DEFINE_DPM_BC) for each boundary.

Usage

```
DEFINE_DPM_BC(name,p,t,f,f_normal,dim)
```

Argument Type	**Description**
`symbol name`	UDF name.
`Tracked_Particle *p`	Pointer to the `Tracked_Particle` data structure which contains data related to the particle being tracked.
`Thread *t`	Pointer to the face thread the particle is currently hitting.
`face_t f`	Index of the face that the particle is hitting.
`real f_normal[]`	Array that contains the unit vector which is normal to the face.
`int dim`	Dimension of the flow problem. The value is `2` in 2d, for 2d-axisymmetric and 2d-axisymmetric-swirling flow, while it is `3` in 3d flows.

Function returns
`int`

There are six arguments to DEFINE_DPM_BC: `name`, `p`, `t`, `f`, `f_normal`, and `dim`. You supply `name`, the name of the UDF. `p`, `t`, `f`, `f_normal`, and `dim` are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to compute the new velocity of a particle after hitting the wall, and then return the status of the particle track (as an `int`), after it has hit the wall.

Pointer `p` can be used as an argument to the particle-specific macros (defined in Section 3.2.7: DPM Macros) to obtain information about particle properties.

Example 1

This example shows the usage of DEFINE_DPM_BC for a simple reflection at walls. It is similar to the reflection method executed by FLUENT except that FLUENT accommodates moving walls. The function must be executed as a compiled UDF.

The function assumes an ideal reflection for the normal velocity component (nor_coeff = 1) while the tangential component is damped (tan_coeff = 0.3). First, the angle of incidence is computed. Next, the normal particle velocity, with respect to the wall, is computed and subtracted from the particles velocity. The reflection is complete once the reflected normal velocity is added. The new particle velocity has to be stored in state0 to account for the change of particle velocity in the momentum balance for coupled flows. The function returns PATH_ACTIVE for inert particles while it stops particles of all other types.

```
/* reflect boundary condition for inert particles */
#include "udf.h"
DEFINE_DPM_BC(bc_reflect,p,t,f,f_normal,dim)
{
  real alpha;  /* angle of particle path with face normal */
  real vn=0.;
  real nor_coeff = 1.;
  real tan_coeff = 0.3;
  real normal[3];
  int i, idim = dim;
  real NV_VEC(x);

#if RP_2D
  /* dim is always 2 in 2D compilation. Need special treatment for 2d
     axisymmetric and swirl flows */
  if (rp_axi_swirl)
    {
      real R = sqrt(p->state.pos[1]*p->state.pos[1] +
                    p->state.pos[2]*p->state.pos[2]);
      if (R > 1.e-20)
        {
          idim = 3;
          normal[0] = f_normal[0];
          normal[1] = (f_normal[1]*p->state.pos[1])/R;
          normal[2] = (f_normal[1]*p->state.pos[2])/R;
        }
      else
        {
          for (i=0; i<idim; i++)
```

```
            normal[i] = f_normal[i];
        }
    }
  else
#endif
    for (i=0; i<idim; i++)
      normal[i] = f_normal[i];

  if(p->type==DPM_TYPE_INERT)
    {
      alpha = M_PI/2. - acos(MAX(-1.,MIN(1.,NV_DOT(normal,p->state.V)/
                            MAX(NV_MAG(p->state.V),DPM_SMALL))));
      if ((NNULLP(t)) && (THREAD_TYPE(t) == THREAD_F_WALL))
        F_CENTROID(x,f,t);

      /* calculate the normal component, rescale its magnitude by
         the coefficient of restitution and subtract the change */

      /* Compute normal velocity. */
      for(i=0; i<idim; i++)
        vn += p->state.V[i]*normal[i];

      /* Subtract off normal velocity. */
      for(i=0; i<idim; i++)
        p->state.V[i] -= vn*normal[i];

      /* Apply tangential coefficient of restitution. */
      for(i=0; i<idim; i++)
        p->state.V[i] *= tan_coeff;

      /* Add reflected normal velocity. */
      for(i=0; i<idim; i++)
        p->state.V[i] -= nor_coeff*vn*normal[i];

      /* Store new velocity in state0 of particle */
      for(i=0; i<idim; i++)
        p->state0.V[i] = p->state.V[i];

      return PATH_ACTIVE;
    }

  return PATH_ABORT;
}
```

Example 2

This example shows how to use DEFINE_DPM_BC for a wall impingement model. The function must be executed as a compiled UDF.

```
#include "udf.h"
#include "dpm.h"
#include "surf.h"
#include "random.h"

/* define a user-defined dpm boundary condition routine
 * bc_reflect: name
 * p:          the tracked particle
 * t:          the touched face thread
 * f:          the touched face
 * f_normal:   normal vector of touched face
 * dim:        dimension of the problem (2 in 2d and 2d-axi-swirl, 3 in 3d)
 *
 * return is the status of the particle, see enumeration of Path_Status
 * in dpm.h
 */

#define V_CROSS(a,b,r)\
        ((r)[0] = (a)[1]*(b)[2] - (b)[1]*(a)[2],\
         (r)[1] = (a)[2]*(b)[0] - (b)[2]*(a)[0],\
         (r)[2] = (a)[0]*(b)[1] - (b)[0]*(a)[1])



DEFINE_DPM_BC(bc_wall_jet, p, thread, f, f_normal, dim)
{
  /*
     Routine implementing the Naber and Reitz Wall
     impingement model (SAE 880107)
  */

  real normal[3];
  real tan_1[3];
  real tan_2[3];
  real rel_vel[3];
  real face_vel[3];

  real alpha, beta, phi, cp, sp;
  real rel_dot_n, vmag, vnew, dum;
  real weber_in, weber_out;

  int i, idim = dim;

  cxboolean moving = (SV_ALLOCATED_P (thread,SV_WALL_GRID_V) &&
    SV_ALLOCATED_P (thread,SV_WALL_V     )   );

#if RP_2D
  if (rp_axi_swirl)
    {
      real R = sqrt(p->state.pos[1]*p->state.pos[1] +
    p->state.pos[2]*p->state.pos[2]);

      if (R > 1.e-20)
{
  idim = 3;
  normal[0] = f_normal[0];
  normal[1] = (f_normal[1]*p->state.pos[1])/R;
  normal[2] = (f_normal[1]*p->state.pos[2])/R;
}
      else
{
  for (i=0; i<idim; i++)
    normal[i] = f_normal[i];
}
    }
  else
#endif
    for (i=0; i<idim; i++)
      normal[i] = f_normal[i];

  /*
     Set up velocity vectors and calculate the Weber number
     to determine the regime.
  */

  for (i=0; i < idim; i++)
    {
      if (moving)
face_vel[i] = WALL_F_VV(f,thread)[i] + WALL_F_GRID_VV(f,thread)[i];
      else
face_vel[i] = 0.0;
```

```
      rel_vel[i] = P_VEL(p)[i] - face_vel[i];
    }

  vmag = MAX(NV_MAG(rel_vel),DPM_SMALL);

  rel_dot_n = MAX(NV_DOT(rel_vel,normal),DPM_SMALL);

  weber_in = P_RHO(p) * DPM_SQR(rel_dot_n) * P_DIAM(p) /
     MAX(DPM_SURFTEN(p), DPM_SMALL);

  /*
     Regime where bouncing occurs (We_in < 80).
     (Data from Mundo, Sommerfeld and Tropea
      Int. J. of Multiphase Flow, v21, #2, pp151-173, 1995)
  */

  if (weber_in <= 80.)
    {
      weber_out = 0.6785*weber_in*exp(-0.04415*weber_in);
      vnew = rel_dot_n * (1.0 + sqrt( weber_out /
         MAX( weber_in, DPM_SMALL )));

      /*
 The normal component of the velocity is changed based
 on the experimental paper above (i.e. the Weber number
 is based on the relative velocity).
      */

      for (i=0; i < idim; i++)
P_VEL(p)[i] = rel_vel[i] - vnew*normal[i] + face_vel[i];

    }

  if (weber_in > 80.)
    {
      alpha = acos(-rel_dot_n/vmag);

      /*
         Get one tangent vector by subtracting off the normal
         component from the impingement vector, then cross the
         normal with the tangent to get an out of plane vector.
      */
      for (i=0; i < idim; i++)
tan_1[i] = rel_vel[i] - rel_dot_n*normal[i];

      UNIT_VECT(tan_1,tan_1);

      V_CROSS(tan_1,normal,tan_2);

      /*
         beta is calculated by neglecting the coth(alpha)
         term in the paper (it is approximately right).
      */

      beta = MAX(M_PI*sqrt(sin(alpha)/(1.0-sin(alpha))),DPM_SMALL);

      phi= -M_PI/beta*log(1.0-cheap_uniform_random()*(1.0-exp(-beta)));

      if (cheap_uniform_random() > 0.5)
phi = -phi;

      vnew = vmag;

      cp = cos(phi);
      sp = sin(phi);

      for (i=0; i < idim; i++)
P_VEL(p)[i] = vnew*(tan_1[i]*cp + tan_2[i]*sp) + face_vel[i];

    }

  /*
    Subtract off from the original state.
  */
  for (i=0; i < idim; i++)
    P_VEL0(p)[i] = P_VEL(p)[i];

  if ( DPM_STOCHASTIC_P(p->injection) )
    {

      /* Reflect turbulent fluctuations also */
      /* Compute normal velocity. */

      dum = 0;
      for(i=0; i<idim; i++)
```

```
dum += p->V_prime[i]*normal[i];

      /* Subtract off normal velocity. */

      for(i=0; i<idim; i++)
p->V_prime[i] -= 2.*dum*normal[i];
    }
  return PATH_ACTIVE;
}
```

Hooking a DPM Boundary Condition UDF to FLUENT

After the UDF that you have defined using DEFINE_DPM_BC is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible in the appropriate boundary condition panel (e.g., the Velocity Inlet panel) in FLUENT. See Section 6.4.1: Hooking DEFINE_DPM_BC UDFs for details on how to hook your DEFINE_DPM_BC UDF to FLUENT.

2.5.2 DEFINE_DPM_BODY_FORCE

Description

You can use DEFINE_DPM_BODY_FORCE to specify a body force other than a gravitational or drag force on the particles.

Usage

DEFINE_DPM_BODY_FORCE(name,p,i)

Argument Type	**Description**
symbol name	UDF name.
Tracked_Particle *p	Pointer to the Tracked_Particle data structure which contains data related to the particle being tracked.
int i	An index (0, 1, or 2) that identifies the Cartesian component of the body force that is to be returned by the function.

Function returns
real

There are three arguments to DEFINE_DPM_BODY_FORCE: name, p, and i. You supply name, the name of the UDF. p and i are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to return the real value of the acceleration due to the body force (in m/s^2) to the FLUENT solver.

> Pointer p can be used as an argument to the macros defined in Section 3.2.7: DPM Macros to obtain information about particle properties (e.g., injection properties).

Example

The following UDF, named particle_body_force, computes the magnetic force on a charged particle. DEFINE_DPM_BODY_FORCE is called at every particle time step in FLUENT and requires a significant amount of CPU time to execute. For this reason, the UDF should be executed as a compiled UDF.

In the UDF presented below a charged particle is introduced upstream, into a laminar flow, and travels downstream until t=tstart when a magnetic field is applied. The particle takes on an approximately circular path (not an exact circular path, because the speed and magnetic force vary as the particle is slowed by the surrounding fluid).

The macro P_TIME(p) gives the current time for a particle traveling along a trajectory, which is pointed to by p.

```
/* UDF for computing the magnetic force on a charged particle */

#include "udf.h"

#define Q 1.0          /* particle electric charge      */
#define BZ 3.0         /* z component of magnetic field */
#define TSTART 18.0    /* field applied at t = tstart   */

/* Calculate magnetic force on charged particle.  Magnetic   */
/* force is particle charge times cross product of particle  */
/* velocity with magnetic field: Fx= q*bz*Vy,  Fy= -q*bz*Vx  */

DEFINE_DPM_BODY_FORCE(particle_body_force,p,i)
{
        real bforce;
        if(P_TIME(p)>=TSTART)
          {
           if(i==0) bforce=Q*BZ*P_VEL(p)[1];

           else if(i==1) bforce=-Q*BZ*P_VEL(p)[0];

          }
        else
           bforce=0.0;
        /* an acceleration should be returned */
        return (bforce/P_MASS(p));
}
```

Hooking a DPM Body Force UDF to FLUENT

After the UDF that you have defined using DEFINE_DPM_BODY_FORCE is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible in the Discrete Phase Model panel in FLUENT. See Section 6.4.2: Hooking DEFINE_DPM_BODY_FORCE UDFs for details on how to hook your DEFINE_DPM_BODY_FORCE UDF to FLUENT.

2.5.3 DEFINE_DPM_DRAG

Description

You can use DEFINE_DPM_DRAG to specify the drag coefficient, C_D, between particles and fluid defined by the following equation:

$$F_D = \frac{18\mu}{\rho_p D_p^2} \frac{C_D \mathrm{Re}}{24}$$

Usage

DEFINE_DPM_DRAG(name,Re,p)

Argument Type	**Description**
symbol name	UDF name.
real Re	particle Reynolds number based on the particle diameter and relative gas velocity.
Tracked_Particle *p	Pointer to the Tracked_Particle data structure which contains data related to the particle being tracked.

Function returns
real

There are three arguments to DEFINE_DPM_DRAG: name, Re, and p. You supply name, the name of the UDF. Re and p are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to return the real value of the drag force on a particle. The value returned to the solver must be dimensionless and represent 18 * Cd * Re / 24.

> i Pointer p can be used as an argument to the macros defined in Section 3.2.7: DPM Macros to obtain information about particle properties (e.g., injection properties).

Example

The following UDF, named particle_drag_force, computes the drag force on a particle and is a variation of the body force UDF presented in Section 2.5.2: DEFINE_DPM_BODY_FORCE. The flow is the same, but a different curve is used to describe the particle drag. DEFINE_DPM_DRAG is called at every particle time step in FLUENT, and requires a significant amount of CPU time to execute. For this reason, the UDF should be executed as a compiled UDF.

```
/************************************************************************
   UDF for computing particle drag coefficient (18 Cd Re/24)
   curve as suggested by R. Clift, J. R. Grace and M.E. Weber
   "Bubbles, Drops, and Particles" (1978)
*************************************************************************/

#include "udf.h"

DEFINE_DPM_DRAG(particle_drag_force,Re,p)
{
  real w, drag_force;

  if (Re < 0.01)
    {
    drag_force=18.0;
    return (drag_force);
    }
  else if (Re < 20.0)
    {
    w = log10(Re);
    drag_force = 18.0 + 2.367*pow(Re,0.82-0.05*w) ;
    return (drag_force);
    }
  else
    /* Note: suggested valid range 20 < Re < 260 */
    {
    drag_force = 18.0 + 3.483*pow(Re,0.6305) ;
    return (drag_force);
    }
}
```

Hooking a DPM Drag Coefficient UDF to FLUENT

After the UDF that you have defined using DEFINE_DPM_DRAG is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible in the Discrete Phase Model panel in FLUENT. See Section 6.4.3: Hooking DEFINE_DPM_DRAG UDFs for details on how to hook your DEFINE_DPM_DRAG UDF to FLUENT.

2.5.4 DEFINE_DPM_EROSION

Description

You can use DEFINE_DPM_EROSION to specify the erosion and accretion rates calculated as the particle stream strikes a wall surface. The function is called when the particle encounters a reflecting surface.

Usage

```
DEFINE_DPM_EROSION(name,p,t,f,normal,alpha,Vmag,mdot)
```

Argument Type	Description
symbol name	UDF name.
Tracked_Particle *p	Pointer to the Tracked_Particle data structure which contains data related to the particle being tracked.
Thread *t	Pointer to the face thread the particle is currently hitting.
face_t f	Index of the face that the particle is hitting.
real normal[]	Array that contains the unit vector that is normal to the face.
real alpha	Variable that represents the impact angle between the particle path and the face (in radians).
real Vmag	Variable that represents the magnitude of the particle velocity (in m/s).
real mdot	Flow rate of the particle stream as it hits the face (in kg/s).

Function returns
void

There are eight arguments to DEFINE_DPM_EROSION: name, p, t, f, normal, alpha, Vmag, and mdot. You supply name, the name of the UDF. p, t, f, normal, alpha, Vmag, and mdot are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to compute the values for the erosion rate and/or accretion rate and store the values at the faces in F_STORAGE_R(f,t,SV_DPMS_EROSION) and F_STORAGE_R (f,t,SV_DPMS_ACCRETION), respectively.

i Pointer p can be used as an argument to the macros defined in Section 3.2.7: DPM Macros to obtain information about particle properties (e.g., injection properties).

Example

The following is an example of a compiled UDF that uses DEFINE_DPM_EROSION to extend post-processing of wall impacts in a 2D axisymmetric flow. It provides additional information on how the local particle deposition rate depends on the diameter and normal velocity of the particles. It is based on the assumption that every wall impact leads to more accretion, and, therefore, every trajectory is "evaporated" at its first wall impact. (This is done by first setting a DPM user scalar within DEFINE_DPM_EROSION, which is then evaluated within DEFINE_DPM_LAW, where P_MASS is set to zero.) User-defined memory locations (UDMLs) are used to store and visualize the following:

- number of wall impacts since UDMLs were reset. (Resetting is typically done at the beginning of a FLUENT session by the use of DEFINE_ON_DEMAND in order to avoid the use of uninitialized data fields. Resetting prevents the addition of sampled data being read from a file).
- average diameter of particles hitting the wall.
- average radial velocity of particles.

Before tracing the particles, you will have to reset the UDMLs and assign the global domain pointer by executing the DEFINE_ON_DEMAND function.

```
/***********************************************************************
   UDF for extending post-processing of wall impacts
***********************************************************************/
#include "udf.h"

#define MIN_IMPACT_VELO -1000.
  /* Minimum particle velocity normal to wall (m/s) to allow Accretion.*/

Domain *domain; /* Get the domain pointer and assign it later to domain*/

enum            /* Enumeration of used User-Defined Memory Locations. */
{
  NUM_OF_HITS,    /* Number of particle hits into wall face considered.*/
  AVG_DIAMETER,    /* Average diameter of particles that hit the wall. */
  AVG_RADI_VELO,    /* Average radial velocity of ""  ""  ------------ */
  NUM_OF_USED_UDM
};

int UDM_checked = 0;     /* Availability of UDMLs checked? */

void reset_UDM_s(void);  /* Function to follow below. */
```

```
int check_for_UDM(void)      /* Check for UDMLs' availability... */
{
  Thread *t;

  if (UDM_checked)
    return UDM_checked;

/* if (!rp_axi)*/
 /* Internal_Error("UDF-Error: only valid for 2d-axisymmetric cases!\n");*/
  thread_loop_c(t,domain)    /* We require all cell threads to */
    {                         /* provide space in memory for UDML */
      if (FLUID_THREAD_P(t))
        if (NULLP(THREAD_STORAGE(t,SV_UDM_I)))
            return 0;
    }

  UDM_checked = 1;     /* To make the following work properly... */
  reset_UDM_s();       /* This line will be executed only once, */
  return UDM_checked;  /* because check_for_UDM checks for */
}                      /* UDM_checked first. */

void
reset_UDM_s(void)
{
  Thread *t;
  cell_t  c;
  face_t  f;
  int     i;

  if (!check_for_UDM())  /* Don't do it, if memory is not available. */
    return;

  Message("Resetting User Defined Memory...\n");

  thread_loop_f(t, domain)
    {
      if (NNULLP(THREAD_STORAGE(t,SV_UDM_I)))
        {
          begin_f_loop(f,t)
            {
              for (i = 0; i < NUM_OF_USED_UDM; i++)
                F_UDMI(f,t,i) = 0.;
            }
          end_f_loop(f, t)
        }
      else
        {
          Message("Skipping FACE thread no. %d..\n", THREAD_ID(t));
        }
    }
  thread_loop_c(t,domain)
    {
      if (NNULLP(THREAD_STORAGE(t,SV_UDM_I)))
        {
          begin_c_loop(c,t)
            {
              for (i = 0; i < NUM_OF_USED_UDM; i++)
                C_UDMI(c,t,i) = 0.;
            }
          end_c_loop(c,t)
        }
      else
        {
          Message(" Skipping CELL thread no. %d..\n", THREAD_ID(t));
        }
    }                /* Skipping Cell Threads can happen if the user */
                            /* uses reset_UDM prior to initializing. */
  Message(" --- Done.\n");
}

DEFINE_DPM_SCALAR_UPDATE(dpm_scalup,c,t,if_init,p)
{  if (if_init)
    P_USER_REAL(p, 0) = 0;    /* Simple initialization. Used later for
                                stopping trajectory calculation */
}

DEFINE_DPM_EROSION(dpm_accr, p, t, f, normal, alpha, Vmag, Mdot)
{
  real A[ND_ND], area;
  int num_in_data;
  Thread *t0;
  cell_t  c0;

  real radi_pos[2], radius, imp_vel[2], vel_ortho;
```

```
/* The following is ONLY valid for 2d-axisymmetric calculations!!! */
/* Additional effort is necessary because DPM tracking is done in  */
/* THREE dimensions for TWO-dimensional axisymmetric calculations. */

  radi_pos[0] = p->state.pos[1];      /* Radial location vector. */
  radi_pos[1] = p->state.pos[2];      /* (Y and Z in 0 and 1...) */

  radius = NV_MAG(radi_pos);
  NV_VS(radi_pos, =, radi_pos, /, radius);
                               /* Normalized radius direction vector.*/
  imp_vel[0] = P_VEL(p)[0];    /* Axial particle velocity component. */
  imp_vel[1] = NVD_DOT(radi_pos, P_VEL(p)[1], P_VEL(p)[2], 0.);
  /* Dot product of normalized radius vector and y & z components */
  /* of particle velocity vector gives _radial_ particle velocity */
  /* component  */
  vel_ortho = NV_DOT(imp_vel, normal); /*velocity orthogonal to wall */

  if (vel_ortho < MIN_IMPACT_VELO)  /* See above, MIN_IMPACT_VELO */
    return;

  if (!UDM_checked)       /* We will need some UDMs, */
    if (!check_for_UDM()) /* so check for their availability.. */
      return;             /* (Using int variable for speed, could */
                          /*  even just call check_for UDFM().) */
  c0 = F_C0(f,t);
  t0 = THREAD_T0(t);

  num_in_data = F_UDMI(f,t,NUM_OF_HITS);

/* Average diameter of particles that hit the particular wall face:*/
  F_UDMI(f,t,AVG_DIAMETER) = (P_DIAM(p)
                          +  num_in_data * F_UDMI(f,t,AVG_DIAMETER))
                             / (num_in_data + 1);
  C_UDMI(c0,t0,AVG_DIAMETER) = F_UDMI(f,t,AVG_DIAMETER);

/* Average velocity normal to wall of particles hitting the wall:*/
  F_UDMI(f,t,AVG_RADI_VELO) = (vel_ortho
                        +  num_in_data * F_UDMI(f,t,AVG_RADI_VELO))
                           / (num_in_data + 1);
  C_UDMI(c0,t0,AVG_RADI_VELO) = F_UDMI(f,t,AVG_RADI_VELO);

  F_UDMI(f, t, NUM_OF_HITS) = num_in_data + 1;
  C_UDMI(c0,t0,NUM_OF_HITS) = num_in_data + 1;
  F_AREA(A,f,t);
  area = NV_MAG(A);
  F_STORAGE_R(f,t,SV_DPMS_ACCRETION) += Mdot / area;
                                            /* copied from source. */

  P_USER_REAL(p,0) = 1.;     /* "Evaporate" */
}

DEFINE_DPM_LAW(stop_dpm_law,p,if_cpld)
{
  if (0. < P_USER_REAL(p,0))
    P_MASS(p) = 0.;          /* "Evaporate" */
}

DEFINE_ON_DEMAND(reset_UDM)
{
  /* assign domain pointer with global domain */
  domain = Get_Domain(1);
  reset_UDM_s();
}
```

Hooking an Erosion/Accretion UDF to FLUENT

After the UDF that you have defined using DEFINE_DPM_EROSION is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible in the Discrete Phase Model panel in FLUENT. See Section 6.4.4: Hooking DEFINE_DPM_EROSION UDFs for details on how to hook your DEFINE_DPM_EROSION UDF to FLUENT.

2.5.5 DEFINE_DPM_HEAT_MASS

Description

You can use DEFINE_DPM_HEAT_MASS to specify the heat and mass transfer of multicomponent particles to the gas phase.

Usage

```
DEFINE_DPM_HEAT_MASS(name,p,C_p,hgas,hvap,cvap_surf,dydt,dzdt)
```

Argument Type	Description
symbol name	UDF name.
Tracked_Particle *p	Pointer to the Tracked_Particle data structure which contains data related to the particle being tracked.
real C_p	Particle heat capacity.
real *hgas	Enthalpies of vaporizing gas phase species.
real *hvap	Vaporization enthalpies of vaporizing components.
real *cvap_surf	Vapor equilibrium concentrations of vaporizing components.
real *dydt	Source terms of the particle temperature and component masses.
dpms_t *dzdt	Source terms of the gas phase enthalpy and species masses.

Function returns
void

There are eight arguments to DEFINE_DPM_HEAT_MASS: name,e,p,C_p,hgas,hvap,cvap_surf, dydt,and dzdt. You supply name, the name of the UDF. e,p,C_p,hgas,hvap,and cvap_surf are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to compute the particle and gas phase source terms and store the values in dydt and dzdt, respectively.

Example

The following is an example of a compiled UDF that uses DEFINE_DPM_HEAT_MASS. It implements the source terms for the following:

Source Term	Variable	Unit
particle temperature	dydt[0]	K/s
particle component mass	dydt[1..]	kg/s
gas phase enthalpy	dzdt>energy	J/s
gas phase species mass	dzdt>species[0..]	kg/s

```
/***********************************************************************
   UDF for defining the heat and mass transport for
   multicomponent particle vaporization
 ***********************************************************************/
#include "udf.h"

DEFINE_DPM_HEAT_MASS(multivap,p,Cp,hgas,hvap,cvap_surf,dydt,dzdt)
{
  int ns;
  int nc = TP_N_COMPONENTS( p ); /* number of particle components */
  cell_t c0 = RP_CELL(&(p->cCell));  /* cell and thread */
  Thread *t0 = RP_THREAD( &(p->cCell) );  /* where the particle is in */
  Material *gas_mix = THREAD_MATERIAL( t0 ); /* gas mixture material */
  Material *cond_mix = p->injection->material;/* particle mixture material */
  cphase_state_t *c = &(p->cphase); /* cell info of particle location */
  real molwt[MAX_SPE_EQNS];  /* molecular weight of gas species */
  real Tp = P_T(p);  /* particle temperature */
  real mp = P_MASS(p);  /* particle mass */
  real molwt_bulk = 0.;  /* average molecular weight in bulk gas */
  real Dp = DPM_DIAM_FROM_VOL( mp / P_RHO(p) );  /* particle diameter */
  real Ap = DPM_AREA(Dp);                  /* particle surface */
  real Pr = c->sHeat * c->mu / c->tCond;   /* Prandtl number */
  real Nu = 2.0 + 0.6 * sqrt( p->Re ) * pow( Pr, 1./3. );  /* Nusselt number */
  real h = Nu * c->tCond / Dp;      /* Heat transfer coefficient */
  real dh_dt = h * ( c->temp - Tp ) * Ap;  /* heat source term */
  dydt[0] += dh_dt / ( mp * Cp );
  dzdt->energy -= dh_dt;
  {
    Material *sp;
    mixture_species_loop(gas_mix,sp,ns)
      {
molwt[ns] = MATERIAL_PROP(sp,PROP_mwi); /* molecular weight of gas species */
      molwt_bulk += C_YI(c0,t0,ns) / molwt[ns];  /* average molecular weight */
      }
  }

  /* prevent division by zero */
  molwt_bulk = MAX(molwt_bulk,DPM_SMALL);

  for( ns = 0; ns < nc; ns++ )
    {
      /* gas species index of vaporization */
      int gas_index = TP_COMPONENT_INDEX_I(p,ns);
      if( gas_index >= 0 )
{
  /* condensed material */
  Material * cond_c = MIXTURE_COMPONENT(cond_mix, ns );
  /* vaporization temperature */
  real vap_temp = MATERIAL_PROP(cond_c,PROP_vap_temp);
  /* diffusion coefficient */
  real D = MATERIAL_PROP_POLYNOMIAL( cond_c, PROP_binary_diffusivity, c->temp);
  /* Schmidt number */
  real Sc = c->mu / ( c->rho * D );
  /* mass transfer coefficient */
  real k = ( 2. + 0.6 * sqrt(p->Re) * pow( Sc, 1./3. ) ) * D / Dp;
  /* bulk gas concentration */
  real cvap_bulk = c->pressure / UNIVERSAL_GAS_CONSTANT / c->temp
    * c->yi[gas_index] / molwt_bulk / solver_par.molWeight[gas_index];
  /* vaporization rate */
  real vap_rate = k * molwt[gas_index] * Ap * ( cvap_surf[ns] - cvap_bulk );
  /* only condensation below vaporization temperature */
  if( 0. < vap_rate && Tp < vap_temp )
    vap_rate = 0.;

  dydt[1+ns] -= vap_rate;
  dzdt->species[gas_index] += vap_rate;
  /* dT/dt = dh/dt / (m Cp)*/
  dydt[0] -= hvap[gas_index] * vap_rate / ( mp * Cp );
  /* gas enthalpy source term */
  dzdt->energy += hgas[gas_index] * vap_rate;
}
    }
}
```

Hooking a DPM Particle Heat and Mass Transfer UDF to FLUENT

After the UDF that you have defined using DEFINE_DPM_HEAT_MASS is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., multivap) will become visible in the Set Injection Properties panel in FLUENT. See Section 6.4.5: Hooking DEFINE_DPM_HEAT_MASS UDFs for details on how to hook your DEFINE_DPM_HEAT_MASS UDF to FLUENT.

2.5.6 DEFINE_DPM_INJECTION_INIT

Description

You can use DEFINE_DPM_INJECTION_INIT to initialize a particle's injection properties such as location, diameter, and velocity.

Usage

```
DEFINE_DPM_INJECTION_INIT(name,I)
```

Argument Type	Description
symbol name	UDF name.
Injection *I	Pointer to the Injection structure which is a container for the particles being created. This function is called twice for each Injection before the first DPM iteration, and then called once for each Injection before the particles are injected into the domain at each subsequent DPM iteration.

Function returns
void

There are two arguments to DEFINE_DPM_INJECTION_INIT: name and I. You supply name, the name of the UDF. I is a variable that is passed by the FLUENT solver to your UDF.

Example

The following UDF, named init_bubbles, initializes particles on a surface injection due to a surface reaction. This function must be executed as a compiled UDF and can be used *only* on UNIX and Linux systems. Note that if you are going to use this UDF in a transient simulation to compute transient particles, you will need to replace loop(p, I->p) with loop(p, I->p_init). Transient particle initialization cannot be performed with a loop over I->p.

```
/**********************************************************************
   UDF that initializes particles on a surface injection due
   to a surface reaction
***********************************************************************/

#include "udf.h"
#include "surf.h"  /* RP_CELL and RP_THREAD are defined in surf.h */

#define REACTING_SURFACE_ID 2
#define MW_H2 2
#define STOIC_H2 1

/* ARRHENIUS CONSTANTS */
#define PRE_EXP 1e+15
#define ACTIVE 1e+08
#define BETA 0.0

real arrhenius_rate(real temp)
{
 return
PRE_EXP*pow(temp,BETA)*exp(-ACTIVE/(UNIVERSAL_GAS_CONSTANT*temp));
}

/* Species numbers. Must match order in Fluent panel /*
#define HF  0

/* Reaction Exponents */
#define HF_EXP  2.0


/* Reaction Rate Routine used in UDF */

real reaction_rate(cell_t c, Thread *cthread,real mw[],real yi[])

*/ Note that all arguments in the reaction_rate function
call in your .c source file MUST be on the same line or a
compilation error will occur */

{
 real concenHF = C_R(c,cthread)*yi[HF]/mw[HF];

 return arrhenius_rate(C_T(c,cthread))*pow(concenHF,HF_EXP);
}
```

```
real contact_area(cell_t c,Thread *t,int s_id,int *n);


DEFINE_DPM_INJECTION_INIT(init_bubbles,I)
{
 int count,i;
 real area, mw[MAX_SPE_EQNS], yi[MAX_SPE_EQNS];
   /*  MAX_SPE_EQNS is a Fluent constant in materials.h  */

 Particle *p;
 cell_t cell;
 Thread *cthread;
 Material *mix, *sp;

 Message("Initializing Injection: %s\n",I->name);

 loop(p,I->p)  /* Standard Fluent Looping Macro to get particle
                 streams in an Injection */
 {
  cell = P_CELL(p);   /* Get the cell and thread that the particle
                         is currently in   */
  cthread = P_CELL_THREAD(p);

  /* Set up molecular weight & mass fraction arrays */
  mix = THREAD_MATERIAL(cthread);
  mixture_species_loop(mix,sp,i)
  {
   mw[i] = MATERIAL_PROP(sp,PROP_mwi);
   yi[i] = C_YI(cell,cthread,i);
  }

  area = contact_area(cell, cthread, REACTING_SURFACE_ID,&count);
   /* Function that gets total area of REACTING_SURFACE faces in
      contact with cell */
   /* count is the number of contacting faces, and is needed
      to share the total bubble emission between the faces      */
  if (count > 0)  /* if cell is in contact with REACTING_SURFACE */
  {
   P_FLOW_RATE(p) = (area *MW_H2* STOIC_H2 *
                 reaction_rate(cell, cthread, mw, yi))/
                 (real)count;    /* to get correct total flow
                     rate when multiple faces contact the same cell */
   P_DIAM(p) = 1e-3;
   P_RHO(p) = 1.0;
   P_MASS(p) = P_RHO(p)*M_PI*pow(P_DIAM(p),3.0)/6.0;
  }
  else
   P_FLOW_RATE(p) = 0.0;
 }
}

real contact_area(cell_t c, Thread *t, int s_id, int *n)
{
 int i = 0;
 real area = 0.0, A[ND_ND];

 *n = 0;
 c_face_loop(c,t,i)
 {
  if(THREAD_ID(C_FACE_THREAD(c,t,i)) == s_id)
  {
  (*n)++;
   F_AREA(A,C_FACE(c,t,i), C_FACE_THREAD(c,t,i));
   area += NV_MAG(A);
  }
 }
return area;
}
```

Hooking a DPM Initialization UDF to FLUENT

After the UDF that you have defined using DEFINE_DPM_INJECTION_INIT is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible in the Set Injection Properties panel in FLUENT.

See Section 6.4.6: Hooking DEFINE_DPM_INJECTION_INIT UDFs for details on how to hook your DEFINE_DPM_INJECTION_INIT UDF to FLUENT.

2.5.7 DEFINE_DPM_LAW

Description

You can use DEFINE_DPM_LAW to customize laws for particles. For example your UDF can specify custom laws for heat and mass transfer rates for droplets and combusting particles. Additionally, you can specify custom laws for mass, diameter, and temperature properties as the droplet or particle exchanges mass and energy with its surroundings.

Usage

DEFINE_DPM_LAW(name,p,ci)

Argument Type	**Description**
symbol name	UDF name.
Tracked_Particle *p	Pointer to the Tracked_Particle data structure which contains data related to the particle being tracked.
int ci	Variable that indicates whether the continuous and discrete phases are coupled (equal to 1 if coupled with continuous phase, 0 if not coupled).

Function returns
void

There are three arguments to DEFINE_DPM_LAW: name, p, and ci. You supply name, the name of the UDF. p and ci are variables that are passed by the FLUENT solver to your UDF.

i Pointer p can be used as an argument to the macros defined in Section 3.2.7: DPM Macros to obtain information about particle properties (e.g., injection properties).

Example

The following UDF, named Evapor_Swelling_Law, models a custom law for the evaporation swelling of particles. The source code can be interpreted or compiled in FLUENT. See Section 2.5.13: Example for another example of DEFINE_DPM_LAW usage.

```
/**********************************************************************
   UDF that models a custom law for evaporation swelling of particles
***********************************************************************/

#include "udf.h"

DEFINE_DPM_LAW(Evapor_Swelling_Law,p,ci)
{
  real swelling_coeff = 1.1;

  /* first, call standard evaporation routine to calculate
     the mass and heat transfer                            */
  VaporizationLaw(p);
  /* compute new particle diameter and density */
  P_DIAM(p) = P_INIT_DIAM(p)*(1. + (swelling_coeff - 1.)*
   (P_INIT_MASS(p)-P_MASS(p))/(DPM_VOLATILE_FRACTION(p)*P_INIT_MASS(p)));
  P_RHO(p) = P_MASS(p) / (3.14159*P_DIAM(p)*P_DIAM(p)*P_DIAM(p)/6);
  P_RHO(p) = MAX(0.1, MIN(1e5, P_RHO(p)));
}
```

Hooking a Custom DPM Law to FLUENT

After the UDF that you have defined using DEFINE_DPM_LAW is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible in the Custom Laws panel in FLUENT. See Section 6.4.7: Hooking DEFINE_DPM_LAW UDFs for details on how to hook your DEFINE_DPM_LAW UDF to FLUENT.

2.5.8 DEFINE_DPM_OUTPUT

Description

You can use DEFINE_DPM_OUTPUT to modify what is written to the sampling device output. This function allows access to the variables that are written as a particle passes through a sampler (see Chapter 22: Modeling Discrete Phase in the User's Guide for details).

Usage

```
DEFINE_DPM_OUTPUT(name,header,fp,p,t,plane)
```

Argument Type	**Description**
symbol name	UDF name.
int header	Variable that is equal to 1 at the first call of the function before particles are tracked and set to 0 for subsequent calls.
FILE *fp	Pointer to the file to or from which you are writing or reading.
Tracked_Particle *p	Pointer to the Tracked_Particle data structure which contains data related to the particle being tracked.
Thread *t	Pointer to the thread that the particle is passing through if the sampler is represented by a grid surface. If the sampler is not defined as a grid surface, then the value of t is NULL.
Plane *plane	Pointer to the Plane structure (see dpm.h) if the sampling device is defined as a planar slice (line in 2d). If a grid surface is used by the sampler, then plane is NULL.

Function returns

void

There are six arguments to DEFINE_DPM_OUTPUT: name, header, fp, p, t, and plane. You supply name, the name of the UDF. header, fp, p, t, and plane are variables that are passed by the FLUENT solver to your UDF. The output of your UDF will be written to the file indicated by fp.

Pointer p can be used as an argument to the macros defined in Section 3.2.7: DPM Macros to obtain information about particle properties (e.g., injection properties).

Example

The following UDF named discrete_phase_sampler samples the size and velocity of discrete phase particles at selected planes downstream of an injection. For 2d axisymmetric simulations, it is assumed that droplets/particles are being sampled at planes (lines) corresponding to constant x. For 3d simulations, the sampling planes correspond to constant z.

To remove particles from the domain after they have been sampled, change the value of REMOVE_PARCELS to TRUE. In this case, particles will be deleted following the time step in which they cross the plane. This is useful when you want to sample a spray immediately in front of an injector and you don't wish to track the particles further downstream.

> This UDF works with unsteady and steady simulations that include droplet break-up or collisions. Note that the discrete phase must be traced in an unsteady manner.

```
#include "udf.h"
/******************************************************************/
/* UDF that samples discrete phase size and velocity distributions*/
/* within the domain.                                             */
/******************************************************************/
#define REMOVE_PARTICLES FALSE

DEFINE_DPM_OUTPUT(discrete_phase_sample,header,fp,p,t,plane)
{

#if RP_2D

  real flow_time = solver_par.flow_time;
  real y;

  if(header)
    par_fprintf_head(fp,"  #Time[s]   R [m]   X-velocity[m/s]
    W-velocity[m/s]  R-velocity[m/s]  Drop Diameter[m]
    Number of Drops   Temperature [K]  Initial Diam [m]
    Injection Time [s]  \n");

  if(NULLP(p))
    return;

  if (rp_axi && (sg_swirl || rp_ke))
    y = MAX(sqrt(SQR(p->state.pos[1]) + SQR(p->state.pos[2])),DPM_SMALL);
  else
```

```
    y = p->state.pos[1];

#if PARALLEL
  par_fprintf(fp,"%d %d  %e %f %f  %f  %f  %e  %e  %f  %e  %f  \n",
       p->injection->try_id,p->part_id, P_TIME(p),y,p->state.V[0],
       p->state.V[1],p->state.V[2],P_DIAM(p),p->number_in_parcel,
       P_T(p), P_INIT_DIAM(p),p->time_of_birth);
#else
  par_fprintf(fp,"%e %f %f  %f %f %e %e %f %e %f \n",
       P_TIME(p), y,p->state.V[0],p->state.V[1],p->state.V[2],P_DIAM(p),
       p->number_in_parcel, P_T(p), P_INIT_DIAM(p), p->time_of_birth);
#endif /* PARALLEL */
#else

  real flow_time = solver_par.flow_time;
  real r, x, y;

  if(header)
    par_fprintf_head(fp,"  #Time[s]  R [m]  x-velocity[m/s]
    y-velocity[m/s]  z-velocity[m/s]   Drop Diameter[m]
    Number of Drops  Temperature [K]   Initial Diam [m]
    Injection Time [s]  \n");

  if(NULLP(p))
    return;

  x = p->state.pos[0];
  y = p->state.pos[1];
  r = sqrt(SQR(x) + SQR(y));

#if PARALLEL
  par_fprintf(fp,"%d %d %e %f  %f %f  %f %e %e %f %e %f \n",
 p->injection->try_id, p->part_id, P_TIME(p), r,p->state.V[0],
         p->state.V[1],p->state.V[2],P_DIAM(p),p->number_in_parcel,
         P_T(p), P_INIT_DIAM(p), p->time_of_birth);
#else
  par_fprintf(fp,"%e %f %f %f %f %e %e %f %e %f  \n",
 P_TIME(p), r,p->state.V[0],p->state.V[1],p->state.V[2],
         P_DIAM(p),p->number_in_parcel,P_T(p), P_INIT_DIAM(p),
         p->time_of_birth);
#endif /* PARALLEL */
#endif
```

```
#if REMOVE_PARCELS
  p->stream_index=-1;
#endif
}
```

Hooking a DPM Output UDF to FLUENT

After the UDF that you have defined using DEFINE_DPM_OUTPUT is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible in the Sample Trajectories panel in FLUENT. See Section 6.4.8: Hooking DEFINE_DPM_OUTPUT UDFs for details on how to hook your DEFINE_DPM_OUTPUT UDF to FLUENT.

2.5.9 DEFINE_DPM_PROPERTY

Description

You can use DEFINE_DPM_PROPERTY to specify properties of discrete phase materials. For example, you can model the following dispersed phase propertieswith this type of UDF:

- particle emissivity
- vapor pressure
- vaporization temperature
- particle scattering factor
- boiling point
- particle viscosity
- particle surface tension

Usage

```
DEFINE_DPM_PROPERTY(name,c,t,p)
```

Argument Type	**Description**
symbol name	UDF name.
cell_t c	Index that identifies the cell where the particle is located in the given thread.
Thread *t	Pointer to the thread where the particle is located.
Tracked_Particle *p	Pointer to the Tracked_Particle data structure which contains data related to the particle being tracked.

Function returns

real

There are four arguments to DEFINE_DPM_PROPERTY: name, c, t, and p. DEFINE_DPM_PROPERTY has the same arguments as the DEFINE_PROPERTY function (described in Section 2.3.14: DEFINE_PROPERTY UDFs), with the addition of the pointer to the Tracked_Particle p. You supply name, the name of the UDF. c, t, and p are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to compute the real value of the discrete phase property and return it to the solver.

> *i* Pointer p can be used as an argument to the macros defined in Section 3.2.7: DPM Macros to obtain information about particle properties (e.g., injection properties).

Example

In the following example, two discrete phase material property UDFs (named coal_emissivity and coal_scattering, respectively) are concatenated into a single C source file. These UDFs must be executed as compiled UDFs in FLUENT.

```
/*********************************************************************
   UDF that specifies discrete phase materials
*********************************************************************/

#include "udf.h"

DEFINE_DPM_PROPERTY(coal_emissivity,c,t p)
{
  real mp0= P_INIT_MASS(p);
  real mp = P_MASS(p);
  real vf, cf;

  /* get the material char and volatile fractions and store them */
  /* in vf and cf                                                 */
  vf=DPM_VOLATILE_FRACTION(p);
  cf=DPM_CHAR_FRACTION(p);

  if (!(((mp/mp0) >= 1) || ((mp/mp0) <= 0)))
    {
      if ((mp/mp0) < (1-(vf)-(cf)))
        {
          /* only ash left */
          /* vf = cf = 0; */
          return .001;
        }
      else if ((mp/mp0) < (1-(vf)))
        {
          /* only ash and char left */
          /* cf = 1 - (1-(vf)-(cf))/(mp/mp0); */
          /* vf = 0; */
          return 1.0;
        }

      else
        {
          /* volatiles, char, and ash left */
          /* cf =  (cf)/(mp/mp0); */
          /* vf = 1. - (1.-(vf))/(mp/mp0); */
          return 1.0;
        }
    }
  return 1.0;
}

DEFINE_DPM_PROPERTY(coal_scattering,c,t,p)
{
  real mp0= P_INIT_MASS(p);
  real mp = P_MASS(p);
  real cf, vf;

  /* get the original char and volatile fractions and store them */
  /* in vf and cf                                                */
  vf=DPM_VOLATILE_FRACTION(p);
  cf=DPM_CHAR_FRACTION(p);

  if (!(((mp/mp0) >= 1) || ((mp/mp0) <= 0)))
    {
      if ((mp/mp0) < (1-(vf)-(cf)))
        {
          /* only ash left */
          /* vf = cf = 0; */
          return 1.1;
        }
      else if ((mp/mp0) < (1-(vf)))
        {
          /* only ash and char left */
          /* cf = 1 - (1-(vf)-(cf))/(mp/mp0); */
          /* vf = 0; */
          return 0.9;
        }

      else
        {
          /* volatiles, char, and ash left */
          /* cf =  (cf)/(mp/mp0); */
          /* vf = 1. - (1.-(vf))/(mp/mp0); */
          return 1.0;
        }
    }
  return 1.0;
}
```

Hooking a DPM Material Property UDF to FLUENT

After the UDF that you have defined using DEFINE_DPM_PROPERTY is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible in the Materials panel in FLUENT. See Section 6.4.9: Hooking DEFINE_DPM_PROPERTY UDFs for details on how to hook your DEFINE_DPM_PROPERTY UDF to FLUENT.

2.5.10 DEFINE_DPM_SCALAR_UPDATE

Description

You can use DEFINE_DPM_SCALAR_UPDATE to update scalar quantities every time a particle position is updated. The function allows particle-related variables to be updated or integrated over the life of the particle. Particle values can be stored in an array associated with the Tracked_Particle (accessed with the macro P_USER_REAL(p,i)). Values calculated and stored in the array can be used to color the particle trajectory.

During FLUENT execution, the DEFINE_DPM_SCALAR_UPDATE function is called at the start of particle integration (when initialize is equal to 1) and then after each time step for the particle trajectory integration.

Usage

```
DEFINE_DPM_SCALAR_UPDATE(name,c,t,initialize,p)
```

Argument Type	**Description**
symbol name	UDF name.
cell_t c	Index that identifies the cell that the particle is currently in.
Thread *t	Pointer to the thread the particle is currently in.
int initialize	Variable that has a value of 1 when the function is called at the start of the particle integration, and 0 thereafter.
Tracked_Particle *p	Pointer to the Tracked_Particle data structure which contains data related to the particle being tracked.

Function returns
void

There are five arguments to DEFINE_DPM_SCALAR_UPDATE: name, c, t, initialize, and p. You supply name, the name of the UDF. c, t, initialize, and p are variables that are passed by the FLUENT solver to your UDF.

i Pointer p can be used as an argument to the macros defined in Section 3.2.7: DPM Macros to obtain information about particle properties (e.g., injection properties). Also, the real array user is available for storage. The size of this array should be set in the Discrete Phase Model panel in the Number of Scalars field.

Example

The following compiled UDF computes the melting index along a particle trajectory. The DEFINE_DPM_SCALAR_UPDATE function is called at every particle time step in FLUENT and requires a significant amount of CPU time to execute.

The melting index is computed from

$$\text{melting index} = \int_0^t \frac{1}{\mu} dt \tag{2.5-1}$$

Also included in this UDF is an initialization function DEFINE_INIT that is used to initialize the scalar variables. DPM_OUTPUT is used to write the melting index at sample planes and surfaces. The macro NULLP, which expands to ((p) == NULL), checks if its argument is a null pointer.

```
/*********************************************************************
  UDF for computing the melting index along a particle trajectory
**********************************************************************/
#include "udf.h"

static real viscosity_0;

DEFINE_INIT(melt_setup,domain)
{
        /* if memory for the particle variable titles has not been
         * allocated yet, do it now */

  if (NULLP(user_particle_vars)) Init_User_Particle_Vars();

         /* now set the name and label */

  strcpy(user_particle_vars[0].name,"melting-index");
  strcpy(user_particle_vars[0].label,"Melting Index");
}

        /* update the user scalar variables */

DEFINE_DPM_SCALAR_UPDATE(melting_index,cell,thread,initialize,p)
{
  cphase_state_t *c = &(p->cphase);
  if (initialize)
    {
     /* this is the initialization call, set:
      * p->user[0] contains the melting index, initialize to 0
      * viscosity_0 contains the viscosity at the start of a time step*/

      p->user[0] = 0.;
      viscosity_0 = c->mu;
    }

  else
    {
      /* use a trapezoidal rule to integrate the melting index */
      p->user[0] += P_DT(p) * .5 * (1/viscosity_0 + 1/c->mu);

      /* save current fluid viscosity for start of next step */
      viscosity_0 = c->mu;
    }
}

    /* write melting index when sorting particles at surfaces */
DEFINE_DPM_OUTPUT(melting_output,header,fp,p,thread,plane)
{
  char name[100];

  if (header)
   {
   if (NNULLP(thread))
     par_fprintf_head(fp,"(%s %d)\n",thread->head->
                     dpm_summary.sort_file_name,11);
   else
     par_fprintf_head(fp,"(%s %d)\n",plane->sort_file_name,11);
     par_fprintf_head(fp,"(%10s %10s  %10s  %10s  %10s  %10s  %10s"
               " %10s  %10s  %10s  %10s  %s)\n",
                 "X","Y","Z","U","V","W","diameter","T","mass-flow",
                 "time","melt-index","name");
    }

  else
    {
      sprintf(name,"%s:%d",p->injection->name,p->part_id);
#if PARALLEL
      /* add try_id and part_id for sorting in parallel */
      par_fprintf(fp,
           "%d %d ((%10.6g  %10.6g  %10.6g  %10.6g  %10.6g  %10.6g  "
           "%10.6g  %10.6g  %10.6g  %10.6g %10.6g) %s)\n",
           p->injection->try_id, p->part_id,
           p->state.pos[0], p->state.pos[1], p->state.pos[2],
           p->state.V[0], p->state.V[1], p->state.V[2],
           p->state.diam, p->state.temp, p->flow_rate, p->state.time,
           p->user[0], name);
#else
      par_fprintf(fp,
           "((%10.6g  %10.6g  %10.6g  %10.6g  %10.6g  %10.6g  "
           "%10.6g  %10.6g  %10.6g  %10.6g %10.6g) %s)\n",
           p->state.pos[0], p->state.pos[1], p->state.pos[2],
           p->state.V[0], p->state.V[1], p->state.V[2],
           p->state.diam, p->state.temp, p->flow_rate, p->state.time,
           p->user[0], name);
#endif
    }
}
```

Hooking a DPM Scalar Update UDF to FLUENT

After the UDF that you have defined using DEFINE_DPM_SCALAR_UPDATE is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible in the Discrete Phase Model panel in FLUENT.

See Section 6.4.10: Hooking DEFINE_DPM_SCALAR_UPDATE UDFs for details on how to hook your DEFINE_DPM_SCALAR_UPDATE UDF to FLUENT.

2.5.11 DEFINE_DPM_SOURCE

Description

You can use DEFINE_DPM_SOURCE to specify particle source terms. The function allows access to the accumulated source terms for a particle in a given cell before they are added to the mass, momentum, and energy exchange terms for coupled DPM calculations.

Usage

```
DEFINE_DPM_SOURCE(name,c,t,S, strength,p)
```

Argument Type	Description
symbol name	UDF name.
cell_t c	Index that identifies the cell that the particle is currently in.
Thread *t	Pointer to the thread the particle is currently in.
dpms_t *S	Pointer to the source structure dpms_t, which contains the source terms for the cell.
real strength	Particle number flow rate in particles/second (divided by the number of tries if stochastic tracking is used).
Tracked_Particle *p	Pointer to the Tracked_Particle data structure which contains data related to the particle being tracked.

Function returns

void

There are six arguments to DEFINE_DPM_SOURCE: name, c, t, S, strength, and p. You supply name, the name of the UDF. c, t, S, strength, and p are variables that are passed by the FLUENT solver to your UDF. The modified source terms, once computed by the function, will be stored in S.

i Pointer p can be used as an argument to the macros defined in Section 3.2.7: DPM Macros to obtain information about particle properties (e.g., injection properties).

Example

See Section 2.5.13: Example for an example of DEFINE_DPM_SOURCE usage.

Hooking a DPM Source Term UDF to FLUENT

After the UDF that you have defined using DEFINE_DPM_SOURCE is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible in the Discrete Phase Model panel in FLUENT. See Section 6.4.11: Hooking DEFINE_DPM_SOURCE UDFs for details on how to hook your DEFINE_DPM_SOURCE UDF to FLUENT.

2.5.12 DEFINE_DPM_SPRAY_COLLIDE

Description

You can use DEFINE_DPM_SPRAY_COLLIDE to side-step the default FLUENT spray collision algorithm. When droplets collide they may bounce (in which case their velocity changes) or they may coalesce (in which case their velocity is changed, as well as their diameter and number in the DPM parcel). A spray collide UDF is called during droplet tracking after every droplet time step and requires that collision is enabled in the DPM panel.

Usage

DEFINE_DPM_SPRAY_COLLIDE(name,tp,p)

Argument Type	Description
symbol name	UDF name.
Tracked_Particle *tp	Pointer to the Tracked_Particle data structure which contains data related to the particle being tracked.
Particle *p	Pointer to the Particle data structure where particles p are stored in a linked list.

Function returns

void

There are three arguments to DEFINE_DPM_SPRAY_COLLIDE: name, tp, and p. You supply name, the name of the UDF. tp and p are variables that are passed by the FLUENT solver to your UDF. When collision is enabled, this linked list is ordered by the cell that the particle is currently in. As particles from this linked list are tracked, they are copied from the particle list into a Tracked_Particle structure.

Example

The following UDF, named man_spray_collide, is a simple (and non-physical) example that demonstrates the usage of DEFINE_SPRAY_COLLIDE. The droplet diameters are assumed to relax to their initial diameter over a specified time t_relax. The droplet velocity is also assumed to relax to the mean velocity of all droplets in the cell over the same time scale.

```
/***********************************************************
   DPM Spray Collide Example UDF
************************************************************/
#include "udf.h"
#include "dpm.h"
#include "surf.h"
DEFINE_DPM_SPRAY_COLLIDE(man_spray_collide,tp,p)
{
  /* non-physical collision UDF that relaxes the particle */
  /* velocity and diameter in a cell to the mean over the */
  /* specified time scale t_relax */

  const real t_relax = 0.001; /* seconds */

  /* get the cell and Thread that the particle is currently in */
  cell_t c  = RP_CELL(&(tp->cCell));
  Thread *t = RP_THREAD(&(tp->cCell));

  /* Particle index for looping over all particles in the cell */
  Particle *pi;

  /* loop over all particles in the cell to find their mass */
  /* weighted mean velocity and diameter */
  int i;
  real u_mean[3]={0.}, mass_mean=0.;
  real d_orig = tp->state.diam;
  real decay = 1. - exp(-t_relax);
  begin_particle_cell_loop(pi,c,t)
    {
     mass_mean += pi->state.mass;
     for(i=0;i<3;i++)
       u_mean[i] += pi->state.V[i]*pi->state.mass;
    }
  end_particle_cell_loop(pi,c,t)

  /* relax particle velocity to the mean and diameter to the */
```

```
    /* initial diameter over the relaxation time scale t_relax */
    if( mass_mean > 0. )
      {
        for(i=0;i<3;i++)
          u_mean[i] /= mass_mean;
        for(i=0;i<3;i++)
          tp->state.V[i] += decay*( u_mean[i] - tp->state.V[i] );
        tp->state.diam += decay*( P_INIT_DIAM(tp) - tp->state.diam );
        /* adjust the number in the droplet parcel to conserve mass */
        tp->number_in_parcel *= CUB( d_orig/tp->state.diam );
      }
}
```

Hooking a DPM Spray Collide UDF to FLUENT

After the UDF that you have defined using DEFINE_DPM_SPRAY_COLLIDE is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible in the User-Defined Function Hooks panel in FLUENT. See
Section 6.4.12: Hooking DEFINE_DPM_SPRAY_COLLIDE UDFs for details on how to hook your DEFINE_DPM_SPRAY_COLLIDE UDF to FLUENT.

2.5.13 DEFINE_DPM_SWITCH

Description

You can use DEFINE_DPM_SWITCH to modify the criteria for switching between laws. The function can be used to control the switching between the user-defined particle laws and the default particle laws, or between different user-defined or default particle laws.

Usage

```
DEFINE_DPM_SWITCH(name,p,ci)
```

Argument Type	Description
symbol name	UDF name.
Tracked_Particle *p	Pointer to the Tracked_Particle data structure which contains data related to the particle being tracked.
int ci	Variable that indicates if the continuous and discrete phases are coupled (equal to 1 if coupled with continuous phase, 0 if not coupled).

Function returns
void

There are three arguments to DEFINE_DPM_SWITCH: name, p, and ci. You supply name, the name of the UDF. p and ci are variables that are passed by the FLUENT solver to your UDF.

Pointer p can be used as an argument to the macros defined in Section 3.2.7: DPM Macros to obtain information about particle properties (e.g., injection properties).

Example

The following is an example of a compiled UDF that uses DEFINE_DPM_SWITCH to switch between DPM laws using a criterion. The UDF switches to DPM_LAW_USER_1 which refers to condenshumidlaw since only one user law has been defined. The switching criterion is the local humidity which is computed in the domain using a DEFINE_ON_DEMAND function, which again calls the function myHumidity for every cell. In the case where the humidity is greater than 1, condensation is computed by applying a simple mass transfer calculation. Otherwise, one of FLUENT's standard laws for Vaporization or Inert Heating are applied, depending on the particle mass. The UDF requires one UDML and needs a species called h2o to compute the local humidity.

```
/*******************************************************************
   Concatenated UDFs for the Discrete Phase Model that includes a
   usage of DPM_SWITCH
********************************************************************/

#include "udf.h"
#include "dpm.h"
#include "surf.h"  /* for  macros: RP_Cell() & RP_Thread()        */
#include "prop.h"  /* for function: Saturation_Pressure() (of water) */

static int counter=0;
static real dpm_relax=1.0; /*dpm source relaxation */

real H2O_Saturation_Pressure(real T)
{
  real ratio, aTmTp;

  aTmTp = .01 * (T - 338.15);
  ratio = (647.286/T - 1.) *
    (-7.419242 + aTmTp*(.29721 +
                 aTmTp*(-.1155286 +
                 aTmTp*(8.685635e-3 +
                 aTmTp*(1.094098e-3 +
                 aTmTp*(-4.39993e-3 +
                 aTmTp*(2.520658e-3 -
                 aTmTp*5.218684e-4)))))));
  return (22.089e6 * exp(MIN(ratio,35.)));
}


real myHumidity(cell_t c,Thread *t)
{
  int i;
  Material *m=THREAD_MATERIAL(t), *sp;
  real yi_h2o,mw_h2o;
  real r_mix=0.0;

  if(MATERIAL_TYPE(m)==MATERIAL_MIXTURE)
  {
   mixture_species_loop (m,sp,i)
   {
     r_mix += C_YI(c,t,i)/MATERIAL_PROP(sp,PROP_mwi);
```

```
      if (0 == strcmp(MIXTURE_SPECIE_NAME(m,i),"h2o") ||
   (0 == strcmp(MIXTURE_SPECIE_NAME(m,i),"H2O")))
      {
  yi_h2o = C_YI(c,t,i);
  mw_h2o = MATERIAL_PROP(sp,PROP_mwi);
      }
    }
   }

   return ((ABS_P(C_P(c,t),op_pres) * yi_h2o / (mw_h2o * r_mix)) /
                 H2O_Saturation_Pressure(C_T(c,t))) ;
}

#define CONDENS 1.0e-4

DEFINE_DPM_LAW(condenshumidlaw,p,coupled)
{
 real area;
 real mp_dot;
 cell_t c = P_CELL(p);               /* Get Cell and Thread from */
 Thread *t = P_THREAD(p);  /* Particle Structure using new macros*/

 area = 4.0* M_PI * (P_DIAM(p)*P_DIAM(p));

 /* Note This law only used if Humidity > 1.0 so mp_dot always positive*/
 mp_dot = CONDENS*sqrt(area)*(myHumidity(c,t)-1.0);

 if(mp_dot>0.0)
 {
   P_MASS(p) = P_MASS(p) + mp_dot*P_DT(p);
   P_DIAM(p) = pow(6.0*P_MASS(p)/(P_RHO(p)* M_PI), 1./3.);
   P_T(p)=C_T(c,t); /* Assume condensing particle is in thermal
          equilibrium with fluid in cell */
 }

}

/* define macro that is not yet standard */

#define C_DPMS_ENERGY(c,t)C_STORAGE_R(c,t,SV_DPMS_ENERGY)

DEFINE_DPM_SOURCE(dpm_source,c,t,S,strength,p)
{
  real mp_dot;
  Material *sp = P_MATERIAL(p);


  /* mp_dot is the (positive) mass source to the continuous phase */
  /* (Difference in mass between entry and exit from cell)         */
  /* multiplied by strength (Number of particles/s in stream)      */

  mp_dot = (P_MASS0(p) - P_MASS(p)) * strength;

   C_DPMS_YI(c,t,0) += mp_dot*dpm_relax;
   C_DPMS_ENERGY(c,t) -= mp_dot*dpm_relax*
MATERIAL_PROP(sp,PROP_Cp)*(C_T(c,t)-298.15);
   C_DPMS_ENERGY(c,t) -= mp_dot*dpm_relax*
MATERIAL_PROP(sp,PROP_latent_heat);
}


#define UDM_RH 0
#define N_REQ_UDM 1
#define CONDENS_LIMIT 1.0e-10

DEFINE_DPM_SWITCH(dpm_switch,p,coupled)
{
 cell_t c = RP_CELL(&p->cCell);
 Thread *t = RP_THREAD(&p->cCell);

 if(C_UDMI(c,t,UDM_RH) > 1.0)
  P_CURRENT_LAW(p) = DPM_LAW_USER_1;
 else
 {
  if(P_MASS(p) < CONDENS_LIMIT)
   P_CURRENT_LAW(p) = DPM_LAW_INITIAL_INERT_HEATING;
  else
   P_CURRENT_LAW(p) = DPM_LAW_VAPORIZATION;
 }
}

DEFINE_ADJUST(adj_relhum,domain)
{
 cell_t cell;
 Thread *thread;
 /* set dpm source underrelaxation */
 dpm_relax = Domainvar_Get_Real(ROOT_DOMAIN_ID,"dpm/relax");

 if(sg_udm<N_REQ_UDM)
    Message("\nNot enough user defined memory allocated. %d required.\n",
            N_REQ_UDM);
 else
 {
  real humidity,min,max;

  min=1e10;
  max=0.0;

  thread_loop_c(thread,domain)
  {
   /* Check if thread is a Fluid thread and has UDMs set up on it */
   if (FLUID_THREAD_P(thread)&& NNULLP(THREAD_STORAGE(thread,SV_UDM_I)))
   {
    begin_c_loop(cell,thread)
     humidity=myHumidity(cell,thread);
     min=MIN(min,humidity);
     max=MAX(max,humidity);
     C_UDMI(cell,thread,UDM_RH)=humidity;
    end_c_loop(cell,thread)
   }
  }
  Message("\nRelative Humidity set in udm-%d
range:(%f,%f)\n",UDM_RH,min,max);
 }/* end if for enough UDSs and UDMs */
}

DEFINE_ON_DEMAND(set_relhum)
{
 adj_relhum(Get_Domain(1));
}
```

Hooking a DPM Switching UDF to FLUENT

After the UDF that you have defined using DEFINE_DPM_SWITCH is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible in the Custom Laws panel in FLUENT. See Section 6.4.13: Hooking DEFINE_DPM_SWITCH UDFs for details on how to hook your DEFINE_DPM_SWITCH UDF to FLUENT.

2.5.14 DEFINE_DPM_TIMESTEP

Description

You can use DEFINE_DPM_TIMESTEP to change the time step for DPM particle tracking based on user-specified inputs. The time step can be prescribed for special applications where a certain time step is needed. It can also be limited to values that are required to validate physical models.

Usage

DEFINE_DPM_TIMESTEP(name,p,ts)

Argument Type	**Description**
symbol name	UDF name.
Tracked_Particle *p	Pointer to the Tracked_Particle data structure which contains data related to the particle being tracked.
real ts	Time step.

Function returns
real

There are three arguments to DEFINE_DPM_TIMESTEP: name, p, and ts. You supply the name of your user-defined function. p and ts are variables that are passed by the FLUENT solver to your UDF. Your function will return the real value of the DPM particle timestep to the solver.

Example 1

The following compiled UDF named limit_to_e_minus_four sets the time step to a maximum value of $1e^{-}4$. If the time step computed by FLUENT (and passed as an argument) is smaller than $1e^{-}4$, then FLUENT's time step is returned.

```
/* Time step control UDF for DPM  */

#include "udf.h"
#include "dpm.h"

DEFINE_DPM_TIMESTEP(limit_to_e_minus_four,p dt)
{
   if (dt > 1.e-4)
     {
/*       p->next_time_step = 1.e-4; */
```

```
         return 1.e-4;
       }

   return dt;
}
```

Example 2

The following compiled UDF named `limit_to_fifty_of_prt` computes the particle relaxation time based on the formula:

$$\tau_p = frac\rho_p d_p^2 18\mu \frac{24}{C_D Re_p} \tag{2.5-2}$$

where

$$Re_p = \frac{\rho d_p \|u - u_p\|}{\mu} \tag{2.5-3}$$

The particle time step is limited to a fifth of the particle relaxation time. If the particle time step computed by FLUENT (and passed as an argument) is smaller than this value, then FLUENT's time step is returned.

```
/* Particle time step control UDF for DPM  */

#include "udf.h"
#include "dpm.h"

DEFINE_DPM_TIMESTEP(limit_to_fifth_of_prt,p,dt)
{
   real drag_factor = 0.;
   real p_relax_time;
   cphase_state_t *c = &(p->cphase);

   /* compute particle relaxation time */
   if (P_DIAM(p) != 0.0)
     drag_factor = DragCoeff(p) * c->mu / ( P_RHO(p) * P_DIAM(p) * P_DIAM(p));
   else
     drag_factor = 1.;

   p_relax_time = 1./drag_factor;

   /* check the condition and return the time step */
   if (dt > p_relax_time/5.)
     {
       return p_relax_time/5.;
     }

   return dt;
}
```

Hooking a DPM Timestep UDF to FLUENT

After the UDF that you have defined using DEFINE_DPM_TIMESTEP is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible and selectable for DPM Timestep in the Discrete Phase Model panel in FLUENT. See Section 6.4.14: Hooking DEFINE_DPM_TIMESTEP UDFs for details on how to hook your DEFINE_DPM_TIMESTEP UDF to FLUENT.

2.5.15 DEFINE_DPM_VP_EQUILIB

Description

You can use DEFINE_DPM_VP_EQUILIB to specify the equilibrium vapor pressure of vaporizing components of multipcomponent particles.

Usage

DEFINE_DPM_VP_EQUILIB(name,p,cvap_surf)

Argument Type	Description
symbol name	UDF name.
Tracked_Particle *p	Pointer to the Tracked_Particle data structure which contains data related to the particle being tracked.
real *cvap_surf	Array that contains the equilibrium vapor concentration over the particle surface.

Function returns
void

There are three arguments to DEFINE_DPM_VP_EQUILIB: name, p, and cvap_surf. You supply the name of your user-defined function. p is passed by the FLUENT solver to your UDF. Your UDF will need to compute the equilibrium vapor concentrations and store the values in cvap_surf.

Example

The following UDF named raoult_vpe computes the equilibrium vapor concentration of a multicomponent particle using hte Raoult law. The vapor pressure in the law is proportional to the molar fraction of the condenses material. DEFINE_VP_EQUILIB is called several times every particle time step in FLUENT and requires a significant amount of CPU time to execute. For this reason, the UDF should be executed as a compiled UDF.

```
/*******************************************************************
   UDF for defining the vapor particle equilibrium
   for multicomponent particles
 *******************************************************************/
#include "udf.h"
#include "dpm.h"
#include "surf.h"
DEFINE_DPM_VP_EQUILIB(raoult_vpe,p,cvap_surf)
{
  int is;
  real molwt[MAX_SPE_EQNS];

  Thread *t0 = RP_THREAD( &(p->cCell) ); /* cell thread of
                                      particle location */
  Material *gas_mix = THREAD_MATERIAL( t0 );  /* gas mixture
                                                material */
  Material *cond_mix = p->injection->material; /* particle
                                        mixture material */
  int nc = TP_N_COMPONENTS( p );   /* number of particle
                                      components */
  real Tp = P_T(p); /* particle temperature */
  real pressure = p->cphase.pressure;  /* gas pressure */
  real molwt_cond = 0.;  /* reciprocal molecular weight
                          of the particle */

  for( is = 0; is < nc; is++ )
    {
      int gas_index = TP_COMPONENT_INDEX_I(p,is);  /* index
                   of vaporizing component in the gas phase */
      if( gas_index >= 0 )
{
  /* the molecular weight of particle material */
  molwt[gas_index] =
       MATERIAL_PROP(MIXTURE_COMPONENT(gas_mix,gas_index),PROP_mwi);
  molwt_cond += TP_COMPONENT_I(p,is) / molwt[gas_index];
}
    }

  /* prevent division by zero */
  molwt_cond = MAX(molwt_cond,DPM_SMALL);

  for( is = 0; is < nc; is++ )
    {
      /* gas species index of vaporization */
      int gas_index = TP_COMPONENT_INDEX_I(p,is);
      if( gas_index >= 0 )
{
  /* condensed material */
  Material * cond_c = MIXTURE_COMPONENT( cond_mix, is );
  /* condensed component molefraction */
  real xi_cond = TP_COMPONENT_I(p,is) /
          ( molwt[gas_index] * molwt_cond );

  /* particle saturation pressure */
  real p_saturation = DPM_vapor_pressure( p, cond_c, Tp );
  if (p_saturation > pressure)
    p_saturation = pressure;
  else if (p_saturation < 0.0)
    p_saturation = 0.0;

  /* vapor pressure over the surface, this is the
             actual Raoult law  */
  cvap_surf[is] = xi_cond * p_saturation /
                  UNIVERSAL_GAS_CONSTANT / Tp;
}
    }
}
```

Hooking a DPM Vapor Equilibrium UDF to FLUENT

After the UDF that you have defined using DEFINE_DPM_VP_EQUILIBRIUM is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible and selectable in the Materials panel in FLUENT. Note that before you hook the UDF, you'll need to create particle injections in the Injections panel with the type Multicomponent chosen. See Section 6.4.15: Hooking DEFINE_DPM_VP_EQUILIB UDFs for details on how to hook your DEFINE_DPM_VP_EQUILIB UDF to FLUENT.

2.6 Dynamic Mesh DEFINE Macros

This section contains descriptions of DEFINE macros that you can use to define UDFs that control the behavior of a dynamic mesh. Note that dynamic mesh UDFs that are defined using DEFINE_CG_MOTION, DEFINE_GEOM, and DEFINE_GRID_MOTION can *only* be executed as compiled UDFs.

Table 2.6.1 provides a quick reference guide to the dynamic mesh DEFINE macros, the functions they define, and the panels where they are activated in FLUENT. Definitions of each DEFINE macro are contained in the udf.h header file. For your convenience, they are listed in Appendix B.

- Section 2.6.1: DEFINE_CG_MOTION
- Section 2.6.2: DEFINE_GEOM
- Section 2.6.3: DEFINE_GRID_MOTION
- Section 2.6.4: DEFINE_SDOF_PROPERTIES

Table 2.6.1: Quick Reference Guide for Dynamic Mesh-Specific DEFINE Macros

Function	DEFINE Macro	Panel Activated In
center of gravity motion	DEFINE_CG_MOTION	Dynamic Zones
grid motion	DEFINE_GRID_MOTION	Dynamic Zones
geometry deformation	DEFINE_GEOM	Dynamic Zones
properties for Six Degrees of Freedom (SDOF) Solver	DEFINE_SDOF_PROPERTIES	Dynamic Zones

2.6.1 DEFINE_CG_MOTION

Description

You can use DEFINE_CG_MOTION to specify the motion of a particular dynamic zone in FLUENT by providing FLUENT with the linear and angular velocities at every time step. FLUENT uses these velocities to update the node positions on the dynamic zone based on solid-body motion. Note that UDFs that are defined using DEFINE_CG_MOTION can *only* be executed as compiled UDFs.

Usage

```
DEFINE_CG_MOTION(name,dt,vel,omega,time,dtime)
```

Argument Type	**Description**
symbol name	UDF name.
Dynamic_Thread *dt	Pointer to structure that stores the dynamic mesh attributes that you have specified (or that are calculated by FLUENT).
real vel[]	Linear velocity.
real omega[]	Angular velocity.
real time	Current time.
real dtime	Time step.

Function returns void

There are six arguments to DEFINE_CG_MOTION: name, dt, vel, omega, time, and dtime. You supply name, the name of the UDF. dt, vel, omega, time, and dtime are variables that are passed by the FLUENT solver to your UDF. The linear and angular velocities are returned to FLUENT by overwriting the arrays vel and omega, respectively.

Example

Consider the following example where the linear velocity is computed from a simple force balance on the body in the x-direction such that

$$\int_{t_o}^{t} dv = \int_{t_o}^{t} (F/m)\ dt \qquad (2.6\text{-}1)$$

where v is velocity, F is the force and m is the mass of the body. The velocity at time t is calculated using an explicit Euler formula as

$$v_t = v_{t-\Delta t} + (F/m)\Delta t \qquad (2.6\text{-}2)$$

```
/************************************************************
 * 1-degree of freedom equation of motion (x-direction)
 * compiled UDF
 ************************************************************/
#include "udf.h"
static real v_prev = 0.0;

DEFINE_CG_MOTION(piston,dt,vel,omega,time,dtime)
{
  Thread *t;
  face_t f;
  real NV_VEC(A);
  real force, dv;

  /* reset velocities */
  NV_S(vel, =, 0.0);
  NV_S(omega, =, 0.0);

  if (!Data_Valid_P())
    return;

  /* get the thread pointer for which this motion is defined */
  t = DT_THREAD(dt);
}
  /* compute pressure force on body by looping through all faces */
  force = 0.0;
  begin_f_loop(f,t)
    {
      F_AREA(A,f,t);
      force += F_P(f,t) * NV_MAG(A);
    }
  end_f_loop(f,t)

  /* compute change in velocity, i.e., dv = F * dt / mass
     velocity update using explicit Euler formula */
  dv = dtime * force / 50.0;
  v_prev += dv;
  Message ("time = %f, x_vel = %f, force = %f\n", time, v_prev,
  force);

  /* set x-component of velocity */
  vel[0] = v_prev;
}
```

Hooking a Center of Gravity Motion UDF to FLUENT

After the UDF that you have defined using DEFINE_CG_MOTION is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible in the Dynamic Zones panel in FLUENT. See Section 6.5.1: Hooking DEFINE_CG_MOTION UDFs for details on how to hook your DEFINE_CG_MOTION UDF to FLUENT.

2.6.2 DEFINE_GEOM

Description

You can use DEFINE_GEOM to specify the geometry of a deforming zone. By default, FLUENT provides a mechanism for defining node motion along a planar or cylindrical surface. When FLUENT updates a node on a deforming zone (e.g., through spring-based smoothing or after local face re-meshing) the node is "repositioned" by calling the DEFINE_GEOM UDF. Note that UDFs that are defined using DEFINE_GEOM can *only* be executed as compiled UDFs.

Usage

DEFINE_GEOM(name,d,dt,position)

Argument Type	**Description**
symbol name	UDF name.
Domain *d	Pointer to domain.
Dynamic_Thread *dt	Pointer to structure that stores the dynamic mesh attributes that you have specified (or that are calculated by FLUENT).
real *position	Pointer to array that stores the position.

Function returns
void

There are four arguments to DEFINE_GEOM: name, d, dt, and position. You supply name, the name of the UDF. d, dt, and position are variables that are passed by the FLUENT solver to your UDF. The new position (after projection to the geometry defining the zone) is returned to FLUENT by overwriting the position array.

Example

The following UDF, named parabola, is executed as a compiled UDF.

```
/************************************************************
 * defining parabola through points (0, 1), (1/2, 5/4), (1, 1)
 ************************************************************/
#include "udf.h"

DEFINE_GEOM(parabola,domain,dt,position)
{
  /* set y = -x^2 + x + 1 */
  position[1] = - position[0]*position[0] + position[0] + 1;
}
```

Hooking a Dynamic Mesh Geometry UDF to FLUENT

After the UDF that you have defined using DEFINE_GEOM is interpreted or compiled (see Chapter 5: Compiling UDFs for details), the name of the argument that you supplied as the first DEFINE macro argument will become visible in the Dynamic Zones panel in FLUENT. See Section 6.5.2: Hooking DEFINE_GEOM UDFs for details on how to hook your DEFINE_GEOM UDF to FLUENT.

2.6.3 DEFINE_GRID_MOTION

Description

By default, FLUENT updates the node positions on a dynamic zone by applying the solid-body motion equation. This implies that there is no relative motion between the nodes on the dynamic zone. However, if you need to control the motion of each node independently, then you can use DEFINE_GRID_MOTION UDF. A grid motion UDF can, for example, update the position of each node based on the deflection due to fluid-structure interaction. Note that UDFs that are defined using DEFINE_GRID_MOTION can be executed *only* as compiled UDFs.

Usage

```
DEFINE_GRID_MOTION(name, d, dt, time, dtime)
```

Argument Type	**Description**
symbol name	UDF name.
Domain *d	Pointer to domain.
Dynamic_Thread *dt	Pointer to structure that stores the dynamic mesh attributes that you have specified (or that are calculated by FLUENT).
real time	Current time.
real dtime	Time step.

Function returns
void

There are five arguments to DEFINE_GRID_MOTION: name, d, dt, time, and dtime. You supply name, the name of the UDF. d, dt, time, and dtime are variables that are passed by the FLUENT solver to your UDF.

Example

Consider the following example where you want to specify the deflection on a cantilever beam based on the x position such that

$$\omega_y(x) = -10.4\sqrt{x}\sin 26.178\ t \qquad x > 0.02 \qquad (2.6\text{-}3)$$
$$\omega_y(x) = 0 \qquad x <= 0.02 \qquad (2.6\text{-}4)$$

where $\omega_y(x)$ is the y-component of the angular velocity at a position x. The node position is updated based on

$$(\vec{r})^{t+\Delta t} = (\vec{r})^t + \vec{\Omega} \times (\vec{r})^t \Delta t \qquad (2.6\text{-}5)$$

where $\vec{\Omega}$ is the angular velocity and $\vec{r}$ is the position vector of a node on the dynamic zone.

```
/**********************************************************
 node motion based on simple beam deflection equation
 compiled UDF
 **********************************************************/
#include "udf.h"

DEFINE_GRID_MOTION(beam,domain,dt,time,dtime)
{
  Thread *tf = DT_THREAD(dt);
  face_t f;
  Node *v;
  real NV_VEC(omega), NV_VEC(axis), NV_VEC(dx);
  real NV_VEC(origin), NV_VEC(rvec);
  real sign;
  int n;

  /* set deforming flag on adjacent cell zone */
  SET_DEFORMING_THREAD_FLAG(THREAD_T0(tf));

  sign = -5.0 * sin (26.178 * time);

  Message ("time = %f, omega = %f\n", time, sign);

  NV_S(omega, =, 0.0);
  NV_D(axis, =, 0.0, 1.0, 0.0);
  NV_D(origin, =, 0.0, 0.0, 0.152);

  begin_f_loop(f,tf)
    {
      f_node_loop(f,tf,n)
        {
          v = F_NODE(f,tf,n);

          /* update node if x position is greater than 0.02
             and that the current node has not been previously
             visited when looping through previous faces */
          if (NODE_X(v) > 0.020 && NODE_POS_NEED_UPDATE (v))
            {
              /* indicate that node position has been update
                 so that it's not updated more than once */
              NODE_POS_UPDATED(v);

              omega[1] = sign * pow (NODE_X(v)/0.230, 0.5);
              NV_VV(rvec, =, NODE_COORD(v), -, origin);
              NV_CROSS(dx, omega, rvec);
              NV_S(dx, *=, dtime);
              NV_V(NODE_COORD(v), +=, dx);
            }
        }
    }

  end_f_loop(f,tf);
}
```

Hooking a DEFINE_GRID_MOTION to FLUENT

After the UDF that you have defined using DEFINE_GRID_MOTION is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible in the Dynamic Zones panel in FLUENT. See Section 6.5.3: Hooking DEFINE_GRID_MOTION UDFs for details on how to hook your DEFINE_GRID_MOTION UDF to FLUENT.

2.6.4 DEFINE_SDOF_PROPERTIES

Description

You can use DEFINE_SDOF_PROPERTIES to specify custom properties of moving objects for the six-degrees of freedom (SDOF) solver in FLUENT. These include mass, moment and products of inertia, and external forces and moment properties. The properties of an object which can consist of multiple zones can change in time, if desired. External load forces and moments can either be specified as global coordinates or body coordinates. In addition, you can specify custom transformation matrices using DEFINE_SDOF_PROPERTIES.

Usage

DEFINE_SDOF_PROPERTIES(name,properties,dt,time,dtime)

Argument Type	Description
symbol name	UDF name.
real *properties	Pointer to the array that stores the SDOF properties.
Dynamic_Thread *dt	Pointer to structure that stores the dynamic mesh attributes that you have specified (or that are calculated by FLUENT).
real time	Current time.
real dtime	Time step.

Function returns
void

There are four arguments to DEFINE_SDOF_PROPERTIES: name, properties, dt, and dtime. You provide the name of the UDF. properties, dt, and dtime are variables that are passed by the FLUENT solver to your UDF. The property array pointer that is passed to your function allows you to specify values for any of the following SDOF properties:

```
SDOF_MASS         /* mass */
SDOF_IXX,         /* moment of inertia */
SDOF_IYY,         /* moment of inertia */
SDOF_IZZ,         /* moment of inertia */
SDOF_IXY,         /* product of inertia */
SDOF_IXZ,         /* product of inertia */
SDOF_IYZ,         /* product of inertia */
SDOF_LOAD_LOCAL,  /* boolean */
SDOF_LOAD_F_X,    /* external force */
SDOF_LOAD_F_Y,    /* external force */
```

```
SDOF_LOAD_F_Z,    /* external force */
SDOF_LOAD_M_X,    /* external moment */
SDOF_LOAD_M_Y,    /* external moment */
SDOF_LOAD_M_Z,    /* external moment */
```

The boolean prop[SDOF_LOAD_LOCAL] can be used to determine whether the forces and moments are expressed in terms of global coordinates (FALSE) or body coordinates (TRUE). The default value for prop[SDOF_LOAD_LOCAL] is FALSE.

Custom Transformation Variables

The default transformations used by FLUENT are typical for most aerospace and other types of applications. However, if your model requires custom transformations, you can specify these matrices in your SDOF UDF. First set the SDOF_CUSTOM_TRANS boolean to TRUE. Then use the macros listed below to define custom coordination rotation and derivative rotation matrices. CTRANS is the body-global coordinate rotation matrix and DTRANS is the body-global derivative rotation matrix.

```
SDOF_CUSTOM_TRANS,       /* boolean */
SDOF_CTRANS_11,          /* coordinate rotation matrices */
SDOF_CTRANS_12,
SDOF_CTRANS_13,
SDOF_CTRANS_21,
SDOF_CTRANS_22,
SDOF_CTRANS_23,
SDOF_CTRANS_31,
SDOF_CTRANS_32,
SDOF_CTRANS_33,
SDOF_DTRANS_11,          /* derivative rotation matrices */
SDOF_DTRANS_12,
SDOF_DTRANS_13,
SDOF_DTRANS_21,
SDOF_DTRANS_22,
SDOF_DTRANS_23,
SDOF_DTRANS_31,
SDOF_DTRANS_32,
SDOF_DTRANS_33,
```

Example 1

The following UDF, named stage, is a simple example of setting mass and moments of inertia properties for a moving object. This UDF is typical for applications in which a body is dropped and the SDOF solver computes the body's motion in the flow field.

```
/*************************************************************
 Simple example of a SDOF property UDF for a moving body
***************************************************************/
#include "udf.h"

DEFINE_SDOF_PROPERTIES(stage, prop, dt, time, dtime)
{
   prop[SDOF_MASS]       = 800.0;
   prop[SDOF_IXX]        = 200.0;
   prop[SDOF_IYY]        = 100.0;
   prop[SDOF_IZZ]        = 100.0;

   printf ("\nstage: updated 6DOF properties");
}
```

Example 2

The following UDF named delta_missile specifies case injector forces and moments that are time-dependent. Specifically, the external forces and moments depend on the current angular orientation of the moving object. Note that this UDF must be executed as a compiled UDF.

```
/********************************************************
SDOF property compiled UDF with external forces/moments
********************************************************/
#include "udf.h"

DEFINE_SDOF_PROPERTIES(delta_missile, prop, dt, time, dtime)
{
   prop[SDOF_MASS]       = 907.185;
   prop[SDOF_IXX]        = 27.116;
   prop[SDOF_IYY]        = 488.094;
   prop[SDOF_IZZ]        = 488.094;

   /* add injector forces, moments */
   {
     register real dfront = fabs (DT_CG (dt)[2] -
                            (0.179832*DT_THETA (dt)[1]));
     register real dback  = fabs (DT_CG (dt)[2] +
                            (0.329184*DT_THETA (dt)[1]));

     if (dfront <= 0.100584)
       {
         prop[SDOF_LOAD_F_Z] = 10676.0;
         prop[SDOF_LOAD_M_Y] = -1920.0;
       }

     if (dback <= 0.100584)
       {
         prop[SDOF_LOAD_F_Z] += 42703.0;
         prop[SDOF_LOAD_M_Y] += 14057.0;
       }
   }

   printf ("\ndelta_missile: updated 6DOF properties");
}
```

Hooking a DEFINE_SDOF_PROPERTIES UDF to FLUENT

After the UDF that you have defined using DEFINE_SDOF_PROPERTIES is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument will become visible in the Six DOF UDF drop-down list in the Dynamic Zones panel in FLUENT. See Section 6.5.4: Hooking DEFINE_SDOF_PROPERTIES UDFs for details on how to hook your DEFINE_SDOF_PROPERTIES UDF to FLUENT.

2.7 User-Defined Scalar (UDS) Transport Equation DEFINE Macros

This section provides information on how you can define UDFs that can be used in UDS transport equations in FLUENT. See Section 9.3: User-Defined Scalar (UDS) Transport Equations in the User's Guide for UDS equation theory and details on how to setup scalar equations. Descriptions of DEFINE macros for UDS applications are provided below. Definitions of DEFINE macros are contained in the udf.h header file. For your convenience, they are also listed in Appendix B. Detailed examples of user-defined scalar transport UDFs can be found in Section 8.2.5: User-Defined Scalars.

- Section 2.7.1: Introduction
- Section 2.7.2: DEFINE_ANISOTROPIC_DIFFUSIVITY
- Section 2.7.3: DEFINE_UDS_FLUX
- Section 2.7.4: DEFINE_UDS_UNSTEADY

2.7.1 Introduction

For each of the N scalar equations you specified in your FLUENT model you can supply a unique UDF for the diffusion coefficients, flux, and unsteady terms in the scalar transport equation. For multiphase you have the added benefit of specifying UDFs on a per-phase basis in both fluid and solid zones. Additionally, you can specify a UDF for each source term you define for a given scalar equation as well as boundary conditions on wall, inflow, and outflow boundaries.

Diffusion Coefficient UDFs

For each of the N scalar equations you have specified in your FLUENT model using the User-Defined Scalars panel you can supply a unique user-defined function (UDF) for isotropic and anisotropic diffusivity for both fluid and solid materials. Recall that FLUENT computes the diffusion coefficient in the UDS equation.

Isotropic diffusivity UDFs are defined using the DEFINE_DIFFUSIVITY macro (Section 2.3.3: DEFINE_DIFFUSIVITY) and anistropic coefficients UDFs are defined using DEFINE_ANISOTROPIC_DIFFUSIVITY (Section 2.7.2: DEFINE_ANISOTROPIC_DIFFUSIVITY). Additional pre-defined macros that you can use when coding UDS functions are provided in Section 3.2.8: User-Defined Scalar (UDS) Transport Equation Macros.

Flux UDFs

For each of the N scalar equations you have specified in your FLUENT model using the User-Defined Scalars panel you can supply a unique user-defined function (or UDF) for the advective flux term. Recall that FLUENT computes the flux in the UDS equation.

UDS Flux UDFs are defined using the DEFINE_UDS_FLUX macro (Section 2.7.3: DEFINE_UDS_FLUX). Additional pre-defined macros that you can use when coding scalar flux UDFs are provided in Section 3.2.8: User-Defined Scalar (UDS) Transport Equation Macros.

Unsteady UDFs

For each of the N scalar equations you have specified in your FLUENT model using the User-Defined Scalars panel you can supply a unique UDF for the unsteady function. Recall that FLUENT computes the unsteady term in the UDS equation.

Scalar Unsteady UDFs are defined using the DEFINE_UDS_UNSTEADY macro (Section 2.7.4: DEFINE_UDS_UNSTEADY). Additional pre-defined macros that you can use when coding scalar unsteady UDFs are provided in Section 3.2.8: User-Defined Scalar (UDS) Transport Equation Macros.

Source Term UDFs

For each of the N scalar equations you have specified in your FLUENT model using the User-Defined Scalars panel you can supply a unique UDF for *each* source. Recall that FLUENT computes the source term in the UDS equation.

Scalar source UDFs are defined using the DEFINE_SOURCE macro and must compute the source term, S_{ϕ_k}, and its derivative $\frac{\partial S_{\phi_k}}{\partial \phi_k}$ (Section 2.3.17: DEFINE_SOURCE). Additional pre-defined macros that you can use when coding scalar source term UDFs are provided in Section 3.2.8: User-Defined Scalar (UDS) Transport Equation Macros.

Fixed Value Boundary Condition UDFs

For each of the N scalar equations you have specified in your FLUENT model using the User-Defined Scalars panel you can supply a fixed value profile UDF for fluid boundaries.

Fixed value UDFs are defined using the DEFINE_PROFILE macro. See Section 2.3.13: DEFINE_PROFILE for details. Additional pre-defined macros that you can use for coding scalar transport equation UDFs are provided in Section 3.2.8: User-Defined Scalar (UDS) Transport Equation Macros.

Wall, Inflow, and Outflow Boundary Condition UDFs

For each of the N scalar equations you have specified in your FLUENT model using the User-Defined Scalars panel you can supply a specified value or flux UDF for all wall, inflow, and outflow boundaries.

Wall, inflow, and outflow boundary UDFs are defined using the DEFINE_PROFILE macro (Section 2.3.13: DEFINE_PROFILE). Additional pre-defined macros that you can use for coding scalar transport equation UDFs are provided in Section 3.2.8: User-Defined Scalar (UDS) Transport Equation Macros.

2.7.2 DEFINE_ANISOTROPIC_DIFFUSIVITY

Description

You can use DEFINE_ANISOTROPIC_DIFFUSIVITY to specify an anisotropic diffusivity for a user-defined scalar (UDS) tranpsort equation. See Section 8.6.2: Anisotropic Diffusion in the User's Guide for details about anisotropic diffusivity material properties in FLUENT.

Usage

```
DEFINE_ANISOTROPIC_DIFFUSIVITY(name,c,t,i,dmatrix)
```

Argument Type	Description
symbol name	UDF name.
cell_t c	Cell index.
Thread *t	Pointer to cell thread on which the anisotropic diffusivity function is to be applied.
int i	Index that identifies the user-defined scalar.
real dmatrix[ND_ND][ND_ND]	Anisotropic diffusivity matrix to be filled in by user.

Function returns
void

There are five arguments to DEFINE_ANISOTROPIC_DIFFUSIVITY: name, c, t, i, and dmatrix. You will supply name, the name of the UDF. c, t, i, and dmatrix are variables that are passed by the FLUENT solver to your UDF. Your function will compute the diffusivity tensor for a single cell and fill dmatrix with it. Note that anisotropic diffusivity UDFs are called by FLUENT from within a loop on cell threads. Consequently, your UDF will not need to loop over cells in a thread since FLUENT is doing it outside of the function call.

Example

The following UDF, named cyl_ortho_diff computes the anisotropic diffusivity matrix for a cylindrical shell which has different diffusivities in radial, tangential, and axial directions. This function can be executed as a compiled UDF.

```
/******************************************************************
   Example UDF that demonstrates DEFINE_ANISOTROPIC_DIFFUSIVITY
******************************************************************/
#include "udf.h"

/* Computation of anisotropic diffusivity matrix for
 * cylindrical orthotropic diffusivity */

/* axis definition for cylindrical diffusivity */
static const real origin[3] = {0.0, 0.0, 0.0};
static const real axis[3]   = {0.0, 0.0, 1.0};

/* diffusivities in radial, tangential and axial directions */
static const real diff[3] = {1.0, 0.01, 0.01};

DEFINE_ANISOTROPIC_DIFFUSIVITY(cyl_ortho_diff,c,t,i,dmatrix)
{
    real x[3][3]; /* principal direction matrix for cell in
cartesion coords. */
    real xcent[ND_ND];
    real R;

    C_CENTROID(xcent,c,t);

    NV_VV(x[0],=,xcent,-,origin);
#if RP_3D
    NV_V(x[2],=,axis);
#endif
#if RP_3D
    R = NV_DOT(x[0],x[2]);
    NV_VS(x[0],-=,x[2],*,R);
#endif
    R = NV_MAG(x[0]);
    if (R > 0.0)
      NV_S(x[0],/=,R);
#if RP_3D
    N3V_CROSS(x[1],x[2],x[0]);
#else
```

```
    x[1][0] = -x[0][1];
    x[1][1] =  x[0][0];
#endif

    /* dmatrix is computed as xT*diff*x */
    dmatrix[0][0] = diff[0]*x[0][0]*x[0][0]
      + diff[1]*x[1][0]*x[1][0]
#if RP_3D
      + diff[2]*x[2][0]*x[2][0]
#endif
      ;
    dmatrix[1][1] = diff[0]*x[0][1]*x[0][1]
      + diff[1]*x[1][1]*x[1][1]
#if RP_3D
      + diff[2]*x[2][1]*x[2][1]
#endif
      ;
    dmatrix[1][0] = diff[0]*x[0][1]*x[0][0]
      + diff[1]*x[1][1]*x[1][0]
#if RP_3D
      + diff[2]*x[2][1]*x[2][0]
#endif
      ;
    dmatrix[0][1] = dmatrix[1][0];

#if RP_3D
    dmatrix[2][2] = diff[0]*x[0][2]*x[0][2]
      + diff[1]*x[1][2]*x[1][2]
      + diff[2]*x[2][2]*x[2][2]
      ;
    dmatrix[0][2] = diff[0]*x[0][0]*x[0][2]
      + diff[1]*x[1][0]*x[1][2]
      + diff[2]*x[2][0]*x[2][2]
      ;
    dmatrix[2][0] = dmatrix[0][2];

    dmatrix[1][2] = diff[0]*x[0][1]*x[0][2]
      + diff[1]*x[1][1]*x[1][2]
      + diff[2]*x[2][1]*x[2][2]
      ;
    dmatrix[2][1] = dmatrix[1][2];
#endif
}
```

Hooking an Anisotropic Diffusivity UDF to FLUENT

After the UDF that you have defined using DEFINE_ANISOTROPIC_DIFFUSIVITY is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., cyl_ortho_diff) will become visible and selectable in the User-Defined Functions panel. You'll first need to select defined-per-uds for UDS Diffusivity in the Materials panel, then select the user-defined-anisotropic option for Diffusivity from the UDS Diffusion Coefficients panel for a particular user scalar equation (e.g., uds-0). See Section 6.6.1: Hooking DEFINE_ANISOTROPIC_DIFFUSIVITY UDFs for details.

2.7.3 DEFINE_UDS_FLUX

Description

You can use DEFINE_UDS_FLUX to customize how the advective flux term is computed in your user-defined scalar (UDS) transport equations. See Section 9.3: User-Defined Scalar (UDS) Transport Equations in the User's Guide for details on setting up and solving UDS transport equations.

Usage

```
DEFINE_UDS_FLUX(name,f,t,i)
```

Argument Type	Description
symbol name	UDF name.
face_t f	Face index.
Thread *t	Pointer to face thread on which the user-defined scalar flux is to be applied.
int i	Index that identifies the user-defined scalar for which the flux term is to be set.

Function returns
real

There are four arguments to DEFINE_UDS_FLUX: name, f, t, and i. You supply name, the name of the UDF. f, t, and i are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to return the real value of the mass flow rate through the given face to the solver.

The advection term in the differential transport equation has the following most general form:

$$\nabla \cdot \vec{\psi}\phi \tag{2.7-1}$$

where ϕ is the user-defined scalar conservation quantity and $\vec{\psi}$ is a vector field. In the default advection term, $\vec{\psi}$ is, by default, the product of the scalar density and the velocity vector:

$$\vec{\psi}_{\rm default} = \rho\vec{v} \tag{2.7-2}$$

To define the advection term in Equation 2.7-1 using DEFINE_UDS_FLUX, your UDF needs to return the scalar value $\vec{\psi} \cdot \vec{A}$ to FLUENT, where $\vec{\psi}$ is the same as defined in Equation 2.7-1 and $\vec{A}$ is the face normal vector of the face.

Note that the advective flux field that is supplied by your UDF should be divergence-free (i.e., it satisfies the continuity equation). In discrete terms this means that the sum of fluxes over all the faces of each cell should be zero. If the advective field is not divergence-free, then ϕ is not "conserved" and will result in overshoots/undershoots in the cell value of ϕ.

You will need to compute $\vec{\psi}$ in your UDF using, for example, predefined macros for velocity vector and scalar density that Fluent has provided (see Chapter 3: Additional Macros for Writing UDFs) or using your own prescription. The first case is illustrated in the sample C source code, shown below.

Note that if more than one scalar is being solved, you can use a conditional `if` statement in your UDF to define a different flux function for each `i`. `i` = 0 is associated with scalar-0 (the first scalar equation being solved).

Note also that $\vec{\psi} \cdot \vec{A}$ must have units of mass flow rate in SI (i.e., kg/s).

```
/*********************************************************************
    sample C source code that computes dot product of psi and A
    Note that this is not a complete C function
**********************************************************************/

real NV_VEC(psi), NV_VEC(A);         /* declaring vectors psi and A  */

                          /* defining psi in terms of velocity field */
NV_D(psi,  =, F_U(f,t), F_V(f,t), F_W(f,t));

NV_S(psi, *=, F_R(f,t))   /* multiplying density to get psi vector   */

F_AREA(A,f,t)             /* face normal vector returned from F_AREA */

return NV_DOT(psi,A);     /* dot product of the two returned         */
```

Additionally, since most quantities in FLUENT are not allocated in memory for interior faces, only for boundary faces (e.g., wall zones), your UDF will also need to calculate interior face values from the cell values of adjacent cells. This is most easily done using the arithmetic mean method. Vector arithmetic can be coded in C using the `NV_` and `ND_` macros (see Chapter 3: Additional Macros for Writing UDFs).

Note that if you had to implement the default advection term in a UDF without the fluid density in the definition of ψ (see above), you could simply put the following line in your `DEFINE_UDS_FLUX` UDF:

```
return F_FLUX(f,t) / rho;
```

where the denominator ρ can be determined by averaging the adjacent cell's density values C_R(F_C0(f,t),THREAD_T0(t)) and C_R(F_C1(f,t),THREAD_T1(t)).

Example

The following UDF, named my_uds_flux, returns the mass flow rate through a given face. The flux is usually available through the Fluent-supplied macro F_FLUX(f,t) (Section 3.2.4: Face Macros). The sign of flux that is computed by the FLUENT solver is positive if the flow direction is the same as the face area normal direction (as determined by F_AREA - see Section 3.2.4: Face Area Vector (F_AREA)), and is negative if the flow direction and the face area normal directions are opposite. By convention, face area normals always point out of the domain for boundary faces, and they point in the direction from cell c0 to cell c1 for interior faces.

The UDF must be executed as a compiled UDF.

```
/**********************************************************************/
/*    UDF that implements a simplified advective term in the         */
/*    scalar transport equation                                      */
/**********************************************************************/

#include "udf.h"

DEFINE_UDS_FLUX(my_uds_flux,f,t,i)
{
  cell_t  c0,  c1 = -1;
  Thread *t0, *t1 = NULL;

  real NV_VEC(psi_vec), NV_VEC(A), flux = 0.0;

  c0 = F_C0(f,t);
  t0 = F_C0_THREAD(f,t);
  F_AREA(A, f, t);

  /* If face lies at domain boundary, use face values; */
  /* If face lies IN the domain, use average of adjacent cells. */

 if (BOUNDARY_FACE_THREAD_P(t)) /*Most face values will be available*/
    {
      real dens;
      /* Depending on its BC, density may not be set on face thread*/
      if (NNULLP(THREAD_STORAGE(t,SV_DENSITY)))
        dens = F_R(f,t);   /* Set dens to face value if available */
      else
        dens = C_R(c0,t0); /* else, set dens to cell value */

      NV_DS(psi_vec,  =, F_U(f,t), F_V(f,t), F_W(f,t), *, dens);

      flux = NV_DOT(psi_vec, A); /* flux through Face */
    }
  else
    {
      c1 = F_C1(f,t);       /* Get cell on other side of face */
      t1 = F_C1_THREAD(f,t);

      NV_DS(psi_vec,  =, C_U(c0,t0),C_V(c0,t0),C_W(c0,t0),*,C_R(c0,t0));
      NV_DS(psi_vec, +=, C_U(c1,t1),C_V(c1,t1),C_W(c1,t1),*,C_R(c1,t1));

      flux = NV_DOT(psi_vec, A)/2.0; /* Average flux through face */
    }

  /* Fluent will multiply the returned value by phi_f (the scalar's
     value at the face) to get the ``complete'' advective term.  */

  return flux;
}
```

Hooking a UDS Flux Function to FLUENT

After the UDF that you have defined using DEFINE_UDS_FLUX is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., my_uds_flux) will become visible and selectable in the User-Defined Scalars panel in FLUENT. See Section 6.6.2: Hooking DEFINE_UDS_FLUX UDFs for details.

2.7.4 DEFINE_UDS_UNSTEADY

Description

You can use DEFINE_UDS_UNSTEADY to customize unsteady terms in your user-defined scalar (UDS) transport equations. See Section 9.3: User-Defined Scalar (UDS) Transport Equations in the User's Guide for details on setting up and solving UDS transport equations.

Usage

```
DEFINE_UDS_UNSTEADY(name,c,t,i,apu,su)
```

Argument Type	Description
symbol name	UDF name.
cell_t c	Cell index.
Thread *t	Pointer to cell thread on which the unsteady term for the user-defined scalar transport equation is to be applied.
int i	Index that identifies the user-defined scalar for which the unsteady term is to be set.
real *apu	Pointer to central coefficient.
real *su	Pointer to source term.

Function returns
void

There are six arguments to DEFINE_UDS_UNSTEADY: name, c, t, i, apu, and su. You supply name, the name of the UDF. c, t, and i are variables that are passed by the FLUENT solver to your UDF. Your UDF will need to set the values of the unsteady terms referenced by the real pointers apu and su to the central coefficient and source term, respectively.

The FLUENT solver expects that the transient term will be decomposed into a source term, su, and a central coefficient term, apu. These terms are included in the equation set in a similar manner to the way the explicit and implicit components of a source term might be handled. Hence, the unsteady term is moved to the right-hand side and discretized as follows:

$$\begin{aligned}\text{unsteady term} &= -\int \frac{\partial}{\partial t}(\rho\phi)\,dV \\ &\approx -\left[\frac{(\rho\phi)^n - (\rho\phi)^{n-1}}{\Delta t}\right]\cdot \Delta V\end{aligned}$$

$$= \underbrace{-\frac{\rho\Delta V}{\Delta t}}_{\texttt{apu}}\phi^n + \underbrace{\frac{\rho\Delta V}{\Delta t}\phi^{n-1}}_{\texttt{su}} \qquad (2.7\text{-}3)$$

Equation 2.7-3 shows how su and apu are defined. Note that if more than one scalar is being solved, a conditional if statement can be used in your UDF to define a different unsteady term for each i. i = 0 is associated with scalar-0 (the first scalar equation being solved).

Example

The following UDF, named my_uds_unsteady, modifies user-defined scalar time derivatives using DEFINE_UDS_UNSTEADY. The source code can be interpreted or compiled in FLUENT.

```
/*********************************************************************
   UDF for specifying user-defined scalar time derivatives
*********************************************************************/

#include "udf.h"

DEFINE_UDS_UNSTEADY(my_uds_unsteady,c,t,i,apu,su)
{
  real physical_dt, vol, rho, phi_old;
  physical_dt = RP_Get_Real("physical-time-step");
  vol = C_VOLUME(c,t);

  rho = C_R_M1(c,t);
  *apu = -rho*vol / physical_dt;/*implicit part*/
  phi_old = C_STORAGE_R(c,t,SV_UDSI_M1(i));
  *su  = rho*vol*phi_old/physical_dt;/*explicit part*/
}
```

Hooking a UDS Unsteady Function to FLUENT

After the UDF that you have defined using DEFINE_UDS_UNSTEADY is interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs), the name of the argument that you supplied as the first DEFINE macro argument (e.g., my_uds_unsteady) will become visible and selectable in the User-Defined Scalars panel in FLUENT. See Section 6.6.3: Hooking DEFINE_UDS_UNSTEADY UDFs for details.

Chapter 3. Additional Macros for Writing UDFs

This chapter provides predefined macros that you can use when defining your user-defined function (UDF).

3.1 Introduction

FLUENT provides numerous C types, functions, and preprocessor macros to facilitate the programming of UDFs and the use of CFD objects as defined inside FLUENT. The previous chapter presented DEFINE macros that you must use to define your UDF with. This chapter presents predefined functions (implemented as macros in the code) that are supplied by Fluent Inc. that you will use to code your UDF. These macros allow you to access data in a FLUENT solver such as cell variables (e.g., cell temperature, centroid), face variables (e.g., face temperature, area), or connectivity variables (e.g., adjacent cell thread and index) that your UDF can use in a computation. A special set of macros commonly used in UDFs is provided that return such values as the thread ID pointer (an internal FLUENT structure) when passed the Zone ID (the number assigned to a zone in a boundary conditions panel). Another special macro (F_PROFILE) enables your UDF to set a boundary condition value in the solver. Other types of macros are provided that enable your function to loop over nodes, cells, and faces in a thread or domain in order to retrieve and/or set values. Finally, data access macros that are specific to a particular model (e.g., DPM, NO_x) are presented, as well as macros that perform vector, time-dependent, Scheme, and I/O operations.

Function definitions for the macros provided in this chapter are contained in header files. Header files are identified by the .h suffix as in mem.h, metric.h, and dpm.h and are stored in the source code directory: .../Fluent.Inc/fluent6.x/src. The header files, unless explicitly noted, are included in the udf.h file, so your UDF does not need to contain a special #include compiler directive. You must, however, remember to include the #include "udf.h" directive in any UDF that you write.

Access to data from a FLUENT solver is accomplished by hooking your UDF C function (once it is compiled or interpreted) to the code through the graphical user interface (GUI). Once the UDF is correctly hooked, the solver's data is passed to the function and is available to use whenever it is called. These data are automatically passed by the solver to your UDF as function arguments. Note that all solver data, regardless of whether they are passed to your UDF by the solver or returned to the solver by the UDF, are specified in SI units. Macros in this chapter are listed with their arguments, argument types, returned value(s), if applicable, and header file.

Each function behind a macro either outputs a value to the solver as an argument, or returns a value that is then available for assignment in your UDF. Input arguments belong to the following FLUENT data types:

`Node *node`	pointer to a node
`cell_t c`	cell identifier
`face_t f`	face identifier
`Thread *t`	pointer to a thread
`Thread **pt`	pointer to an array of phase threads

Below is an example of a UDF that utilizes two data acess macros `C_T` and `C_CENTROID` and two looping macros `begin..end_c_loop_all` and `thread_loop_c`. `C_CENTROID` outputs a value to the solver as an argument which is then operated on in the UDF and `C_T` returns a value that is then available for assignment in the UDF. Two looping macros are used to set the cell temperature of *each* cell in *every* thread in the computational domain. `begin..end_c_loop_all`, is used to loop over all the cells in a cell thread to get the cell centroid and set the cell temperature, and `thread_loop_c` allows this loop to be repeated over all cell threads in the domain.

`C_CENTROID` has three arguments: `xc`, `c`, and `t`. Cell identifier `c` and cell thread pointer `t` are input arguments, and the argument array `xc` (the cell centroid) is output (as an argument) to the solver and used in the UDF in a conditional test.

`C_T` is used to set the cell temperature to the value of 400 or 300, depending on the outcome of the conditional test. It is passed the cell's ID `c` and thread pointer `t` and returns the `real` value of the cell temperature to the FLUENT solver.

Example

```
/***********************************************************************
   UDF for initializing flow field variables
   Example of C_T and C_CENTROID usage.
***********************************************************************/

#include "udf.h"

DEFINE_INIT(my_init_func,d)
{
  cell_t c;
  Thread *t;
  real xc[ND_ND];

  /* loop over all cell threads in the domain  */
  thread_loop_c(t,d)
    {

      /* loop over all cells  */
      begin_c_loop_all(c,t)
        {
          C_CENTROID(xc,c,t);
          if (sqrt(ND_SUM(pow(xc[0] - 0.5,2.),
                          pow(xc[1] - 0.5,2.),
                          pow(xc[2] - 0.5,2.))) < 0.25)
            C_T(c,t) = 400.;
          else
            C_T(c,t) = 300.;
        }
      end_c_loop_all(c,t)
    }
}
```

3.2 Data Access Macros

3.2.1 Introduction

The macros presented in this section access FLUENT data that you can utilize in your UDF. Unless indicated, these macros can be used in UDFs for single-phase and multiphase applications.

- Section 3.2.1: Introduction
- Section 3.2.2: Node Macros
- Section 3.2.3: Cell Macros
- Section 3.2.4: Face Macros
- Section 3.2.5: Connectivity Macros
- Section 3.2.6: Special Macros
- Section 3.2.7: Model-Specific Macros
- Section 3.2.8: User-Defined Scalar (UDS) Transport Equation Macros
- Section 3.2.9: User-Defined Memory (UDM) Macros

Axisymmetric Considerations for Data Access Macros

C-side calculations for axisymmetric models in FLUENT are made on a 1 radian basis. Therefore, when you are utilizing certain data access macros (e.g., F_AREA or F_FLUX) for axissymetric flows, your UDF will need to multiply the result by 2*PI (utilizing the macro M_PI) to get the desired value.

3.2.2 Node Macros

A grid in FLUENT is defined by the position of its nodes and how the nodes are connected. The macros listed in Table 3.2.1 and Table 3.2.2 can be used to return the real Cartesian coordinates of the cell node (at the cell corner) in SI units. The variables are available in both the pressure-based and the density-based solver. Definitions for these macros can be found in metric.h. The argument Node *node for each of the variables defines a node.

Node Position

Table 3.2.1: Macros for Node Coordinates Defined in metric.h

Macro	Argument Types	Returns
NODE_X(node)	Node *node	real x coordinate of node
NODE_Y(node)	Node *node	real y coordinate of node
NODE_Z(node)	Node *node	real z coordinate of node

Number of Nodes in a Face (F_NNODES)

The macro F_NNODES shown in Table 3.2.2 returns the integer number of nodes associated with a face.

Table 3.2.2: Macro for Number of Nodes Defined in mem.h

Macro	Argument Types	Returns
F_NNODES(f,t)	face_t f, Thread *t	int number of nodes in a face

3.2.3 Cell Macros

The macros listed in Table 3.2.3–3.2.19 can be used to return `real` cell variables in SI units. They are identified by the `C_` prefix. These variables are available in the pressure-based and the density-based solver. The quantities that are returned are available only if the corresponding physical model is active. For example, species mass fraction is available only if species transport has been enabled in the Species Model panel in FLUENT. Definitions for these macros can be found in the referenced header file (e.g., `mem.h`).

Cell Centroid (`C_CENTROID`)

The macro listed in Table 3.2.3 can be used to obtain the `real` centroid of a cell. `C_CENTROID` finds the coordinate position of the centroid of the cell `c` and stores the coordinates in the `x` array. Note that the array `x` can be a one-, two-, or three-dimensional array.

Table 3.2.3: Macro for Cell Centroids Defined in `metric.h`

Macro	Argument Types	Outputs
`C_CENTROID(x,c,t)`	`real x[ND_ND]`, `cell_t c`, `Thread * t`	`x` (cell centroid)

See Section 2.2.7: `DEFINE_INIT` for an example UDF that utilizes `C_CENTROID`.

Cell Volume (`C_VOLUME`)

The macro listed in Table 3.2.4 can be used to obtain the `real` cell volume for 2D, 3D, and axisymmetric simulations.

Table 3.2.4: Macro for Cell Volume Defined in `mem.h`

Macro	Argument Types	Returns
`C_VOLUME(c,t)`	`cell_t c`, `Thread *t`	`real` cell volume for 2D or 3D, `real` cell volume/2π for axisymmetric

See Section 2.7.4: `DEFINE_UDS_UNSTEADY` for an example UDF that utilizes `C_VOLUME`.

Number of Faces (C_NFACES) and Nodes (C_NNODES) in a Cell

The macro C_NFACES shown in Table 3.2.5 returns the integer number of faces for a given cell. C_NNODES, also shown in Table 3.2.2, returns the integer number of nodes for a given cell.

Table 3.2.5: Macros for Number of Node and Faces Defined in mem.h

Macro	Argument Types	Returns
C_NNODES(c,t)	cell_t c, Thread *t	int number of nodes in a cell
C_NFACES(c,t)	cell_t c, Thread *t	int number of faces in a cell

Cell Face Index (C_FACE)

C_FACE expands to return the global face index face_t f for the given cell_t c, Thread *t, and local face index number i. Specific faces can be accessed via the integer index i and all faces can be looped over with c_face_loop. The macro is defined in mem.h.

Table 3.2.6: Macro for Cell Face Index Defined in mem.h

Macro	Argument Types	Returns
C_FACE(c,t,i)	cell_t c, Thread *t, int i	global face index face_t f

Cell Face Index (C_FACE_THREAD)

C_FACE_THREAD expands to return the Thread *t of the face_t f that is returned by C_FACE (see above). Specific faces can be accessed via the integer index i and all faces can be looped over with c_face_loop. The macro is defined in mem.h.

Table 3.2.7: Macro for Cell Face Index Defined in mem.h

Macro	Argument Types	Returns
C_FACE_THREAD	cell_t c, Thread *t, int i	Thread *t of face_t f returned by C_FACE.

Flow Variable Macros for Cells

You can access flow variables using macros listed in Table 3.2.8.

Table 3.2.8: Macros for Cell Flow Variables Defined in `mem.h`

Macro	Argument Types	Returns
`C_R(c,t)`	`cell_t c`, `Thread *t`	density
`C_P(c,t)`	`cell_t c`, `Thread *t`	pressure
`C_U(c,t)`	`cell_t c`, `Thread *t`	u velocity
`C_V(c,t)`	`cell_t c`, `Thread *t`	v velocity
`C_W(c,t)`	`cell_t c`, `Thread *t`	w velocity
`C_T(c,t)`	`cell_t c`, `Thread *t`	temperature
`C_H(c,t)`	`cell_t c`, `Thread *t`	enthalpy
`C_K(c,t)`	`cell_t c`, `Thread *t`	turb. kinetic energy
`C_NUT(c,t)`	`cell_t c`, `Thread *t`	turbulent viscosity for Spalart-Allmaras
`C_D(c,t)`	`cell_t c`, `Thread *t`	turb. kinetic energy dissipation rate
`C_O(c,t)`	`cell_t c`, `Thread *t`	specific dissipation rate
`C_YI(c,t,i)`	`cell_t c`, `Thread *t`, `int i` note: `int i` is species index	species mass fraction

Gradient (G) and Reconstruction Gradient (RG) Vector Macros

You can access gradient and reconstruction gradient vectors (and components) for many of the cell variables listed in Table 3.2.8. FLUENT calculates the gradient of flow in a cell (based on the divergence theory) and stores this value in the variable identified by the suffix `_G`. For example cell temperature is stored in the variable `C_T`, and the temperature gradient of the cell is stored in `C_T_G`. The gradients stored in variables with the `_G` suffix are non-limited values and if used to reconstruct values within the cell (at faces, for example), may potentially result in values that are higher (or lower) than values in the surrounding cells. Therefore, if your UDF needs to compute face values from cell gradients, you should use the reconstruction gradient (RG) values instead of non-limited gradient (G) values. Reconstruction gradient variables are identified by the suffix `_RG`, and use the limiting method that you have activated in your FLUENT model to limit the cell gradient values.

Gradient (G) Vector Macros

Table 3.2.9 shows a list of cell gradient vector macros. Note that gradient variables are available *only* when the equation for that variable is being solved. For example, if you are defining a source term for energy, your UDF can access the cell temperature gradient (using C_T_G), but it cannot get access to the x-velocity gradient (using C_U_G). The reason for this is that the solver continually removes data from memory that it doesn't need. In order to retain the gradient data (when you want to set up user-defined scalar transport equations, for example), you can prevent the solver from freeing up memory by issuing the text command solve/set/expert and then answering yes to the question Keep temporary solver memory from being freed?. Note that when you do this, all of the gradient data is retained, but the calculation requires more memory to run.

You can access a component of a gradient vector by specifying it as an argument in the gradient vector call (0 for the x component; 1 for y; and 2 for z). For example,

```
C_T_G(c,t)[0];    /* returns the x-component of the cell temperature
                     gradient vector */
```

returns the x component of the temperature gradient vector.

Table 3.2.9: Macros for Cell Gradients Defined in mem.h

Macro	Argument Types	Returns
C_R_G(c,t)	cell_t c, Thread *t	density gradient vector
C_P_G(c,t)	cell_t c, Thread *t	pressure gradient vector
C_U_G(c,t)	cell_t c, Thread *t	velocity gradient vector
C_V_G(c,t)	cell_t c, Thread *t	velocity gradient vector
C_W_G(c,t)	cell_t c, Thread *t	velocity gradient vector
C_T_G(c,t)	cell_t c, Thread *t	temperature gradient vector
C_H_G(c,t)	cell_t c, Thread *t	enthalpy gradient vector
C_NUT_G(c,t)	cell_t c, Thread *t	turbulent viscosity for Spalart-Allmaras gradient vector
C_K_G(c,t)	cell_t c, Thread *t	turbulent kinetic energy gradient vector
C_D_G(c,t)	cell_t c, Thread *t	turbulent kinetic energy dissipation rate gradient vector
C_O_G(c,t)	cell_t c, Thread *t	specific dissipation rate gradient vector
C_YI_G(c,t,i)	cell_t c, Thread *t, int i note: int i is species index	species mass fraction gradient vector

Note that you can access vector components of each of the variables listed in Table 3.2.9 by using the integer index `[i]` for each macro listed in Table 3.2.9. For example, `C_T_G(c,t)[i]` will access a component of the temperature gradient vector.

`C_R_G` can be used only in the density-based solver and `C_P_G` can be used only in the pressure-based solver.

`C_YI_G` can be used only in the density-based solver. To use this in the pressure-based solver, you will need to set the rpvar `'species/save-gradients?` to `#t`.

Reconstruction Gradient (RG) Vector Macros

Table 3.2.10 shows a list of cell reconstruction gradient vector macros. Like gradient variables, RG variables are available only when the equation for that variable is being solved. As in the case of gradient variables, you can retain all of the reconstruction gradient data by issuing the text command `solve/set/expert` and then answering `yes` to the question `Keep temporary solver memory from being freed?`. Note that when you do this, the reconstruction gradient data is retained, but the calculation requires more memory to run.

You can access a component of a reconstruction gradient vector by specifying it as an argument in the reconstruction gradient vector call (`0` for the x component; `1` for y; and `2` for z). For example,

```
C_T_RG(c,t)[0];    /* returns the x-component of the cell temperature
                      reconstruction gradient vector */
```

returns the x component of the temperature reconstruction gradient vector.

Note that you can access vector components by using the integer index `[i]` for each macro listed in Table 3.2.10. For example, `C_T_RG(c,t)[i]` will access a component of the temperature reconstruction gradient vector.

`C_P_RG` can be used in the pressure-based solver only when the second order discretization scheme for pressure is specified.

`C_YI_RG` can be used only in the density-based solver.

Table 3.2.10: Macros for Cell Reconstruction Gradients (RG) Defined in `mem.h`

Macro	Argument Types	Returns
`C_R_RG(c,t)`	`cell_t c`, `Thread *t`	density RG vector
`C_P_RG(c,t)`	`cell_t c`, `Thread *t`	pressure RG vector
`C_U_RG(c,t)`	`cell_t c`, `Thread *t`	velocity RG vector
`C_V_RG(c,t)`	`cell_t c`, `Thread *t`	velocity RG vector
`C_W_RG(c,t)`	`cell_t c`, `Thread *t`	velocity RG vector
`C_T_RG(c,t)`	`cell_t c`, `Thread *t`	temperature RG vector
`C_H_RG(c,t)`	`cell_t c`, `Thread *t`	enthalpy RG vector
`C_NUT_RG(c,t)`	`cell_t c`, `Thread *t`	turbulent viscosity for Spalart-Allmaras RG vector
`C_K_RG(c,t)`	`cell_t c`, `Thread *t`	turbulent kinetic energy RG vector
`C_D_RG(c,t)`	`cell_t c`, `Thread *t`	turbulent kinetic energy dissipation rate RG vector
`C_YI_RG(c,t,i)`	`cell_t c`, `Thread *t`, `int i` note: `int i` is species index	species mass fraction RG vector

Previous Time Step Macros

The `_M1` suffix can be applied to some of the cell variable macros in Table 3.2.8 to allow access to the value of the variable at the previous time step (i.e., $t - \Delta t$). These data may be useful in unsteady simulations. For example,

```
C_T_M1(c,t);
```

returns the value of the cell temperature at the previous time step. Previous time step macros are shown in Table 3.2.11.

Note that data from `C_T_M1` is available *only* if user-defined scalars are defined. It can also be used with adaptive time stepping.

See Section 2.7.4: `DEFINE_UDS_UNSTEADY` for an example UDF that utilizes `C_R_M1`.

Table 3.2.11: Macros for Cell Time Level 1 Defined in mem.h

Macro	Argument Types	Returns
C_R_M1(c,t)	cell_t c, Thread *t	density, previous time step
C_P_M1(c,t)	cell_t c, Thread *t	pressure, previous time step
C_U_M1(c,t)	cell_t c, Thread *t	velocity, previous time step
C_V_M1(c,t)	cell_t c, Thread *t	velocity, previous time step
C_W_M1(c,t)	cell_t c, Thread *t	velocity, previous time step
C_T_M1(c,t)	cell_t c, Thread *t	temperature, previous time step
C_YI_M1(c,t,i)	cell_t c, Thread *t, int i note: int i is species index	species mass fraction, previous time step

The M2 suffix can be applied to some of the cell variable macros in Table 3.2.11 to allow access to the value of the variable at the time step before the previous one (i.e., $t-2\Delta t$). These data may be useful in unsteady simulations. For example,

```
C_T_M2(c,t);
```

returns the value of the cell temperature at the time step before the previous one (referred to as second previous time step). Two previous time step macros are shown in Table 3.2.12.

Note that data from C_T_M2 is available *only* if user-defined scalars are defined. It can also be used with adaptive time stepping.

Derivative Macros

The macros listed in Table 3.2.13 can be used to return real velocity derivative variables in SI units. The variables are available in both the pressure-based and the density-based solver. Definitions for these macros can be found in the mem.h header file.

Table 3.2.12: Macros for Cell Time Level 2 Defined in `mem.h`

Macro	Argument Types	Returns
`C_R_M2(c,t)`	`cell_t c`, `Thread *t`	density, second previous time step
`C_P_M2(c,t)`	`cell_t c`, `Thread *t`	pressure, second previous time step
`C_U_M2(c,t)`	`cell_t c`, `Thread *t`	velocity, second previous time step
`C_V_M2(c,t)`	`cell_t c`, `Thread *t`	velocity, second previous time step
`C_W_M2(c,t)`	`cell_t c`, `Thread *t`	velocity, second previous time step
`C_T_M2(c,t)`	`cell_t c`, `Thread *t`	temperature, second previous time step
`C_YI_M2(c,t,i)`	`cell_t c`, `Thread *t`, `int i`	species mass fraction, second previous time step

Table 3.2.13: Macros for Cell Velocity Derivatives Defined in `mem.h`

Macro	Argument Types	Returns
`C_STRAIN_RATE_MAG(c,t)`	`cell_t c`, `Thread *t`	strain rate magnitude
`C_DUDX(c,t)`	`cell_t c`, `Thread *t`	velocity derivative
`C_DUDY(c,t)`	`cell_t c`, `Thread *t`	velocity derivative
`C_DUDZ(c,t)`	`cell_t c`, `Thread *t`	velocity derivative
`C_DVDX(c,t)`	`cell_t c`, `Thread *t`	velocity derivative
`C_DVDY(c,t)`	`cell_t c`, `Thread *t`	velocity derivative
`C_DVDZ(c,t)`	`cell_t c`, `Thread *t`	velocity derivative
`C_DWDX(c,t)`	`cell_t c`, `Thread *t`	velocity derivative
`C_DWDY(c,t)`	`cell_t c`, `Thread *t`	velocity derivative
`C_DWDZ(c,t)`	`cell_t c`, `Thread *t`	velocity derivative

Material Property Macros

The macros listed in Tables 3.2.14–3.2.16 can be used to return `real` material property variables in SI units. The variables are available in both the pressure-based and the density-based solver. Argument `real prt` is the turbulent Prandtl number. Definitions for material property macros can be found in the referenced header file (e.g., `mem.h`).

Table 3.2.14: Macros for Diffusion Coefficients Defined in `mem.h`

Macro	Argument Types	Returns
`C_MU_L(c,t)`	`cell_t c`, `Thread *t`	laminar viscosity
`C_MU_T(c,t)`	`cell_t c`, `Thread *t`	turbulent viscosity
`C_MU_EFF(c,t)`	`cell_t c`, `Thread *t`	effective viscosity
`C_K_L(c,t)`	`cell_t c`, `Thread *t`	thermal conductivity
`C_K_T(c,t,prt)`	`cell_t c`, `Thread *t`, `real prt`	turbulent thermal conductivity
`C_K_EFF(c,t,prt)`	`cell_t c`, `Thread *t`, `real prt`	effective thermal conductivity
`C_DIFF_L(c,t,i,j)`	`cell_t c`, `Thread *t`, `int i`, `int j`	laminar species diffusivity
`C_DIFF_EFF(c,t,i)`	`cell_t c`, `Thread *t`, `int i`	effective species diffusivity

Table 3.2.15: Macros for Thermodynamic Properties Defined in `mem.h`

Name(Arguments)	Argument Types	Returns
`C_CP(c,t)`	`cell_t c`, `Thread *t`	specific heat
`C_RGAS(c,t)`	`cell_t c`, `Thread *t`	universal gas constant/molecular weight
`C_NUT(c,t)`	`cell_t c`, `Thread *t`	turbulent viscosity for Spalart-Allmaras

Table 3.2.16: Additional Material Property Macros Defined in `sg_mem.h`

Macro	Argument Types	Returns
`C_FMEAN(c,t)`	`cell_t c`, `Thread *t`	primary mean mixture fraction
`C_FMEAN2(c,t)`	`cell_t c`, `Thread *t`	secondary mean mixture fraction
`C_FVAR(c,t)`	`cell_t c`, `Thread *t`	primary mixture fraction variance
`C_FVAR2(c,t)`	`cell_t c`, `Thread *t`	secondary mixture fraction variance
`C_PREMIXC(c,t)`	`cell_t c`, `Thread *t`	reaction progress variable
`C_LAM_FLAME_SPEED(c,t)`	`cell_t c`, `Thread *t`	laminar flame speed
`C_SCAT_COEFF(c,t)`	`cell_t c`, `Thread *t`	scattering coefficient
`C_ABS_COEFF(c,t)`	`cell_t c`, `Thread *t`	absorption coefficient
`C_CRITICAL_STRAIN_RATE(c,t)`	`cell_t c`, `Thread *t`	critical strain rate
`C_LIQF(c,t)`	`cell_t c`, `Thread *t`	liquid fraction in a cell
`C_POLLUT(c,t,i)`	`cell_t c`, `Thread *t`, `int i`	ith pollutant species mass fraction (see table below)

i `C_LIQF` is available only in fluid cells and only if solidification is turned ON.

Note: Concentration in particles $\times 10^{-15}$/kg. For mass fraction concentrations in the table above, see Equation 20.3-7 of the User's Guide for the defining equation.

Reynolds Stress Model Macros

The macros listed in Table 3.2.18 can be used to return `real` variables for the Reynolds stress turbulence model in SI units. The variables are available in both the pressure-based and the density-based solver. Definitions for these macros can be found in the `metric.h` header file.

Table 3.2.17: Table of Definitions for Argument i of the Pollutant Species Mass Fraction Function C_POLLUT

i	Definitions
0	Mass Fraction of NO
1	Mass Fraction of HCN
2	Mass Fraction of NH3
3	Mass Fraction of N2O
4	Soot Mass Fraction
5	Normalized Radical Nuclei

Table 3.2.18: Macros for Reynolds Stress Model Variables Defined in sg_mem.h

Macro	Argument Types	Returns
C_RUU(c,t)	cell_t c, Thread *t	*uu* Reynolds stress
C_RVV(c,t)	cell_t c, Thread *t	*vv* Reynolds stress
C_RWW(c,t)	cell_t c, Thread *t	*ww* Reynolds stress
C_RUV(c,t)	cell_t c, Thread *t	*uv* Reynolds stress
C_RVW(c,t)	cell_t c, Thread *t	*vw* Reynolds stress
C_RUW(c,t)	cell_t c, Thread *t	*uw* Reynolds stress

VOF Multiphase Model Macro

The macro C_VOF can be used to return real variables associated with the VOF multiphase model in SI units. The variables are available in both the pressure-based and the density-based solver, with the exception of the VOF variable, which is available only for the pressure-based solver. Definitions for these macros can be found in sg_mphase.h, which is included in udf.h.

Table 3.2.19: Macros for Multiphase Variables Defined in sg_mphase.h

Macro	Argument Types	Returns
C_VOF(c,t)	cell_t c, Thread *t (has to be a phase thread)	volume fraction for the phase corresponding to phase thread t.

3.2.4 Face Macros

The macros listed in Table 3.2.20–3.2.23 can be used to return real face variables in SI units. They are identified by the F_ prefix. Note that these variables are available *only* in the pressure-based solver. In addition, quantities that are returned are available only if the corresponding physical model is active. For example, species mass fraction is available only if species transport has been enabled in the Species Model panel in FLUENT. Definitions for these macros can be found in the referenced header files (e.g., mem.h).

Face Centroid (F_CENTROID)

The macro listed in Table 3.2.20 can be used to obtain the real centroid of a face. F_CENTROID finds the coordinate position of the centroid of the face f and stores the coordinates in the x array. Note that the array x can be a one-, two-, or three-dimensional array.

Table 3.2.20: Macro for Face Centroids Defined in metric.h

Macro	Argument Types	Outputs
F_CENTROID(x,f,t)	real x[ND_ND], face_t f, Thread *t	x (face centroid)

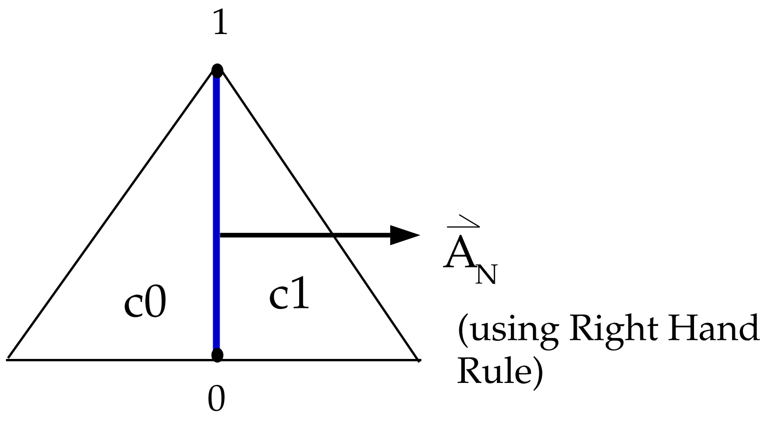


Figure 3.2.1: FLUENT Determination of Face Area Normal Direction: 2D Face

The ND_ND macro returns 2 or 3 in 2D and 3D cases, respectively, as defined in Section 3.4.2: The ND Macros. Section 2.3.13: DEFINE_PROFILE contains an example of F_CENTROID usage.

Face Area Vector (F_AREA)

F_AREA can be used to return the real face area vector (or 'face area normal') of a given face f in a face thread t. See Section 2.7.3: DEFINE_UDS_FLUX for an example UDF that utilizes F_AREA.

Table 3.2.21: Macro for Face Area Vector Defined in metric.h

Macro	Argument Types	Outputs
F_AREA(A,f,t)	A[ND_ND], face_t f, Thread *t	A (area vector)

By convention in FLUENT, boundary face area normals always point out of the domain. FLUENT determines the direction of the face area normals for interior faces by applying the right hand rule to the nodes on a face, in order of increasing node number. This is shown in Figure 3.2.1.

FLUENT assigns adjacent cells to an interior face (c0 and c1) according to the following convention: the cell *out* of which a face area normal is pointing is designated as cell C0, while the cell *in* to which a face area normal is pointing is cell c1 (Figure 3.2.1). In other words, face area normals always point from cell c0 to cell c1.

Flow Variable Macros for Boundary Faces

The macros listed in Table 3.2.20 access flow variables at a boundary face.

Table 3.2.22: Macros for Boundary Face Flow Variables Defined in mem.h

Macro	Argument Types	Returns
F_U(f,t)	face_t f, Thread *t,	u velocity
F_V(f,t)	face_t f, Thread *t,	v velocity
F_W(f,t)	face_t f, Thread *t,	w velocity
F_T(f,t)	face_t f, Thread *t,	temperature
F_H(f,t)	face_t f, Thread *t,	enthalpy
F_K(f t)	face_t f, Thread *t,	turbulent kinetic energy
F_D(f,t)	face_t f, Thread *t,	turbulent kinetic energy dissipation rate
F_YI(f,t,i)	face_t f, Thread *t, int i	species mass fraction

See Section 2.7.3: DEFINE_UDS_FLUX for an example UDF that utilizes some of these macros.

Flow Variable Macros at Interior and Boundary Faces

The macros listed in Table 3.2.20 access flow variables at interior faces and boundary faces.

Table 3.2.23: Macros for Interior and Boundary Face Flow Variables Defined in mem.h

Macro	Argument Types	Returns
F_P(f,t)	face_t f, Thread *t,	pressure
F_FLUX(f,t)	face_t f, Thread *t	mass flow rate through a face

F_FLUX can be used to return the real scalar mass flow rate through a given face f in a face thread t. The sign of F_FLUX that is computed by the FLUENT solver is positive if the flow direction is the same as the face area normal direction (as determined by F_AREA - see Section 3.2.4: Face Area Vector (F_AREA)), and is negative if the flow direction and the face area normal directions are opposite. In other words, the flux is positive if the flow is *out* of the domain, and is negative if the flow is *in* to the domain.

Note that the sign of the flux that is computed by the solver is opposite to that which is reported in the FLUENT graphical user-interface (e.g., Reports ⟶Fluxes...).

3.2.5 Connectivity Macros

FLUENT provides macros that allow the vectors connecting cell centroids and the vectors connecting cell and face centroids to be readily defined. These macros return information that is helpful in evaluating face values of scalars which are generally not stored, as well as the diffusive flux of scalars across cell boundaries. The geometry and gradients involved with these macros are summarized in Figure 3.2.2 below.

To better understand the parameters that are returned by these macros, it is best to consider how the aforementioned calculations are evaluated. Assuming that the gradient of a scalar is available, the face value of a scalar, ϕ, can be approximated by

$$\phi_f = \phi_0 + \nabla\phi \cdot \vec{dr} \tag{3.2-1}$$

where $\vec{dr}$ is the vector that connects the cell centroid with the face centroid. The gradient in this case is evaluated at the cell centroid where ϕ_0 is also stored.

The diffusive flux, D_f, across a face, f, of a scalar ϕ is given by,

$$D_f = \Gamma_f \nabla\phi \cdot \vec{A} \tag{3.2-2}$$

where Γ_f is the diffusion coefficient at the face. In FLUENT's unstructured solver, the gradient along the face normal direction may be approximated by evaluating gradients along the directions that connect cell centroids and along a direction confined within the plane of the face. Given this, D_f may be approximated as,

$$D_f = \Gamma_f \frac{(\phi_1 - \phi_0)}{ds} \frac{\vec{A} \cdot \vec{A}}{\vec{A} \cdot \vec{e_s}} + \Gamma_f \left(\overline{\nabla}\phi \cdot \vec{A} - \overline{\nabla}\phi \cdot \vec{e_s} \frac{\vec{A} \cdot \vec{A}}{\vec{A} \cdot \vec{e_s}} \right) \tag{3.2-3}$$

where the first term on the right hand side represents the primary gradient directed along the vector $\vec{e_s}$ and the second term represents the 'cross' diffusion term. In this equation, A is the area normal vector of face f directed from cell `c0` to `c1`, ds is the distance between the cell centroids, and $\vec{e_s}$ is the unit normal vector in this direction. $\overline{\nabla}\phi$ is the average of the gradients at the two adjacent cells. (For boundary faces, the variable is the gradient of the c0 cell.) This is shown in Figure 3.2.2 below.

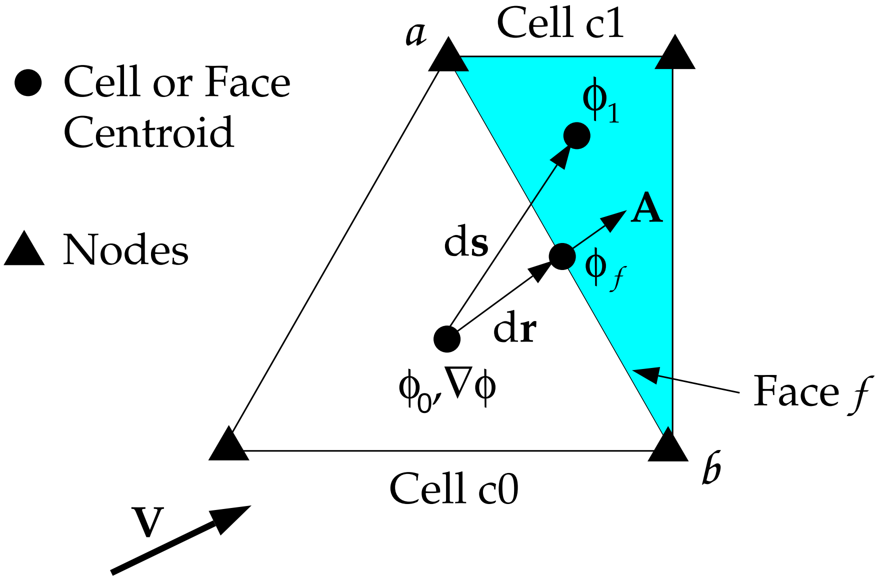


Figure 3.2.2: Adjacent Cells c0 and c1 with Vector and Gradient Definitions

Adjacent Cell Index (F_C0, F_C1)

The cells on either side of a face may or may not belong to the same cell thread. Referring to Figure 3.2.2, if a face is on the boundary of a domain, then only c0 exists. (c1 is undefined for an external face). Alternatively, if the face is in the interior of the domain, then both c0 and c1 exist.

There are two macros, F_C0(f,t) and F_C1(f,t), that can be used to identify cells that are adjacent to a given face thread t. F_C0 expands to a function that returns the index of a face's neighboring c0 cell (Figure 3.2.2), while F_C1 returns the cell index for c1 (Figure 3.2.2), if it exists.

Table 3.2.24: Adjacent Cell Index Macros Defined in mem.h

Macro	Argument Types	Returns
F_C0(f,t)	face_t f, Thread *t	cell_t c for cell c0
F_C1(f,t)	face_t f, Thread *t	cell_t c for cell c1

See Section 2.7.3: DEFINE_UDS_FLUX for an example UDF that utilizes F_C0.

Adjacent Cell Thread (THREAD_T0, THREAD_T1)

The cells on either side of a face may or may not belong to the same cell thread. Referring to Figure 3.2.2, if a face is on the boundary of a domain, then only c0 exists. (c1 is undefined for an external face). Alternatively, if the face is in the interior of the domain, then both c0 and c1 exist.

There are two macros, THREAD_T0(t) and THREAD_T1(t), that can be used to identify cell threads that are adjacent to a given face f in a face thread t. THREAD_T0 expands to a function that returns the cell thread of a given face's adjacent cell c0, and THREAD_T1 returns the cell thread for c1 (if it exists).

Table 3.2.25: Adjacent Cell Thread Macros Defined in mem.h

Macro	Argument Types	Returns
THREAD_T0(t)	Thread *t	cell thread pointer for cell c0
THREAD_T1(t)	Thread *t	cell thread pointer for cell c1

Interior Face Geometry (INTERIOR_FACE_GEOMETRY)

INTERIOR_FACE_GEOMETRY(f,t,A,ds,es,A_by_es,dr0,dr1) expands to a function that outputs the following variables to the solver, for a given face f, on face thread t. The macro is defined in the sg.h header file which is *not* included in udf.h. You will need to include this file in your UDF using the #include directive.

real A[ND_ND]	the area normal vector
real ds	distance between the cell centroids
real es[ND_ND]	the unit normal vector in the direction from cell c0 to c1
real A_by_es	the value $\frac{\vec{A}\cdot\vec{A}}{\vec{A}\cdot\vec{e_s}}$
real dr0[ND_ND]	vector that connects the centroid of cell c0 to the face centroid
real dr1[ND_ND]	the vector that connects the centroid of cell c1 to the face centroid

Note that INTERIOR_FACE_GEOMETRTY can be called to retrieve some of the terms needed to evaluate Equations 3.2-1 and 3.2-3.

Boundary Face Geometry (BOUNDARY_FACE_GEOMETRY)

BOUNDARY_FACE_GEOMETRY(f,t,A,ds,es,A_by_es,dr0) expands to a function that outputs the following variables to the solver, for a given face f, on face thread t. It is defined in the sg.h header file which is *not* included in udf.h. You will need to include this file in your UDF using the #include directive.

BOUNDARY_FACE_GEOMETRY can be called to retrieve some of the terms needed to evaluate Equations 3.2-1 and 3.2-3.

real A[ND_ND]	area normal vector
real ds	distance between the cell centroid and the face centroid
real es[ND_ND]	unit normal vector in the direction from centroid of cell c0 to the face centroid
real A_by_es	value $\frac{\vec{A}\cdot\vec{A}}{\vec{A}\cdot\vec{e_s}}$
real dr0[ND_ND]	vector that connects the centroid of cell c0 to the face centroid

Boundary Face Thread (BOUNDARY_FACE_THREAD)

BOUNDARY_FACE_THREAD_P(t) expands to a function that returns TRUE if Thread *t is a boundary face thread. The macro is defined in threads.h which is included in udf.h. See Section 2.7.3: DEFINE_UDS_FLUX for an example UDF that utilizes BOUNDARY_FACE_THREAD_P.

3.2.6 Special Macros

The macros listed in this section are special macros that are used often in UDFs.

- Lookup_Thread
- THREAD_ID
- Get_Domain
- F_PROFILE
- THREAD_SHADOW

Thread Pointer for Zone ID (Lookup_Thread)

You can use Lookup_Thread when you want to retrieve the pointer t to the thread that is associated with a given integer zone ID number for a boundary zone. The zone_ID that is passed to the macro is the zone number that FLUENT assigns to the boundary and displays in the boundary condition panel (e.g., Fluid). Note that this macro does the inverse of THREAD_ID (see below).

There are two arguments to Lookup_Thread. domain is passed by FLUENT and is the pointer to the domain structure. You supply the integer value of zone_ID.

For example, the code

```
int zone_ID = 2;
Thread *thread_name = Lookup_Thread(domain,zone_ID);
```

passes a zone ID of 2 to Lookup_Thread. A zone ID of 2 may, for example, correspond to a wall zone in your case.

Now suppose that your UDF needs to operate on a particular thread in a domain (instead of looping over all threads), and the DEFINE macro you are using to define your UDF doesn't have the thread pointer passed to it from the solver (e.g., DEFINE_ADJUST). You can use Lookup_Thread in your UDF to get the desired thread pointer. This is a two-step process.

First, you will need to get the integer ID of the zone by visiting the boundary condition panel (e.g., Fluid) and noting the zone ID. You can also obtain the value of the Zone ID from the solver using RP_Get_Integer. Note that in order to use RP_Get_Integer, you will have had to define the zone ID variable first, either in another UDF using RP_Set_Integer, or on the Scheme side using rp-var-define (see Section 3.6: Scheme Macros for details.)

Next, you supply the zone_ID as an argument to Lookup_Thread either as a hard-coded integer (e.g., 1, 2) or as the variable assigned from RP_Get_Integer. Lookup_Thread returns the pointer to the thread that is associated with the given zone ID. You can then assign the thread pointer to a thread_name and use it in your UDF.

> Note that when Lookup_Thread is utilized in a multiphase flow problem, the domain pointer that is passed to the function depends on the UDF that it is contained within. For example, if Lookup_Thread is used in an adjust function (DEFINE_ADJUST) then the mixture domain is passed and the thread pointer returned is the mixture-level thread.

Example

Below is a UDF that uses Lookup_Thread. In this example, the pointer to the thread for a given zone_ID is retrieved by Lookup_Thread and is assigned to thread. The thread pointer is then used in begin_f_loop to loop over all faces in the given thread, and and in F_CENTROID to get the face centroid value.

```
/*******************************************************************/
    Example of an adjust UDF that uses Lookup_Thread.
    Note that if this UDF is applied to a multiphase flow problem,
    the thread that is returned is the mixture-level thread
********************************************************************/

#include "udf.h"

/* domain passed to Adjust function is mixture domain for multiphase*/

DEFINE_ADJUST(print_f_centroids, domain)
{
  real FC[2];
  face_t f;
  int ID = 1;
       /* Zone ID for wall-1 zone from Boundary Conditions panel */
  Thread *thread = Lookup_Thread(domain, ID);
  begin_f_loop(f, thread)
     {
        F_CENTROID(FC,f,thread);
        printf("x-coord = %f  y-coord = %f", FC[0], FC[1]);
     }
  end_f_loop(f,thread)
}
```

Zone ID (THREAD_ID)

You can use THREAD_ID when you want to retrieve the integer zone ID number (displayed in a boundary conditions panel such as Fluid) that is associated with a given thread pointer t. Note that this macro does the inverse of Lookup_Thread (see above).

```
int zone_ID = THREAD_ID(t);
```

Domain Pointer (Get_Domain)

You can use the Get_Domain macro to retrieve a domain pointer when it is not explicitly passed as an argument to your UDF. This is commonly used in ON_DEMAND functions since DEFINE_ON_DEMAND is not passed any arguments from the FLUENT solver. It is also used in initialization and adjust functions for multiphase applications where a phase domain pointer is needed but only a mixture pointer is passed.

```
Get_Domain(domain_id);
```

domain_id is an integer whose value is 1 for the mixture domain, but the values for the phase domains can be any integer greater than 1. The ID for a particular phase can be found be selecting it in the Phases panel in FLUENT.

Define ⟶Phases...

Single-Phase Flows

In the case of single-phase flows, domain_id is 1 and Get_Domain(1) will return the fluid domain pointer.

```
DEFINE_ON_DEMAND(my_udf)
{
  Domain *domain;          /* domain is declared as a variable   */
  domain = Get_Domain(1);  /* returns fluid domain pointer       */
  ...
}
```

Multiphase Flows

In the case of multiphase flows, the value returned by Get_Domain is either the mixture-level, a phase-level, or an interaction phase-level domain pointer. The value of domain_id is always 1 for the mixture domain. You can obtain the domain_id using the FLUENT graphical user interface much in the same way that you can determine the zone ID from the Boundary Conditions panel. Simply go to the Phases panel in FLUENT and select the desired phase. The domain_id will then be displayed. You will need to hard code this integer ID as an argument to the macro as shown below.

```
DEFINE_ON_DEMAND(my_udf)
{
  Domain *mixture_domain;
  mixture_domain = Get_Domain(1);   /* returns mixture domain pointer */
                                    /* and assigns to variable        */

  Domain *subdomain;
  subdomain = Get_Domain(2); /* returns phase with ID=2 domain pointer*/
                             /* and assigns to variable               */
  ...
}
```

Example

Below is a UDF named `get_coords` that prints the thread face centroids for two specified thread IDs. The function implements the `Get_Domain` utility for a single-phase application. In this example, the function `Print_Thread_Face_Centroids` uses the `Lookup_Thread` function to determine the pointer to a thread, and then writes the face centroids of all the faces in a specified thread to a file. The `Get_Domain(1)` function call returns the pointer to the domain (or mixture domain, in the case of a multiphase application). This argument is not passed to `DEFINE_ON_DEMAND`.

```
/*******************************************************************
    Example of UDF for single phase that uses Get_Domain utility
********************************************************************/

#include "udf.h"

FILE *fout;

void Print_Thread_Face_Centroids(Domain *domain, int id)
{
  real FC[2];
  face_t f;
  Thread *t = Lookup_Thread(domain, id);

  fprintf(fout,"thread id %d\n", id);
  begin_f_loop(f,t)
    {
     F_CENTROID(FC,f,t);
     fprintf(fout, "f%d %g %g %g\n", f, FC[0], FC[1], FC[2]);
    }
  end_f_loop(f,t)
  fprintf(fout, "\n");
}

DEFINE_ON_DEMAND(get_coords)
{
  Domain *domain;
  domain = Get_Domain(1);
  fout = fopen("faces.out", "w");
  Print_Thread_Face_Centroids(domain, 2);
  Print_Thread_Face_Centroids(domain, 4);
  fclose(fout);
}
```

Note that `Get_Domain(1)` replaces the `extern Domain *domain` expression used in previous releases of FLUENT 6.

Set Boundary Condition Value (F_PROFILE)

`F_PROFILE` is typically used in a `DEFINE_PROFILE` UDF to set a boundary condition value in memory for a given face and thread. The index `i` that is an argument to `F_PROFILE` is also an argument to `DEFINE_PROFILE` and identifies the particular boundary variable (e.g., pressure, temperature, velocity) that is to be set. `F_PROFILE` is defined in `mem.h`.

Macro:	`F_PROFILE(f, t, i)`

Argument types:	`face_t f`
	`Thread *t`
	`int i`

Function returns:	`void`

The arguments of `F_PROFILE` are `f`, the index of the face `face_t`; `t`, a pointer to the face's thread `t`; and `i`, an integer index to the particular face variable that is to be set. `i` is defined by FLUENT when you hook a `DEFINE_PROFILE` UDF to a particular variable (e.g., pressure, temperature, velocity) in a boundary condition panel. This index is passed to your UDF by the FLUENT solver so that the function knows which variable to operate on.

Suppose you want to define a custom inlet boundary pressure profile for your FLUENT case defined by the following equation:

$$p(y) = 1.1 \times 10^5 - 0.1 \times 10^5 \left(\frac{y}{0.0745} \right)^2$$

You can set the pressure profile using a DEFINE_PROFILE UDF. Since a profile is an array of data, your UDF will need to create the pressure array by looping over all faces in the boundary zone, and for each face, set the pressure value using F_PROFILE. In the sample UDF source code shown below, the y coordinate of the centroid is obtained using F_CENTROID, and this value is used in the pressure calculation that is stored for each face. The solver passes the UDF the right index to the pressure variable because the UDF is hooked to Gauge Total Pressure in the Pressure Inlet boundary condition panel. See Section 2.3.13: DEFINE_PROFILE for more information on DEFINE_PROFILE UDFs.

```
/***********************************************************************
   UDF for specifying a parabolic pressure profile boundary profile
************************************************************************/

#include "udf.h"

DEFINE_PROFILE(pressure_profile,t,i)
{
  real x[ND_ND];                /* this will hold the position vector */
  real y;
  face_t f;

  begin_f_loop(f,t)
    {
      F_CENTROID(x,f,t);
      y = x[1];
      F_PROFILE(f,t,i) = 1.1e5 - y*y/(.0745*.0745)*0.1e5;
    }
  end_f_loop(f,t)
}
```

THREAD_SHADOW(t)

THREAD_SHADOW returns the face thread that is the shadow of Thread *t if it is one of a face/face-shadow pair that comprise a thin wall. It returns NULL if the boundary is not part of a thin wall and is often used in an if statement such as:

```
if (!NULLP(ts = THREAD_SHADOW(t)))
{
    /* Do things here using the shadow wall thread (ts)  */
}
```

3.2.7 Model-Specific Macros

DPM Macros

The macros listed in Tables 3.2.26–3.2.31 can be used to return real variables associated with the Discrete Phase Model (DPM), in SI units. They are typically used in DPM UDFs that are described in Section 2.5: Discrete Phase Model (DPM) DEFINE Macros. The variables are available in both the pressure-based and the density-based solver. The macros are defined in the dpm.h header file, which is included in udf.h.

The variable p indicates a pointer to the Tracked_Particle structure (Tracked_Particle *p) which gives you the value for the particle at the current position.

Refer to the following sections for examples of UDFs that utilize some of these macros: Section 2.5.7: DEFINE_DPM_LAW, Section 2.5.1: DEFINE_DPM_BC, Section 2.5.6: DEFINE_DPM_INJECTION_INIT, Section 2.5.13: DEFINE_DPM_SWITCH, and Section 2.5.9: DEFINE_DPM_PROPERTY.

Table 3.2.26: Macros for Particles at Current Position Defined in dpm.h

Macro	Argument Types	Returns
P_POS(p)[i]	Tracked_Particle *p int i	position i=0,1,2
P_VEL(p)[i]	Tracked_Particle *p int i	velocity i=0,1,2
P_DIAM(p)	Tracked_Particle *p	diameter
P_T(p)	Tracked_Particle *p	temperature
P_RHO(p)	Tracked_Particle *p	density
P_MASS(p)	Tracked_Particle *p	mass
P_TIME(p)	Tracked_Particle *p	current particle time
P_DT(p)	Tracked_Particle *p	time step
P_FLOW_RATE(p)	Tracked_Particle *p	flow rate of particles in a stream in kg/s (see below for details)
P_LF(p)	Tracked_Particle *p	liquid fraction (wet combusting particles only)
P_VFF(p)	Tracked_Particle *p	volatile fraction (combusting particles only)

P_FLOW_RATE(p)

Each particle in a steady flow calculation represents a “stream” of many particles that follow the same path. The number of particles in this stream that passes a particular point in a second is the “strength” of the stream. P_FLOW_RATE returns the strength multiplied by P_MASS(p) at the current particle position.

Table 3.2.27: Macros for Particles at Entry to Current Cell Defined in dpm.h

Macro	Argument Types	Returns
P_POS0(p)[i]	Tracked_Particle *p int i	position i=0,1,2
P_VEL0(p)[i]	Tracked_Particle *p int i	velocity i=0,1,2
P_DIAM0(p)	Tracked_Particle *p	diameter
P_T0(p)	Tracked_Particle *p	temperature
P_RHO0(p)	Tracked_Particle *p	density
P_MASS0(p)	Tracked_Particle *p	mass
P_TIME0(p)	Tracked_Particle *p	particle time at entry
P_LF0(p)	Tracked_Particle *p	liquid fraction (wet combusting particles only)

i Note that when you are the using the macros listed in Table 3.2.27 to track transient particles, the particle state is the beginning of the fluid flow time step only if the particle does *not* cross a cell boundary.

Table 3.2.28: Macros for Particles at Injection into Domain Defined in dpm.h

Name(Arguments)	Argument Types	Returns
P_CELL(p)	Tracked_Particle *p	cell index of the cell that the particle is currently in
P_CELL_THREAD(p)	Tracked_Particle *p	pointer to the thread of the cell that the particle is currently in

Table 3.2.29: Macros for Particle Cell Index and Thread Pointer Defined in `dpm.h`

Macro	**Argument Types**	**Returns**
`P_INIT_POS(p)[i]`	`Tracked_Particle *p int i`	position `i`=0,1,2
`P_INIT_VEL(p)[i]`	`Tracked_Particle *p int i`	velocity `i`=0,1,2
`P_INIT_DIAM(p)`	`Tracked_Particle *p`	diameter
`P_INIT_TEMP(p)`	`Tracked_Particle *p`	temperature
`P_INIT_RHO(p)`	`Tracked_Particle *p`	density
`P_INIT_MASS(p)`	`Tracked_Particle *p`	mass
`P_INIT_LF(p)`	`Tracked_Particle *p`	liquid fraction (wet combusting particles only)

Table 3.2.30: Macros for Particle Species, Laws, and User Scalars Defined in `dpm.h`

Macro	**Argument Types**	**Returns**
`P_EVAP_SPECIES_INDEX(p)`	`Tracked_Particle *p`	evaporating species index in mixture
`P_DEVOL_SPECIES_INDEX(p)`	`Tracked_Particle *p`	devolatilizing species index in mixture.
`P_OXID_SPECIES_INDEX(p)`	`Tracked_Particle *p`	oxidizing species index in mixture
`P_PROD_SPECIES_INDEX(p)`	`Tracked_Particle *p`	combustion products species index in mixture
`P_CURRENT_LAW(p)`	`Tracked_Particle *p`	current particle law index
`P_NEXT_LAW(p)`	`Tracked_Particle *p`	next particle law index
`P_USER_REAL(p,i)`	`Tracked_Particle *p`	storage array for user-defined values (indexed by `i`)

Table 3.2.31: Macros for Particle Material Properties Defined in dpm.h

Macro	Argument Types	Returns
P_MATERIAL(p)	Tracked_Particle *p	material pointer
DPM_BOILING_TEMPERATURE (p,m)	Tracked_Particle *p, Material *m	boiling temperature
DPM_CHAR_FRACTION(p)	Tracked_Particle *p	char fraction
DPM_DIFFUSION_COEFF(p,t)	Tracked_Particle *p, particle temperature t	diffusion coefficient to be used the gaseous boundary layer around particle
DPM_EMISSIVITY(p,m)	Tracked_Particle *p, Material *m	emissivity for the radiation model
DPM_EVAPORATION_ TEMPERATURE(p,m)	Tracked_Particle *p, Material *m	evaporation temperature
DPM_HEAT_OF_PYROLYSIS(p)	Tracked_Particle *p	heat of pyrolysis
DPM_HEAT_OF_REACTION(p)	Tracked_Particle *p	heat of reaction
DPM_LATENT_HEAT(p)	Tracked_Particle *p	latent heat
DPM_LIQUID_SPECIFIC_HEAT (p,t)	Tracked_Particle *p, particle temperatire t Note: particle temp. typically determined by P_T(p)	specific heat of material used for liquid associated with particle
DPM_MU(p)	Tracked_Particle *p	dynamic viscosity of droplets
DPM_SCATT_FACTOR(p,m)	Tracked_Particle *p, Material *m	scattering factor for radiation model
DPM_SPECIFIC_HEAT(p,t)	Tracked_Particle *p, particle temperature t Note: particle temperature is typically determined by P_T(p)	specific heat at temperature t
DPM_SWELLING_COEFF(p)	Tracked_Particle *p	swelling coefficient for devolatilization
DPM_SURFTEN(p)	Tracked_Particle *p	surface tension of droplets
DPM_VAPOR_PRESSURE(p,m)	Tracked_Particle *p, Material *m	vapor pressure of liquid part of particle
DPM_VAPOR_TEMP(p,m)	Tracked_Particle *p, Material *m	vaporization temperature used to switch to vaporization law
DPM_VOLATILE_FRACTION(p)	Tracked_Particle *p	volatile fraction

NO_x Macros

The following macros can be used in NO_x model UDFs in the calculation of pollutant rates. These macros are defined in the header file `sg_nox.h`, which is included in `udf.h`. They can be used to return `real` NO_x variables in SI units, and are available in both the pressure-based and the density-based solver. See Section 2.3.10: `DEFINE_NOX_RATE` for an example of a `DEFINE_NOX_RATE` UDF that utilize these macros.

Table 3.2.32: Macros for NO_x UDFs Defined in `sg_nox.h`

Macro	Returns
`POLLUT_EQN(Pollut_Par)`	index of pollutant equation being solved (see below)
`MOLECON(Pollut,SPE)`	molar concentration of species specified by `SPE` (see below)
`NULLIDX(Pollut_Par,SPE)`	TRUE if the species specified by `SPE` doesn't exist in FLUENT case (i.e., in the Species panel)
`ARRH(Pollut,K)`	Arrhenius rate calculated from the constants specified by `K` (see below)
`POLLUT_FRATE(Pollut)`	production rate of the pollutant species being solved
`POLLUT_RRATE(Pollut)`	reduction rate of the pollutant species being solved

`Pollut_Par` is a pointer to the `Pollut_Parameter` data structure that contains auxilliary data common to all pollutant species and `NOx` is a pointer to the `NOx_Parameter` data structure that contains data specific to the NO_x model.

- `POLLUT_EQN(Pollut_Par)` returns the index of the pollutant equation currently being solved. The indices are `EQ_NO` for NO, `EQ_HCN` for HCN, `EQ_N2O` for N_2O, and `EQ_NH3` for NH_3.
- `MOLECON(Pollut,SPE)` returns the molar concentration of a species specified by `SPE`, which is either the name of species or `IDX(i)` when the species is a pollutant like NO. .`SPE` must be replaced by one of the following identifiers: `FUEL, O2, O, OH, H2O, N2, N, CH, CH2, CH3, IDX(NO), IDX(N2O), IDX(HCN), IDX(NH3)`. For example, for O2 molar concentration you can call `MOLECON(Pollut, O2)` whereas for NO molar concentration the call should be `MOLECON(Pollut, IDX(NO))`. Identifier `FUEL` represents the fuel species as specified in the Fuel Species drop-down list under Prompt NO Parameters in the NOx Model panel.

- ARRH(Pollut,K) returns the Arrhenius rate calculated from the constants specified by K. K is defined using the Rate_Const data type and has three elements - A, B, and C. The Arrhenius rate is given in the form of

  $$R = AT^B \exp(-C/T)$$

  where T is the temperature.

  Note that the units of K must be in m-gmol-J-s.

SO_x Macros

The following macros can be used in SO_x model UDFs in the calculation of pollutant rates. The are defined in the header file sg_nox.h, which is included in udf.h. They can be used to return real SO_x variables in SI units and are available in both the pressure-based and the density-based solver. See Section 2.3.18: DEFINE_SOX_RATE for an example of a DEFINE_SOX_RATE UDF that utilizes these macros.

Table 3.2.33: Macros for SO_x UDFs Defined in sg_nox.h

Macro	Returns
POLLUT_EQN(Pollut_Par)	index of pollutant equation being solved (see below)
MOLECON(Pollut,SPE)	molar concentration of species specified by SPE (see below)
NULLIDX(Pollut_Par,SPE)	TRUE if the species specified by SPE doesn't exist in FLUENT case (i.e., in the Species panel)
ARRH(Pollut,K)	Arrhenius rate calculated from the constants specified by K (see below)
POLLUT_FRATE(Pollut)	production rate of the pollutant species being solved
POLLUT_RRATE(Pollut)	reduction rate of the pollutant species being solved

Pollut_Par is a pointer to the Pollut_Parameter data structure that contains auxillary data common to all pollutant species and SOx is a pointer to the SOx_Parameter data structure that contains data specific to the SO_x model.

- POLLUT_EQN(Pollut_Par) returns the index of the pollutant equation currently being solved. The indices are EQ_SO2 for SO2 and EQ_SO3 for SO3, etc.

- MOLECON(Pollut, SPE) returns the molar concentration of a species specified by SPE. SPE is either the name of species or IDX(i) when the species is a pollutant like SO2. For example, for O2 molar concentration you can call MOLECON(Pollut, O2) whereas for SO2 molar concentration the call should be MOLECON(Pollut, IDX(SO2)).

- ARRH(Pollut,K) returns the Arrhenius rate calculated from the constants specified by K. K is defined using the Rate_Const data type and has three elements - A, B, and C. The Arrhenius rate is given in the form of

  $$R = AT^B \exp(-C/T)$$

  where T is the temperature.

  Note that the units of K must be in m-gmol-J-s.

Dynamic Mesh Macros

The macros listed in Table 3.2.34 are useful in dynamic mesh UDFs. The argument dt is a pointer to the dynamic thread structure. These macros are defined in the dynamesh_tools.h.

Table 3.2.34: Macros for Dynamic Mesh Variables Defined in dynamesh_tools.h

Name(Arguments)	Argument Types	Returns
DT_THREAD(dt)	Dynamic_Thread *dt	pointer to face thread
DT_CG(dt)	Dynamic_Thread *dt	center of gravity vector
DT_VEL_CG(dt)	Dynamic_Thread *dt	cg velocity vector
DT_OMEGA_CG(t)	Dynamic_Thread *dt	angular velocity vector
DT_THETA(dt)	Dynamic_Thread *dt	orientation of body-fixed axis vector

See Section 2.6.3: DEFINE_GRID_MOTION for an example UDF that utilizes DT_THREAD.

3.2.8 User-Defined Scalar (UDS) Transport Equation Macros

This section contains macros that you can use when defining scalar transport UDFs in FLUENT. Note that if you try to use the macros listed below (e.g., F_UDSI, C_UDSI) before you have specified user-defined scalars in your FLUENT model (in the User-Defined Scalars panel), then an error will result.

Set_User_Scalar_Name

FLUENT assigns a default name for every user-defined scalar that you allocate in the graphical user-interface. For example, if you specify 2 as the Number of User-Defined Scalars, then two variables with default names User Scalar 0 and User Scalar 1 will be defined and the variables with these default names will appear in setup and postprocessing panels. You can change the default names if you wish, using Set_User_Scalar_Name as described below.

The default name that appears in the graphical user interface and on plots in FLUENT for user-defined scalars (e.g., User Scalar 0) can now be changed using the function Set_User_Scalar_Name.

```
void Set_User_Scalar_Name(int i,char *name);
```

i is the index of the scalar and name is a string containing the name you wish to assign. It is defined in sg_udms.h.

Set_User_Scalar_Name should be used only once and is best used in an EXECUTE_ON_LOADING UDF (see Section 2.2.6: DEFINE_EXECUTE_ON_LOADING). Due to the mechanism used, UDS variables cannot be renamed once they have been set, so if the name is changed in a UDF, for example, and the UDF library is reloaded, then the old name could remain. In this case, restart FLUENT and load the library again.

F_UDSI

You can use F_UDSI when you want to access face variables that are computed for user-defined scalar transport equations (Table 3.2.35). See Section 3.2.9: Example UDF that Utilizes UDM and UDS Variables for an example of F_UDSI usage.

Table 3.2.35: Accessing User-Defined Scalar Face Variables (mem.h)

Macro	Argument Types	Returns
F_UDSI(f,t,i)	face_t f, Thread *t, int i Note: i is index of scalar	UDS face variables

i Note that F_UDSI is available for wall and flow boundary faces, only. If a UDS attempts to access any other face zone, then an error will result.

C_UDSI

You can use C_UDSI when you want to access cell variables that are computed for user-defined scalar transport equations. Macros for accessing UDS cell variables are listed in Table 3.2.36. Some examples of usage for these macros include defining non-constant source terms for UDS transport equations and initializing equations. See Section 3.2.9: Example UDF that Utilizes UDM and UDS Variables for an example of C_UDSI usage.

Table 3.2.36: C_UDSI for Accessing UDS Transport Cell Variables (mem.h)

Macro	Argument Types	Returns
C_UDSI(c,t,i)	cell_t c, Thread *t, int i	UDS cell variables
C_UDSI_G(c,t,i)	cell_t c, Thread *t, int i	UDS gradient
C_UDSI_M1(c,t,i)	cell_t c, Thread *t, int i	UDS previous time step
C_UDSI_M2(c,t,i)	cell_t c, Thread *t, int i	UDS second previous time step
C_UDSI_DIFF(c,t,i)	cell_t c, Thread *t, int i Note: i is index of scalar	UDS diffusivity

Reserving UDS Variables

Reserve_User_Scalar_Vars

The new capability of loading more than one UDF library into FLUENT raises the possibility of user-defined scalar (UDS) clashes. To avoid data contention between multiple UDF libraries using the same user-defined scalars, FLUENT has provided the macro Reserve_User_Scalar_Vars that allows you to reserve scalars prior to use.

```
int Reserve_User_Scalar_Vars(int num)
```

int num is the number of user-defined scalars that the library uses. The integer returned is the lowest UDS index that the library may use. After calling:

```
offset = Reserve_User_Scalar_Vars(int num);
```

the library may safely use C_UDSI(c,t,offset) to C_UDSI(c,t,offset+num-1). See Section 2.2.6: DEFINE_EXECUTE_ON_LOADING for an example of macro usage. Note that there are other methods you can use within UDFs to hardcode the offset to prevent data contention.

Reserve_User_Scalar_Vars (defined in sg_udms.h) is designed to be called from an EXECUTE_ON_LOADING UDF (Section 2.2.6: DEFINE_EXECUTE_ON_LOADING). An on-loading UDF, as its name implies, executes as soon as the shared library is loaded into FLUENT. The macro can also be called from an INIT or ON_DEMAND UDF. Once reserved, user scalars can be set to unique names for the particular library using Set_User_Memory_Name (see below for details on Set_User_Memory_Name). Once the number of UDS that are needed by a particular library is set in the GUI and the variables are successfully reserved for the loaded library, the other functions in the library can safely use C_UDMI(c,t,offset) up to C_UDMI(c,t,offset+num-1) to store values in user scalars without interference.

Unreserving UDS Variables

FLUENT does not currently provide the capability to unreserve UDS variables using a macro. Unreserve macros will be available in future versions of FLUENT.

N_UDS

You can use N_UDS to access the number of user-defined scalar (UDS) transport equations that have been specified in FLUENT. The macro takes no arguments and returns the integer number of equations. It is defined in models.h.

3.2.9 User-Defined Memory (UDM) Macros

This section contains macros that access user-defined memory (UDM) variables in FLUENT.

Before you can store variables in memory using the macros provided below, you will first need to allocate the appropriate number of memory location(s) in the User-Defined Memory panel in FLUENT. (See Section 6.1.8: User-Defined Memory Storage for more details.)

Define ⟶ User-Defined ⟶Memory...

i Note that if you try to use F_UDMI or C_UDMI before you have allocated memory, then an error will result.

A variable will be created for every user-defined memory location that you allocate in the graphical user-interface. For example, if you specify 2 as the Number of User-Defined Memory, then two variables with default names User Memory 0 and User Memory 1 will be defined for your model and the default variable names will appear in postprocessing panels. You can change the default names if you wish, using Set_User_Memory_Name as described below.

Set_User_Memory_Name

The default name that appears in the graphical user interface and on plots for user defined memory (UDM) values in FLUENT (e.g., User Memory 0) can now be changed using the function Set_User_Memory_Name.

```
void Set_User_Memory_Name(int i,char *name);
```

i is the index of the memory value and name is a string containing the name you wish to assign. It is defined in sg_udms.h.

The Set_User_Memory_Name function should be used only once and is best used in an EXECUTE_ON_LOADING UDF (see Section 2.2.6: DEFINE_EXECUTE_ON_LOADING). Due to the mechanism used, User Memory values cannot be renamed once they have been set, so if the name is changed in a UDF, for example, and the UDF library is reloaded, then the old name could remain. In this case, restart FLUENT and load the library again.

F_UDMI

You can use F_UDMI (Table 3.2.37) to access or store the value of the user-defined memory on a face. F_UDMI can be used to allocate up to 500 memory locations in order to store and retrieve the values of face field variables computed by UDFs. These stored values can then be used for postprocessing, for example, or by other UDFs.

i Note that F_UDMI is available for wall and flow boundary faces, only.

Table 3.2.37: Storage of User-Defined Memory on Faces (mem.h)

Macro	**Argument Types**	**Usage**
F_UDMI(f,t,i)	face_t f, Thread *t, int i	stores the face value of a user-defined memory with index i

There are three arguments to F_UDMI: f, t, and i. f is the face identifier, t is a pointer to the face thread, and i is an integer index that identifies the memory location where data is to be stored. An index i of 0 corresponds to user-defined memory location 0 (or User Memory 0).

Example

```
/* Compute face temperature and store in user-defined memory  */
begin_f_loop(f,t)
  {
    temp = F_T(f,t);
    F_UDMI(f,t,0) = (temp - tmin) / (tmax-tmin);
  }
end_f_loop(f,t)
}
```

See Section 2.5.4: DEFINE_DPM_EROSION for another example of F_UDMI usage.

C_UDMI

You can use C_UDMI to access or store the value of the user-defined memory in a cell. C_UDMI can be used to allocate up to 500 memory locations in order to store and retrieve the values of cell field variables computed by UDFs (Table 3.2.38). These stored values can then be used for postprocessing, for example, or by other UDFs. See Section 3.2.9: Example UDF that Utilizes UDM and UDS Variables for an example of C_UDMI usage.

Table 3.2.38: Storage of User-Defined Memory in Cells (mem.h)

Macro	Argument Types	Usage
C_UDMI(c,t,i)	cell_t c, Thread *t, int i	stores the cell value of a user-defined memory with index i

There are three arguments to C_UDMI: c, thread, and i. c is the cell identifier, thread is a pointer to the cell thread, and i is an integer index that identifies the memory location where data is to be stored. An index i of 0 corresponds to user-defined memory location 0 (or User Memory 0).

Example UDF that Utilizes UDM and UDS Variables

UDMs are often used to store diagnostic values derived from calculated values of a UDS. Below is an example that shows a technique for plotting the gradient of any flow variable. In this case, the volume fraction of a phase is loaded into a user scalar. If an iteration is made such that the UDS is not calculated, the gradients of the scalar will nevertheless be updated without altering the values of the user scalar. The gradient is then available to be copied into a User Memory variable for displaying.

```
# include "udf.h"
# define domain_ID 2

DEFINE_ADJUST(adjust_gradient, domain)
{
  Thread *t;
  cell_t c;
  face_t f;

  domain = Get_Domain(domain_ID);

  /* Fill UDS with the variable. */
  thread_loop_c (t,domain)
```

```
    {
       begin_c_loop (c,t)
         {
           C_UDSI(c,t,0) = C_VOF(c,t);
         }
       end_c_loop (c,t)
    }

  thread_loop_f (t,domain)
    {
       if (THREAD_STORAGE(t,SV_UDS_I(0))!=NULL)
       begin_f_loop (f,t)
         {
           F_UDSI(f,t,0) = F_VOF(f,t);
         }
       end_f_loop (f,t)
    }
}

DEFINE_ON_DEMAND(store_gradient)
{
  Domain *domain;
  cell_t c;
  Thread *t;

  domain=Get_Domain(1);

  /* Fill the UDM with magnitude of gradient. */
  thread_loop_c (t,domain)
    {
       begin_c_loop (c,t)
         {
           C_UDMI(c,t,0) = NV_MAG(C_UDSI_G(c,t,0));
         }
       end_c_loop (c,t)
    }
}
```

Reserving UDM Variables Using Reserve_User_Memory_Vars

The new capability of loading more than one UDF library into FLUENT raises the possibility of user-defined memory (UDM) clashes. If, for example, you want to use one UDF library that has a fixed 2D magnetic field stored in User Memory 0 and User Memory 1 and you want to use another UDF library that models the mass exchange between phases using User Memory 0 for the exchange rates and these two libraries are loaded at the same time, then the two models are going to interfere with each other's data in User Memory 0. To avoid data contention problems, a new macro has been added that will allow a UDF library to "reserve" UDM locations prior to usage. Note that there are other methods you can use within UDFs to hardcode the offset for UDMs to prevent contention that are not discussed here.

```
    int Reserve_User_Memory_Vars(int num)
```

The integer given as an argument to the macro (num) specifies the number of UDMs needed by the library. The integer returned by the function is the starting point or "offset" from which the library may use the UDMs. It should be saved as a global integer such as offset in the UDF and it should be initialized to the special variable UDM_UNRESERVED.

```
offset = Reserve_User_Memory_Vars(int num);
```

Reserve_User_Memory_Vars (defined in sg_udms.h) is designed to be called from an EXECUTE_ON_LOADING UDF (Section 2.2.6: DEFINE_EXECUTE_ON_LOADING). An on-loading UDF, as its name implies, executes as soon as the shared library is loaded into FLUENT. The macro can also be called from an INIT or ON_DEMAND UDF, although this is discouraged except for testing purposes. Once reserved, UDMs can be set to unique names for the particular library using Set_User_Memory_Name (see below for details.) Once the number of UDMs that are needed by a particular library is set in the GUI and the UDMs are successfully reserved for the loaded library, the other functions in the library can safely use C_UDMI(c,t,offset) up to C_UDMI(c,t,offset+num-1) to store values in memory locations without interference. Two example source code files named udm_res1.c and udm_res2.c each containing two UDFs are listed below. The first UDF is an EXECUTE_ON_LOADING UDF that is used to reserve UDMs for the library and set unique names for the UDM locations so that they can be easily identified in postprocessing. The second UDF is an ON_DEMAND UDF that is used to set the values of the UDM locations after the solution has been initialized. The ON_DEMAND UDF sets the initial values of the UDM locations using udf_offset, which is defined in the EXECUTE_ON_LOADING UDF. Note that the on demand UDF must be executed *after* the solution is initialized to reset the initial values for the UDMs.

The following describes the process of reserving five UDMs for two libraries named `libudf` and `libudf2`.

1. In the User-Defined Memory panel, specify 5 for the Number of User-Defined Memory Locations.
2. In the Compiled UDFs panel, build the compiled library named `libudf` for `udm_res1.c` and load the library.
3. Build the compiled library for `udm_res2.c` named `libudf2` and load the library.
4. Initialize the solution.
5. Execute the `on-demand` UDFs for `libudf` and `libudf2` in the Execute On Demand panel.
6. Iterate the solution.
7. Postprocess the results.

```
/**********************************************************************
udm_res1.c contains two UDFs: an execute on loading UDF that reserves
three UDMs for libudf and renames the UDMs to enhance postprocessing,
and an on-demand UDF that sets the initial value of the UDMs.
**********************************************************************/
#include "udf.h"

#define NUM_UDM 3
static int udm_offset = UDM_UNRESERVED;

DEFINE_EXECUTE_ON_LOADING(on_loading, libname)
{
  if (udm_offset == UDM_UNRESERVED) udm_offset =
            Reserve_User_Memory_Vars(NUM_UDM);

  if (udm_offset == UDM_UNRESERVED)
      Message("\nYou need to define up to %d extra UDMs in GUI and
      then reload current library %s\n", NUM_UDM, libname);
  else
         {
  Message("%d UDMs have been reserved by the current
          library %s\n",NUM_UDM, libname);

  Set_User_Memory_Name(udm_offset,"lib1-UDM-0");
  Set_User_Memory_Name(udm_offset+1,"lib1-UDM-1");
```

```
         Set_User_Memory_Name(udm_offset+2,"lib1-UDM-2");
}
  Message("\nUDM Offset for Current Loaded Library = %d",udm_offset);
}

DEFINE_ON_DEMAND(set_udms)
{
  Domain *d;
  Thread *ct;
  cell_t c;
  int i;

  d=Get_Domain(1);

  if(udm_offset != UDM_UNRESERVED)
        {
         Message("Setting UDMs\n");

         for (i=0;i<NUM_UDM;i++)
                 {
                  thread_loop_c(ct,d)
                         {
                          begin_c_loop(c,ct)
                             {
                              C_UDMI(c,ct,udm_offset+i)=3.0+i/10.0;
                              }
                          end_c_loop(c,ct)
                         }
                  }
        }
  else
     Message("UDMs have not yet been reserved for library 1\n");
}
```

```
*********************************************************************/
udm_res2.c contains two UDFs: an execute on loading UDF that reserves
two UDMs for libudf and renames the UDMs to enhance postprocessing,
and an on-demand UDF that sets the initial value of the UDMs.
*********************************************************************/
#include "udf.h"

#define NUM_UDM 2
static int udm_offset = UDM_UNRESERVED;

DEFINE_EXECUTE_ON_LOADING(on_loading, libname)
{
  if (udm_offset == UDM_UNRESERVED) udm_offset =
            Reserve_User_Memory_Vars(NUM_UDM);

  if (udm_offset == UDM_UNRESERVED)
      Message("\nYou need to define up to %d extra UDMs in GUI and
      then reload current library %s\n", NUM_UDM, libname);
  else
         {
  Message("%d UDMs have been reserved by the current
          library %s\n",NUM_UDM, libname);

  Set_User_Memory_Name(udm_offset,"lib2-UDM-0");
  Set_User_Memory_Name(udm_offset+1,"lib2-UDM-1");
}
  Message("\nUDM Offset for Current Loaded Library = %d",udm_offset);
}

DEFINE_ON_DEMAND(set_udms)
{
  Domain *d;
  Thread *ct;
  cell_t c;
  int i;

  d=Get_Domain(1);

  if(udm_offset != UDM_UNRESERVED)
         {
          Message("Setting UDMs\n");

          for (i=0;i<NUM_UDM;i++)
```

```
                  {
                   thread_loop_c(ct,d)
                         {
                          begin_c_loop(c,ct)
                             {
                              C_UDMI(c,ct,udm_offset+i)=2.0+i/10.0;
                              }
                          end_c_loop(c,ct)
                         }
                   }
         }
  else
     Message("UDMs have not yet been reserved for library 1\n");
}
```

If your model uses a number of UDMs, it may be useful to define your variables in an easy-to-read format, either at the top of the source file or in a separate header file using the preprocessor `#define` directive:

```
    #define C_MAG_X(c,t)C_UDMI(c,t,udm_offset)
    #define C_MAG_Y(c,t)C_UDMI(c,t,udm_offset+1)
```

Following this definition, in the remainder of your UDF you can simply use `C_MAG_X(c,t)` and `C_MAG_Y(c,t)` to specify the fixed magnetic field components.

Unreserving UDM variables

FLUENT does not currently provide the capability to unreserve UDM variables using a macro. `Unreserve` macros will be available in future versions of FLUENT. You will need to exit FLUENT to ensure that all UDM variables are reset.

3.3 Looping Macros

Many UDF tasks require repeated operations to be performed on nodes, cells, and threads in a computational domain. For your convenience, Fluent Inc. has provided you with a set of predefined macros to accomplish.looping tasks. For example, to define a custom boundary profile function you will need to loop over all the faces in a face thread using `begin..end_f_loop` looping macros. For operations where you want to loop over all the faces or cells in a domain, you will need to nest a `begin..end_f_loop` or `begin..end_c_loop` inside a `thread_loop_f` or `thread_loop_c`, respectively.

The following general looping macros can be used for UDFs in single-phase or multiphase models in FLUENT. Definitions for these macros are contained in the `mem.h` header file.

> i You should not access a scheme variable using any of the `RP_GET_...` functions from inside a cell or face looping macro (c_loop or f_loop). This type of communication between the solver and cortex is very time consuming and therefore should be done outside of loops.

Looping Over Cell Threads in a Domain (`thread_loop_c`)

You can use `thread_loop_c` when you want to loop over all cell threads in a given domain. It consists of a single statement, followed by the operation(s) to be performed on all cell threads in the domain enclosed within braces `{}` as shown below. Note that `thread_loop_c` is similar in implementation to the `thread_loop_f` macro described below.

```
Domain *domain;
Thread *c_thread;
thread_loop_c(c_thread, domain) /*loops over all cell threads in domain*/
  {
  }
```

Looping Over Face Threads in a Domain (`thread_loop_f`)

You can use `thread_loop_f` when you want to loop over all face threads in a given domain. It consists of a single statement, followed by the operation(s) to be performed on all face threads in the domain enclosed within braces `{}` as shown below. Note that `thread_loop_f` is similar in implementation to the `thread_loop_c` macro described above.

```
Thread *f_thread;
Domain *domain;
thread_loop_f(f_thread, domain)/* loops over all face threads in a domain*/
  {
  }
```

Looping Over Cells in a Cell Thread (begin...end_c_loop)

You can use begin_c_loop and end_c_loop when you want to loop over all cells in a given cell thread. It contains a begin and end loop statement, and performs operation(s) on each cell in the cell thread as defined between the braces {}. This loop is usually nested within thread_loop_c when you want to loop over all cells in all cell threads in a domain.

```
cell_t c;
Thread *c_thread;
begin_c_loop(c, c_thread)    /* loops over cells in a cell thread  */
  {
  }
end_c_loop(c, c_thread)
```

Example

```
/* Loop over cells in a thread to get information stored in cells. */
  begin_c_loop(c, c_thread)
    {
     /* C_T gets cell temperature. The += will cause all of the cell
        temperatures to be added together. */

      temp += C_T(c, c_thread);
    }
  end_c_loop(c, c_thread)
}
```

Looping Over Faces in a Face Thread (begin...end_f_loop)

You can use begin_f_loop and end_f_loop when you want to loop over all faces in a given face thread. It contains a begin and end loop statement, and performs operation(s) on each face in the face thread as defined between the braces {}. This loop is usually nested within thread_loop_f when you want to loop over all faces in all face threads in a domain.

```
face_t f;
Thread *f_thread;
begin_f_loop(f, f_thread)    /* loops over faces in a face thread  */
  {
  }
end_f_loop(f, f_thread)
```

Example

```
/* Loop over faces in a face thread to get the information stored on faces. */
  begin_f_loop(f, f_thread)
    {
      /*  F_T gets face temperature. The += will cause all of the face
          temperatures to be added together. */

      temp += F_T(f, f_thread);
    }
  end_f_loop(f, f_thread)
```

Looping Over Faces of a Cell (c_face_loop)

The following looping function loops over all faces of a given cell. It consists of a single loop statement, followed by the action to be taken in braces {}.

```
cell_t c;
Thread *t;
face_t f;
Thread *tf;
int n;
c_face_loop(c, t, n)         /* loops over all faces of a cell */
  {
  .
  .
  .
  f = C_FACE(c,t,n);
  tf = C_FACE_THREAD(c,t,n);
  .
  .
  .
  }
```

The argument n is the local face index number. The local face index number is used in the C_FACE macro to obtain the global face number (e.g., f = C_FACE(c,t,n)).

Another useful macro that is often used in c_face_loop is C_FACE_THREAD. This macro is used to reference the associated face thread (e.g., tf = C_FACE_THREAD(c,t,n)).

Refer to Section 3.8: Miscellaneous Macros for other macros that are associated with c_face_loop.

Looping Over Nodes of a Cell (c_node_loop)

c_node_loop(c,t,n) is a function that loops over all nodes of a given cell. It consists of a single loop statement, followed by the action to be taken in braces {}.

Example:

```
cell_t c;
Thread *t;
int n;
Node *node;
c_node_loop(c,t,n)
  {
  .
  .
  node = C_NODE(c,t,n);
  .
  .
  }
```

Here, n is the local node index number. The index number can be used with the C_NODE macro to obtain the global cell node number (e.g., node = C_NODE(c,t,n)).

Looping Over Nodes of a Face (f_node_loop)

f_node_loop(f,t,n) is a function that loops over all nodes of a given face. It consists of a single loop statement, followed by the action to be taken in braces {}.

Example

```
face_t f;
Thread *t;
int n;
Node *node;
f_node_loop(f,t,n)
  {
  .
  .
  .
  node = F_NODE(f,t,n);
  .
  .
  .
  }
```

Here, n is the local node index number. The index number can be used with the F_NODE macro to obtain the global face node number (e.g., node = F_NODE(f,t,n)).

See Section 2.6.3: DEFINE_GRID_MOTION for an example of a UDF that uses f_node_loop.

3.3.1 Multiphase Looping Macros

This section contains a description of looping macros that are to be used for multiphase UDFs only. They enable your function to loop over all cells and faces for given threads or domains. Refer to Section 1.10.1: Multiphase-specific Data Types and, in particular, Figure 1.10.1 for a discussion on hierarchy of structures within FLUENT.

Looping Over Phase Domains in Mixture (sub_domain_loop)

The sub_domain_loop macro loops over all phase domains (subdomains) within the mixture domain. The macro steps through and provides each phase domain pointer defined in the mixture domain as well as the corresponding phase_domain_index. As discussed in Section 1.10.1: Multiphase-specific Data Types, the domain pointer is needed, in part, to gain access to data within each phase. Note that sub_domain_loop is similar in implementation to the sub_thread_loop macro described below.

```
int phase_domain_index;    /* index of subdomain pointers  */
Domain *mixture_domain;
Domain *subdomain;
sub_domain_loop(subdomain, mixture_domain, phase_domain_index)
```

The variable arguments to sub_domain_loop are subdomain, mixture_domain, and phase_domain_index. subdomain is a pointer to the phase-level domain, and mixture_domain is a pointer to the mixture-level domain. The mixture_domain is automatically passed to your UDF by the FLUENT solver when you use a DEFINE macro that contains a domain variable argument (e.g., DEFINE_ADJUST) and your UDF is hooked to the mixture. If mixture_domain is not explicitly passed to your UDF, you will need to use another utility macro to retrieve it (e.g., Get_Domain(1)) before calling sub_domain_loop (see Section 3.2.6: Domain Pointer (Get_Domain)). phase_domain_index is an index of subdomain pointers. phase_domain_index is 0 for the primary phase, and is incremented by one for each secondary phase in the mixture. Note that subdomain and phase_domain_index are set within the sub_domain_loop macro.

Example

The following interpreted UDF patches an initial volume fraction for a particular phase in a solution. It is executed once at the beginning of the solution process. The function sets up a spherical volume centered at 0.5, 0.5, 0.5 with a radius of 0.25. A secondary-phase volume fraction of 1 is then patched to the cells within the spherical volume, while the volume fraction for the secondary phase in all other cells is set to 0.

```
/*****************************************************************
   UDF for initializing phase volume fraction
******************************************************************/

#include "udf.h"

/* domain pointer that is passed by INIT function is mixture domain  */
DEFINE_INIT(my_init_function, mixture_domain)
{
  int phase_domain_index;
  cell_t cell;
  Thread *cell_thread;
  Domain *subdomain;
  real xc[ND_ND];

  /* loop over all subdomains (phases) in the superdomain (mixture) */
  sub_domain_loop(subdomain, mixture_domain, phase_domain_index)
  {
     /* loop if secondary phase  */
     if (DOMAIN_ID(subdomain) == 3)

     /* loop over all cell threads in the secondary phase domain  */
     thread_loop_c (cell_thread,subdomain)
     {
         /* loop over all cells in secondary phase cell threads  */
         begin_c_loop_all (cell,cell_thread)
         {
             C_CENTROID(xc,cell,cell_thread);
             if (sqrt(ND_SUM(pow(xc[0] - 0.5,2.),
                             pow(xc[1] - 0.5,2.),
                             pow(xc[2] - 0.5,2.))) < 0.25)

               /*  set volume fraction to 1 for centroid  */
               C_VOF(cell,cell_thread) = 1.;
             else
               /*  otherwise initialize to zero  */
               C_VOF(cell,cell_thread) = 0.;
         }
         end_c_loop_all (cell,cell_thread)
     }

   }
}
```

Looping Over Phase Threads in Mixture (sub_thread_loop)

The sub_thread_loop macro loops over all phase-level threads (subthreads) associated with a mixture-level thread. The macro steps through and returns the pointer to each subthread as well as the corresponding phase_domain_index. As discussed in Section 1.10.1: Multiphase-specific Data Types, if the subthread pointer is associated with an inlet zone, then the macro will provide the pointers to the face threads associated with the inlet for each of the phases.

```
int phase_domain_index;
Thread *subthread;
Thread *mixture_thread;
sub_thread_loop(subthread, mixture_thread, phase_domain_index)
```

The variable arguments to sub_thread_loop are subthread, mixture_thread, and phase_domain_index. subthread is a pointer to the phase thread, and mixture_thread is a pointer to the mixture-level thread. The mixture_thread is automatically passed to your UDF by the FLUENT solver when you use a DEFINE macro that contains a thread variable argument (e.g., DEFINE_PROFILE) and your UDF is hooked to the mixture. If the mixture_thread is not explicitly passed to your UDF, you will need to use a utility macro to retrieve it before calling sub_thread_loop. phase_domain_index is an index of subdomain pointers that can be retrieved using the PHASE_DOMAIN_INDEX macro. (See Section 3.3.2: Phase Domain Index (PHASE_DOMAIN_INDEX) for details.) The index begins at 0 for the primary phase, and is incremented by one for each secondary phase in the mixture. Note that subthread and phase_domain_index are initialized within the sub_thread_loop macro definition.

Looping Over Phase Cell Threads in Mixture (mp_thread_loop_c)

The mp_thread_loop_c macro loops through all cell threads (at the mixture level) within the mixture domain and provides the pointers of the phase-level (cell) threads associated with each mixture-level thread. This is nearly identical to the thread_loop_c macro (Section 3.3: Looping Over Cell Threads in a Domain (thread_loop_c)) when applied to the mixture domain. The difference is that, in addition to stepping through each cell thread, the macro also returns a pointer array (pt) that identifies the corresponding phase-level threads. The pointer to the cell thread for the ith phase is pt[i], where i is the phase_domain_index. pt[i] can be used as an argument to macros requiring the phase-level thread pointer. phase_domain_index can be retrieved using the PHASE_DOMAIN_INDEX macro. (See Section 3.3.2: Phase Domain Index (PHASE_DOMAIN_INDEX) for details.)

```
Thread **pt;
Thread *cell_threads;
Domain *mixture_domain;
mp_thread_loop_c(cell_threads, mixture_domain, pt)
```

The variable arguments to mp_thread_loop_c are cell_threads, mixture_domain, and pt. cell_threads is a pointer to the cell threads, and mixture_domain is a pointer to the mixture-level domain. pt is an array pointer whose elements contain pointers to phase-level threads.

mixture_domain is automatically passed to your UDF by the FLUENT solver when you use a DEFINE macro that contains a domain variable argument (e.g., DEFINE_ADJUST) and your UDF is hooked to the mixture. If mixture_domain is not explicitly passed to your UDF, you will need to use another utility macro to retrieve it (e.g., Get_Domain(1), described in Section 3.2.6: Domain Pointer (Get_Domain)). Note that the values for pt and cell_threads are set within the looping function.

mp_thread_loop_c is typically used along with begin_c_loop. begin_c_loop loops over cells in a cell thread. When begin_c_loop is nested within mp_thread_loop_c, you can loop over all cells in all phase cell threads within a mixture.

Looping Over Phase Face Threads in Mixture (mp_thread_loop_f)

The mp_thread_loop_f macro loops through all face threads (at the mixture level) within the mixture domain and provides the pointers of the phase-level (face) threads associated with each mixture-level thread. This is nearly identical to the thread_loop_f macro when applied to the mixture domain. The difference is that, in addition to stepping through each face thread, the macro also returns a pointer array (pt) that identifies the corresponding phase-level threads. The pointer to the face thread for the ith phase is pt[i], where i is the phase_domain_index. pt[i] can be used as an argument to macros requiring the phase-level thread pointer. The phase_domain_index can be retrieved using the PHASE_DOMAIN_INDEX macro. (See Section 3.3.2: Phase Domain Index (PHASE_DOMAIN_INDEX) for details.)

```
Thread **pt;
Thread *face_threads;
Domain *mixture_domain;
mp_thread_loop_f(face_threads, mixture_domain, pt)
```

The variable arguments to mp_thread_loop_f are face_threads, mixture_domain, and pt. face_threads is a pointer to the face threads, and mixture_domain is a pointer to the mixture-level domain. pt is an array pointer whose elements contain pointers to phase-level threads.

mixture_domain is automatically passed to your UDF by the FLUENT solver if you are using a DEFINE macro that contains a domain variable argument (e.g., DEFINE_ADJUST) and your UDF is hooked to the mixture. If mixture_domain is not explicitly passed to your UDF, you may use another utility macro to retrieve it (e.g., Get_Domain(1), described in Section 3.2.6: Domain Pointer (Get_Domain)). Note that the values for pt and face_threads are set within the looping function.

mp_thread_loop_f is typically used along with begin_f_loop. begin_f_loop loops over faces in a face thread. When begin_f_loop is nested within mp_thread_loop_f, you can loop over all faces in all phase face threads within a mixture.

3.3.2 Advanced Multiphase Macros

For most standard UDFs written for multiphase models (e.g., source term, material property, profile functions), variables that your function needs (domain pointers, thread pointers, etc.) are passed directly to your UDF as arguments by the solver in the solution process. All you need to do is hook the UDF to your model and everything is taken care of. For example, if your multiphase UDF defines a custom profile for a particular boundary zone (using DEFINE_PROFILE) and is hooked to the appropriate phase or mixture in FLUENT in the relevant boundary condition panel, then appropriate phase or mixture variables will be passed to your function by the solver at run-time.

There may, however, be more complex functions you wish to write that require a variable that is *not* directly passed through its arguments. DEFINE_ADJUST and DEFINE_INIT functions, for example, are passed mixture domain variables only. If a UDF requires a phase domain pointer, instead, then it will need to utilize macros presented in this section to retrieve it. ON_DEMAND UDFS aren't directly passed any variables thorugh their arguments. Consequently, any on demand function that requires access to phase or domain variables will also need to utilize macros presented in this section to retrieve them.

Recall that when you are writing UDFs for multiphase models, you will need to keep in mind the hierarchy of structures within FLUENT (see Section 1.10.1: Multiphase-specific Data Types for details). The particular domain or thread structure that gets passed into your UDF from the solver depends on the DEFINE macro you are using, as well as the domain the function is hooked to (either through the graphical user interface, or hardwired in the code). As mentioned above, it also may depend on the multiphase model that you are using. Refer to Section 1.10.1: Multiphase-specific Data Types and, in particular, Figure 1.10.1 for a discussion on hierarchy of structures within FLUENT.

Phase Domain Pointer (DOMAIN_SUB_DOMAIN)

There are two ways you can get access to a specific phase (or subdomain) pointer within the mixture domain. You can use either the DOMAIN_SUB_DOMAIN macro (described below) or Get_Domain, which is described below.

DOMAIN_SUB_DOMAIN has two arguments: mixture_domain and phase_domain_index. The function returns the phase pointer subdomain for the given phase_domain_index. Note that DOMAIN_SUB_DOMAIN is similar in implementation to the THREAD_SUB_THREAD macro described in Section 3.3.2: Phase-Level Thread Pointer (THREAD_SUB_THREAD).

```
int phase_domain_index = 0;            /* primary phase index is 0 */
Domain *mixture_domain;
Domain *subdomain = DOMAIN_SUB_DOMAIN(mixture_domain,phase_domain_index);
```

mixture_domain is a pointer to the mixture-level domain. It is automatically passed to your UDF by the FLUENT solver when you use a DEFINE macro that contains a domain variable argument (e.g., DEFINE_ADJUST) and your UDF is hooked to the mixture. Otherwise, if the mixture_domain is not explicitly passed to your UDF, you will need to use another utility macro to retrieve it (e.g., Get_Domain(1)) before calling sub_domain_loop.

phase_domain_index is an index of subdomain pointers. It is an integer that starts with 0 for the primary phase and is incremented by one for each secondary phase. phase_domain_index is automatically passed to your UDF by the FLUENT solver when you use a DEFINE macro that contains a phase domain index argument (DEFINE_EXCHANGE_PROPERTY, DEFINE_VECTOR_EXCHANGE_PROPERTY) and your UDF is hooked to a specific interaction phase. Otherwise, you will need to hard code the integer value of phase_domain_index to the DOMAIN_SUB_DOMAIN macro. If your multiphase model has only two phases defined, then phase_domain_index is 0 for the primary phase, and 1 for the secondary phase. However, if you have more than one secondary phase defined for your multiphase model, you will need to use the PHASE_DOMAIN_INDEX utility to retrieve the corresponding phase_domain_index for the given domain. See Section 3.3.2: Phase Domain Index (PHASE_DOMAIN_INDEX) for details.

Phase-Level Thread Pointer (THREAD_SUB_THREAD)

The THREAD_SUB_THREAD macro can be used to retrieve the phase-level thread (subthread) pointer, given the phase domain index. THREAD_SUB_THREAD has two arguments: mixture_thread and phase_domain_index. The function returns the phase-level thread pointer for the given phase_domain_index. Note that THREAD_SUB_THREAD is similar in implementation to the DOMAIN_SUB_DOMAIN macro described in Section 3.3.2: Phase Domain Pointer (DOMAIN_SUB_DOMAIN).

```
int phase_domain_index = 0;             /* primary phase index is 0  */
Thread *mixture_thread;              /* mixture-level thread pointer */
Thread *subthread = THREAD_SUB_THREAD(mixture_thread,phase_domain_index);
```

mixture_thread is a pointer to a mixture-level thread. It is automatically passed to your UDF by the FLUENT solver when you use a DEFINE macro that contains a variable thread argument (e.g., DEFINE_PROFILE), and the function is hooked to the mixture. Otherwise, if the mixture thread pointer is not explicitly passed to your UDF, then you will need to use the Lookup_Thread utility macro to retrieve it (see Section 3.2.6: Thread Pointer for Zone ID (Lookup_Thread)).

phase_domain_index is an index of subdomain pointers. It is an integer that starts with 0 for the primary phase and is incremented by one for each secondary phase. phase_domain_index is automatically passed to your UDF by the FLUENT solver when you use a DEFINE macro that contains a phase domain index argument (DEFINE_EXCHANGE_PROPERTY, DEFINE_VECTOR_EXCHANGE_PROPERTY) and your UDF is hooked to a specific interaction phase. (See Section 2.4.2: DEFINE_EXCHANGE_PROPERTY for an example UDF.) Otherwise, you will need to hard code the integer value of phase_domain_index to the THREAD_SUB_THREAD macro. If your multiphase model has only two phases defined, then phase_domain_index is 0 for the primary phase, and 1 for the secondary phase. However, if you have more than one secondary phase defined for your multiphase model, you will need to use the PHASE_DOMAIN_INDEX utility to retrieve the corresponding phase_domain_index for the given domain. See Section 3.3.2: Phase Domain Index (PHASE_DOMAIN_INDEX) for details.

Phase Thread Pointer Array (THREAD_SUB_THREAD)

The THREAD_SUB_THREADS macro can be used to retrieve the pointer array, pt, whose elements contain pointers to phase-level threads (subthreads). THREADS_SUB_THREADS has one argument, mixture_thread.

```
Thread *mixture_thread;
Thread **pt;   /* initialize pt   */
pt = THREAD_SUB_THREADS(mixture_thread);
```

mixture_thread is a pointer to a mixture-level thread which can represent a cell thread or a face thread. It is automatically passed to your UDF by the FLUENT solver when you use a DEFINE macro that contains a variable thread argument (e.g., DEFINE_PROFILE), and the function is hooked to the mixture. Otherwise, if the mixture thread pointer is not explicitly passed to your UDF, then you will need to use another method to retrieve it. For example you can use the Lookup_Thread utility macro (see Section 3.2.6: Thread Pointer for Zone ID (Lookup_Thread)).

pt[i], an element in the array, is a pointer to the corresponding phase-level thread for the *i*th phase, where i is the phase_domain_index. You can use pt[i] as an argument to some cell variable macros when you want to retrieve specific phase information at a cell. For example, C_R(c,pt[i]) can be used to return the density of the *i*th phase fluid at cell c. The pointer pt[i] can also be retrieved using THREAD_SUB_THREAD, discussed in Section 3.3.2: Phase-Level Thread Pointer (THREAD_SUB_THREAD), using i as an argument. The phase_domain_index can be retrieved using the PHASE_DOMAIN_INDEX macro. See Section 3.3.2: Phase Domain Index (PHASE_DOMAIN_INDEX) for details.

Mixture Domain Pointer (DOMAIN_SUPER_DOMAIN)

You can use DOMAIN_SUPER_DOMAIN when your UDF has access to a particular phase-level domain (subdomain) pointer, and you want to retrieve the mixture-level domain pointer. DOMAIN_SUPER_DOMAIN has one argument, subdomain. Note that DOMAIN_SUPER_DOMAIN is similar in implementation to the THREAD_SUPER_THREAD macro described in Section 3.3.2: Mixture Thread Pointer (THREAD_SUPER_THREAD).

```
Domain *subdomain;
Domain *mixture_domain = DOMAIN_SUPER_DOMAIN(subdomain);
```

subdomain is a pointer to a phase-level domain within the multiphase mixture. It is automatically passed to your UDF by the FLUENT solver when you use a DEFINE macro that contains a domain variable argument (e.g., DEFINE_ADJUST), and the function is hooked to a primary or secondary phase in the mixture. Note that in the current version of FLUENT, DOMAIN_SUPER_DOMAIN will return the same pointer as Get_Domain(1).

Therefore, if a subdomain pointer is available in your UDF, it is recommended that the DOMAIN_SUPER_DOMAIN macro be used instead of the Get_Domain macro to avoid potential incompatibility issues with future releases of FLUENT.

Mixture Thread Pointer (THREAD_SUPER_THREAD)

You can use the THREAD_SUPER_THREAD macro when your UDF has access to a particular phase-level thread (subthread) pointer, and you want to retrieve the mixture-level thread pointer. THREAD_SUPER_THREAD has one argument, subthread.

```
Thread *subthread;
Thread *mixture_thread = THREAD_SUPER_THREAD(subthread);
```

subthread is a pointer to a particular phase-level thread within the multiphase mixture. It is automatically passed to your UDF by the FLUENT solver when you use a DEFINE macro that contains a thread variable argument (e.g., DEFINE_PROFILE, and the function is hooked to a primary or secondary phase in the mixture. Note that THREAD_SUPER_THREAD is similar in implementation to the DOMAIN_SUPER_DOMAIN macro described in Section 3.3.2: Mixture Domain Pointer (DOMAIN_SUPER_DOMAIN).

Domain ID (DOMAIN_ID)

You can use DOMAIN_ID when you want to access the domain_id that corresponds to a given phase-level domain pointer. DOMAIN_ID has one argument, subdomain, which is the pointer to a phase-level domain. The default domain_id value for the top-level domain (mixture) is 1. That is, if the domain pointer that is passed to DOMAIN_ID is the mixture-level domain pointer, then the function will return a value of 1. Note that the domain_id that is returned by the macro is the same integer ID that is displayed in the graphical user interface when you select the desired phase in the Phases panel in FLUENT.

```
Domain *subdomain;
int domain_id = DOMAIN_ID(subdomain);
```

Phase Domain Index (PHASE_DOMAIN_INDEX)

The PHASE_DOMAIN_INDEX macro retrieves the phase_domain_index for a given phase-level domain (subdomain) pointer. PHASE_DOMAIN_INDEX has one argument, subdomain, which is the pointer to a phase-level domain. phase_domain_index is an index of subdomain pointers. It is an integer that starts with 0 for the primary phase and is incremented by one for each secondary phase.

```
Domain *subdomain;
int phase_domain_index = PHASE_DOMAIN_INDEX(subdomain);
```

3.4 Vector and Dimension Macros

Fluent Inc. has provided you with some utilities that you can use in your UDFs to access or manipulate vector quantities in FLUENT and deal with two and three dimensions. These utilities are implemented as macros in the code.

There is a naming convention for vector utility macros. V denotes a vector, S denotes a scalar, and D denotes a sequence of three vector components of which the third is always ignored for a two-dimensional calculation. The standard order of operations convention of parentheses, exponents, multiplication, division, addition, and subtraction (PEMDAS) is not followed in vector functions. Instead, the underscore (_) sign is used to group operands into pairs, so that operations are performed on the elements of pairs before they are performed on groups.

> i Note that all of the vector utilities in this section have been designed to work correctly in 2D and 3D. Consequently, you don't need to do any testing to determine this in your UDF.

3.4.1 Macros for Dealing with Two and Three Dimensions

There are two ways that you can deal with expressions involving two and three dimensions in your UDF. The first is to use an explicit method to direct the compiler to compile separate sections of the code for 2D and 3D, respectively. This is done using RP_2D and RP_3D in conditional-if statements. The second method allows you to include general 3D expressions in your UDF, and use ND and NV macros that will remove the z-components when compiling with RP_2D. NV macros operate on vectors while ND macros operate on separate components.

RP_2D and RP_3D

The use of a RP_2D and RP_3D macro in a conditional-if statement will direct the compiler to compile separate sections of the code for 2D and 3D, respectively. For example, if you want to direct the compiler to compute swirl terms for the 3D version of FLUENT only, then you would use the following conditional compile statement in your UDF:

```
#if RP_3D
   /* compute swirl terms */
#endif
```

3.4.2 The ND Macros

The use of ND macros in a UDF allows you to include general 3D expressions in your code, and the ND macros take care of removing the z components of a vector when you are compiling with RP_2D.

ND_ND

The constant ND_ND is defined as 2 for RP_2D (FLUENT 2D) and RP_3D (FLUENT 3D). It can be used when you want to build a 2 × 2 matrix in 2D and a 3 × 3 matrix in 3D. When you use ND_ND, your UDF will work for both 2D and 3D cases, without requiring any modifications.

```
real A[ND_ND][ND_ND]

for (i=0; i<ND_ND; ++i)
  for (j=0; j<ND_ND; ++j)
    A[i][j] = f(i, j);
```

ND_SUM

The utility ND_SUM computes the sum of ND_ND arguments.

```
ND_SUM(x, y, z)

    2D:  x + y;
    3D:  x + y + z;
```

ND_SET

The utility ND_SET generates ND_ND assignment statements.

```
ND_SET(u, v, w, C_U(c, t), C_V(c, t), C_W(c, t))

    u = C_U(c, t);
    v = C_V(c, t);

if 3D:
21
    w = C_W(c, t);
```

3.4.3 The NV Macros

The NV macros have the same purpose as ND macros, but they operate on vectors (i.e., arrays of length ND_ND) instead of separate components.

NV_V

The utility NV_V performs an operation on two vectors.

```
NV_V(a, =, x);

     a[0] = x[0]; a[1] = x[1]; etc.
```

Note that if you use + = instead of = in the above equation, then you get

```
     a[0]+=x[0];  etc.
```

See Section 2.6.3: DEFINE_GRID_MOTION for an example UDF that utilizes NV_V.

NV_VV

The utility NV_VV performs operations on vector elements. The operation that is performed on the elements depends upon what symbol (-,/,*) is used as an argument in place of the + signs in the following macro call.

```
NV_VV(a, =, x, +, y)

    2D:  a[0] = x[0] + y[0], a[1] = x[1] + y[1];
```

See Section 2.6.3: DEFINE_GRID_MOTION for an example UDF that utilizes NV_VV.

NV_V_VS

The utility NV_V_VS adds a vector to another vector which is multiplied by a scalar.

```
NV_V_VS(a, =, x, +, y, *, 0.5);

    2D:  a[0] = x[0] + (y[0]*0.5), a[1] = x[1] +(y[1]*0.5);
```

Note that the + sign can be replaced by -, /, or *, and the * sign can be replaced by /.

NV_VS_VS

The utility NV_VS_VS adds a vector to another vector which are each multiplied by a scalar.

```
NV_VS_VS(a, =, x, *, 2.0, +, y, *, 0.5);

    2D:  a[0] = (x[0]*2.0) + (y[0]*0.5), a[1] = (x[1]*2.0) + (y[1]*0.5);
```

Note that the + sign can be used in place of -, *, or /, and the * sign can be replaced by /.

3.4.4 Vector Operation Macros

There are macros that you can use in your UDFs that will allow you to perform operations such as computing the vector magnitude, dot product, and cross product. For example, you can use the real function NV_MAG(V) to compute the magnitude of vector V. Alternatively, you can use the real function NV_MAG2(V) to obtain the square of the magnitude of vector V.

Vector Magnitude Using NV_MAG and NV_MAG2

The utility NV_MAG computes the magnitude of a vector. This is taken as the square root of the sum of the squares of the vector components.

```
NV_MAG(x)

    2D:  sqrt(x[0]*x[0] + x[1]*x[1]);
    3D:  sqrt(x[0]*x[0] + x[1]*x[1] + x[2]*x[2]);
```

The utility NV_MAG2 computes the sum of squares of vector components.

```
NV_MAG2(x)

    2D:  (x[0]*x[0] + x[1]*x[1]);
    3D:  (x[0]*x[0] + x[1]*x[1] + x[2]*x[2]);
```

See Section 2.5.1: DEFINE_DPM_BC for an example UDF that utilizes NV_MAG.

Dot Product

The following utilities compute the dot product of two sets of vector components.

```
ND_DOT(x, y, z, u, v, w)

    2D:  (x*u + y*v);
    3D:  (x*u + y*v + z*w);


NV_DOT(x, u)

    2D:  (x[0]*u[0] + x[1]*u[1]);
    3D:  (x[0]*u[0] + x[1]*u[1] + x[2]*u[2]);


NVD_DOT(x, u, v, w)

    2D:  (x[0]*u + x[1]*v);
    3D:  (x[0]*u + x[1]*v + x[2]*w);
```

See Section 2.3.6: DEFINE_DOM_SPECULAR_REFLECTIVITY for an example UDF that utilizes NV_DOT.

Cross Product

For 3D, the CROSS macros return the specified component of the vector cross product. For 2D, the macros return the cross product of the vectors with the *z*-component of each vector set to 0.

```
ND_CROSS_X(x0,x1,x2,y0,y1,y2)
   2D:  0.0
   3D:  (((x1)*(y2))-(y1)*(x2)))

ND_CROSS_Y(x0,x1,x2,y0,y1,y2)
   2D:  0.0
   3D:  (((x2)*(y0))-(y2)*(x0)))

ND_CROSS_Z(x0,x1,x2,y0,y1,y2)
   2D and 3D: (((x0)*(y1))-(y0)*(x1)))

NV_CROSS_X(x,y)
```

```
   ND_CROSS_X(x[0],x[1],x[2],u[0],y[1],y[2])

NV_CROSS_Y(x,y)
    ND_CROSS_X(x[0],x[1],x[2],u[0],y[1],y[2])

NV_CROSS_Z(x,y)
    ND_CROSS_X(x[0],x[1],x[2],u[0],y[1],y[2])

NV_CROSS(a,x,y)

    a[0] = NV_CROSS_X(x,y);
    a[1] = NV_CROSS_Y(x,y);
    a[2] = NV_CROSS_Z(x,y);
```

See Section 2.6.3: DEFINE_GRID_MOTION for an example UDF that utilizes NV_CROSS.

3.5 Time-Dependent Macros

You can access time-dependent variables in your UDF in two different ways: direct access using a solver macro, or indirect access using an RP variable macro. Table 3.5.1 contains a list of solver macros that you can use to access time-dependent variables in FLUENT. An example of a UDF that uses a solver macro to access a time-dependent variable is provided below. See Section 2.2.2: DEFINE_DELTAT for another example that utilizes a time-dependent macro.

Table 3.5.1: Solver Macros for Time-Dependent Variables

Macro Name	Returns
CURRENT_TIME	real current flow time (in seconds)
CURRENT_TIMESTEP	real current physical time step size (in seconds)
PREVIOUS_TIME	real previous flow time (in seconds)
PREVIOUS_2_TIME	real flow time two steps back in time (in seconds)
PREVIOUS_TIMESTEP	real previous physical time step size (in seconds)
N_TIME	integer number of time steps
N_ITER	integer number of iterations

i You *must* include the unsteady.h header file in your UDF source code when using the PREVIOUS_TIME or PREVIOUS_2_TIME macros since it is not included in udf.h.

N_ITER can only be utilized in compiled UDFs.

Some time-dependent variables such as current physical flow time can be accessed directly using a solver macro (CURRENT_TIME), or indirectly by means of the RP variable macro RP_Get_Real("flow-time"). These two methods are shown below.

Solver Macro Usage

```
real current_time;
current_time = CURRENT_TIME;
```

”Equivalent” RP Macro Usage

```
real current_time;
current_time = RP_Get_Real("flow-time");
```

Table 3.5.2 shows the correspondence between solver and RP macros that access the same time-dependent variables.

Table 3.5.2: Solver and RP Macros that Access the Same Time-Dependent Variable

Solver Macro	“Equivalent” RP Variable Macro
CURRENT_TIME	RP_Get_Real("flow-time")
CURRENT_TIMESTEP	RP_Get_Real("physical-time-step")
N_TIME	RP_Get_Integer("time-step")

You should not access a scheme variable using any of the RP_GET_... functions from inside a cell or face looping macro (c_loop or f_loop). This type of communication between the solver and cortex is very time consuming and therefore should be done outside of loops.

Example

The integer time step count (accessed using N_TIME) is useful in DEFINE_ADJUST functions for detecting whether the current iteration is the first in the time step.

```
/**********************************************************************
            Example UDF that uses N_TIME
***********************************************************************/
static int last_ts = -1;   /*  Global variable.  Time step is never <0 */

DEFINE_ADJUST(first_iter_only, domain)
{
  int curr_ts;
  curr_ts = N_TIME;
  if (last_ts != curr_ts)
  {
    last_ts = curr_ts;

    /* things to be done only on first iteration of each time step
       can be put here  */
  }
}
```

i There is a new variable named first_iteration that can be used in the above if statement. first_iteration is true only at the first iteration of a timestep. Since the adjust UDF is also called before timestepping begins, the two methods vary slightly as to when they are true. You must decide which behavior is more appropriate for your case.

3.6 Scheme Macros

The text interface of FLUENT executes a Scheme interpreter which allows you to define your own variables that can be stored in FLUENT and accessed via a UDF. This capability can be very useful, for example, if you want to alter certain parameters in your case, and you do not want to recompile your UDF each time. Suppose you want to apply a UDF to multiple zones in a grid. You can do this manually by accessing a particular Zone ID in the graphical user interface, hardcoding the integer ID in your UDF, and then recompiling the UDF. This can be a tedious process if you want to apply the UDF to a number of zones. By defining your own scheme variable, if you want to alter the variable later, then you can do it from the text interface using a Scheme command.

Macros that are used to define and access user-specified Scheme variables from the text interface are identified by the prefix `rp`, (e.g., `rp-var-define`). Macros that are used to access user-defined Scheme variables in a FLUENT solver, are identified by the prefix `RP` (e.g., `RP_Get_Real`). These macros are executed within UDFs.

3.6.1 Defining a Scheme Variable in the Text Interface

To define a scheme variable named `pres_av/thread-id` in the text interface, you can use the scheme command:

```
      (rp-var-define 'pres_av/thread-id 2 'integer #f)
```

Before you define a scheme variable, it is often good practice to check that the variable is not already defined. You can do this by typing the following command in the text window:

```
  (if (not (rp-var-object 'pres_av/thread-id))
      (rp-var-define 'pres_av/thread-id 2 'integer #f))
```

This command first checks that the variable `pres_av/thread-id` is not already defined, and then sets it up as an integer with an initial value of 2.

Note that the string `'/'` is allowed in Scheme variable names (as in `pres_av/thread-id`), and is a useful way to organize variables so that they do not interfere with each other.

3.6.2 Accessing a Scheme Variable in the Text Interface

Once you define a Scheme variable in the text interface, you can access the variable. For example, if you want to check the current value of the variable (e.g., `pres_av/thread-id`) on the Scheme side, you can type the following command in the text window:

```
(%rpgetvar ’pres_av/thread-id)
```

i It is recommended that you use %rpgetvar when you are retrieving a FLUENT variable using a scheme command. This will ensure that you access the current cached value.

3.6.3 Changing a Scheme Variable to Another Value in the Text Interface

Alternatively, if you want to change the value of the variable you have defined (`pres_av/thread-id`) to say, 7, then you will need to use `rpsetvar` and issue the following command in the text window:

```
(rpsetvar ’pres_av/thread-id 7)
```

3.6.4 Accessing a Scheme Variable in a UDF

Once a new variable is defined on the Scheme side (using a text command), you will need to bring it over to the solver side to be able to use it in your UDF. ‘RP’ macros are used to access Scheme variables in UDFs, and are listed below.

`RP_Get_Real("variable-name")`	Returns the double value of `variable-name`
`RP_Get_Integer("variable-name")`	Returns the integer value of `variable-name`
`RP_Get_String("variable-name")`	Returns the char* value of `variable-name`
`RP_Get_Boolean("variable-name")`	Returns the Boolean value of `variable-name`

For example, to access the user-defined Scheme variable `pres_av/thread-id` in your UDF C function, you will use `RP_Get_Integer`. You can then assign the variable returned to a local variable you have declared in your UDF (e.g., `surface_thread_id`) as demonstrated below:

```
surface_thread_id = RP_Get_Integer("pres_av/thread-id");
```

3.7 Input/Output Macros

Fluent Inc. has provided some utilities in addition to the standard C I/O functions that you can use to perform input/output (I/O) tasks. These are listed below and are described in the following sections:

`Message(format, ...)`	prints a message to the console window
`Error(format, ...)`	prints an error message to the console window

Message

The `Message` macro is a utility that displays data to the console in a format that you specify.

`int Message(char *format, ...);`

The first argument in the `Message` macro is the format string. It specifies how the remaining arguments are to be displayed in the console window. The format string is defined within quotes. The value of the replacement variables that follow the format string will be substituted in the display for all instances of `%type`. The `%` character is used to designate the character type. Some common format characters are: `%d` for integers, `%f` for floating point numbers, `%g` for double data type, and `%e` for floating point numbers in exponential format (with `e` before the exponent). Consult a C programming language manual for more details. The format string for `Message` is similar to `printf`, the standard C I/O function (see Section A.13.3: Standard I/O Functions for details).

In the example below, the text `Volume integral of turbulent dissipation:` will be displayed in the console window, and the value of the replacement variable, `sum_diss`, will be substituted in the message for all instances of `%g`.

Example:

```
Message("Volume integral of turbulent dissipation: %g\n", sum_diss);
     /*  g represents floating point number in f or e format */
     /*  \n denotes a new line  */
```

It is recommended that you use `Message` instead of `printf` in compiled UDFs (UNIX only).

Error

You can use Error when you want to stop execution of a UDF and print an error message to the console window.

Example:

```
if (table_file == NULL)
   Error("error reading file");
```

i Error is not supported by the interpreter and can be used only in compiled UDFs.

3.8 Miscellaneous Macros

N_UDS

You can use N_UDS to access the number of user-defined scalar (UDS) transport equations that have been specified in FLUENT. The macro takes no arguments and returns the integer number of equations. It is defined in models.h.

N_UDM

You can use N_UDM to access the number of user-defined memory (UDM) locations that have been used in FLUENT. The macro takes no arguments, and returns the integer number of memory locations used. It is defined in models.h.

Data_Valid_P()

You can check that the cell values of the variables that appear in your UDF are accessible before you use them in a computation by using the Data_Valid_P macro.

```
cxboolean Data_Valid_P()
```

Data_Valid_P is defined in the id.h header file, and is included in udf.h. The function returns 1 (true) if the data that is passed as an argument is valid, and 0 (false) if it is not.

Example:

```
if(!Data_Valid_P())  return;
```

Suppose you read a case file and, in the process, load a UDF. If the UDF performs a calculation using variables that have not yet been initialized, such as the velocity at interior cells, then an error will occur. To avoid this kind of error, an `if else` condition can be added to your code. If (`if`) the data are available, the function can be computed in the normal way. If the data are not available (`else`), then no calculation, or a trivial calculation can be performed instead. Once the flow field has been initialized, the function can be reinvoked so that the correct calculation can be performed.

FLUID_THREAD_P()

```
cxboolean FLUID_THREAD_P(t);
```

You can use `FLUID_THREAD_P` to check whether a cell thread is a fluid thread. The macro is passed a cell thread pointer `t`, and returns `1` (or `TRUE`) if the thread that is passed is a fluid thread, and `0` (or `FALSE`) if it is not.

Note that `FLUID_THREAD_P(t)` assumes that the thread is a cell thread.

For example,

```
FLUID_THREAD_P(t0);
```

returns `TRUE` if the thread pointer `t0` passed as an argument represents a fluid thread.

NULLP & NNULLP

You can use the `NULLP` and `NNULLP` functions to check whether storage has been allocated for user-defined scalars. `NULLP` returns `TRUE` if storage is *not* allocated, and `NNULLP` returns `TRUE` if storage is allocated. Below are some examples of usage.

```
NULLP(T_STORAGE_R_NV(t0, SV_UDSI_G(p1)))

/*  NULLP returns TRUE if storage is not allocated for
    user-defined storage variable                     */



NNULLP(T_STORAGE_R_NV(t0, SV_UDSI_G(p1)))

/*  NNULLP returns TRUE if storage is allocated for
    user-defined storage variable                     */
```

M_PI

The macro M_PI returns the value of π.

UNIVERSAL_GAS_CONSTANT

UNIVERSAL_GAS_CONSTANT returns the value of the universal gas constant (8314.34 $J/Kmol$-K).

i Note that this constant is *not* expressed in SI units.

See Section 2.3.22: DEFINE_VR_RATE for an example UDF that utilizes UNIVERSAL_GAS_CONSTANT.

SQR(k)

SQR(k) returns the square of the given variable k, or $k * k$.

Chapter 4. Interpreting UDFs

Once you have written your UDF using any text editor and have saved the source code file it with a .c extension in your working directory, you are ready to interpret the source file. Follow the instructions below in Section 4.2: Interpreting a UDF Source File Using the Interpreted UDFs Panel. Once interpreted, the UDF function name(s) that you supplied in the DEFINE macro(s) will appear in drop-down lists in graphical panels in FLUENT, ready for you to hook to your CFD model. Alternatively, if you wish to compile your UDF source file, see Chapter 5: Compiling UDFs for details.

4.1 Introduction

An interpreted UDF is a function that is interpreted directly from a source file (e.g., udfexample.c) at *runtime*. The process involves a visit to the Interpreted UDFs panel where you can interpret all of the functions in a source file (e.g., udfexample.c) in a single step. Once a source file is interpreted, you can write the case file and the names and contents of the interpreted function(s) will be stored in the case. In this way, the function(s) will be *automatically* interpreted whenever the case file is subsequently read. Once interpreted (either manually through the Interpreted UDFs panel or automatically upon reading a case file), all of the interpreted UDFs that are contained within a source file will become visible and selectable in graphical user interface panel(s) in FLUENT.

Inside FLUENT, the source code is compiled into an intermediate, architecture-independent machine code using a C preprocessor. This machine code then executes on an internal emulator, or interpreter, when the UDF is invoked. This extra layer of code incurs a performance penalty, but allows an interpreted UDF to be shared effortlessly between different architectures, operating systems, and FLUENT versions. If execution speed does become an issue, an interpreted UDF can always be run in compiled mode without modification.

4.1.1 Location of the `udf.h` File

UDFs are defined using `DEFINE` macros (see Chapter 2: `DEFINE` Macros) and the definitions for `DEFINE` macros are included in `udf.h` header file. Consequently, before you can interpret a UDF source file, `udf.h` will need to be accessible in your path, or saved locally within your working directory.

The location of the `udf.h` file is:

path/Fluent.Inc/fluent6.$\overset{\Downarrow}{x}$/src/udf.h

where *path* is the directory in which you have installed the release directory, `Fluent.Inc`, and x is replaced by the appropriate number for the release you have (e.g., `2` for `fluent6.2`).

ℹ In general, you should not copy `udf.h` from the installation area. The compiler is designed to look for this file locally (in your current directory) first. If it is not found in your current directory, the compiler will look in the `/src` directory automatically. In the event that you upgrade your release area, but do not remove an old copy of `udf.h` from your working directory, you will not be accessing the most recent version of this file.

ℹ You should not, under any circumstances, alter the `udf.h` file.

4.1.2 Limitations

Due to limitations in the interpreter used to compile interpreted UDF source code in FLUENT, interpreted UDFs are limited in their use of the C programming language. In particular, the following elements of C cannot be used in interpreted UDFs:

- goto statements
- non ANSI-C prototypes for syntax
- direct data structure references
- declarations of local structures
- unions
- pointers to functions
- arrays of functions
- multi-dimensional arrays

4.2 Interpreting a UDF Source File Using the Interpreted UDFs Panel

This section presents the steps for interpreting a source file in FLUENT. Once interpreted, the names of UDFs contained within the source file will appear in drop-down lists in graphics panels in FLUENT.

The general procedure for interpreting a source file is as follows:

1. Make sure that the UDF source file is in the same directory that contains your case and data files.

   > If you are running the parallel version of FLUENT on a network of Windows machines, you must 'share' the working directory that contains your UDF source, case, and data files so that all of the compute nodes in the cluster can see it. To do this:

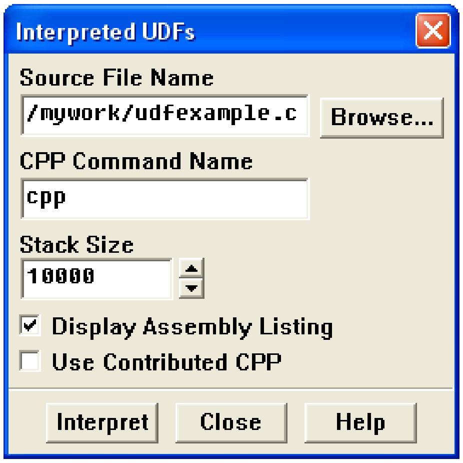
   (a) Open the Windows Explorer application, right click on the folder for the working directory (e.g., mywork), select the Sharing... option, and specify a Share Name (e.g., mywork).

2. Start FLUENT from your working directory.

3. Read (or set up) your case file.

4. Open the Interpreted UDFs panel (Figure 4.2.1).

   Define ⟶ User-Defined ⟶ Functions ⟶ Interpreted...



Source File Name: /mywork/udfexample.c

CPP Command Name: cpp

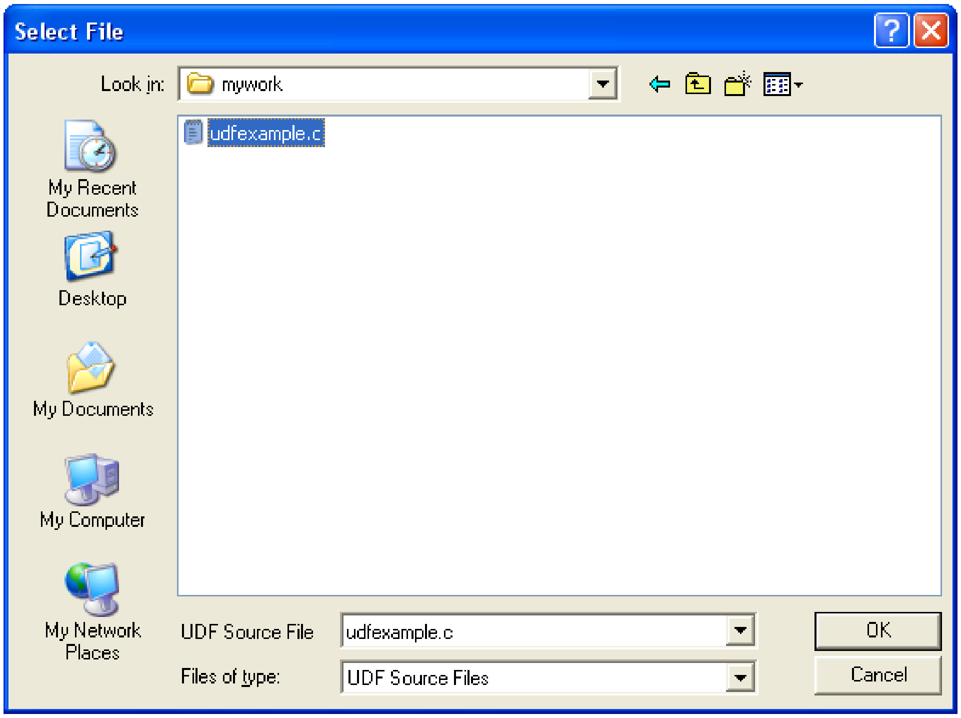
Stack Size: 10000

☑ Display Assembly Listing

□ Use Contributed CPP

Figure 4.2.1: The Interpreted UDFs Panel

5. In the Interpreted UDFs panel, select the UDF source file you want to interpret by either typing the complete path in the Source File Name field or click Browse.... This will open the Select File panel (Figure 4.2.2).



Look in: mywork

UDF Source File: udfexample.c

Files of type: UDF Source Files

Figure 4.2.2: The Select File Panel

6. In the Select File panel, highlight the directory path under Directories (e.g., /nfs/homeserver/home/clb/mywork/ when running Linux), and the desired file (e.g., udfexample.c) under Files. Once highlighted, the complete path to the source file will be displayed under Source File(s). Click OK.

   The Select File panel will close and the complete path to the file you selected (e.g., `udfexample.c`) will appear under Source File Name in the Interpreted UDFs panel (Figure 4.2.1).

   If you are running FLUENT on a network of Windows machines, you may need to type the file's complete path in the Source File Name field, instead of using the browser option. For example, to interpret `udfexample.c` that is located in a shared working directory named `mywork`, you would enter the following:

```
\\<fileserver>\mywork\udfexample.c
```

   This text goes into the Source File Name field in the Interpreted UDFs panel, replacing `<fileserver>` with the name of the computer on which your working directory (`mywork`) and source file (`udfexample.c`) are located.

7. In the Interpreted UDFs panel, specify the C preprocessor to be used in the CPP Command Name field. You can keep the default cpp or you can select Use Contributed CPP to use the preprocessor supplied by Fluent Inc.

   If you installed the `/contrib` component from the "PrePost" CD, then by default, the cpp preprocessor will appear in the panel. For Windows NT users, the standard Windows NT installation of the FLUENT product includes the cpp preprocessor.

   For Windows NT systems, if you are using the Microsoft compiler, then use the command `cl -E`.

8. Keep the default Stack Size setting of 10000, unless the number of local variables in your function will cause the stack to overflow. In this case, set the Stack Size to a number that is greater than the number of local variables used.

9. Keep the Display Assembly Listing option on if you want a listing of assembly language code to appear in your console window when the function interprets. This option will be saved in your case file, so that when you read the case in a subsequent FLUENT session, the assembly code will be automatically displayed.

10. Click Interpret to interpret your UDF.

    If the compilation is successful and you choose to Display Assembly Listing then the assembler code is printed on the console window. If you chose not to display the listing and the compilation is successful then the CPP Command Name that was executed will appear on the console. If the compilation is unsuccessful, then FLUENT will report an error and you will need to debug your program. See Section 4.3: Common Errors Made While Interpreting A Source File. You can also view the compilation history in the 'log' file that is saved in your working directory.

11. Close the Interpreted UDFs panel when the interpreter has finished.

12. Write the case file if you want the interpreted function(s) (e.g., `inlet_x_velocity`) to be saved with the case, and *automatically* interpreted when the case is subsequently read. If the Display Assembly Listing option was chosen, then the assembly code will appear in the console window.

4.3 Common Errors Made While Interpreting A Source File

If there are compilation errors when you interpret a UDF source file, they will appear in the console window. However, you may not see all the error messages if they scroll off the screen too quickly. For this reason, you may want to turn off the Display Assembly Listing option while debugging your UDF. You can view the compilation history in the 'log' file that is saved in your working directory.

If you keep the Interpreted UDFs panel open while you are in the process of debugging your UDF, the Interpret button can be used repeatedly since you can make changes with an editor in a separate window. Then, you can continue to debug and interpret until no errors are reported. Remember to save changes to the source code file in the editor window before trying to interpret again.

One of the more common errors made when interpreting source files is trying to interpret code that contains elements of C that the interpreter does not accommodate. For example, if you have code that contains a structured reference call (which is not supported by the C preprocessor), the interpretation will fail and you will get an error message similar to the following:

```
Error: /nfs/clblnx/home/clb/fluent/udfexample.c:
line 15: structure reference
```

4.4 Special Considerations for Parallel FLUENT

If you are running the parallel version of FLUENT on a Windows network and you encounter errors when trying to interpret a source file, it could be the result of an improper installation of cpp. Proper installation of parallel FLUENT for Windows ensures that the FLUENT_INC environment variable is set to the shared directory where FLUENT is installed. If the variable is defined locally instead, the following error message will be reported when you try to interpret a source file:

```
Warning: unable to run cpp
```

You will need to see your system administrator to reset the FLUENT_INC environment variable.

Chapter 5. Compiling UDFs

Once you have written your UDF(s) using any text editor and have saved the source file with a `.c` extension in your working directory, you are ready to compile the UDF source file, build a shared library from the resulting objects, and load the library into FLUENT. Once loaded, the function(s) contained in the library will appear in drop-down lists in graphical interface panels, ready for you to hook to your CFD model. Follow the instructions in Section 5.2: Compile a UDF Using the GUI to compile UDF source files using the graphical user interface (GUI). Section 5.3: Compile a UDF Using the TUI explains how you can use the text user interface (TUI) to do the same. The text interface option provides the added capability of allowing you to link precompiled object files derived from non-FLUENT sources (e.g., Fortran sources) to your UDF (Section 5.4: Link Precompiled Object Files From Non-FLUENT Sources). This feature is not available in the GUI. Section 5.5: Load and Unload Libraries Using the UDF Library Manager Panel describes how you can load (and unload) multiple UDF libraries using the Library Manager panel. The capability of loading more than one UDF library into FLUENT raises the possibility of data contention if multiple libraries use the same user-defined scalar (UDS) and user-defined memory (UDM) locations. These clashes can be avoided if libraries reserve UDS or UDM prior to usage. See Sections 3.2.8 and 3.2.9, respectively, for details.

5.1 Introduction

Compiled UDFs are built in the same way that the FLUENT executable itself is built. Internally, a script called Makefile is used to invoke the system C compiler to build an object code library that contains the native machine language translation of your higher-level C source code. The object library is specific to the computer architecture being used during the FLUENT session, as well as to the particular version of the FLUENT executable being run. Therefore, UDF object libraries must be rebuilt any time FLUENT is upgraded, when the computer's operating system level changes, or when the job is run on a different type of computer architecture. The generic process for compiling a UDF involves two steps: compile/build and load.

The compile/build step takes one or more source files (e.g., myudf.c) containing at least one UDF and compiles them into object files (e.g., myudf.o or myudf.obj) and then builds a ”shared library” (e.g., libudf) with the object files. If you compile your source file using the GUI, this compile/build process is executed when you click the Build pushbutton in the Compiled UDFs panel. The shared library that you name (e.g., libudf) is automatically built for the architecture and version of FLUENT you are running during that session (e.g., hpux11/2d), and will store the UDF object file(s).

If you compile your source file using the TUI, you will first need to setup target directories for the shared libraries, modify a file named makefile to specify source parameters, and then execute the Makefile which directs the compile/build process. Compiling a UDF using the TUI has the added advantage of allowing precompiled object files derived from non-FLUENT sources to be linked to FLUENT (Section 5.4: Link Precompiled Object Files From Non-FLUENT Sources). This option is not available using the GUI.

Once the shared library is built (using the TUI or GUI) you will need to load the UDF library into FLUENT before you can use it. This can be done using the Load pushbutton in the Compiled UDFs panel. Once loaded, all of the compiled UDFs that are contained within the shared library will become visible and selectable in graphics panels in FLUENT. Note that compiled UDFs are displayed in FLUENT panels with the associated UDF library name separated by two colons (::). For example, a compiled UDF named rrate that is associated with a shared library named libudf would appear in FLUENT panels as rrate::libudf. This distinguishes UDFs that are compiled from those that are interpreted.

If you write your case file when a UDF library is loaded, the library will be saved with the case and will be *automatically* loaded whenever that case file is subsequently read. This process of “dynamic loading” saves you having to reload the compiled library every time you want to run a simulation.

Before you compile your UDF source file(s) using one of the two methods provided in Sections 5.2 and 5.3, you will first need to make sure that the `udf.h` header file is accessible in your path, or is saved locally within your working directory (Section 5.1.1: Location of the `udf.h` File).

5.1.1 Location of the `udf.h` File

UDFs are defined using `DEFINE` macros (see Chapter 2: `DEFINE` Macros) and the definitions for `DEFINE` macros are included in `udf.h`. Consequently, before you compile your source file, the `udf.h` header file will need to be accessible in your path, or saved locally within your working directory.

The location of the `udf.h` file is:

path`/Fluent.Inc/fluent6.`$\overset{\Downarrow}{x}$`/src/udf.h`

where *path* is the directory in which you have installed the release directory, `Fluent.Inc`, and x is replaced by the appropriate number for the release you have (e.g., `3` for `fluent6.3`).

> *i* In general, you should not copy `udf.h` from the installation area. The compiler is designed to look for this file locally (in your current directory) first. If it is not found in your current directory, the compiler will look in the `/src` directory automatically. In the event that you upgrade your release area, but do not remove an old copy of `udf.h` from your working directory, you will not be accessing the most recent version of this file.

> *i* You should not, under any circumstances, alter the `udf.h` file.

There may be instances when will want to include additional header files in the compilation process. Make sure that all header files needed for UDFs are located in the `/src` directory.

5.1.2 Compilers

The graphical and text interface processes for a compiled UDF require the use of a C compiler that is native to the operating system and machine you are running on. Most UNIX operating systems provide a C compiler as a standard feature. If you are operating on a Windows system, you will need to ensure that a Microsft Visual C++ compiler is installed on your machine before you proceed. If you are unsure about compiler requirements for your system, please contact FLUENT installation support. For Linux machines, FLUENT supports any ANSI-compliant compiler.

> Obsolete versions of any native compiler may not work properly with compiled UDFs.

5.2 Compile a UDF Using the GUI

The general procedure for compiling a UDF source file and building a shared library for the resulting objects, and loading the compiled UDF library into FLUENT using the graphical user interface (GUI) is as follows.

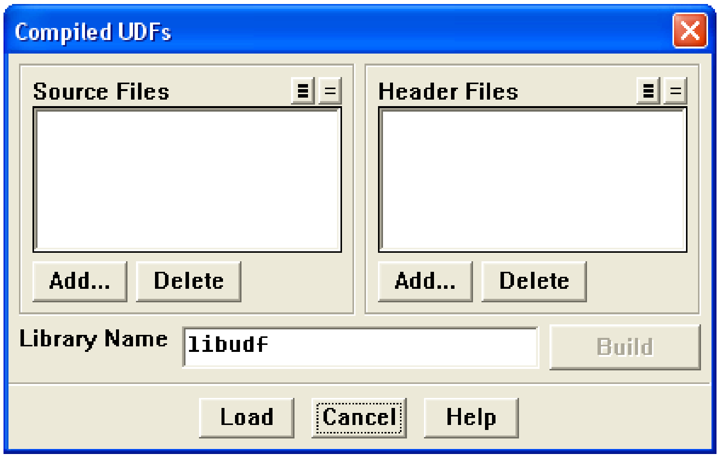
> Note that if you are running serial or parallel FLUENT on a Windows system, then you must have Microsoft Visual Studio installed on your machine and have launched FLUENT from the Visual Studio console window to compile a UDF.

1. Make sure that the UDF source file you want to compile is in the same directory that contains your case and data files.

   > Note that if you wish to compile a UDF while running FLUENT on a Windows parallel network, then you *must* ‘share’ the directory where the UDF is located so that all computers on the cluster can see this directory. To share the directory that the case, data, and compiled UDF reside in, using the Windows Explorer right-click on the directory, choose Sharing... from the menu, click Share this folder, and then click OK.
   > If you forget to enable the sharing option for the directory using the Windows Explorer, then FLUENT will hang when you try to load the library in the Compiled UDFs panel.

2. Start FLUENT from your working directory.
3. Read (or set up) your case file.
4. Open the Compiled UDFs panel (Figure 5.2.1).

   Define ⟶ User-Defined ⟶ Functions ⟶ Compiled...



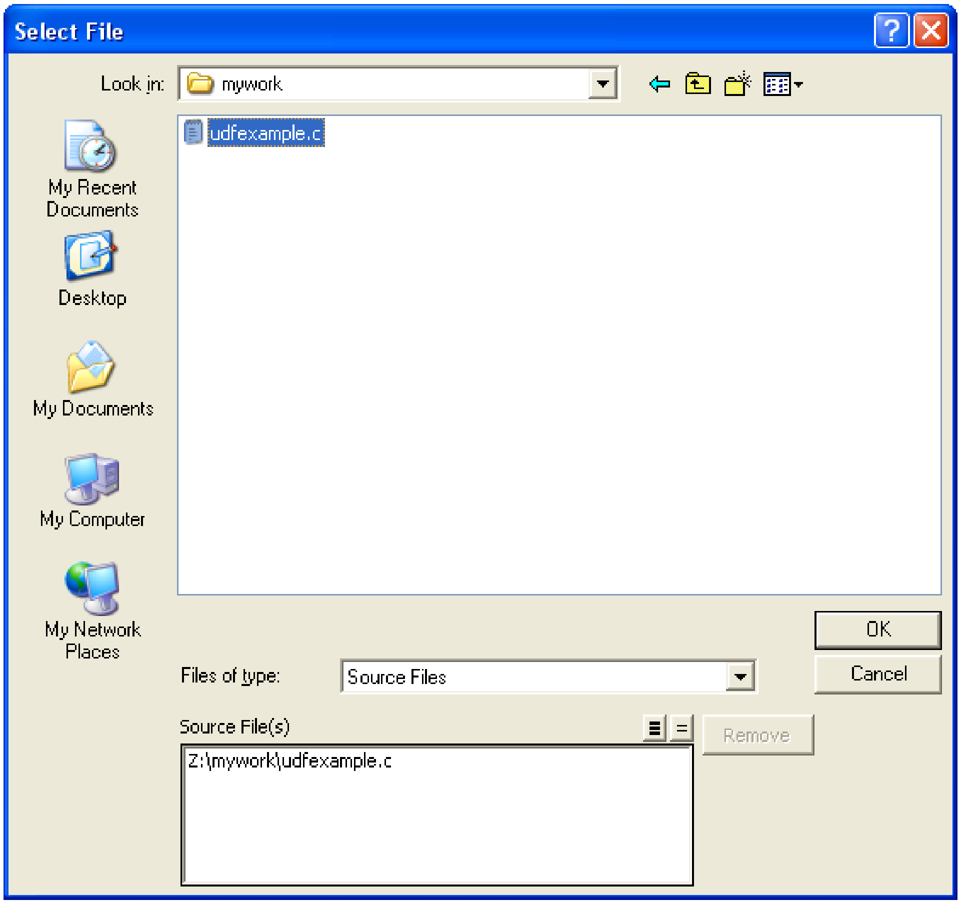
Library Name: libudf

Figure 5.2.1: The Compiled UDFs Panel

5. In the Compiled UDFs panel click on Add... under Source Files to select the UDF source file (or files) you want to compile. This will open the Select File panel (shown in Figure 5.2.2 for Linux/Unix systems).
6. In the Select File panel, highlight the directory path under Directories, and the desired file (e.g., udfexample.c) under Files. Once highlighted, the complete path to the source file will be displayed under Source File(s). Click OK.

   The Select File panel will close and the file you added (e.g., `udfexample.c`) will appear in the Source Files list in the Compiled UDFs panel (Figure 5.2.3). You can delete a file after adding it by selecting the source file and then clicking Delete in the Compiled UDFs panel.

   Repeat this step until all source files have been added.



Look in: mywork

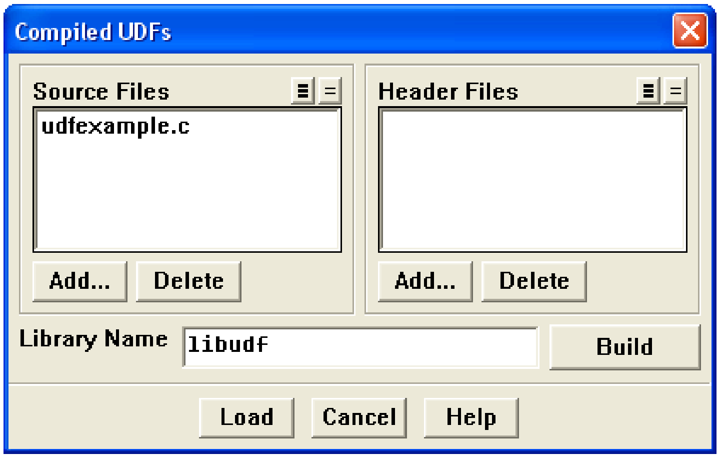
udfexample.c

Files of type: Source Files

Source File(s)

Z:\mywork\udfexample.c

Figure 5.2.2: The Select File Panel



Source Files

udfexample.c

Header Files

Library Name libudf

Figure 5.2.3: The Compiled UDFs Panel

i If you are running FLUENT on a network of Windows machines, you may need to type the file's complete path in the Source File Name field in the Interpreted UDFs panel, instead of using the browser option. For example, to compile `udfexample.c` from a shared working directory named `mywork`, you would enter the following in the Source File Name field:

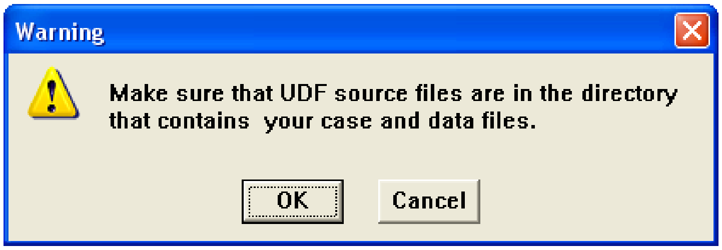
```
\\<fileserver>\mywork\udfexample.c
```

i Here, you replace `<fileserver>` with the name of the computer on which your working directory (`mywork`) and source file (`udfexample.c`) are located.

7. In the Compiled UDFs panel, select additional header files that you want to include in the compilation by clicking Add... under Header File(s) and repeat the previous step.

8. In the Compiled UDFs panel (Figure 5.2.3), enter the name of the shared library you want to build in the Library Name field (or leave the default name libudf), and click Build. All of the UDFs that are contained within each C source file you selected will be compiled and the build files will be stored in the shared library you specified (e.g., `libudf`).

   As the compile/build process begins, a Warning dialog box (Figure 5.2.4) will appear reminding you that the source file(s) need to be in the same directory as the case and data files. Click OK to close the dialog and continue with the build.



Make sure that UDF source files are in the directory that contains your case and data files.

Figure 5.2.4: The Warning Dialog Box

As the build process progresses, the results of the build will be displayed on the console window. You can also view the compilation history in the ‘log’ file that is saved in your working directory.

Console messages for a successful compile/build for a source file named `udfexample.c` and a UDF library named `libudf` for a Windows architecture are shown below.

```
Deleted old libudf\ntx86\2d\libudf.dll
        1 file(s) copied.
(system "copy C:\Fluent.Inc\fluent6.3.23\src\makefile_nt.udf
libudf\ntx86\2d\makefile")
        1 file(s) copied.
(chdir "libudf")()
(chdir "ntx86\2d")()
udfexample.c
# Generating udf_names.c because of makefile udfexample.obj
udf_names.c
# Linking libudf.dll because of makefile user_nt.udf udf_names.obj
 udfexample.obj
Microsoft (R) Incremental Linker Version 7.10.3077
Copyright (C) Microsoft Corporation.  All rights reserved.

   Creating library libudf.lib and object libudf.exp

Done.
```

9. In the Compiled UDFs panel (Figure 5.2.3), load the shared library that was just built into FLUENT by clicking Load.

   A message will be displayed on the console window providing a status of the load process. For example:

```
"C:/Fluent.Inc/ntbin/ntx86"

Opening library "libudf"...
Library "libudf\ntx86\2d\libudf.dll" opened
inlet_x_velocity
Done.
```

indicates that the shared library named libudf was successfully loaded (on a Windows machine) and it contains one function named `inlet_x_velocity`.

i Note that compiled UDFs are displayed in FLUENT panels with the associated UDF library name using the :: identifier. For example, a compiled UDF named `inlet_x_velocity` that is associated with a shared library named `libudf` will appear in FLUENT panels as `inlet_x_velocity::libudf`. This visually distinguishes UDFs that are compiled from those that are interpreted.

Once the compiled UDF(s) become visible and selectable in graphics panels in FLUENT they can be hooked to your model. See Chapter 6: Hooking UDFs to FLUENT for details. You can use the UDF Library Manager panel to unload the shared library, if desired. See Section 5.5: Load and Unload Libraries Using the UDF Library Manager Panel for details.

10. Write the case file if you want the compiled function(s) in the shared library to be saved with the case. The functions will be loaded *automatically* into FLUENT whenever the case is subsequently read.

i If you do not want the shared library saved with your case file, then you must remember to load it into FLUENT using the Compiled UDFs panel or the UDF Library Manager panel in subsequent sessions.

5.3 Compile a UDF Using the TUI

The first step in compiling a UDF source file using the text user interface (TUI) involves setting up the directory structure where the shared (compiled) library will reside, for each of the versions of FLUENT you wish to run (e.g., 2d, 3d). You will then modify the file named `makefile` to setup source file parameters. Subsequently, you will execute the `Makefile` which compiles the source file and builds the shared library from the resulting object files. Finally, you will load the UDF library into FLUENT. Using the TUI option allows you the added advantage of building a shared library for precompiled object file(s) that are derived from non-FLUENT sources (e.g., `.o` objects from `.f` sources). See Section 5.4: Link Precompiled Object Files From Non-FLUENT Sources for details.

i Note that if you are running serial or parallel FLUENT on a Windows system, then you must have Microsoft Visual Studio installed on your machine and have launched FLUENT from the Visual Studio console window to compile a UDF.

5.3.1 Set Up the Directory Structure

The directory structures for UNIX and Windows systems are different, so the procedure for setting up the directory structure is described separately for each.

Windows Systems

For compiled UDFs on Windows systems, two Fluent Inc. files are required to build your shared UDF library: `makefile_nt.udf` and `user_nt.udf`. The file `user_nt.udf` has a user-modifiable section that allows you to specify source file parameters.

The procedure below outlines steps that you need to follow in order to set up the directory structure required for the shared library.

1. In your working directory, make a directory that will store your UDF library (e.g., `libudf`).

2. Make a directory below this called `src`.

3. Put all your UDF source files into this directory (e.g., `libudf\src`).

4. Make an architecture directory below the library directory called `ntx86` for Intel systems running Windows(e.g., `libudf\ntx86`).

5. In the architecture directory (e.g., `libudf\ntx86`), create directories for the FLUENT versions you want to build for your architecture. (e.g., `ntx86\2d` and `ntx86\3d`). Possible versions are:

`2d` or `3d`	single-precision serial 2D or 3D
`2ddp` or `3ddp`	double-precision serial 2D or 3D
`2d_node` and `2d_host`	single-precision parallel 2D
`3d_node` and `3d_host`	single-precision parallel 3D
`2ddp_node` and `2ddp_host`	double-precision parallel 2D
`3ddp_node` and `3ddp_host`	double-precision parallel 3D

i Note that you must create *two* build directories for each parallel version of the solver (two for the 3D version, two for the 2D double-precision version, etc.), regardless of the number of compute nodes.

6. Copy `user_nt.udf` from

   path`/Fluent.Inc/fluent6.`$\overset{\Downarrow}{x}$`/src/user_nt.udf`

   to all the version subdirectories you have made (e.g., `libudf\ntx86\3d`).

   Note that *path* is the directory in which you have installed the release directory, `Fluent.Inc`, and *x* is replaced by the appropriate number for the release you have (e.g., `3` for `fluent6.3`).

7. Copy `makefile_nt.udf` from

   path`/Fluent.Inc/fluent6.`$\overset{\Downarrow}{x}$`/src/makefile_nt.udf`

   to all the version subdirectories you have made (e.g., `libudf\ntx86\3d`) and rename it `makefile`.

   Note that *path* is the directory in which you have installed the release directory, `Fluent.Inc`, and *x* is replaced by the appropriate number for the release you have.

UNIX and Linux Systems

For compiled UDFs on UNIX systems, two Fluent Inc. files are required to build your shared UDF library: `makefile.udf` and `makefile.udf2`. The file `makefile` has a user-modifiable section that allows you to specify source file parameters. The procedure below outlines steps that you need to follow in order to set up the directory structure required for the shared library.

1. In your working directory, make a directory that will store your UDF library (e.g., `libudf`).

2. Copy `makefile.udf2` from

   path`/Fluent.Inc/fluent6.3.`$\overset{\Downarrow}{x}$`/src/makefile.udf2`

   where *path* is the directory in which you have installed the release directory, `Fluent.Inc`, and x is replaced by the appropriate number for the release (e.g., `1` for `fluent6.2.1`) to the library directory (e.g., `libudf`), and name it `Makefile`.

3. In the library directory you just created in Step 1, make a directory that will store your source file and name it `src`.

4. Copy your source file (e.g., `myudf.c`) to the source directory (`/src`).

5. Copy `makefile.udf` from

   path`/Fluent.Inc/fluent6.3.`$\overset{\Downarrow}{x}$`/src/makefile.udf`

   where *path* is the directory in which you have installed the release directory, `Fluent.Inc`, and x is replaced by the appropriate number for the release (e.g., `1` for `fluent6.3.1`) to the `/src` directory, and name it `makefile`.

6. Identify the architecture name of the machine that you are running from (e.g., `ultra`). This can be done by either typing the command `(fluent-arch)` in the FLUENT TUI window, or running the FLUENT utility program `fluent_arch` at the command line of a UNIX shell.

   > ℹ Note that if you are running a 64-bit version of FLUENT the architecture name will have a `_64` appended to it (e.g., `ultra_64`).

7. In the library directory (e.g., `libudf`), use the architecture identifier determined in the previous step to create directories for the FLUENT versions you want to build shared libraries for (e.g., `ultra/2d` and `ultra/3d`). Possible versions are:

`2d` or `3d`	single-precision serial 2D or 3D
`2ddp` or `3ddp`	double-precision serial 2D or 3D
`2d_node` and `2d_host`	single-precision parallel 2D
`3d_node` and `3d_host`	single-precision parallel 3D
`2ddp_node` and `2ddp_host`	double-precision parallel 2D
`3ddp_node` and `3ddp_host`	double-precision parallel 3D

> ℹ Note that you must create *two* build directories for each parallel version of the solver (two for the 3D version, two for the 2D double-precision version, etc.), regardless of the number of compute nodes.

5.3.2 Build the UDF Library

After you have set up the directory structure and put the files in the proper places, you can compile and build the shared library using the TUI.

Windows Systems

1. Using a text editor, edit every user_nt.udf file in each version directory to set the following parameters: SOURCES, VERSION, and PARALLEL_NODE.

   SOURCES = the user-defined source file(s) to be compiled.
   Use the prefix $(SRC) before each filename. For example,
   $(SRC)udfexample.c for one file, and
   $(SRC)udfexample1.c $(SRC)udfexample2.c for two files.

   VERSION = the version of the solver you are running which will be the name of the build directory where user_nt.udf is located. (2d, 3d, 2ddp, 3ddp, 2d_host, 2d_node, 3d_host, 3d_node, 2ddp_host, 2ddp_node, 3ddp_host, or 3ddp_node).

   PARALLEL_NODE = the parallel communications library.
   Specify none for a serial version of the solver or one of the following:
   smpi: parallel using shared memory (for multiprocessor machines)
   vmpi: parallel using shared memory or network with vendor MPI software
   net: parallel using network communicator with RSHD software

   If you are using a parallel version of the solver, be sure to edit *both* copies of user_nt.udf (the one in the host directory and the one in the node directory), and specify the appropriate SOURCE, VERSION, and PARALLEL_NODE in each file. Set PARALLEL_NODE = none for the host version and one of the other options smpi, vmpi, net, nmpi for the node version depending on which message passing method you are going to use.

   An excerpt from a sample user_nt.udf file is shown below:

```
# Replace text in " " (and remove quotes)
#  | indicates a choice
#  note: $(SRC) is defined in the makefile
```

```
SOURCES = $(SRC)udfexample.c
VERSION = 2d
PARALLEL_NODE = none
```

2. In the Visual Studio command prompt window, go to each version directory (e.g., `\libudf\ntx86\2d\`), and type `nmake`.

   ```
   C:\users\user_name\work_dir\libudf\ntx86\2d>nmake
   ```

   The following messages will be displayed:

   ```
   Microsoft (R) Program Maintenance Utility Version 7.10.3077
   Copyright (C) Microsoft Corporation.  All rights reserved.
   cl /c /Za /DUDF_EXPORTING
   -Ic:\fluent.inc\fluent6.3.23\ntx86\2d
    -Ic:\fluent.inc\fluent6.3.23\src
   -Ic:\fluent.inc\fluent6.3.23\cortex\src
   -Ic:\fluent.inc\fluent6.3.23\client\src
    -Ic:\fluent.inc\fluent6.3.23\tgrid\src
    -Ic:\fluent.inc\fluent6.3.23\multiport\src  ..\..\src\udfexample.c
   Microsoft (R) 32-bit C/C++ Standard Compiler Version 13.10.3077 for 80x86
   Copyright (C) Microsoft Corporation 1984-2002. All rights reserved.

   udfexample.c
   # Generating udf_names.c because of makefile udfexample.obj
           cl /c /Za /DUDF_EXPORTING
    -Ic:\fluent.inc\fluent6.3.13\ntx86\2d
    -Ic:\fluent.inc\fluent6.3.23\src
    -Ic:\fluent.inc\fluent6.3.13\cortex\src
    -Ic:\fluent.inc\fluent6.3.23\client\src
    -Ic:\fluent.inc\fluent6.3.23\tgrid\src
    -Ic:\fluent.inc\fluent6.3.23\multiport\src  udf_names.c
   Microsoft (R) 32-bit C/C++ Standard Compiler Version 13.10.3077 for 80x86
   Copyright (C) Microsoft Corporation 1984-2002. All rights reserved.

   udf_names.c
   # Linking libudf.dll because of makefile user_nt.udf
   udf_names.obj udfexample.obj
   link  /Libpath:c:\fluent.inc\fluent6.3.23\ntx86\2d /dll
    /out:libudf.dl
   l  udf_names.obj udfexample.obj   fl6323s.lib
   Microsoft (R) Incremental Linker Version 7.10.3077
   ```

```
Copyright (C) Microsoft Corporation.  All rights reserved.

   Creating library libudf.lib and object libudf.exp

C:\Fluent.Inc\ntbin\ntx86\libudf\ntx86\2d>
```

Note that if there are problems with the build, you can do a complete rebuild by typing `nmake clean` and then `nmake` again.

UNIX and Linux Systems

1. Using a text editor, edit the file `makefile` in your `src` directory to set the following two parameters: `SOURCES` and `FLUENT_INC`.

   `SOURCES =` the name of your source file(s) (e.g., `udfexample.c`)
   Multiple sources can be specified by using a space delimiter (e.g., `udfexample1.c udfexample2.c`)

   `FLUENT_INC =` the path to your release directory

2. If your architecture is `irix6.5`, make the following additional change to the `makefile`.

   (a) Find the following line in the `makefile`:

   ```
   CFLAGS_IRIX6R10=        -KPIC -ansi -fullwarn -O -n32
   ```

   (b) Change `-ansi` to `-xansi`:

   ```
   CFLAGS_IRIX6R10=        -KPIC -xansi -fullwarn -O -n32
   ```

   For all other architectures, do not make any further changes to the `makefile`.

   An excerpt from a sample `makefile` is shown below:

   ```
   #------------------------------------------------------------#
   # makefile for user defined functions.
   #
   #------------------------------------------------------------#

   #------------------------------------------------------------#
   # User modifiable section.
   ```

```
#--------------------------------------------------------------#
SOURCES= udfexample1.c
FLUENT_INC= /path/Fluent.Inc

# Precompiled User Object files (for example .o files from .f
sources)
USER_OBJECTS=


#--------------------------------------------------------------#
# Build targets (do not modify below this line).
#--------------------------------------------------------------#
.
.
.
```

3. In your library directory (e.g., libudf), execute the Makefile by typing a command that begins with make and includes the architecture of the machine you will run FLUENT on, which you identified in a previous step. For example, for the Linux (lnx86) architecture type:

   ```
   make "FLUENT_ARCH=lnx86"
   ```

   FLUENT will build a shared library for each version you created a directory for (Section 5.3.1: Set Up the Directory Structure) and will display messages about the compile/build process on the console window. You can view the compilation history in the 'log' file that is saved in your working directory.

   For example, when compiling/building a shared library for a source file named profile.c and a UDF library named libudf on a Linux architecture, the console messages may include the following:

   ```
   Working...
   for d in lnx86[23]*; do \
      ( \
        cd $d; \
        for f in ../../src*.[ch] ../../src/makefile; do \
          if [ ! -f 'basename $f' ]; then \
            echo "# linking to " $f "in" $d; \
            ln -s $f .; \
          fi; \
        done; \
   ```

```
          echo ""; \
          echo "# building library in" $d; \
          make -k>makelog 2>&1; \
          cat makelog; \
       ) \
done
# linking to ...   myudf.c in lnx86/2d

# building library in lnx86/2d
make[1]: Entering directory ..../udf_names.c
# Generating udf_names
make[2]: Entering directory ..../profile.c
make libudf.so ...
# Compiling udf_names.o ...
# Compiling profile.o ...
# Linking libudf.so ...
make[2]: Leaving directory ..../udf_names.c
make[1]: Leaving directory ..../profile.c

You can also see the 'log'-file in
the working directory for compilation history
Done.
```

5.3.3 Load the UDF Library

You can load the shared library you compiled and built using the TUI from the Compiled UDFs panel or the UDF Library Manager panel. Follow the procedure outlined in Step 9 of Section 5.2: Compile a UDF Using the GUI or in Section 5.5: Load and Unload Libraries Using the UDF Library Manager Panel, respectively.

5.4 Link Precompiled Object Files From Non-FLUENT Sources

FLUENT allows you to build a shared library for precompiled object file(s) that are derived from external sources using the text user interface (TUI) option. For example, you can link precompiled objects derived from FORTRAN sources (`.o` objects from `.f` sources) to FLUENT for use by a UDF. The procedures for doing this on a UNIX, Linux, and Windows system is described below.

Windows Systems

1. Follow the procedure for setting up the directory structure described in Section Section 5.3.1: Set Up the Directory Structure.

2. Copy your precompiled object files (e.g. myobject1.obj myobject2.obj) to all of the architecture/version directories you created in Step 1 (e.g. `ntx86/2d`, `ntx86/3d`).

   i The object files should be compiled using similar flags to those used by Fluent.(e.g. `/c /Za`)

3. Using a text editor, edit the user_nt.udf files in each architecture/version directory.

5.4.1 Example - Link Precompiled Objects to FLUENT

The following example demonstrates the linking of a FORTRAN object file `test.o` to FLUENT, for use in a UDF named `test_use.c`. This particular UDF is not a practical application but has rather been designed to demonstrate the functionality. It uses data from a FORTRAN-derived object file to display parameters that are passed to the C function named `fort_test`. This on-demand UDF, when executed from the User-Defined Function Hooks panel, displays the values of the FORTRAN parameters and the common block and common complex numbers that are computed by the UDF, using the FORTRAN parameters.

Note that the names of the functions and data structures have been changed from the capital form in FORTRAN (e.g., ADDAB goes to addab_). This name ”mangling” is done by the compiler and is strongly system-dependent. Note also that functions returning complex numbers have different forms on different machine types, since C can return only single values and not structures. Consult your system and compiler manuals for details.

1. In the first step of this example, a FORTRAN source file named test.f is compiled and the resulting object file (test.o) is placed in the shared library directory for the ultra/2d version.

   ```
   libudf/ultra/2d
   ```

   The source listing for test.f is shown below.

   ```
   C  FORTRAN function
   C  test.f
   C
   C  compile to .o file using:
   C  f77 -KPIC -n32 -O -c test.f (irix6 & suns)

         REAL*8 FUNCTION ADDAB(A,B,C)

         REAL A
         REAL*8 B
         REAL*8 YCOM
         COMPLEX ZCOM
         INTEGER C
         INTEGER SIZE

         COMMON //SIZE,ARRAY(10)
         COMMON /TSTCOM/ICOM,XCOM,YCOM,ZCOM

         ICOM=C
         XCOM=A
         YCOM=B
         ZCOM=CMPLX(A,REAL(B))

         SIZE=10
         DO 100 I=1,SIZE
   ```

```
      ARRAY(I)=I*A
100  CONTINUE

     ADDAB=(A*C)*B
     END

     COMPLEX FUNCTION CCMPLX(A,B)

     REAL A,B

     CCMPLX=CMPLX(A,B)
     END
```

2. The UDF C source file named test_use.c is placed in the source directory for the ultra/2d version:

```
src/ultra/2d
```

The source listing for test_use.c is as follows.

```
   #include "udf.h"

   #if defined(_WIN32)
     /*  Visual Fortran makes uppercase functions provide lowercase
         mapping to be compatible with UNIX code  */
   #  define addab_ ADDAB
   #endif

   typedef struct {float r,i;} Complex;
   typedef struct {double r,i;} DComplex;
   typedef struct {long double r,i;} QComplex; /* FORTRAN QUAD
                                                  PRECISION */

   /* FORTRAN FUNCTION */
   extern double addab_(float *a,double *b,int *c);

/* NOTE on SUN machines that FORTRAN functions returning a complex
   number are actually implemented as void but with an extra
   initial argument.*/

   extern void ccmplx_(Complex *z,float *a,float *b);
   extern void qcmplx_(QComplex *z,float *a,float *b);

   /* BLANK COMMON BLOCK */
   extern struct
   {
    int size;
    float array[10];
   } _BLNK__;

   /* FORTRAN NAMED COMMON BLOCK */
   extern struct
   {
    int int_c;
    float float_a;
    double double_b;
    float cmplx_r;
    float cmplx_i;
   } tstcom_;

   DEFINE_ON_DEMAND(fort_test)
   {
    float a=3.0,float_b;
    double d,b=1.5;
    int i,c=2;
    Complex z;
    QComplex qz;

    d = addab_(&a,&b,&c);
    Message("\n\nFortran code gives (%f * %d) * %f = %f\n",a,c,b,d);
    Message("Common Block TSTCOM set to: %g %g %d\n",
             tstcom_.float_a,tstcom_.double_b,tstcom_.int_c);
    Message("Common Complex Number is (%f + %fj)\n",
             tstcom_.cmplx_r,tstcom_.cmplx_i);
    Message("BLANK Common Block has an array of size %d:
                                               \n",_BLNK__.size);
    for (i=0; i <_BLNK__.size ; i++)
      {
        Message("array[%d] = %g\n",i,_BLNK__.array[i]);
      }

    float_b=(float)b;
    ccmplx_(&z,&a,&float_b);
    Message("Function CCMPLX returns Complex Number:
```

```
                                        (%g + %gj)\n",z.r,z.i);
     qcmplx_(&qz,&a,&float_b);
     Message("Function QCMPLX returns Complex Number:
                                        (%g + %gj)\n",qz.r,qz.i);
    }
```

3. The `makefile` is then modified to specify the UDF C source file (`test_use.c`) and the external object file (`test.o`) as shown below.

```
#-----------------------------------------------------------------#
# User modifiable section.
#-----------------------------------------------------------------#
SOURCES= test_use.c
FLUENT_INC= /usr/local/Fluent.Inc/

# Precompiled User Object files (for example .o files from .f
sources)
USER_OBJECTS= test.o
```

4. Finally, the `Makefile` is executed by issuing the following command in the `libudf` directory:

```
make "FLUENT_ARCH=ultra"
```

UNIX and Linux Systems

1. Follow the procedure for setting up the directory structure described in Section 5.3.1: Set Up the Directory Structure.

2. Copy your precompiled object files (e.g., `myobject1.o myobject2.o`) to all of the architecture/version directories you created in Step 1 (e.g., `ultra/2d` and `ultra/3d`).

   > The object files should be compiled using similar flags to those used for FLUENT. Common flags used by FLUENT are: `-KPIC`, `-O`, and `-ansi` which often have equivalents such as `-fpic`, `-O3`, and `-xansi`.

3. Using a text editor, edit the file `makefile` in your `src` directory to set the following three parameters: `SOURCES`, `FLUENT_INC`, and `USER_OBJECTS`.

`SOURCES =` Put the names of your UDF C files here. They will be calling the functions in the User Objects.

`FLUENT_INC =` the path to your release directory.

`USER_OBJECTS =` the precompiled object file(s) that you want to build a shared library for (e.g., `myobject1.o`). Use a space delimiter to specify multiple object files (e.g., `myobject1.o myobject2.o`).

An excerpt from a sample `makefile` is shown below:

```
#-----------------------------------------------------------#
# makefile for user defined functions
#
#-----------------------------------------------------------#

#-----------------------------------------------------------#
# User modifiable section.
#-----------------------------------------------------------#
SOURCES=udf_source1.c
FLUENT_INC= /path/Fluent.Inc

# Precompiled User Object files (for example .o files from .f
sources)
USER_OBJECTS= myobject1.o myobject2.o


#-----------------------------------------------------------#
# Build targets (do not modify below this line).
#-----------------------------------------------------------#
.
.
.
```

4. In your library directory (e.g., `libudf`), execute the `Makefile` by typing a command that begins with `make` and includes the architecture of the machine you will run FLUENT on, which you identified in a previous step (e.g., `ultra`).

```
make  "FLUENT_ARCH=ultra"
```

The following messages will be displayed:

```
# linking to ../../src/makefile in ultra/2d
# building library in ultra/2d
# linking to ../../src/makefile in ultra/3d
# building library in ultra/3d
```

5.5 Load and Unload Libraries Using the UDF Library Manager Panel

You can use the UDF Library Manager panel to load and unload multiple shared libraries in FLUENT.

Load the UDF Library

To load a UDF library in FLUENT, open the UDF Library Manager panel (Figure 5.5.1).

Define ⟶ User-Defined ⟶ Functions ⟶ Manage...

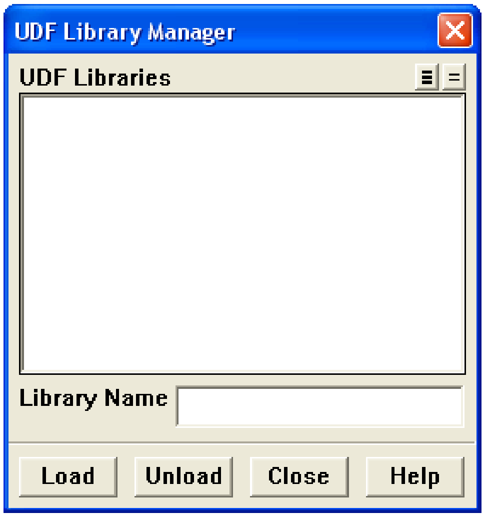


Figure 5.5.1: The UDF Library Manager Panel

1. In the UDF Library Manager panel, type the name of the shared library in the Library Name field and click Load (Figure 5.5.1).

   A message will be displayed on the console window providing a status of the load process. For example:

```
Opening library "libudf"...
Library "libudf/hpux11/2d/libudf.so" opened
        inlet_x_velocity
Done.
```

indicates that the shared library named libudf was successfully loaded (on an HP machine) and contains one UDF named `inlet_x_velocity`. In the UDF Library Manager panel, the library name (e.g., `libudf`) will be added under UDF Libraries. Repeat this step to load additional libraries.

Unload the UDF Library

To unload a UDF library in FLUENT, open the UDF Library Manager panel (Figure 5.5.2).

Define ⟶ User-Defined ⟶ Functions ⟶ Manage...

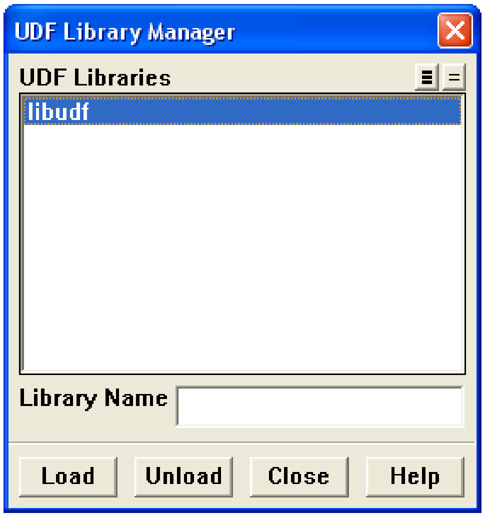


Figure 5.5.2: The UDF Library Manager Panel

1. In the UDF Library Manager panel, highlight the shared library name (e.g., `libudf`) that is listed under UDF Libraries (or type the Library Name) and click Unload (Figure 5.5.2).

   Once unloaded, the library (e.g., `libudf`) will be removed from the UDF Libraries list in the panel. Repeat this step to unload additional libraries.

5.6 Common Errors When Building and Loading a UDF Library

A common compiler error occurs when you forget to put an `#include "udf.h"` statement at the beginning of your source file. You'll get a long list of compiler error messages that include illegal declarations of variables. Similarly, if your function requires an auxiliary header file (e.g., `sg_pdf.h`) and you forgot to include it, you'll get a similar compiler error message.

Another common error occurs when the argument list for a `DEFINE` statement is placed on multiple lines. (All `DEFINE` macro arguments must be listed on the same line in a C file.) The compiler will typically not report any error message but it will report a single warning message in the log file to indicate that this occurred:

```
    warning:  no newline at end of file
```

If your compiled UDF library loads successfully then each function contained within the library will be reported to the console (and log file). For example, if you built a shared library named `libudf` containing two user-defined functions `superfluid_density` and `speed_sound`, a successful library load (on a Linux machine) will result in the following message reported to the console (and log file) for a Linux machine:

```
Opening library "libudf"...
Library "libudf/lnx86/3d/libudf.so" opened
        superfluid_density
        speed_sound
Done.
```

If, instead, no function names are listed, then it is likely that your source file did not successfully compile. In this case, you'll need to consult the log to view the compilation history, and debug your function(s). Note that you'll need to unload the UDF library using the UDF Library Manager panel before you reload the debugged version of your library.

Another common error occurs when you try to read a case file that was saved with a shared library, and that shared library has subsequently been moved to another location. In this case, the following error will be reported to the console (and log file) on a Linux machine:

```
Opening library "libudf"...
Error: open_udf_library: couldn’t open library: libudf/ln86/2d/libudf.so
```

Similarly, you will get an error message when you try to load a shared library before it has been built.

```
Opening library "libudf"...
Error: open_udf_library: No such file or directory
```

Windows Parallel

If you are trying to load a compiled UDF while running FLUENT in network parallel, you may receive this error:

```
Error: open_udf_library: The system cannot find the path specified
```

This error occurs because the other computer(s) on the cluster cannot "see" the UDF through the network. To remedy this, you will need to 1) modify the environment variables on the computer where the compiled UDF, case, and data files reside; and 2) share the directory where the files reside. See Section 5.2: Compile a UDF Using the GUI for details on file sharing or contact FLUENT installation support for additional assistance.

There are instances when FLUENT can hang when trying to read a compiled UDF using network parallel as a result of a network communicator problem. Contact FLUENT installation support for details.

You may receive an error message when you invoke the command `nmake` if you have the wrong compiler installed or if you have not launched the Visual Studio Command Prompt prior to building the UDF. See Section 5.1.2: Compilers and Section 5.2: Compile a UDF Using the GUI for details or contact FLUENT installation support for further assistance.

5.7 Special Considerations for Parallel FLUENT

If you are running serial or parallel FLUENT on a Windows system, then you *must* have Microsoft Visual Studio installed on your machine and have launched FLUENT from the Visual Studio console window in order to compile UDFs in your model.

Also note that if you have compiled a UDF while running FLUENT on a Windows parallel network, you *must* 'share' the directory where the UDF is located so that all computers on the cluster can see this directory. To share the directory that the case, data, and compiled UDF reside in, using the Windows Explorer right-click on the directory, choose Sharing... from the menu, click Share this folder, and then click OK.

> ℹ If you forget to enable the sharing option for the directory using the Windows Explorer, then FLUENT will hang when you try to load the library in the Compiled UDFs panel.

See Section 5.6: Common Errors When Building and Loading a UDF Library for a list of errors you can encounter that are specific to Windows parallel.

Chapter 6. Hooking UDFs to FLUENT

Once you have interpreted or compiled your UDF using the methods described in Chapters 4 and 5, respectively, you are ready to hook the function to FLUENT using a graphic interface panel. Once hooked, the function will be utilized in your FLUENT model. Details about hooking a UDF to FLUENT can be found in the following sections. Note that these sections relate to corresponding sections in Chapter 2: DEFINE Macros.

- Section 6.1: Hooking General Purpose UDFs
- Section 6.2: Hooking Model-Specific UDFs
- Section 6.3: Hooking Multiphase UDFs
- Section 6.4: Hooking Discrete Phase Model (DPM) UDFs
- Section 6.5: Hooking Dynamic Mesh UDFs
- Section 6.6: Hooking User-Defined Scalar (UDS) Transport Equation UDFs
- Section 6.7: Common Errors While Hooking a UDF to FLUENT

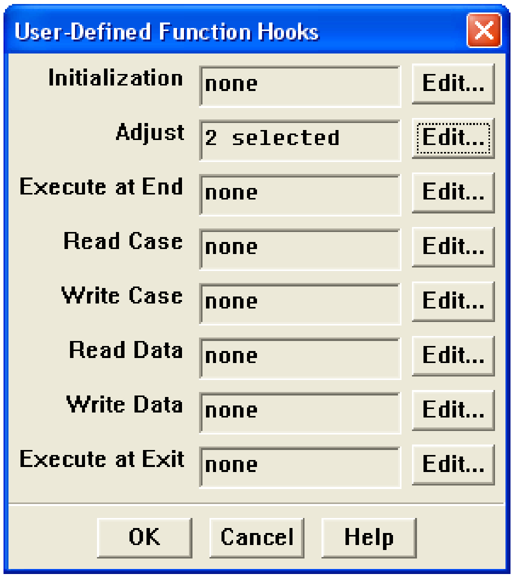
6.1 Hooking General Purpose UDFs

This section contains methods for hooking general purpose UDFs to FLUENT. General purpose UDFs are those that have been defined using macros described in Section 2.2: General Purpose DEFINE Macros and then interpreted or compiled and loaded using methods described in Chapters 4 or 5, respectively.

6.1.1 Hooking `DEFINE_ADJUST` UDFs

Once you interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your `DEFINE_ADJUST` UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Function Hooks panel (Figure 6.1.1). Note that you can hook multiple adjust UDFs to your model, if desired.

Define ⟶ User-Defined ⟶Function Hooks...



Initialization none

Adjust 2 selected

Execute at End none

Read Case none

Write Case none

Read Data none

Write Data none

Execute at Exit none

Figure 6.1.1: The User-Defined Function Hooks Panel

Click on Edit... next to Adjust to open the Adjust Functions panel (Figure 6.1.2).

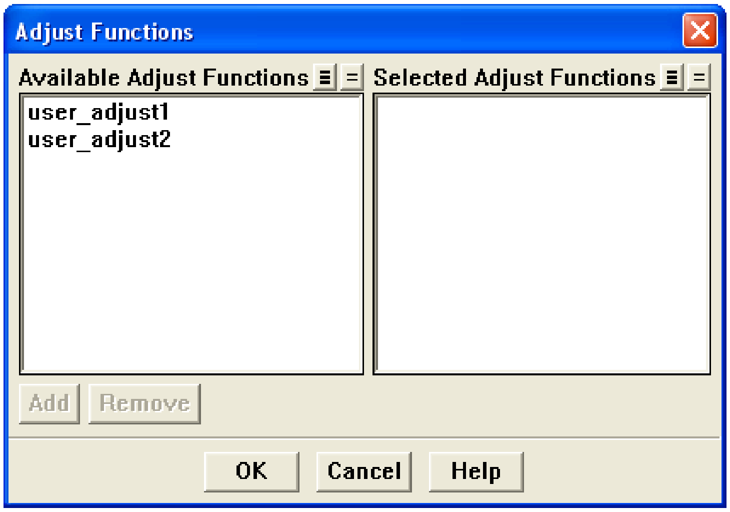


Figure 6.1.2: The Adjust Functions Panel

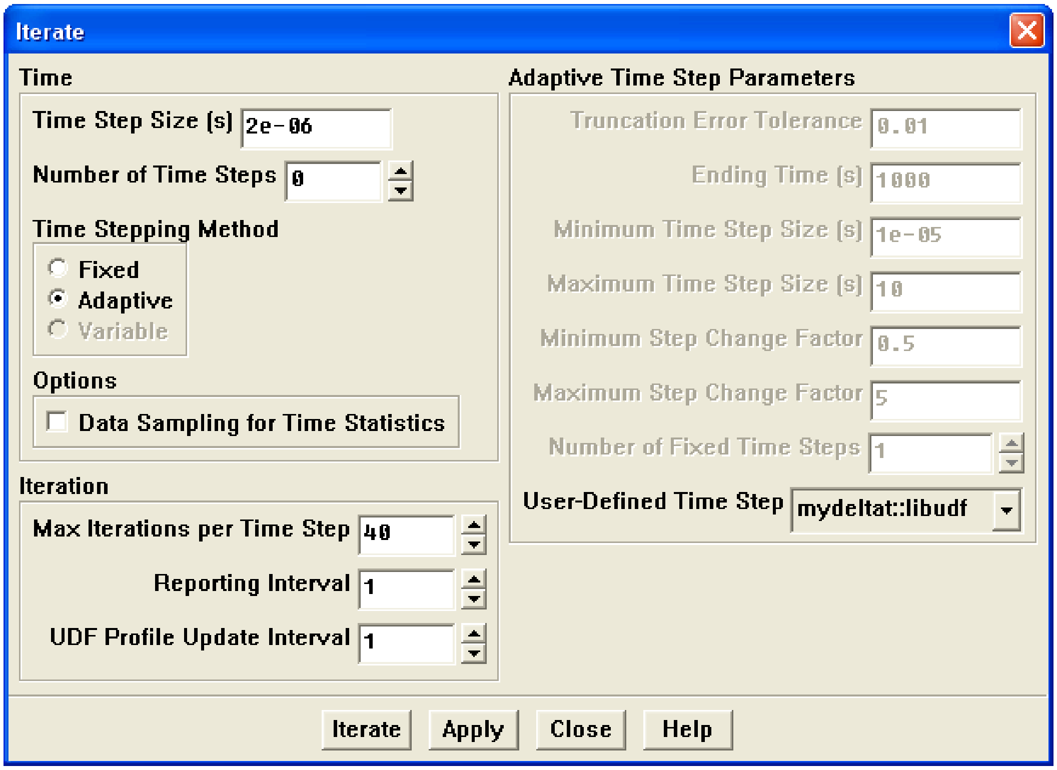
Select the function(s) you wish to hook to your model from the Available Adjust Functions list. Click Add and then OK to close the panel. Click OK in the User-Defined Function Hooks panel to apply the settings. Once added, the name of the function you selected will be displayed in the User-Defined Function Hooks panel. If you select more than one function, the number will be indicated (e.g., 2 selected).

See Section 2.2.1: DEFINE_ADJUST for details about defining adjust functions using the DEFINE_ADJUST macro.

6.1.2 Hooking DEFINE_DELTAT UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DELTAT UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Iterate panel (Figure 6.1.3) in FLUENT.

Solve ⟶Iterate...



Time

Time Step Size (s) 2e-06

Number of Time Steps 0

Time Stepping Method

○ Fixed
● Adaptive
○ Variable

Options

□ Data Sampling for Time Statistics

Iteration

Max Iterations per Time Step 40

Reporting Interval 1

UDF Profile Update Interval 1

Adaptive Time Step Parameters

Truncation Error Tolerance 0.01

Ending Time (s) 1000

Minimum Time Step Size (s) 1e-05

Maximum Time Step Size (s) 10

Minimum Step Change Factor 0.5

Maximum Step Change Factor 5

Number of Fixed Time Steps 1

User-Defined Time Step mydeltat::libudf

Figure 6.1.3: The Iterate Panel

To hook the UDF to FLUENT, the Unsteady time method must be chosen in the Solver panel. You will then need to select Adaptive as the Time Stepping Method in the Iterate panel, choose the function name (e.g., mydeltat) in the User-Defined Time Step drop-down list under Adaptive Time Step Parameters, and click Apply.

i Note that when you are using the VOF Multiphase Model, you will need to select Variable as the Time Stepping Method to hook the time step UDF.

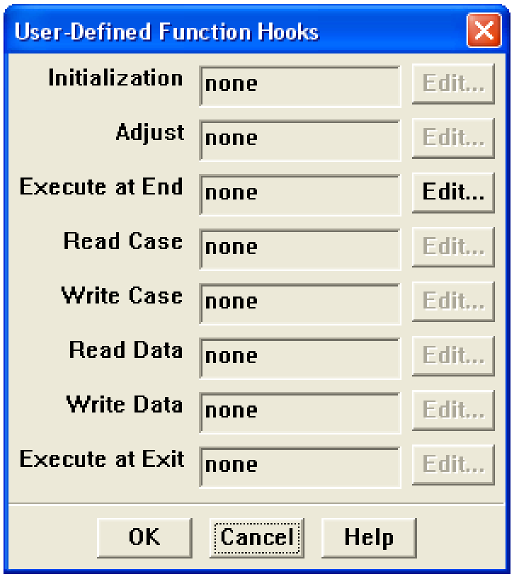
See Section 2.2.2: DEFINE_DELTAT for details about defining DEFINE_DELTAT functions.

6.1.3 Hooking DEFINE_EXECUTE_AT_END UDFs

Once you interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_EXECUTE_AT_END UDF, it is ready to be hooked to FLUENT. Note that you can hook multiple at-end UDFs to your model, if desired.

Open the User-Defined Function Hooks panel. (Figure 6.1.4)

Define ⟶ User-Defined ⟶Function Hooks...



User-Defined Function Hooks

Initialization	none	Edit...
Adjust	none	Edit...
Execute at End	none	Edit...
Read Case	none	Edit...
Write Case	none	Edit...
Read Data	none	Edit...
Write Data	none	Edit...
Execute at Exit	none	Edit...

Figure 6.1.4: The User-Defined Function Hooks Panel

Click on the Edit button next to Execute At End. This will open the Execute At End Functions panel (Figure 6.1.5).

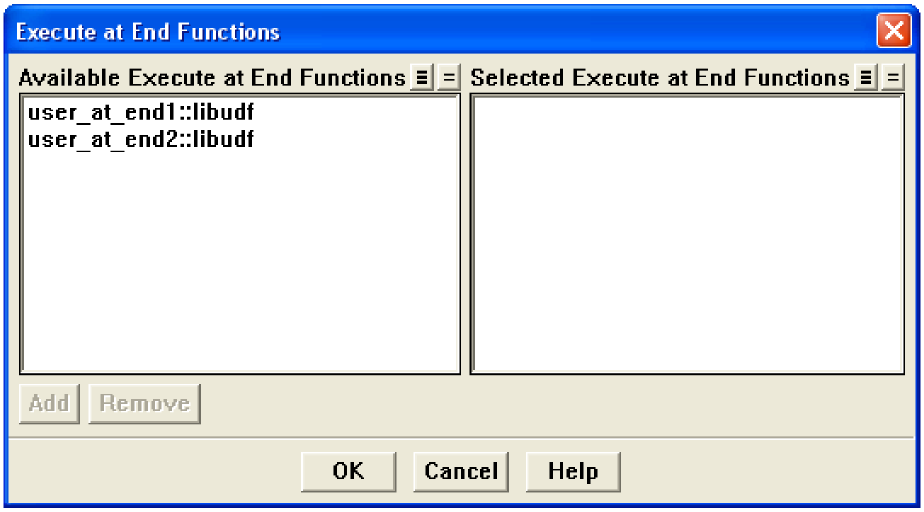


Figure 6.1.5: The Execute At End Functions Panel

In the Execute At End Functions panel, from the list of available UDFs you have interpreted or compiled and loaded, select the functions you wish to hook to your model and click Add and then OK. Click OK in the User-Defined Function Hooks panel to apply the settings. The number of functions you select will then appear in the User-Defined Function Hooks panel. For example, if you select two adjust functions (e.g., user_at_end1, user_at_end2), then the text box for Execute At End in the User-Defined Function Hooks panel will display 2 selected.

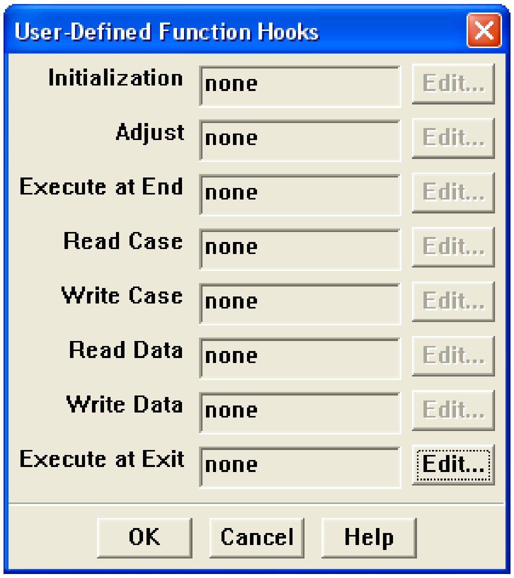
See Section 2.2.3: DEFINE_EXECUTE_AT_END for details about defining DEFINE_EXECUTE_AT_END functions.

6.1.4 Hooking DEFINE_EXECUTE_AT_EXIT UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_EXECUTE_AT_EXIT UDF, it is ready to be hooked to FLUENT. Note that you can hook multiple at-exit UDFs to your model, if desired.

Open the User-Defined Function Hooks panel. (Figure 6.1.6)

Define ⟶ User-Defined ⟶Function Hooks...



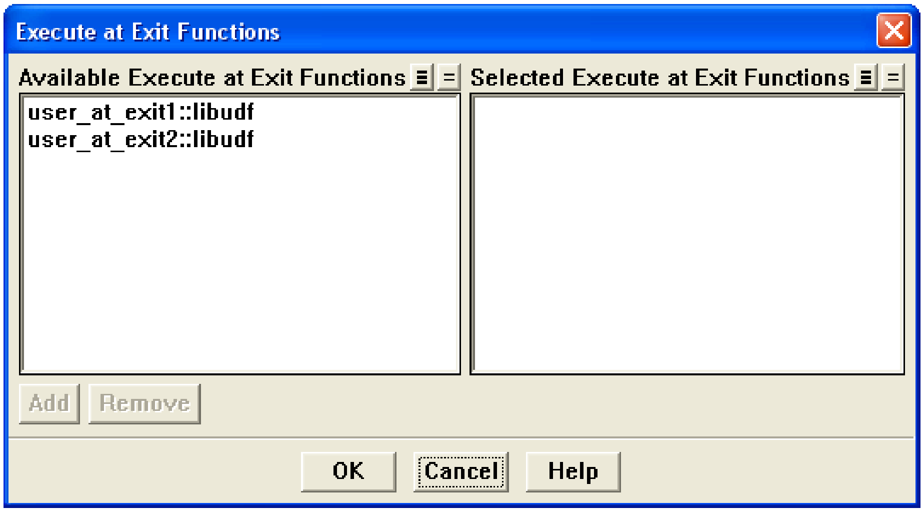
Initialization: none
Adjust: none
Execute at End: none
Read Case: none
Write Case: none
Read Data: none
Write Data: none
Execute at Exit: none

Figure 6.1.6: The User-Defined Function Hooks Panel

Click on the Edit button next to Execute At Exit. This will open the Execute At Exit Functions panel (Figure 6.1.7).

In the Execute At Exit Functions panel, from the list of Available Execute At End Functions that you have interpreted or compiled and loaded, select the functions you wish to hook to your model and click Add and then OK. Click OK in the User-Defined Function Hooks panel to apply the settings. The number of functions you select will then appear in the User-Defined Function Hooks panel. For example, if you select two at-exit functions (user-at-exit1, user_at_exit2), then the text box for Execute At Exit in the User-Defined Function Hooks panel will display 2 selected.

See Section 2.2.4: DEFINE_EXECUTE_AT_EXIT for details about defining DEFINE_EXECUTE_AT_EXIT functions.



Execute at Exit Functions

Available Execute at Exit Functions

user_at_exit1::libudf
user_at_exit2::libudf

Selected Execute at Exit Functions

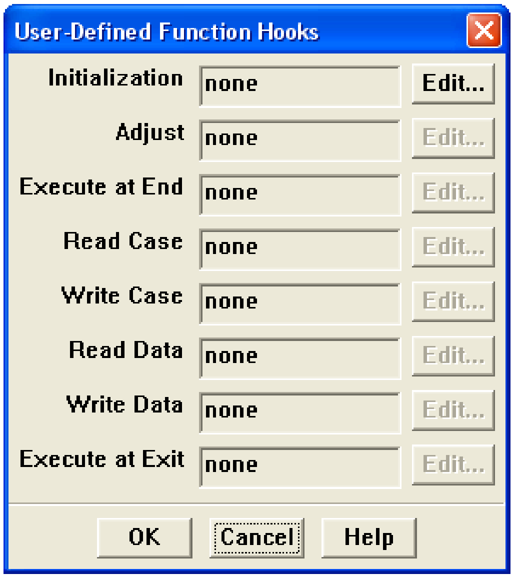
Figure 6.1.7: The Execute At Exit Functions Panel

6.1.5 Hooking DEFINE_INIT UDFs

Once you interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_INIT UDF, it is ready to be hooked to FLUENT. Note that you can hook multiple initialization UDFs to your model, if desired.

Open the User-Defined Function Hooks panel. (Figure 6.1.8)

Define ⟶ User-Defined ⟶Function Hooks...



User-Defined Function Hooks

Initialization none

Adjust none

Execute at End none

Read Case none

Write Case none

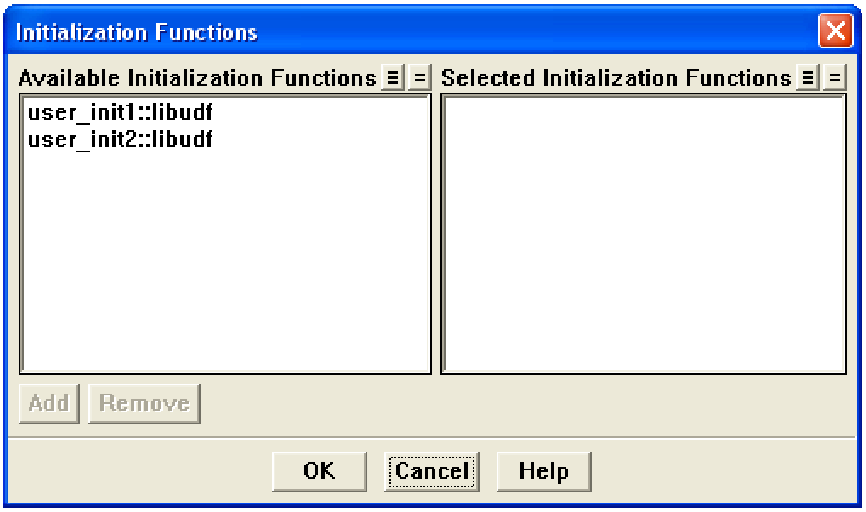
Read Data none

Write Data none

Execute at Exit none

Figure 6.1.8: The User-Defined Function Hooks Panel

Click on the Edit button next to Initialization. This will open the Initialization Functions panel (Figure 6.1.9).


Initialization Functions
Available Initialization Functions
Selected Initialization Functions
Add
Remove
OK
Cancel
Help

user_init1::libudf
user_init2::libudf

Figure 6.1.9: The Initialization Functions Panel

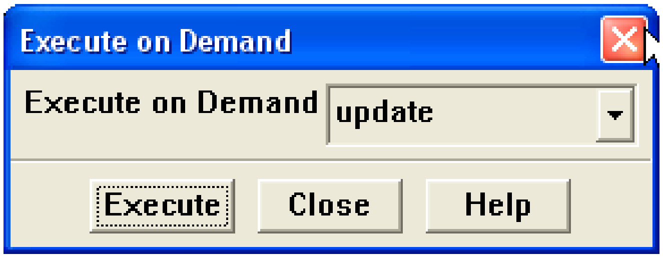
In the Initialization Functions panel, from the Available Initialization Functions you have interpreted or compiled and loaded, select the functions you wish to hook to your model and click Add and then OK. Click OK in the User-Defined Function Hooks panel to apply the settings. The number of functions you select will then appear in the User-Defined Function Hooks panel. For example, if you select two initialization functions (e.g., user_init1, user_init2), then the text box for Initialization in the User-Defined Function Hooks panel will display 2 selected.

See Section 2.2.7: `DEFINE_INIT` for details about defining `DEFINE_INIT` functions.

6.1.6 Hooking DEFINE_ON_DEMAND UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_ON_DEMAND UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Execute On Demand panel (Figure 6.1.10) in FLUENT.

Define ⟶ User-Defined ⟶ Execute On Demand...


Execute on Demand

Execute on Demand: update

Figure 6.1.10: The Execute On Demand Panel

To hook the UDF to FLUENT, choose the function name (e.g., update) in the Function drop-down list in the Execute On Demand panel, and click Execute. FLUENT will execute the UDF immediately. Click Close to close the panel.

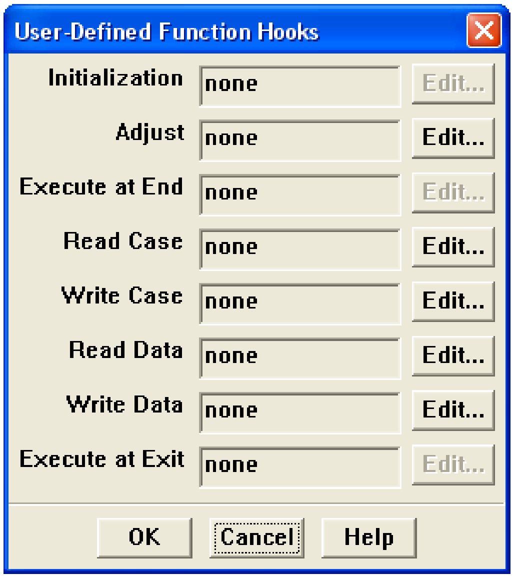
See Section 2.2.8: DEFINE_ON_DEMAND for details about defining DEFINE_ON_DEMAND functions.

6.1.7 Hooking DEFINE_RW_FILE UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_RW_FILE UDF, it is ready to be hooked to FLUENT. Note that you can hook multiple read/write file UDFs to your model, if desired.

Open the User-Defined Function Hooks panel. (Figure 6.1.11)

Define ⟶ User-Defined ⟶Function Hooks...


User-Defined Function Hooks

Initialization none

Adjust none

Execute at End none

Read Case none

Write Case none

Read Data none

Write Data none

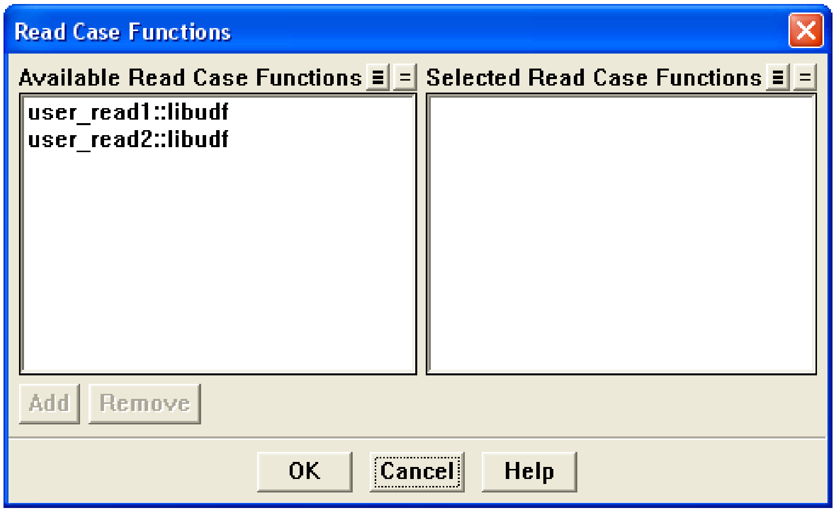
Execute at Exit none

Figure 6.1.11: The User-Defined Function Hooks Panel

You have the choice of hooking a UDF to read and write a case and data file. Below is a description of what each function does.

- Read Case is called when you read a case file into FLUENT. It will specify the customized section that is to be read from the case file.
- Write Case is called when you write a case file from FLUENT. It will specify the customized section that is to be written to the case file.
- Read Data is called when you read a data file into FLUENT. It will specify the customized section that is to be read from the data file.
- Write Data is called when you write a data file from FLUENT. It will specify the customized section that is to be written to the data file.

To hook a read case file UDF, for example, click on the Edit button next to Read Case. This will open the Read Case Functions panel (Figure 6.1.12).



user_read1::libudf
user_read2::libudf

Figure 6.1.12: The Read Case Functions Panel

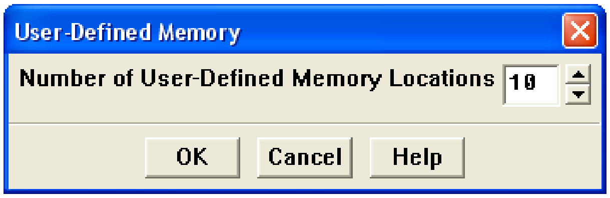
In the Read Case Functions panel, from the Available Read Case Functions you have interpreted or compiled and loaded, select the functions you wish to hook to your model and click Add and then OK. Click OK in the User-Defined Function Hooks panel to apply the settings. The number of functions you select will then appear in the User-Defined Function Hooks panel. For example, if you select two functions (e.g., user_read1, user_read2), then the text box for Read Case in the User-Defined Function Hooks panel will display 2 selected.

See Section 2.2.9: DEFINE_RW_FILE for details about defining DEFINE_RW_FILE functions.

6.1.8 User-Defined Memory Storage

You can store values computed by your UDF in memory so that they can be retrieved later, either by a UDF or for postprocessing within FLUENT. In order to have access to this memory, you will need to allocate memory by spcifying the Number of User-Defined Memory Locations in the User-Defined Memory panel (Figure 6.1.13).

Define ⟶ User-Defined ⟶Memory...


User-Defined Memory

Number of User-Defined Memory Locations 10

Figure 6.1.13: The User-Defined Memory Panel

The macros C_UDMI or F_UDMI can be used in your UDF to access a particular user-defined memory location in a cell or face, respectively. See Sections 3.2.3 and 3.2.4 for details.

Field values that have been stored in user-defined memory will be saved to the data file when you next write one. These fields will also appear in the User Defined Memory... category in the drop-down lists in FLUENT's postprocessing panels. They will be named User Memory 0, User Memory 1, etc., based on the memory location index. The total number of memory locations is limited to 500. For large numbers of user-defined memory locations, system memory requirements will increase.

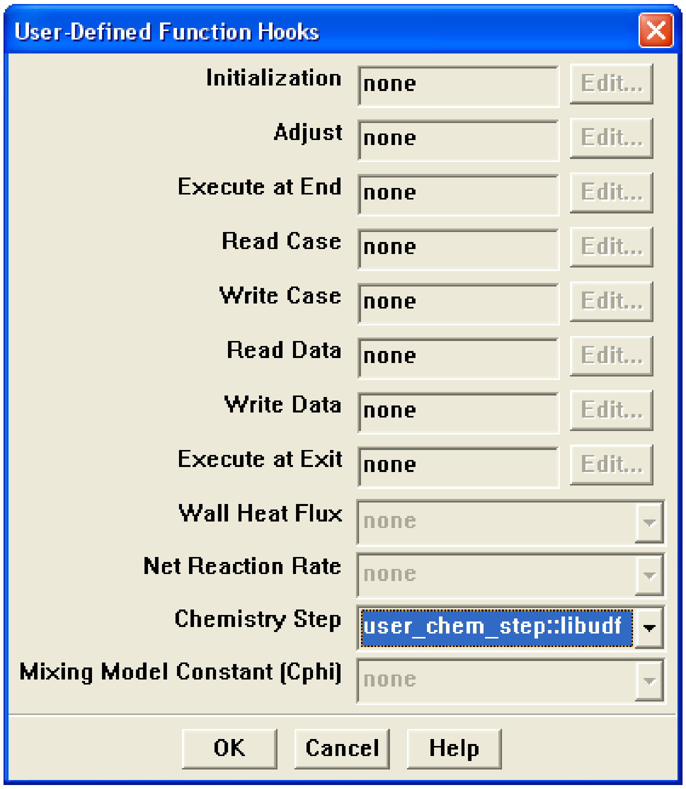
6.2 Hooking Model-Specific UDFs

This section contains methods for hooking model-specific UDFs to FLUENT that have been defined using DEFINE macros found in Section 2.3: Model-Specific DEFINE Macros, and interpreted or compiled using methods described in Chapters 4 or 5, respectively.

6.2.1 Hooking `DEFINE_CHEM_STEP` UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your `DEFINE_CHEM_STEP` UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Function Hooks panel (Figure 6.2.1) in FLUENT.

Define ⟶ User-Defined ⟶ Function Hooks...



Initialization	none
Adjust	none
Execute at End	none
Read Case	none
Write Case	none
Read Data	none
Write Data	none
Execute at Exit	none
Wall Heat Flux	none
Net Reaction Rate	none
Chemistry Step	user_chem_step::libudf
Mixing Model Constant (Cphi)	none

Figure 6.2.1: The User-Defined Function Hooks Panel

EDC or PDF Transport models must be enabled to hook chemistry step UDFs.

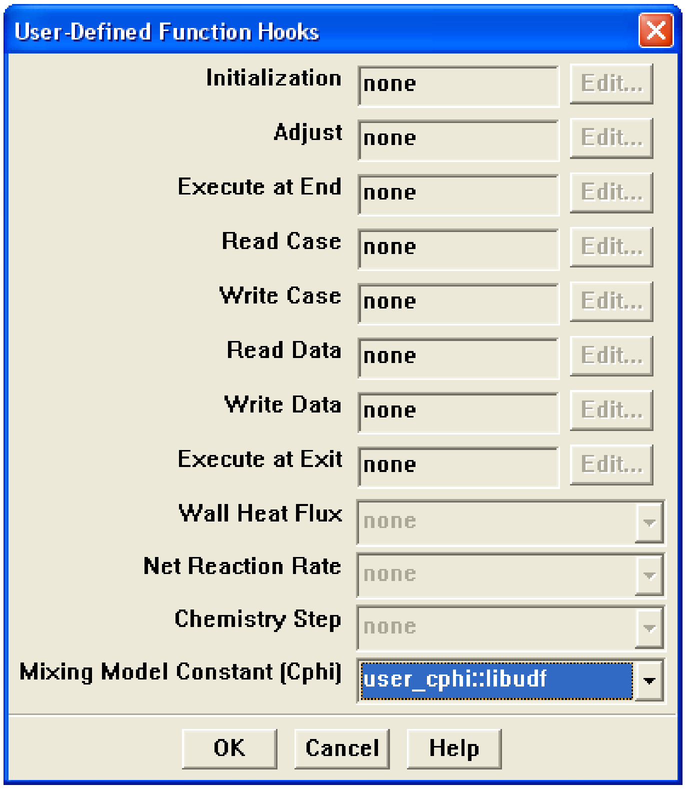
To hook the UDF to FLUENT, choose the function name (e.g., `user_chem_step`) in the Chemistry Step drop-down list in the User-Defined Function Hooks panel, and click OK.

See Section 2.3.1: `DEFINE_CHEM_STEP` for details about defining `DEFINE_CHEM_STEP` functions.

6.2.2 Hooking DEFINE_CPHI UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_CPHI UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Function Hooks panel (Figure 6.2.2) in FLUENT.

Define ⟶ User-Defined ⟶ Function Hooks...



User-Defined Function Hooks

Initialization	none
Adjust	none
Execute at End	none
Read Case	none
Write Case	none
Read Data	none
Write Data	none
Execute at Exit	none
Wall Heat Flux	none
Net Reaction Rate	none
Chemistry Step	none
Mixing Model Constant (Cphi)	user_cphi::libudf

Figure 6.2.2: The User-Defined Function Hooks Panel

EDC or PDF Transport models must be enabled to hook the mixing model constant Cphi UDFs.

In the User-Defined Function Hooks panel, hook the UDF to FLUENT by choosing the function name (e.g., user_cphi) from the drop down list for Mixing Model Constant (Cphi), and click OK.

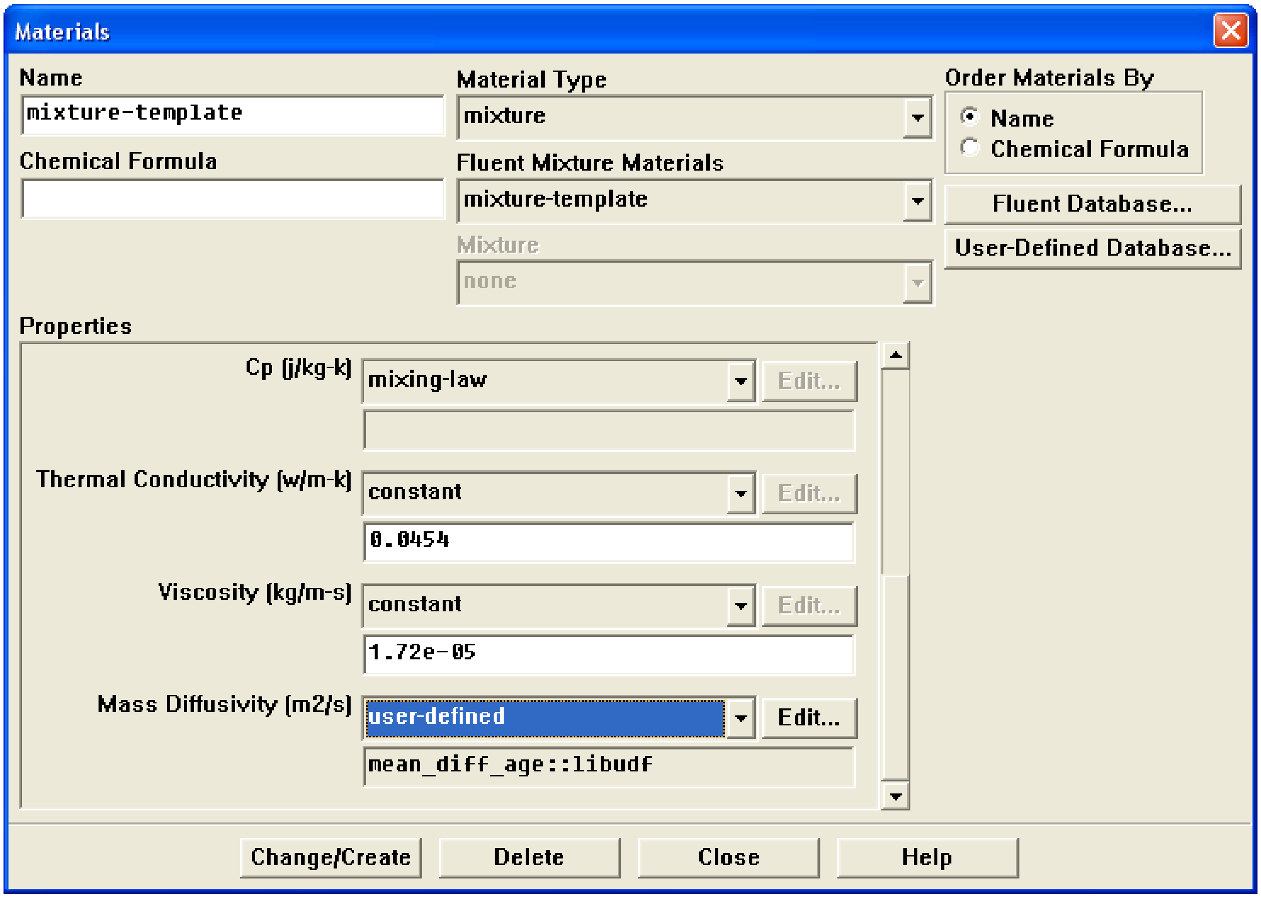
See Section 2.3.2: DEFINE_CPHI for details about defining DEFINE_CPHI functions.

6.2.3 Hooking DEFINE_DIFFUSIVITY UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DIFFUSIVITY UDF, the name of the function you supplied as a DEFINE macro argument (e.g., mean_diff_age) will become visible and selectable in FLUENT. To hook the UDF to FLUENT, you will first need to open the Materials panel.

Define ⟶Materials...

1. To hook a mass diffusivity UDF for the species tranpsort equations, choose user-defined from the drop-down list for Mass Diffusivity (Figure 6.2.3).



Name: mixture-template
Chemical Formula:
Material Type: mixture
Fluent Mixture Materials: mixture-template
Mixture: none

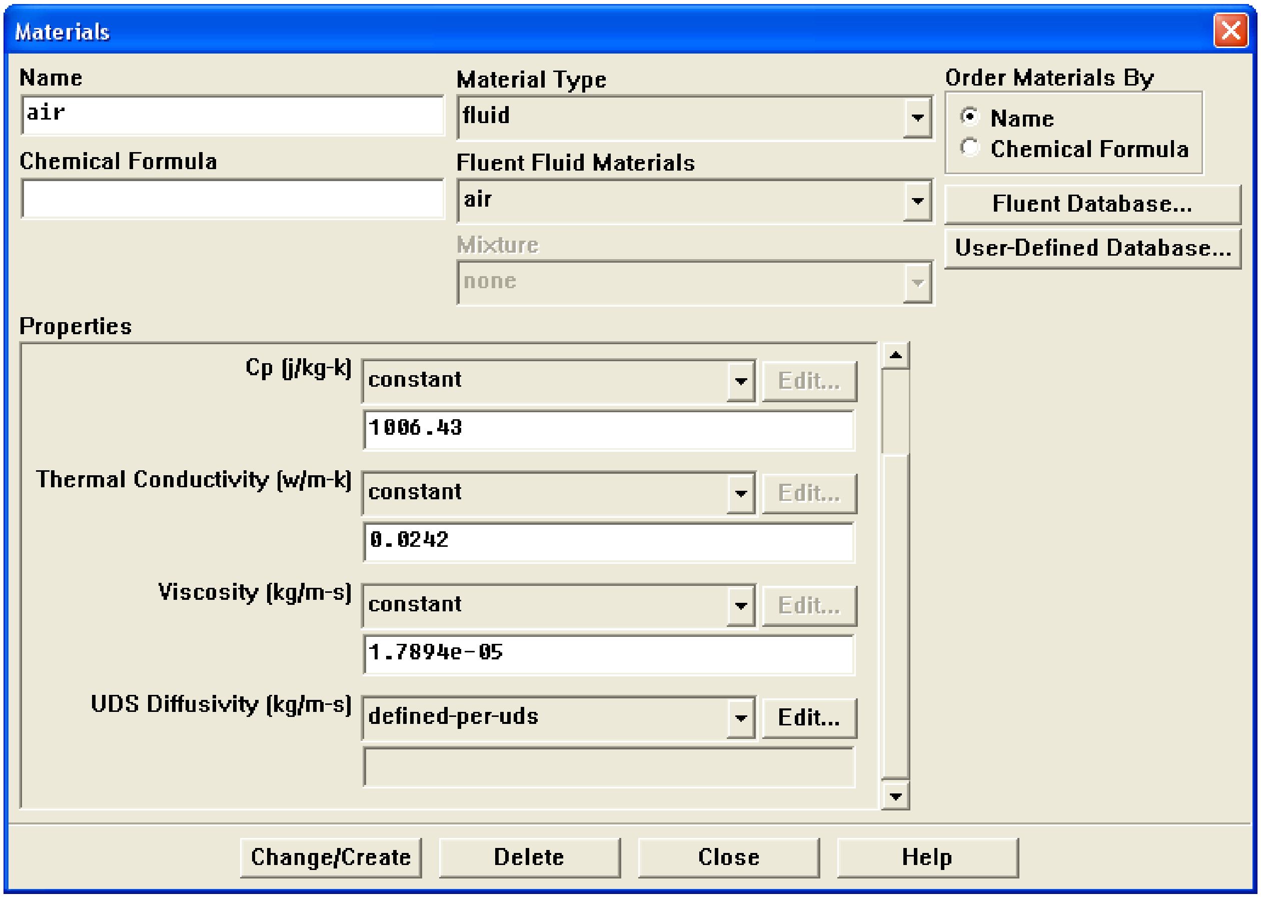
Cp (j/kg-k): mixing-law
Thermal Conductivity (w/m-k): constant, 0.0454
Viscosity (kg/m-s): constant, 1.72e-05
Mass Diffusivity (m2/s): user-defined, mean_diff_age::libudf

Figure 6.2.3: The Materials Panel

If you have previously interpreted or compiled a DEFINE_DIFFUSIVITY UDF, then the User-Defined Functions panel will open allowing you to hook your UDF to FLUENT. Othewise, you will get an error.

2. You have two options available for hooking diffusion coefficient UDFs to UDS equations. You can either specify a UDF on a per-UDS basis, or you can hook a single diffusivity UDF that will apply to all scalar equations.

   In the Materials panel, choose either defined-per-uds or user-defined from the drop-down list for UDS Diffusivity (Figure 6.2.4) and select the desired UDF.



Name: air

Chemical Formula:

Material Type: fluid

Fluent Fluid Materials: air

Mixture: none

Order Materials By: ● Name ○ Chemical Formula

Properties

Cp (j/kg-k): constant, 1006.43

Thermal Conductivity (w/m-k): constant, 0.0242

Viscosity (kg/m-s): constant, 1.7894e-05

UDS Diffusivity (kg/m-s): defined-per-uds

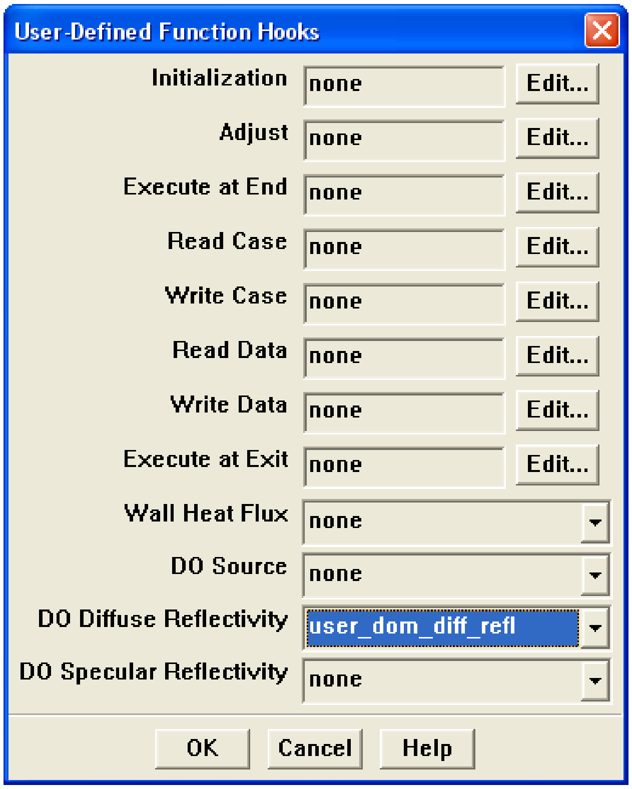
Figure 6.2.4: The Materials Panel

See Section 2.3.3: DEFINE_DIFFUSIVITY for details about defining DEFINE_DIFFUSIVITY UDFs and the User's Guide for general information about UDS diffusivity.

6.2.4 Hooking DEFINE_DOM_DIFFUSE_REFLECTIVITY UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DOM_DIFFUSE_REFLECTIVITY UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Function Hooks panel (Figure 6.2.5) in FLUENT.

Define ⟶ User-Defined ⟶Function Hooks...



User-Defined Function Hooks

Initialization: none
Adjust: none
Execute at End: none
Read Case: none
Write Case: none
Read Data: none
Write Data: none
Execute at Exit: none
Wall Heat Flux: none
DO Source: none
DO Diffuse Reflectivity: user_dom_diff_refl
DO Specular Reflectivity: none

Figure 6.2.5: The User-Defined Function Hooks Panel

> *i* The Discrete Ordinates radiation model must be enabled from the Radiation Model panel.

To hook the UDF to FLUENT, choose the function name (e.g., user_dom_diff_refl) in the DO Diffuse Reflectivity drop-down list in the User-Defined Function Hooks panel, and click OK.

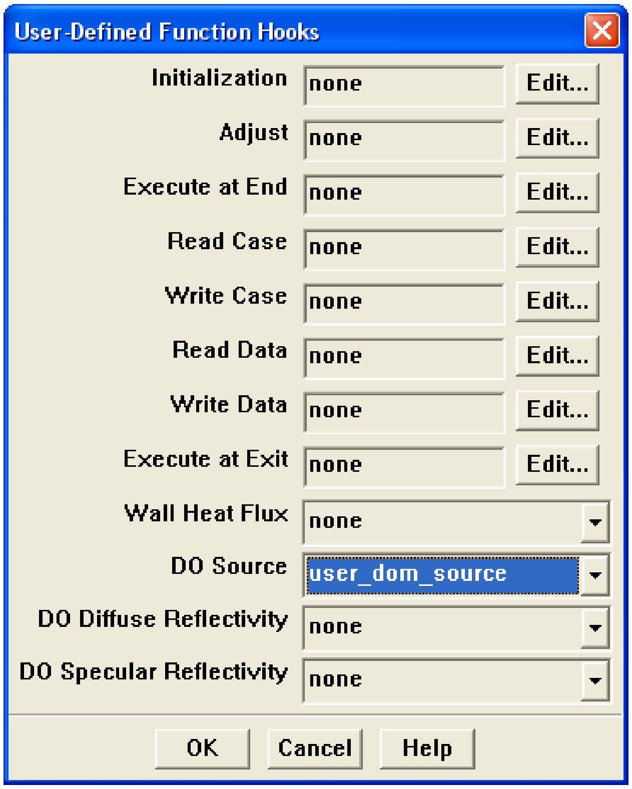
See Section 2.3.4: DEFINE_DOM_DIFFUSE_REFLECTIVITY for details about DEFINE_DOM_DIFFUSE_REFLECTIVITY functions.

6.2.5 Hooking DEFINE_DOM_SOURCE UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DOM_SOURCE UDF, compiled your DEFINE_DOM_SOURCE UDF (see Chapter 5: Compiling UDFs), the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Function Hooks panel (Figure 6.2.6) in FLUENT.

i The Discrete Ordinates radiation model must be enabled.

Define ⟶ User-Defined ⟶ Function Hooks...



User-Defined Function Hooks

Initialization: none
Adjust: none
Execute at End: none
Read Case: none
Write Case: none
Read Data: none
Write Data: none
Execute at Exit: none
Wall Heat Flux: none
DO Source: user_dom_source
DO Diffuse Reflectivity: none
DO Specular Reflectivity: none

Figure 6.2.6: The User-Defined Function Hooks Panel

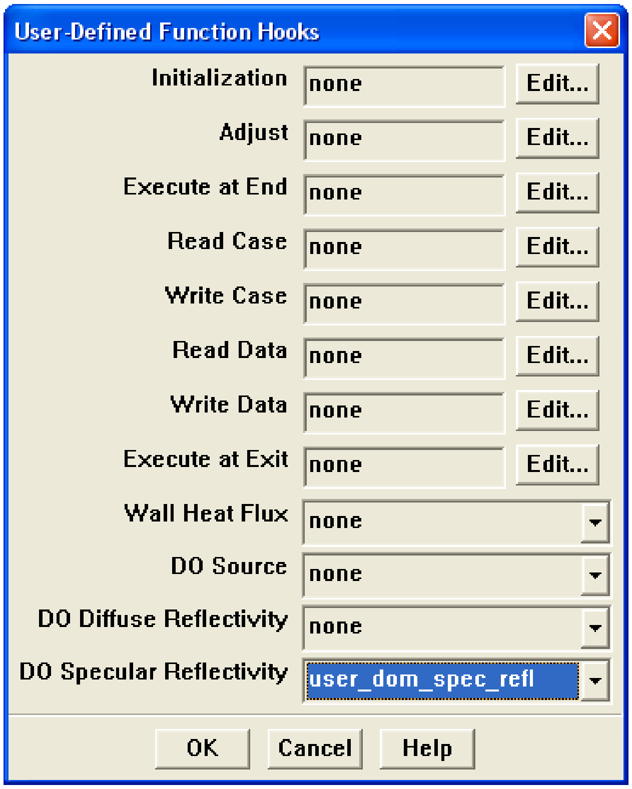
To hook the UDF to FLUENT, choose the function name (e.g., user_dom_source) in the DO Source drop-down list in the User-Defined Function Hooks panel, and click OK.

See Section 2.3.5: DEFINE_DOM_SOURCE for details about DEFINE_DOM_SOURCE functions.

6.2.6 Hooking DEFINE_DOM_SPECULAR_REFLECTIVITY UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DOM_SPECULAR_REFLECTIVITY UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Function Hooks panel (Figure 6.2.7) in FLUENT.

Define ⟶ User-Defined ⟶ Function Hooks...


User-Defined Function Hooks

Initialization: none

Adjust: none

Execute at End: none

Read Case: none

Write Case: none

Read Data: none

Write Data: none

Execute at Exit: none

Wall Heat Flux: none

DO Source: none

DO Diffuse Reflectivity: none

DO Specular Reflectivity: user_dom_spec_refl

Figure 6.2.7: The User-Defined Function Hooks Panel

> **i** The Discrete Ordinates radiation model must be enabled from the Radiation Model panel.

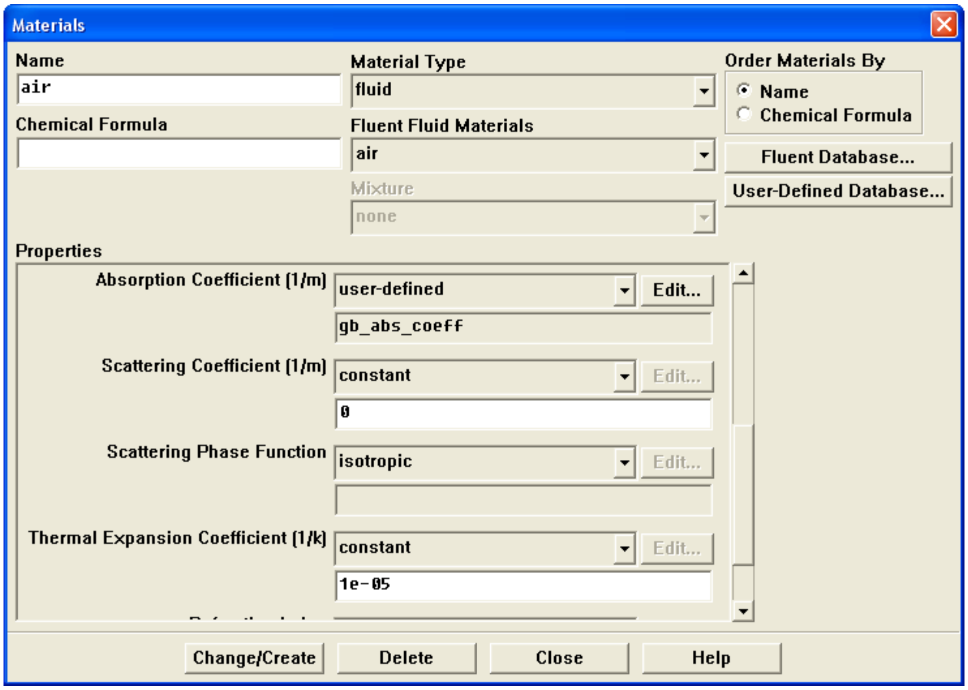
To hook the UDF to FLUENT, choose the function name (e.g., user_dom_spec_refl) in the DO Specular Reflectivity drop-down list in the User-Defined Function Hooks panel, and click OK.

See Section 2.3.4: DEFINE_DOM_DIFFUSE_REFLECTIVITY for details about DEFINE_DOM_SPECULAR_REFLECTIVITY functions.

6.2.7 Hooking DEFINE_GRAY_BAND_ABS_COEFF UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_GRAY_BAND_ABS_COEFF UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Materials panel (shown below) in FLUENT.

Define ⟶Materials...



Materials

Name: air

Chemical Formula:

Material Type: fluid

Fluent Fluid Materials: air

Mixture: none

Order Materials By: ● Name ○ Chemical Formula

Properties

Absorption Coefficient (1/m): user-defined — gb_abs_coeff

Scattering Coefficient (1/m): constant — 0

Scattering Phase Function: isotropic

Thermal Expansion Coefficient (1/k): constant — 1e-05

Figure 6.2.8: The Materials Panel

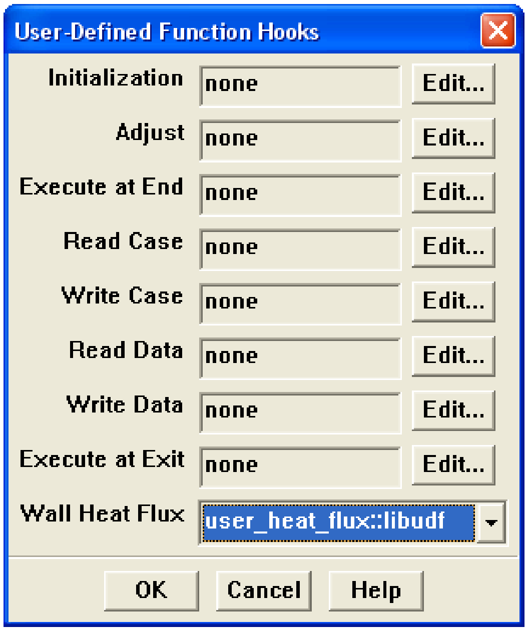
To hook the UDF to FLUENT, first select user-defined-gray-band from the Absorption Coefficient drop-down list in the Materials panel. (This will open the User-Defined Functions panel.) Then choose the name of the function (e.g., gb_abs_coeff) from the list of choices in the panel, and click OK.

See Section 2.3.7: DEFINE_GRAY_BAND_ABS_COEFF for details about DEFINE_GRAY_BAND_ABS_COEFF functions.

6.2.8 Hooking DEFINE_HEAT_FLUX UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_HEAT_FLUX UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Function Hooks panel (Figure 6.2.9) in FLUENT.

Define ⟶ User-Defined ⟶Function Hooks...



Initialization: none

Adjust: none

Execute at End: none

Read Case: none

Write Case: none

Read Data: none

Write Data: none

Execute at Exit: none

Wall Heat Flux: user_heat_flux::libudf

Figure 6.2.9: The User-Defined Function Hooks Panel

i The Energy Equation must be enabled.

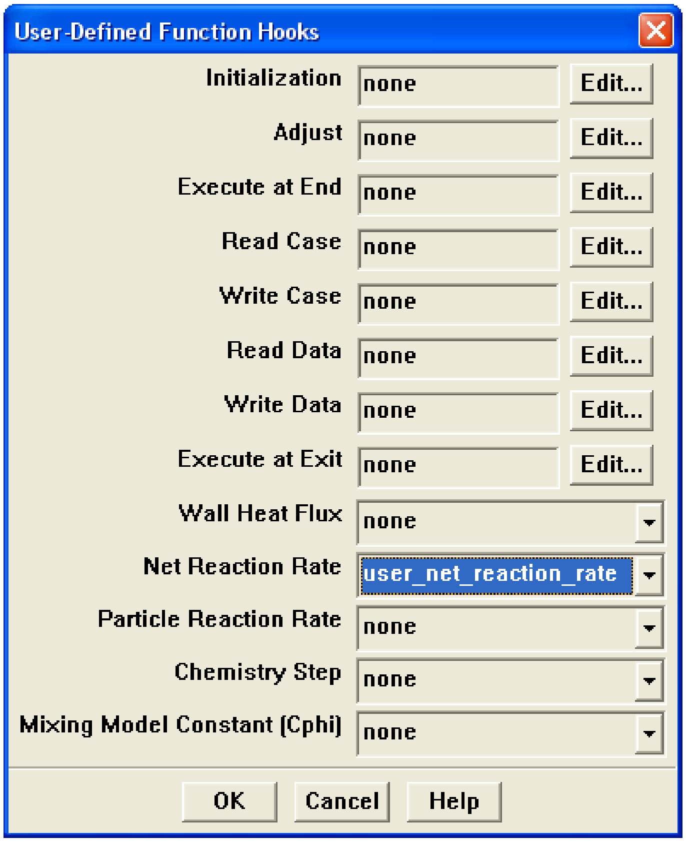
To hook the UDF to FLUENT, simply choose the function name (e.g., user_heat_flux) in the Wall Heat Flux drop-down list in the User-Defined Function Hooks panel, and click OK.

See Section 2.3.8: DEFINE_HEAT_FLUX for details about DEFINE_HEAT_FLUX functions.

6.2.9 Hooking DEFINE_NET_REACTION_RATE UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_NET_REACTION_RATE UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Function Hooks panel (Figure 6.2.10) in FLUENT.

Define ⟶ User-Defined ⟶ Function Hooks...



Initialization: none

Adjust: none

Execute at End: none

Read Case: none

Write Case: none

Read Data: none

Write Data: none

Execute at Exit: none

Wall Heat Flux: none

Net Reaction Rate: user_net_reaction_rate

Particle Reaction Rate: none

Chemistry Step: none

Mixing Model Constant (Cphi): none

Figure 6.2.10: The User-Defined Function Hooks Panel

> Net reaction rate UDFs may be used for the EDC and PDF Transport models, as well as for the surface chemistry model. To enable the PDF Transport models, select Composition PDF Transport and Volumetric reactions in the Species Model panel. To enable the EDC model, select Species Transport and Volumetric reactions in the Species Model panel, and choose EDC under Turbulence-Chemistry Interaction.

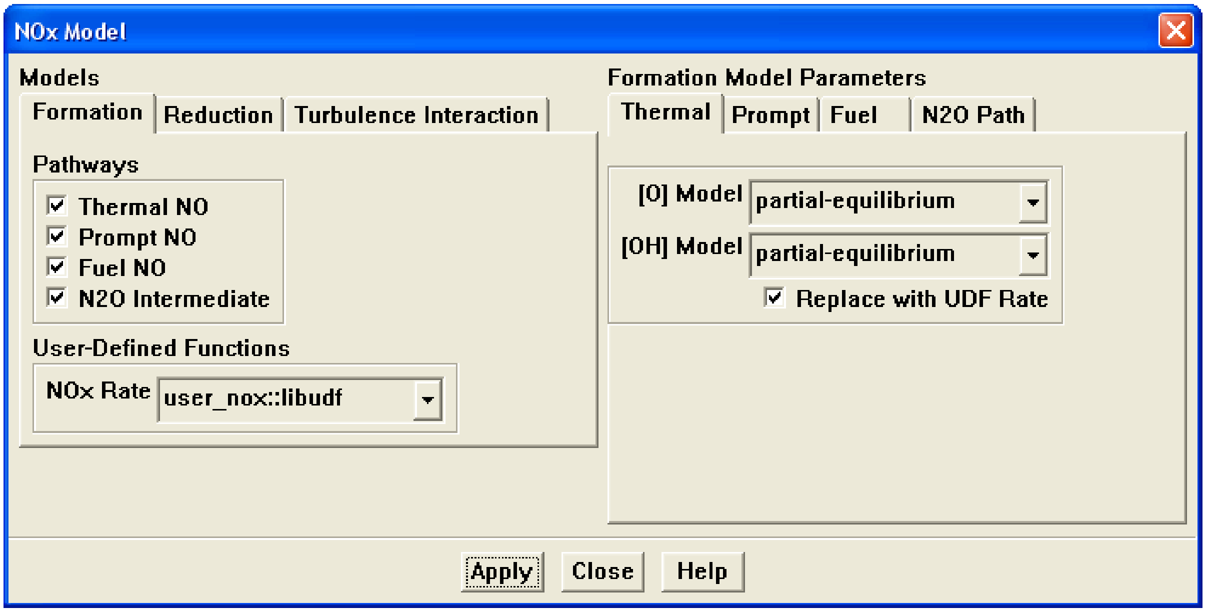
To hook the UDF to FLUENT, choose the function name (e.g., `usr_net_reaction_rate`) in the Net Reaction Rate Function drop-down list, and click OK.

See Section 2.3.9: `DEFINE_NET_REACTION_RATE` for details about `DEFINE_NET_REACTION_RATE` functions.

6.2.10 Hooking `DEFINE_NOX_RATE` UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your `DEFINE_NOX_RATE` UDF in FLUENT, the function name you supplied in the `DEFINE` macro argument will become visible and selectable in the drop-down list for NOx Rate in the NOx Model panel (Figure 6.2.11).

Define ⟶ Models ⟶ Species ⟶ NOx...



Pathways

☑ Thermal NO
☑ Prompt NO
☑ Fuel NO
☑ N2O Intermediate

User-Defined Functions

NOx Rate: user_nox::libudf

[O] Model: partial-equilibrium

[OH] Model: partial-equilibrium

☑ Replace with UDF Rate

Figure 6.2.11: The NOx Model Panel

i Note that the UDF name will not appear in the list until the function has been interpreted or compiled and loaded.

Recall that a single UDF is used to define custom rates for the thermal NO, prompt NO, fuel NO, and N20 NO_x pathways. To replace the internally-calculated NO_x rate with a UDF rate for any of the NO_x pathways, you will first need to choose the UDF name (e.g., user_nox) from the NOx Rate drop-down list, click on the desired NO_x pathway tab (Thermal, Prompt, Fuel, N20 Path) under Formation Model Parameters, check the Replace with UDF Rate box for that pathway, and then click Apply. Repeat this process until all of the NO_x pathways are set to the desired state (default rate or UDF rate). (Note that the Replace with UDF Rate checkbox appears only after you have selected a NO_x rate UDF.)

If you do not check the Replace with UDF Rate box for a particular pathway but hook the UDF function to the interface, then the UDF rate for that NO_x pathway will be *added to* the internally-calculated rate for the source term calculation.

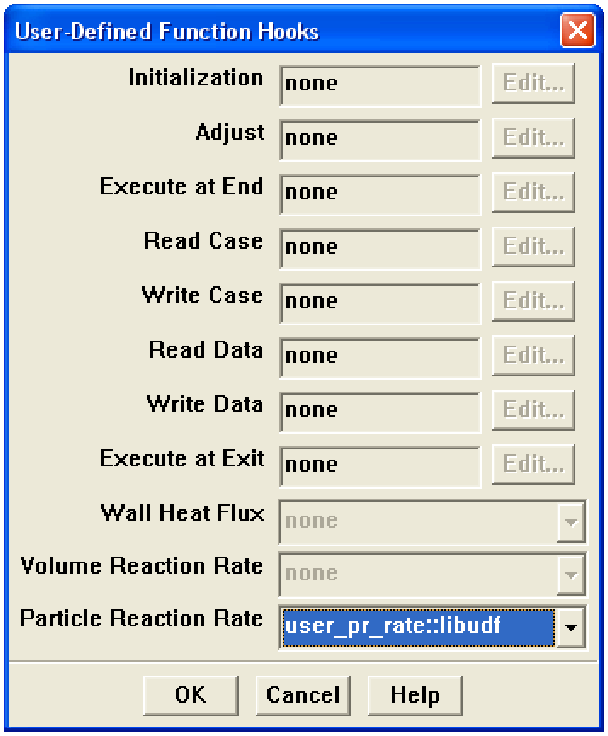
Unless specifically defined in your NO_x rate UDF, data and parameter settings for each individual NO_x pathway will be derived from the settings in the NOx Model panel. Therefore, it is good practice to make the appropriate settings in the NOx Model panel, even though you may use a UDF to replace the default rates with user-specified rates. There is no computational penalty for doing this because the default rate calculations will be skipped over when the Replace by UDF Rate option is selected.

See Section 2.3.10: `DEFINE_NOX_RATE` for details about defining `DEFINE_NOX_RATE` functions.

6.2.11 Hooking DEFINE_PR_RATE UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_PR_RATE UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Function Hooks panel (Figure 6.2.12) in FLUENT.

Define ⟶ User-Defined ⟶Function Hooks...



User-Defined Function Hooks

Initialization: none

Adjust: none

Execute at End: none

Read Case: none

Write Case: none

Read Data: none

Write Data: none

Execute at Exit: none

Wall Heat Flux: none

Volume Reaction Rate: none

Particle Reaction Rate: user_pr_rate::libudf

Figure 6.2.12: The User-Defined Function Hooks Panel

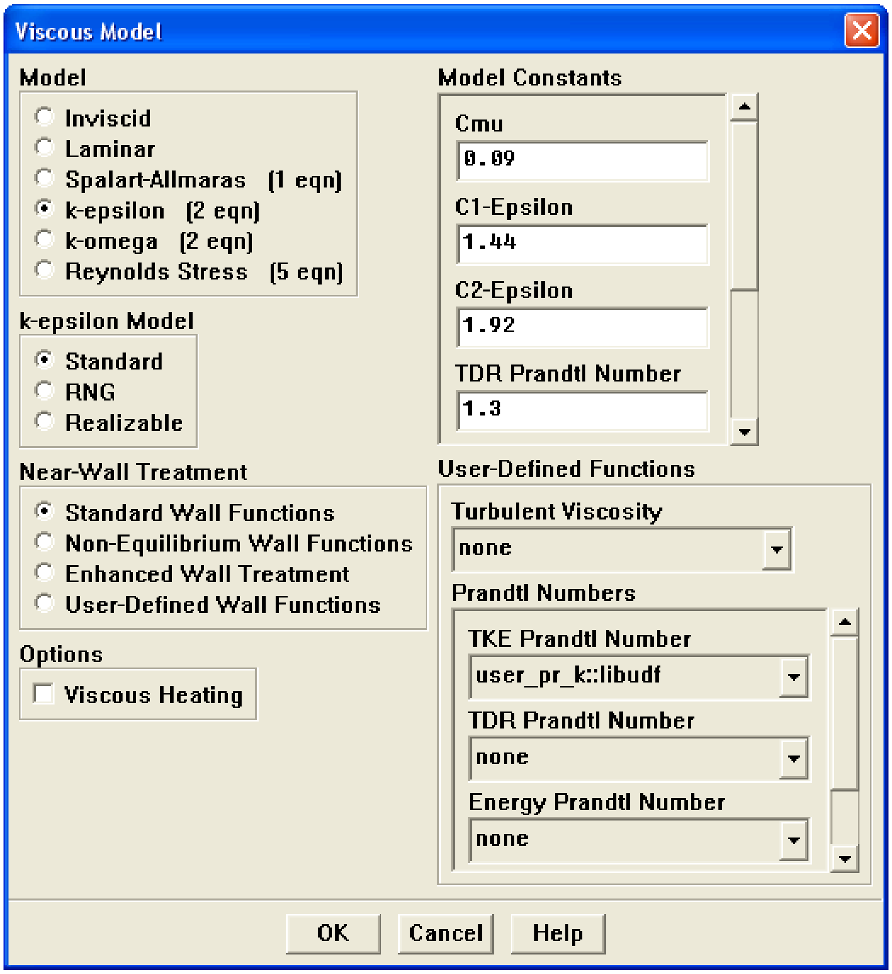
> You must enable the particle surface reactions option before you can hook the UDF by selecting Volumetric and Particle Surface under Reactions in the Species Model panel.

To hook the UDF to FLUENT, choose the function name (e.g., user_pr_rate) in the Particle Reaction Rate Function drop-down list in the User-Defined Function Hooks panel, and click OK.

See Section 2.3.11: DEFINE_PR_RATE for details about defining DEFINE_PR_RATE functions.

6.2.12 Hooking DEFINE_PRANDTL UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_PRANDTL UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Viscous Model panel (Figure 6.2.13) in FLUENT. Define ⟶ Models ⟶ Viscous...



Model
○ Inviscid
○ Laminar
○ Spalart-Allmaras (1 eqn)
● k-epsilon (2 eqn)
○ k-omega (2 eqn)
○ Reynolds Stress (5 eqn)

k-epsilon Model
● Standard
○ RNG
○ Realizable

Near-Wall Treatment
● Standard Wall Functions
○ Non-Equilibrium Wall Functions
○ Enhanced Wall Treatment
○ User-Defined Wall Functions

Options
□ Viscous Heating

Model Constants
Cmu 0.09
C1-Epsilon 1.44
C2-Epsilon 1.92
TDR Prandtl Number 1.3

User-Defined Functions
Turbulent Viscosity none

Prandtl Numbers
TKE Prandtl Number user_pr_k::libudf
TDR Prandtl Number none
Energy Prandtl Number none

Figure 6.2.13: The Viscous Model Panel

To hook the UDF to FLUENT, choose the function name (e.g., user_pr_k) in the TKE Prandtl Number drop-down list under User-Defined Functions in the panel Viscous Model panel, and click OK.

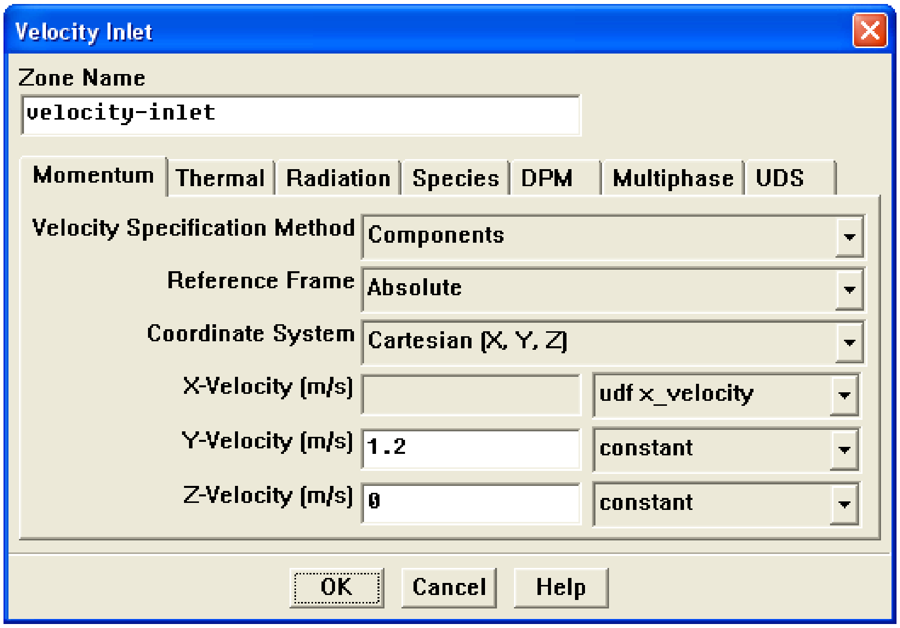
See Section 2.3.12: DEFINE_PRANDTL UDFs for details about DEFINE_PRANDTL functions.

6.2.13 Hooking DEFINE_PROFILE UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_PROFILE UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the appropriate boundary condition panel in FLUENT.

Define ⟶Boundary Conditions...

If, for example, your UDF defines a velocity inlet boundary condition, then to hook it to FLUENT first click on the Momentum tab in the Velocity Inlet panel (Figure 6.2.14) and then choose the function name (e.g., x_velocity) in the appropriate drop-down list (e.g., X Velocity) and click OK. Note that the UDF name that is displayed in the drop-down lists is preceded by the word udf (e.g., udf x_velocity).



Zone Name: velocity-inlet

Velocity Specification Method: Components

Reference Frame: Absolute

Coordinate System: Cartesian (X, Y, Z)

X-Velocity (m/s): udf x_velocity

Y-Velocity (m/s): 1.2 constant

Z-Velocity (m/s): 0 constant

Figure 6.2.14: The Velocity Inlet Panel

If you are using your UDF to specify a fixed value in a cell zone, you will need to turn on the Fixed Values option in the Fluid or Solid panel and click the Fixed Values tab. This will display the fixed values parameters in the scrollable window. Next, select the name of the UDF in the appropriate drop-down list for the value you wish to set.

See Section 2.3.13: DEFINE_PROFILE for details about DEFINE_PROFILE functions.

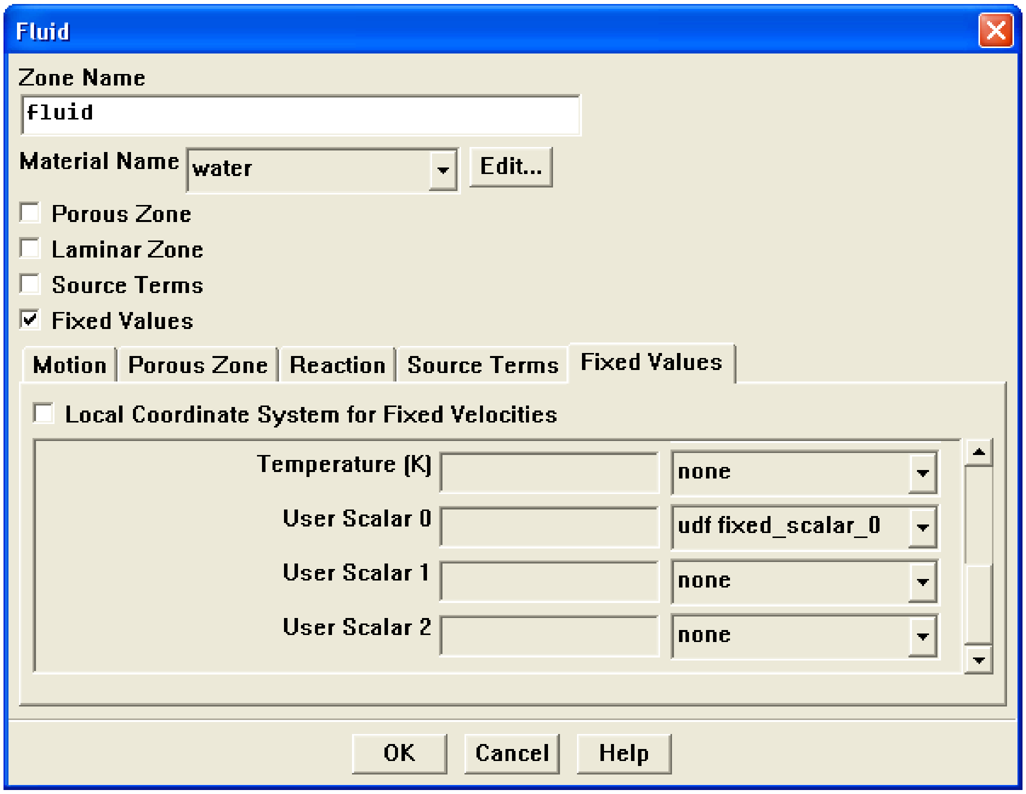
Hooking Profiles for UDS Equations

For each of the N scalar equations you have specified in your FLUENT model using the User-Defined Scalars panel you can hook a fixed value UDF for a cell zone (e.g., Fluid or Solid) and a specified value or flux UDF for all wall, inflow, and outflow boundaries.

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your `DEFINE_PROFILE` UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the appropriate boundary condition panel.

Define ⟶Boundary Conditions...

1. If you are using your UDF to specify a fixed value in a cell zone, you will need to turn on the Fixed Values option in the Fluid or Solid panel and click the Fixed Values tab (Figure 6.2.15). This will display the fixed values parameters in the scrollable window under the Fixed Values tab. Next, select the name of the UDF (e.g., fixed_scalar_0) in the appropriate drop-down list for the value you wish to set.



Fluid

Zone Name: fluid

Material Name: water

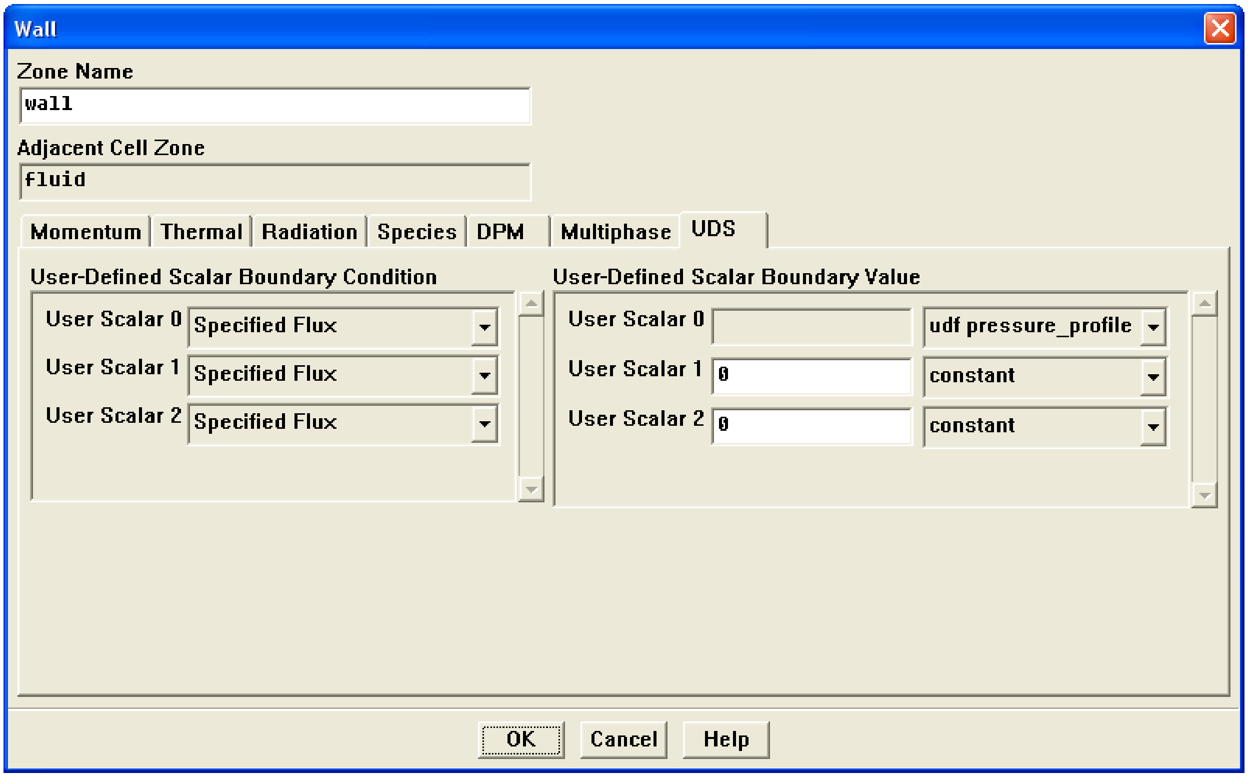
☐ Porous Zone
☐ Laminar Zone
☐ Source Terms
☑ Fixed Values

☐ Local Coordinate System for Fixed Velocities

Temperature (K): none
User Scalar 0: udf fixed_scalar_0
User Scalar 1: none
User Scalar 2: none

Figure 6.2.15: The Fluid Panel with Fixed Value Inputs for User-Defined Scalars

2. If you are using your UDF to define a specific value or flux for a scalar equation, you will need to first select the UDS tab in the wall, inflow, or outflow boundary panel (Figure 6.2.16).



Zone Name: wall

Adjacent Cell Zone: fluid

User-Defined Scalar Boundary Condition

User Scalar 0: Specified Flux
User Scalar 1: Specified Flux
User Scalar 2: Specified Flux

User-Defined Scalar Boundary Value

User Scalar 0: udf pressure_profile
User Scalar 1: 0 constant
User Scalar 2: 0 constant

Figure 6.2.16: The Wall Panel with Inputs for User-Defined Scalars

Next, for each UDS (User Scalar 0, User Scalar 1, etc.) specify the boundary condition value as a constant value or a UDF (e.g., pressure_profile). If you select Specified Flux, then your input will be the value of the flux at the boundary (i.e., the negative of the term in parentheses on the left hand side of Equation 9.3-2 in the User's Guide dot [as in the dot product of] **n** [as in the vector, n], where **n** is the normal into the domain). If you select Specified Value, then your input will be the value of the scalar itself at the boundary. In the sample panel shown above, for example, the Specified Value for User Scalar 0 is set to a pressure_profile UDF.

Note that for interior walls, you will need to select Coupled Boundary if the scalars are to be solved on both sides of a two-sided wall. Note that the Coupled Boundary option will show up only in the drop-down list when the scalar is defined in the fluid and solid zones in the User-Defined Scalars panel.

i In some cases, you may wish to exclude diffusion of the scalar at the inlet of your domain. You can do this by disabling diffusion of the scalar at the inlet in the User-Defined Scalars panel.

See Section 2.3.13: DEFINE_PROFILE for details about DEFINE_PROFILE functions.

6.2.14 Hooking DEFINE_PROPERTY UDFs

Material Properties

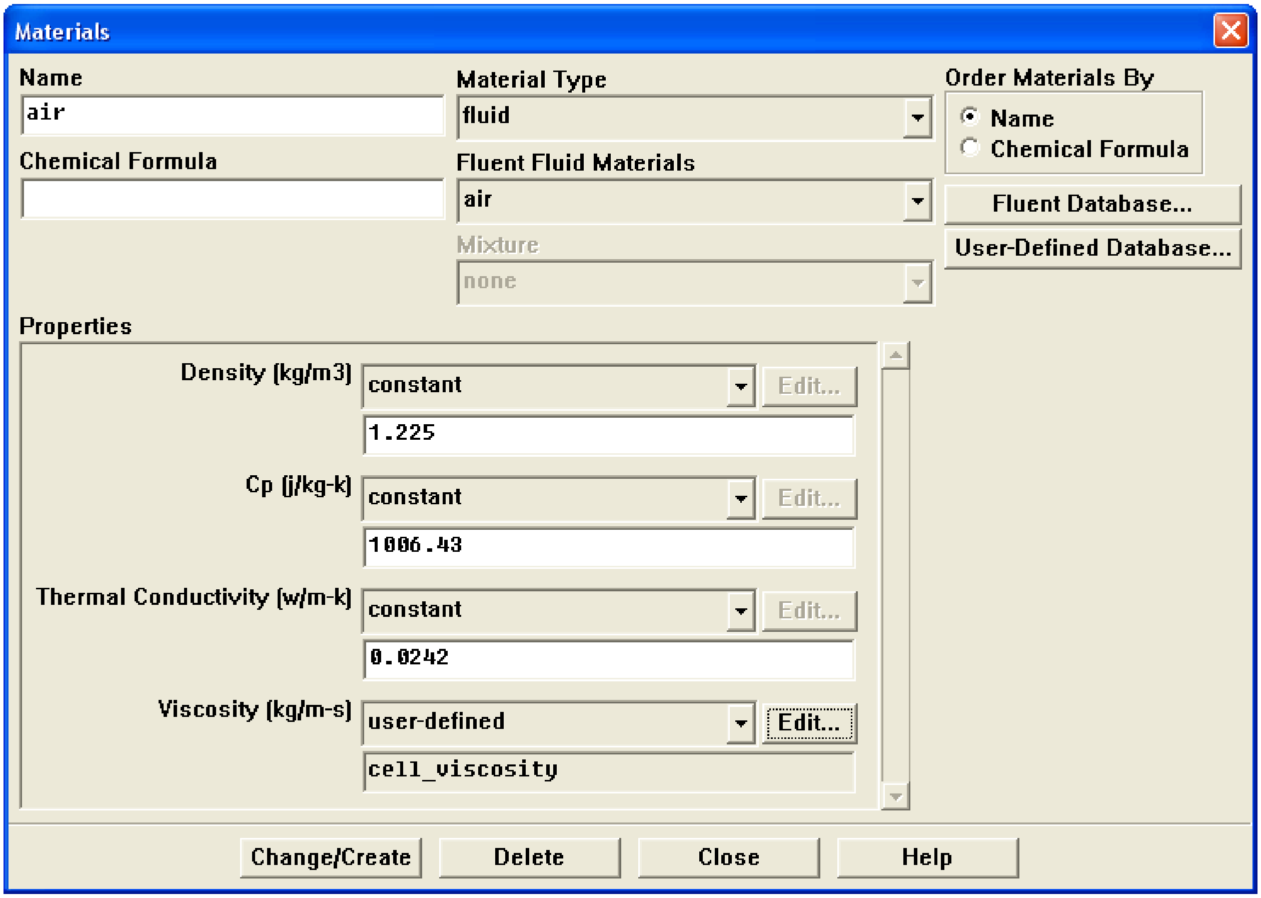
Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your material property UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Functions panel (Figure 6.2.18) in FLUENT. To hook the UDF to FLUENT, you will first need to open the User-Defined Functions panel by choosing user-defined in the drop-down list for the appropriate property (e.g., Viscosity) in the Materials panel (Figure 6.2.17).

Define ⟶Materials...

Next, choose the function name (e.g., cell_viscosity) from the list of UDFs displayed in the User-Defined Functions panel, (Figure 6.2.18) and click OK. The name of the function will subsequently be displayed under the selected property (e.g., Viscosity) in the Materials panel.

i If you plan to define density using a UDF, note that the solution convergence will become poor as the density variation becomes large. Specifying a compressible law (density as a function of pressure) or multiphase behavior (spatially varying density) may lead to divergence. It is recommended that you restrict the use of UDFs for density to weakly compressible flows with mild density variations.

See Section 2.3.14: DEFINE_PROPERTY UDFs for details about DEFINE_PROPERTY functions.



Materials

Name: air

Chemical Formula:

Material Type: fluid

Fluent Fluid Materials: air

Mixture: none

Order Materials By
● Name
○ Chemical Formula

Properties

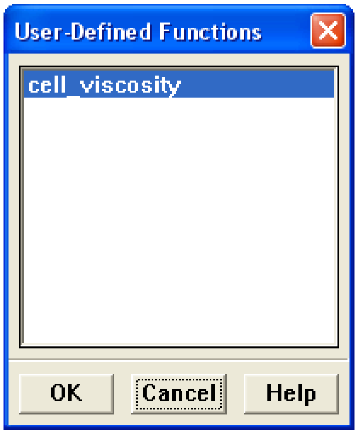
Density (kg/m3): constant
1.225

Cp (j/kg-k): constant
1006.43

Thermal Conductivity (w/m-k): constant
0.0242

Viscosity (kg/m-s): user-defined
cell_viscosity

Figure 6.2.17: The Materials Panel



User-Defined Functions

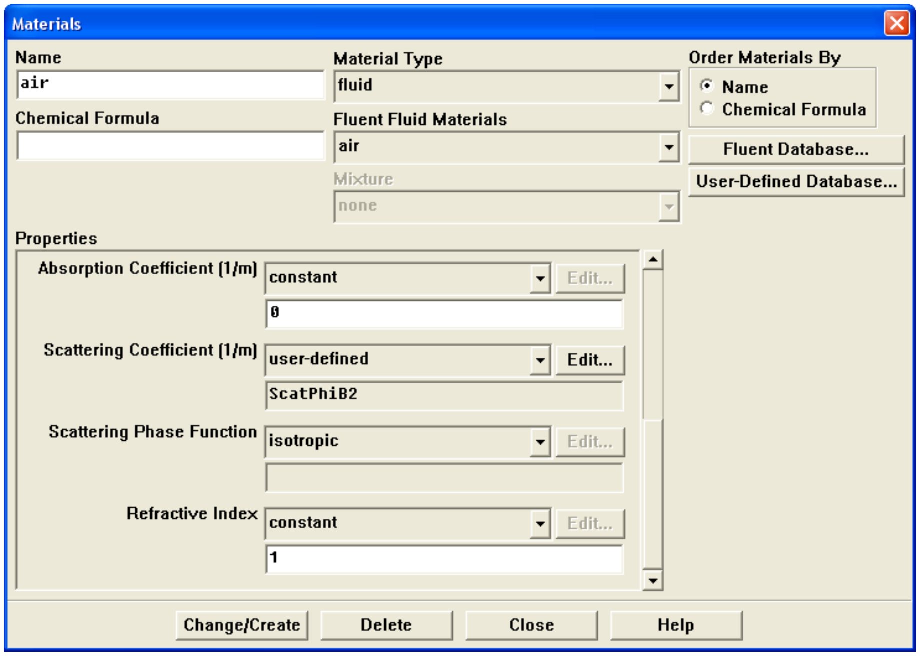
cell_viscosity

Figure 6.2.18: The User-Defined Functions Panel

6.2.15 Hooking `DEFINE_SCAT_PHASE_FUNC` UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your `DEFINE_SCAT_PHASE_FUNC` UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Functions panel (Figure 6.2.20) in FLUENT. To hook the UDF to FLUENT, you will first need to open the User-Defined Functions panel from the Material panel by selecting user-defined in the drop-down list for the Scattering Phase Function property (Figure 6.2.19).

Define ⟶Materials...



Name: air

Chemical Formula:

Material Type: fluid

Fluent Fluid Materials: air

Mixture: none

Order Materials By: ● Name ○ Chemical Formula

Absorption Coefficient (1/m): constant, 0

Scattering Coefficient (1/m): user-defined, ScatPhiB2

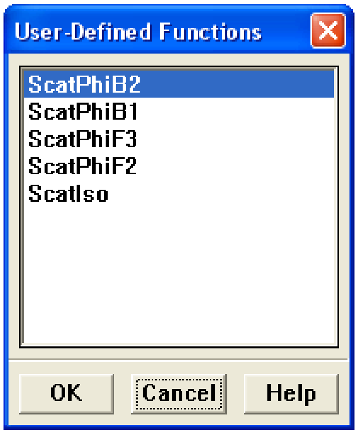
Scattering Phase Function: isotropic

Refractive Index: constant, 1

Figure 6.2.19: The Materials Panel

i The Discrete Ordinates radiation model must be enabled from the Radiation Model panel.

Next, choose the function name (e.g., ScatPhiB2) from the list of UDFs displayed in the User-Defined Functions panel, and click OK. The name of the function will subsequently be displayed under the Scattering Phase Function property in the Materials panel.


User-Defined Functions

ScatPhiB2
ScatPhiB1
ScatPhiF3
ScatPhiF2
ScatIso

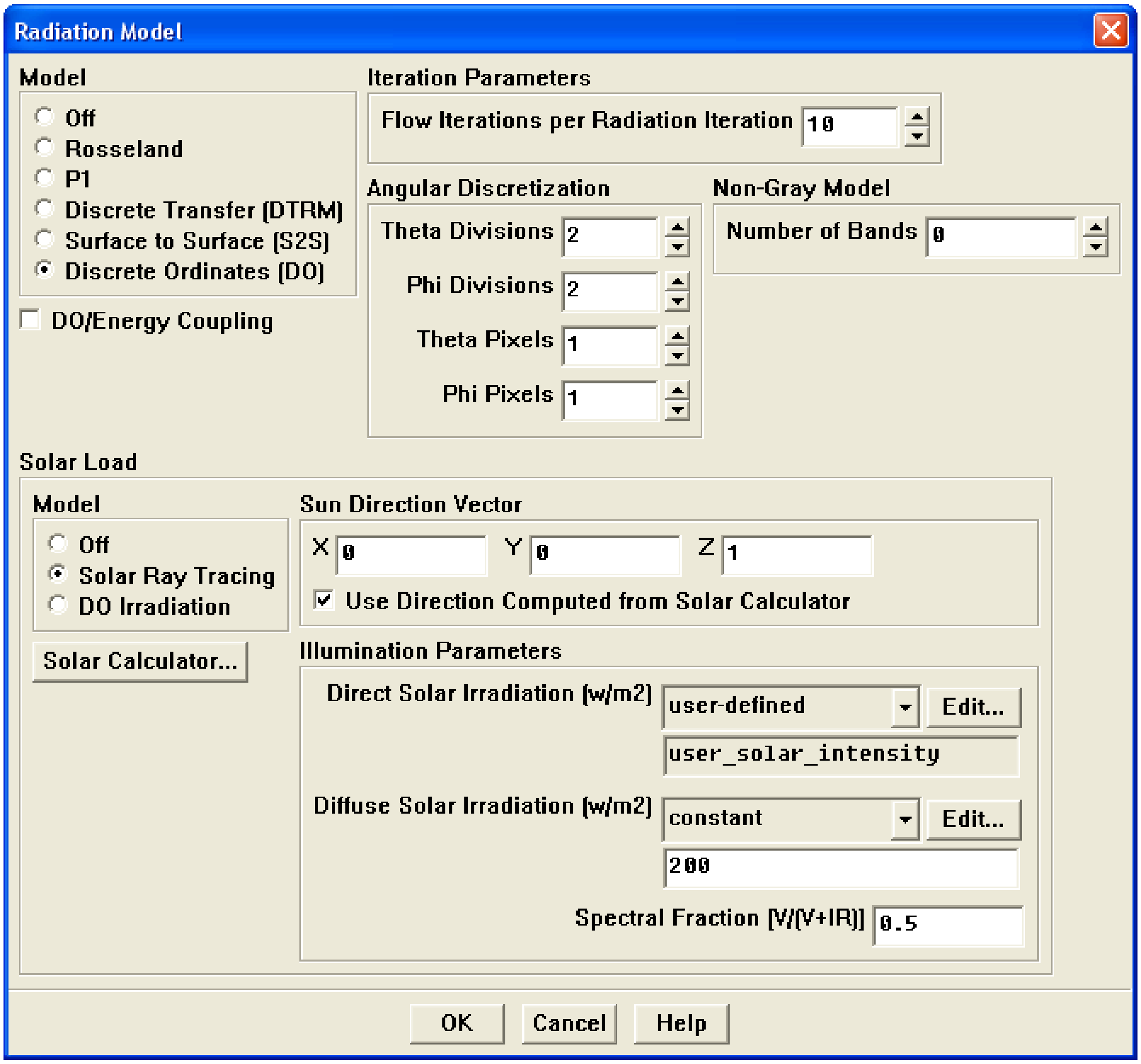
Figure 6.2.20: The User-Defined Functions Panel

See Section 2.3.15: DEFINE_SCAT_PHASE_FUNC for details about DEFINE_SCAT_PHASE_FUNC functions.

6.2.16 Hooking DEFINE_SOLAR_INTENSITY UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_SOLAR_INTENSITY UDF, the name of the function you supplied as a DEFINE macro argument you supplied in the argument of the DEFINE macro will become selectable in the Radiation Model panel for Direct Solar Irradiation and Diffuse Solar Irradiation(Figure 6.2.21).

Define ⟶ Models ⟶Radiation...



Radiation Model

Model
- ○ Off
- ○ Rosseland
- ○ P1
- ○ Discrete Transfer (DTRM)
- ○ Surface to Surface (S2S)
- ● Discrete Ordinates (DO)

□ DO/Energy Coupling

Iteration Parameters

Flow Iterations per Radiation Iteration: 10

Angular Discretization

Theta Divisions: 2

Phi Divisions: 2

Theta Pixels: 1

Phi Pixels: 1

Non-Gray Model

Number of Bands: 0

Solar Load

Model
- ○ Off
- ● Solar Ray Tracing
- ○ DO Irradiation

Sun Direction Vector

X: 0 Y: 0 Z: 1

☑ Use Direction Computed from Solar Calculator

Illumination Parameters

Direct Solar Irradiation (w/m2): user-defined

user_solar_intensity

Diffuse Solar Irradiation (w/m2): constant

200

Spectral Fraction [V/(V+IR)]: 0.5

Figure 6.2.21: The Radiation Model Panel

To hook the UDF to FLUENT, first choose user-defined from the Direct or Diffuse Solar Irradiation drop-down list under Illumination Parameters in the Radiation Model panel. (This will open the User-Defined Functions panel.) Select the function name (e.g., `user_solar_intensity`) from the UDF list in the User-Defined Functions panel and click OK. The UDF name will appear in the text entry box below the parameter drop-down list in the Radiation Model panel. (Figure 6.2.21)

See Section 2.3.16: `DEFINE_SOLAR_INTENSITY` for details about `DEFINE_SOLAR_INTENSITY` functions.

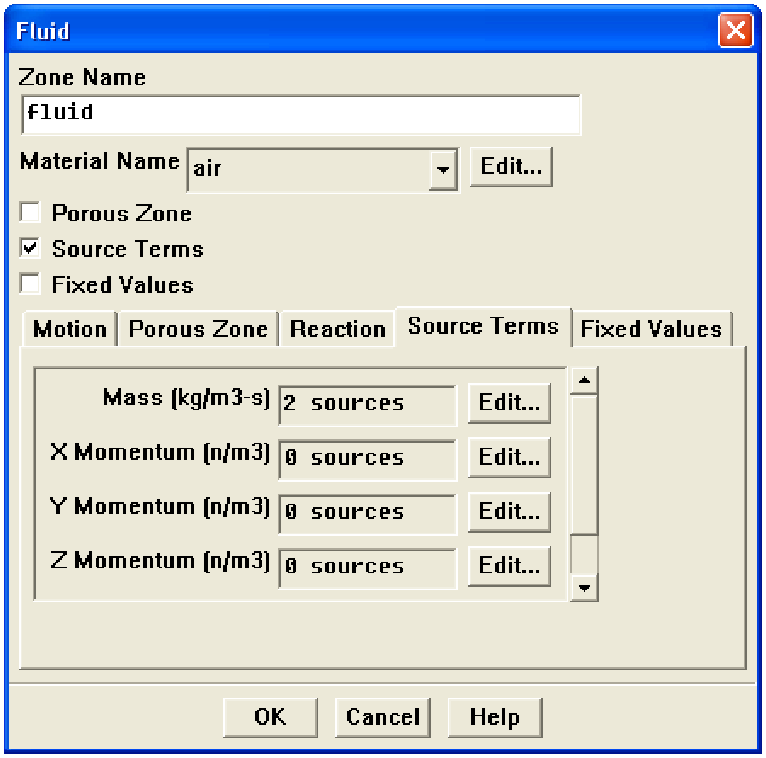
6.2.17 Hooking `DEFINE_SOURCE` UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your `DEFINE_SOURCE` UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Fluid or Solid panel in FLUENT. To hook the UDF to FLUENT, you will first need to turn on the Source Terms option in the Fluid or Solid panel (Figure 6.2.22) and click the Source Terms tab. This will display the source term parameters (mass, momentum, etc.) in the scrollable window.

Define ⟶Boundary Conditions...

Next, click the Edit... button next to the source term (e.g., Mass) you wish to customize (Figure 6.2.22).

Next, click the Edit... button next to the X Momentum source term. This will open the Mass Sources panel where you will select the number of terms you wish to model (Figure 6.2.23).



Fluid

Zone Name

fluid

Material Name air

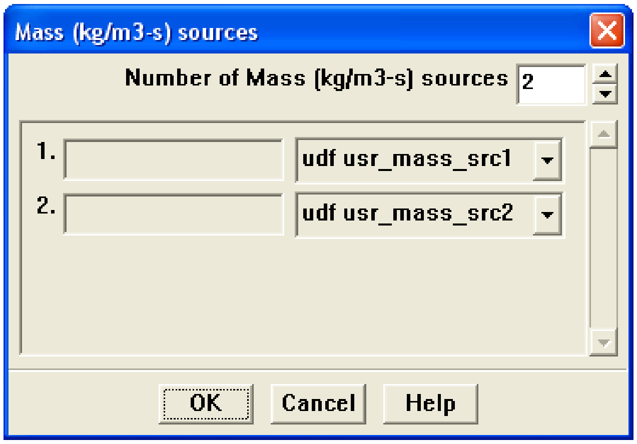
□ Porous Zone

☑ Source Terms

□ Fixed Values

Mass (kg/m3-s)	2 sources
X Momentum (n/m3)	0 sources
Y Momentum (n/m3)	0 sources
Z Momentum (n/m3)	0 sources

Figure 6.2.22: The Fluid Panel



Mass (kg/m3-s) sources

Number of Mass (kg/m3-s) sources 2

1. udf usr_mass_src1

2. udf usr_mass_src2

Figure 6.2.23: The Fluid Panel

Increment the Number of Mass Sources counter (e.g., 2) and then choose the function name (e.g., udf usr_mass_src1 and udf usr_mass_src2) from the appropriate drop-down list. (Note that the UDF name that is displayed in the drop-down lists is preceeded by the word udf.) Click OK in the Mass Sources panel to accept the new boundary condition and close the panel. The Mass source term in the Fluid panel will now display 2 sources. Click OK to close the Fluid panel and fix the new mass source terms for the solution calculation.

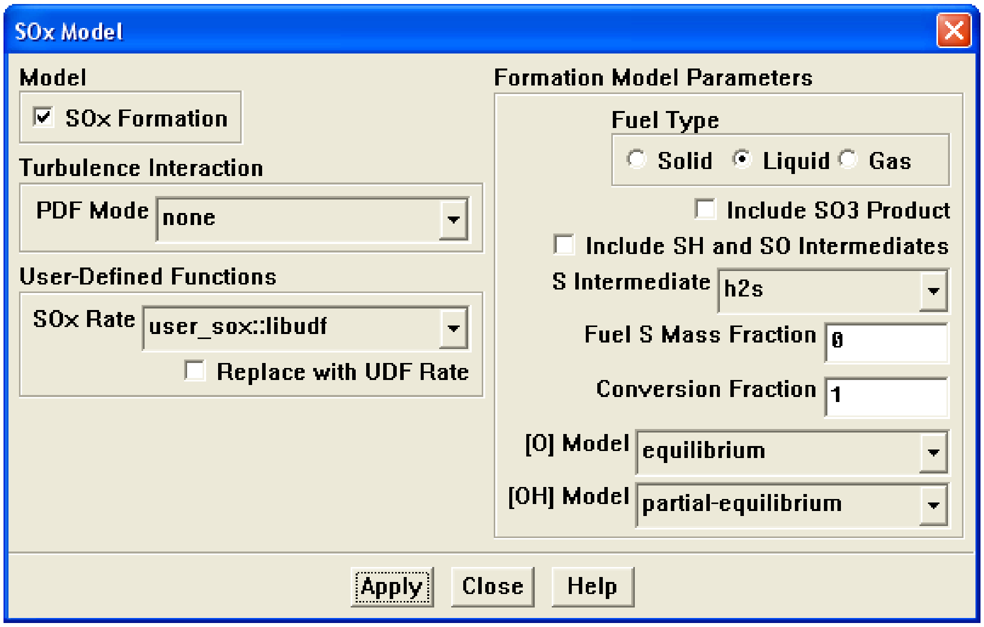
Repeat this step for all of the source terms you wish to customize using a UDF.

See Section 2.3.17: `DEFINE_SOURCE` for details about `DEFINE_SOURCE` functions.

6.2.18 Hooking DEFINE_SOX_RATE UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_SOX_RATE UDF in FLUENT, the function name you supplied in the DEFINE macro argument will become visible and selectable for the SOx Rate in the SOx Model panel (Figure 6.2.24).

Define ⟶ Models ⟶ Species ⟶ SOx...



Model
☑ SOx Formation

Turbulence Interaction
PDF Mode: none

User-Defined Functions
SOx Rate: user_sox::libudf
□ Replace with UDF Rate

Formation Model Parameters
Fuel Type: ○ Solid ● Liquid ○ Gas
□ Include SO3 Product
□ Include SH and SO Intermediates
S Intermediate: h2s
Fuel S Mass Fraction: 0
Conversion Fraction: 1
[O] Model: equilibrium
[OH] Model: partial-equilibrium

Figure 6.2.24: The SOx Model Panel

Note that the UDF name will not appear in the list until the function has been interpreted or compiled and loaded.

Recall that a single UDF can be used to define custom rates for SOx Formation. To replace the internally-calculated SO_x rate with a UDF rate, you will first need to choose the UDF name (e.g., user_sox) from the SOx Rate drop-down list, check the Replace with UDF Rate box, and then click Apply. (Note that the Replace with UDF Rate checkbox appears only after you have selected a SO_x rate UDF.)

If you don't check the Replace with UDF Rate box but hook the UDF function to the interface, then the UDF rate for that SO_x formation will be *added to* the internally-calculated rate for the source term calculation.

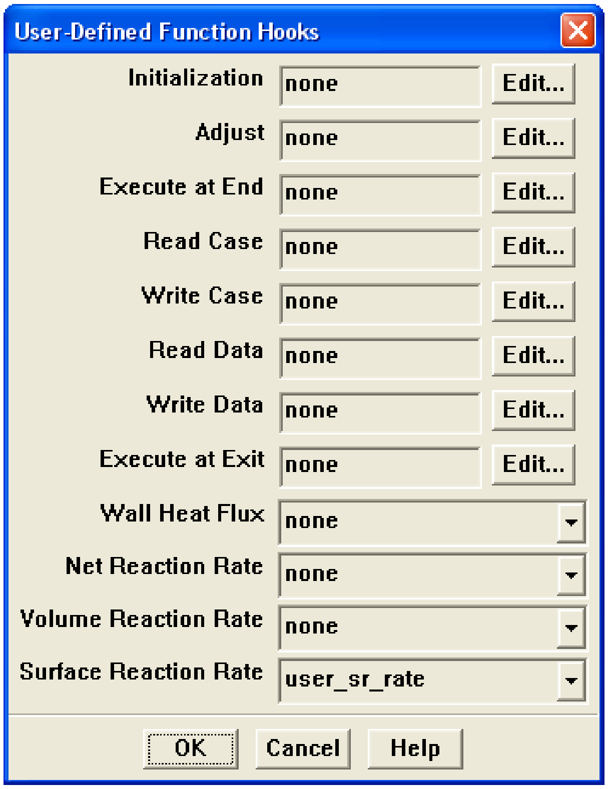
Unless specifically defined in your SO_x rate UDF, data and parameter settings will be derived from the settings in the SOx Model panel. Therefore, it is good practice to make the appropriate settings in the SOx Model panel, even though you may use a UDF to replace the default rates with user-specified rates. There is no computational penalty for doing this because the default rate calculations will be skipped over when the Replace by UDF Rate option is selected.

See Section 2.3.18: DEFINE_SOX_RATE for details about defining DEFINE_SOX_RATE functions.

6.2.19 Hooking DEFINE_SR_RATE UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_SR_RATE UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Function Hooks panel (Figure 6.2.25) in FLUENT.

Define ⟶ User-Defined ⟶Function Hooks...



Initialization: none
Adjust: none
Execute at End: none
Read Case: none
Write Case: none
Read Data: none
Write Data: none
Execute at Exit: none
Wall Heat Flux: none
Net Reaction Rate: none
Volume Reaction Rate: none
Surface Reaction Rate: user_sr_rate

Figure 6.2.25: The User-Defined Function Hooks Panel

You must enable the wall surface reactions option before you can hook the UDF by selecting Volumetric and Wall Surface under Reactions in the Species Model panel.

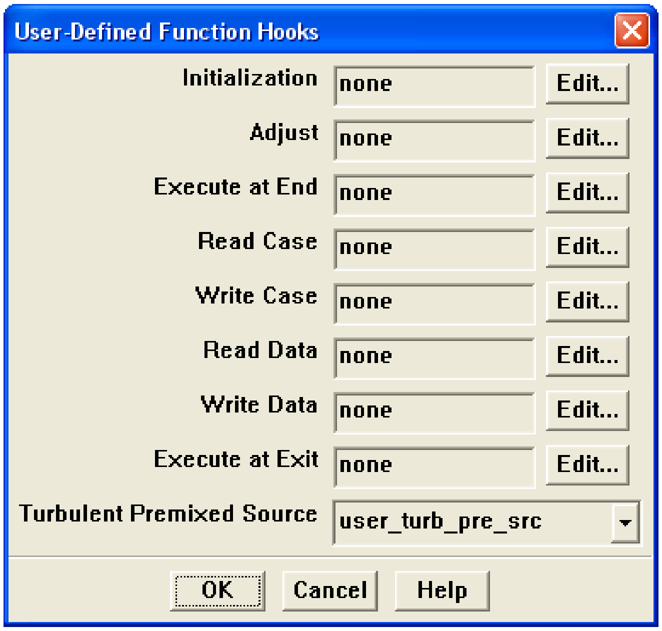
To hook the UDF to FLUENT, choose the function name (e.g., user_sr_rate) in the Surface Reaction Rate Function drop-down list in the User-Defined Function Hooks panel, and click OK.

See Section 2.3.19: `DEFINE_SR_RATE` for details about `DEFINE_SR_RATE` functions.

6.2.20 Hooking `DEFINE_TURB_PREMIX_SOURCE` UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your `DEFINE_TURB_PREMIX_SOURCE` UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Function Hooks panel (Figure 6.2.26) in FLUENT.

Define ⟶ User-Defined ⟶Function Hooks...



Initialization: none
Adjust: none
Execute at End: none
Read Case: none
Write Case: none
Read Data: none
Write Data: none
Execute at Exit: none
Turbulent Premixed Source: user_turb_pre_src

Figure 6.2.26: The User-Defined Function Hooks Panel

You must have a premixed combustion model enabled in the Species Model panel.

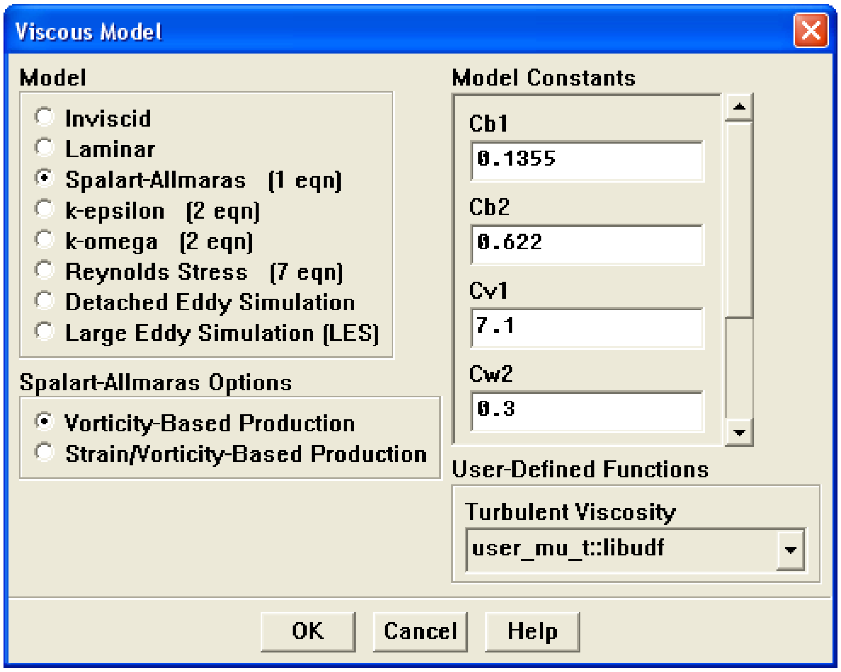
To hook the UDF to FLUENT, choose the function name (e.g., user_turb_pre_src) in the Turbulent Premixed Source Function drop-down list in the User-Defined Function Hooks panel, and click OK.

See Section 2.3.20: DEFINE_TURB_PREMIX_SOURCE for details about DEFINE_TURB_PREMIX_SOURCE functions.

6.2.21 Hooking DEFINE_TURBULENT_VISCOSITY UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_TURBULENT_VISCOSITY UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Viscous Model panel (Figure 6.2.27) in FLUENT.

Define ⟶ Models ⟶ Viscous...



Viscous Model

Model
○ Inviscid
○ Laminar
● Spalart-Allmaras (1 eqn)
○ k-epsilon (2 eqn)
○ k-omega (2 eqn)
○ Reynolds Stress (7 eqn)
○ Detached Eddy Simulation
○ Large Eddy Simulation (LES)

Spalart-Allmaras Options
● Vorticity-Based Production
○ Strain/Vorticity-Based Production

Model Constants
Cb1: 0.1355
Cb2: 0.622
Cv1: 7.1
Cw2: 0.3

User-Defined Functions
Turbulent Viscosity: user_mu_t::libudf

Figure 6.2.27: The Viscous Model Panel

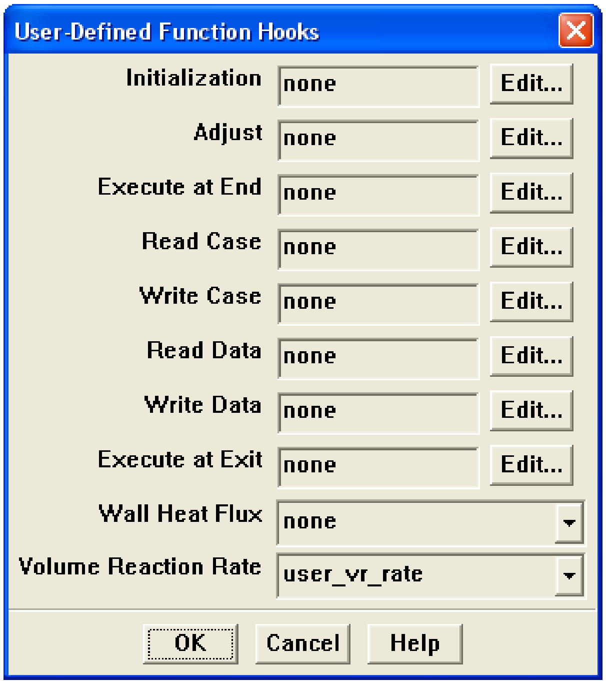
To hook the UDF to FLUENT, choose the function name (e.g., user_mu_t) in the Turbulence Viscosity drop-down list under User-Defined Functions in the Viscous Model panel, and click OK.

See Section 2.3.21: DEFINE_TURBULENT_VISCOSITY for details about DEFINE_TURBULENT_VISCOSITY functions.

6.2.22 Hooking DEFINE_VR_RATE UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_VR_RATE UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Function Hooks panel (Figure 6.2.28) in FLUENT.

Define ⟶ User-Defined ⟶ Function Hooks...



Initialization: none
Adjust: none
Execute at End: none
Read Case: none
Write Case: none
Read Data: none
Write Data: none
Execute at Exit: none
Wall Heat Flux: none
Volume Reaction Rate: user_vr_rate

Figure 6.2.28: The User-Defined Function Hooks Panel

You must turn on the volumetric reactions option before you can hook the UDF by selecting Volumetric under Reactions in the Species Model panel.

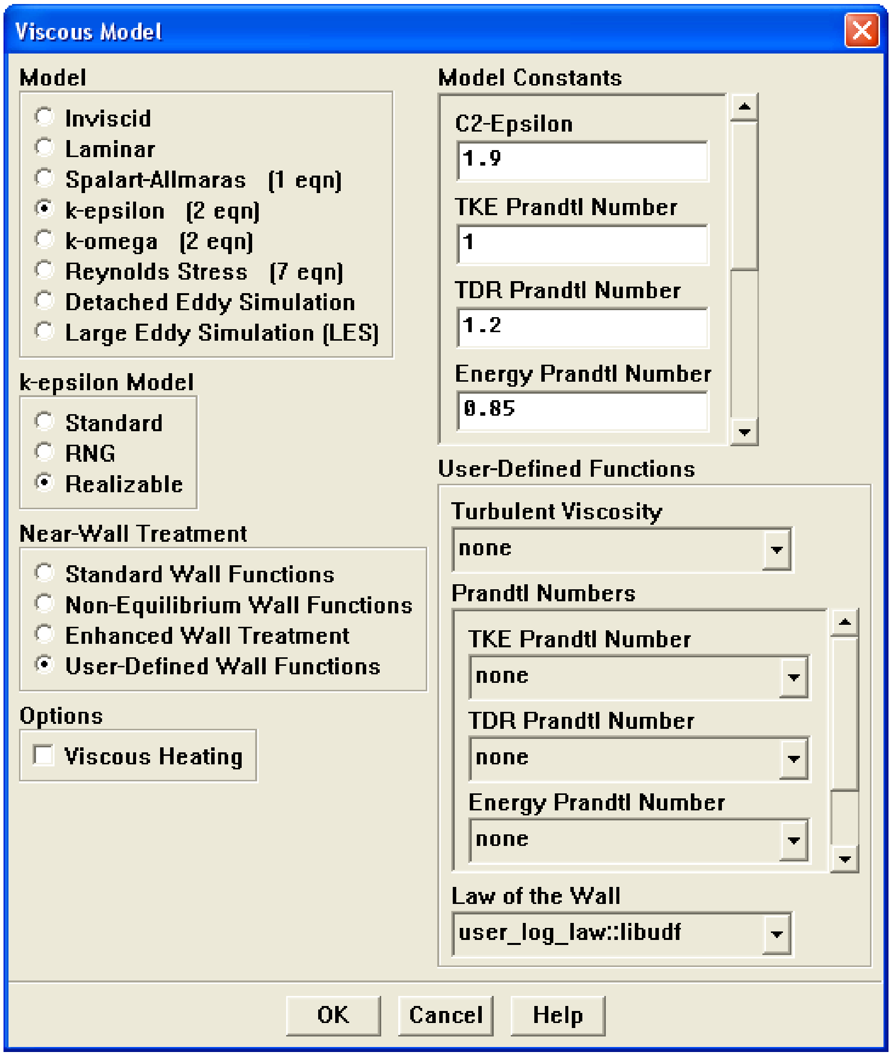
To hook the UDF to FLUENT, choose the function name (e.g., user_vr_rate) in the Volume Reaction Rate Function drop-down list in the User-Defined Function Hooks panel, and click OK.

See Section 2.3.22: DEFINE_VR_RATE for details about DEFINE_VR_RATE functions.

6.2.23 Hooking DEFINE_WALL_FUNCTIONS UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_WALL_FUNCTIONS UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Viscous Model panel (Figure 6.2.29) in FLUENT.

Define ⟶ Models ⟶Viscous...


Viscous Model

Model
○ Inviscid
○ Laminar
○ Spalart-Allmaras (1 eqn)
● k-epsilon (2 eqn)
○ k-omega (2 eqn)
○ Reynolds Stress (7 eqn)
○ Detached Eddy Simulation
○ Large Eddy Simulation (LES)

k-epsilon Model
○ Standard
○ RNG
● Realizable

Near-Wall Treatment
○ Standard Wall Functions
○ Non-Equilibrium Wall Functions
○ Enhanced Wall Treatment
● User-Defined Wall Functions

Options
□ Viscous Heating

Model Constants
C2-Epsilon: 1.9
TKE Prandtl Number: 1
TDR Prandtl Number: 1.2
Energy Prandtl Number: 0.85

User-Defined Functions
Turbulent Viscosity: none
Prandtl Numbers
TKE Prandtl Number: none
TDR Prandtl Number: none
Energy Prandtl Number: none
Law of the Wall: user_log_law::libudf

Figure 6.2.29: The Viscous Model Panel

To hook the UDF to FLUENT, choose the function name (e.g., user_log_law) in the Law of the Wall drop-down list, and click OK.

See Section 2.3.23: DEFINE_WALL_FUNCTIONS for details about defining DEFINE_WALL_FUNCTIONS functions in FLUENT.

6.3 Hooking Multiphase UDFs

This section contains methods for hooking UDFs to FLUENT that have been defined using DEFINE macros (described in Section 2.4: Multiphase DEFINE Macros), and interpreted or compiled using methods (described in Chapters 4 or 5), respectively.

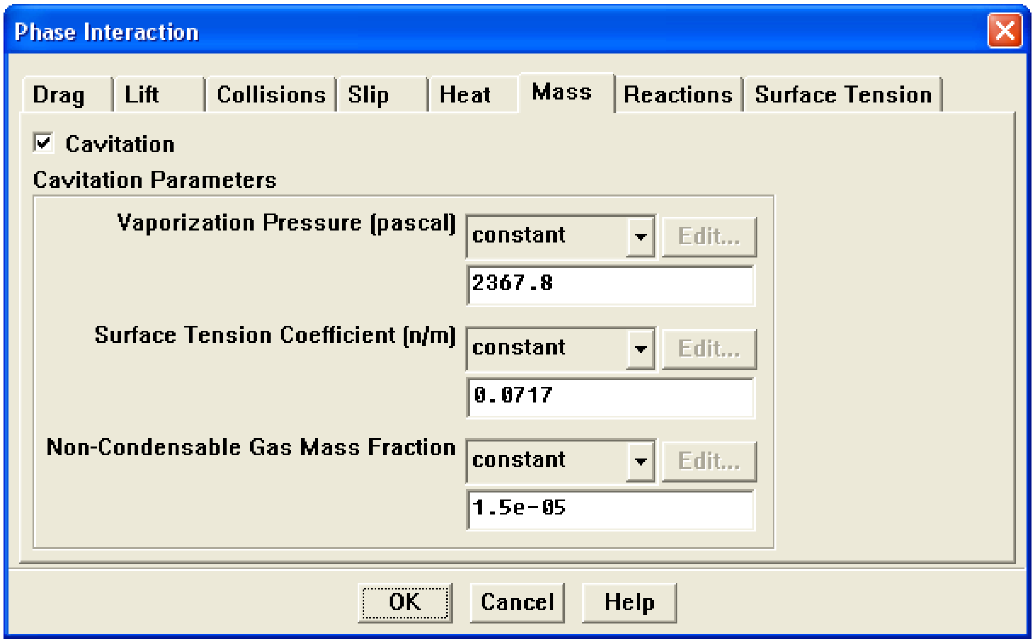
6.3.1 Hooking DEFINE_CAVITATION_RATE UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_CAVITATION_RATE UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Function Hooks panel (Figure 6.3.2) in FLUENT. Note that cavitation rate UDFs can be applied only to the Mixture multiphase model.

To hook the UDF to FLUENT, you will first need to enable the Mixture model in the Multiphase Model panel.

Define → Models → Multiphase...

Then, in the Mass tab of the Phase Interaction panel (Figure 6.3.1), select Cavitation.



☑ Cavitation

Cavitation Parameters

Vaporization Pressure (pascal) constant 2367.8

Surface Tension Coefficient (n/m) constant 0.0717

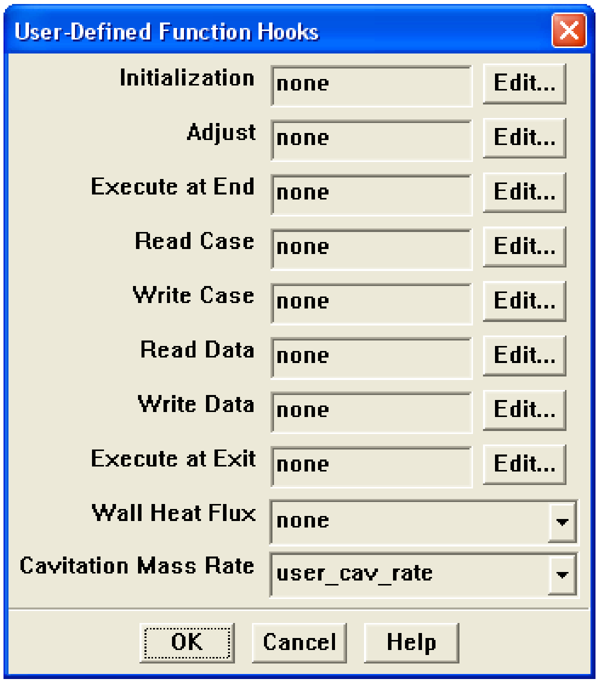
Non-Condensable Gas Mass Fraction constant 1.5e-05

Figure 6.3.1: The Phase Interaction Panel

Next, open the User-Defined Function Hooks panel,

Define → User-Defined → Function Hooks...

choose the function name (e.g., user_cav_rate) in the Cavitation Mass Rate Function drop-down list (Figure 6.3.2), and click OK.



User-Defined Function Hooks

Initialization: none

Adjust: none

Execute at End: none

Read Case: none

Write Case: none

Read Data: none

Write Data: none

Execute at Exit: none

Wall Heat Flux: none

Cavitation Mass Rate: user_cav_rate

Figure 6.3.2: The User-Defined Function Hooks Panel

See Section 2.4.1: DEFINE_CAVITATION_RATE for details about DEFINE_CAVITATION_RATE functions.

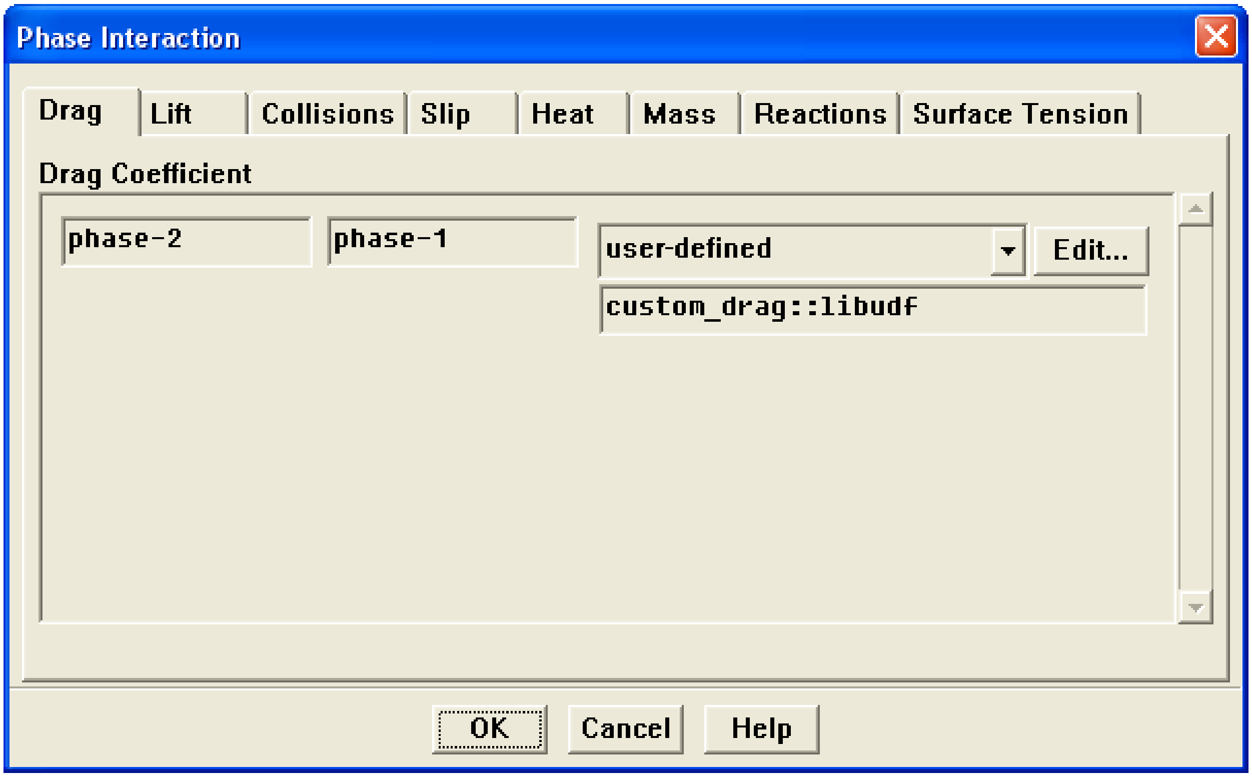
6.3.2 Hooking DEFINE_EXCHANGE_PROPERTY UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_EXCHANGE_RATE UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Functions panel (see below) in FLUENT.

Customized mass transfer UDFs can be applied to VOF, Mixture, and Eulerian multiphase models. Drag coefficient UDFs can be applied to Mixture and Eulerian models, while heat transfer and lift coefficient UDFs can be applied only to the Eulerian model. You will need to have the multiphase model enabled before you can hook your function.

To hook an exchange property UDF to FLUENT, you will first need to open the Phase Interaction panel (see below) by clicking Interactions... in the Phases panel.

Define ⟶Phases...



phase-2 phase-1 user-defined

custom_drag::libudf

Next, click on the appropriate tab (e.g., Drag) in the Phase Interaction panel, and choose user-defined in the drop-down list for the corresponding exchange property (e.g., Drag Coefficient) that you desire. This will open the User-Defined Functions panel.

i Make sure that you select Slip Velocity under Mixture Parameters in the Multiphase Model panel in order to display the drag coefficient for the Mixture model.

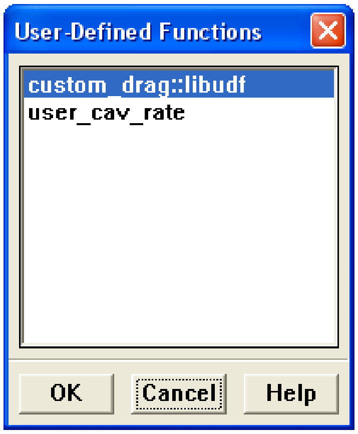


Figure 6.3.3: The User-Defined Functions Panel

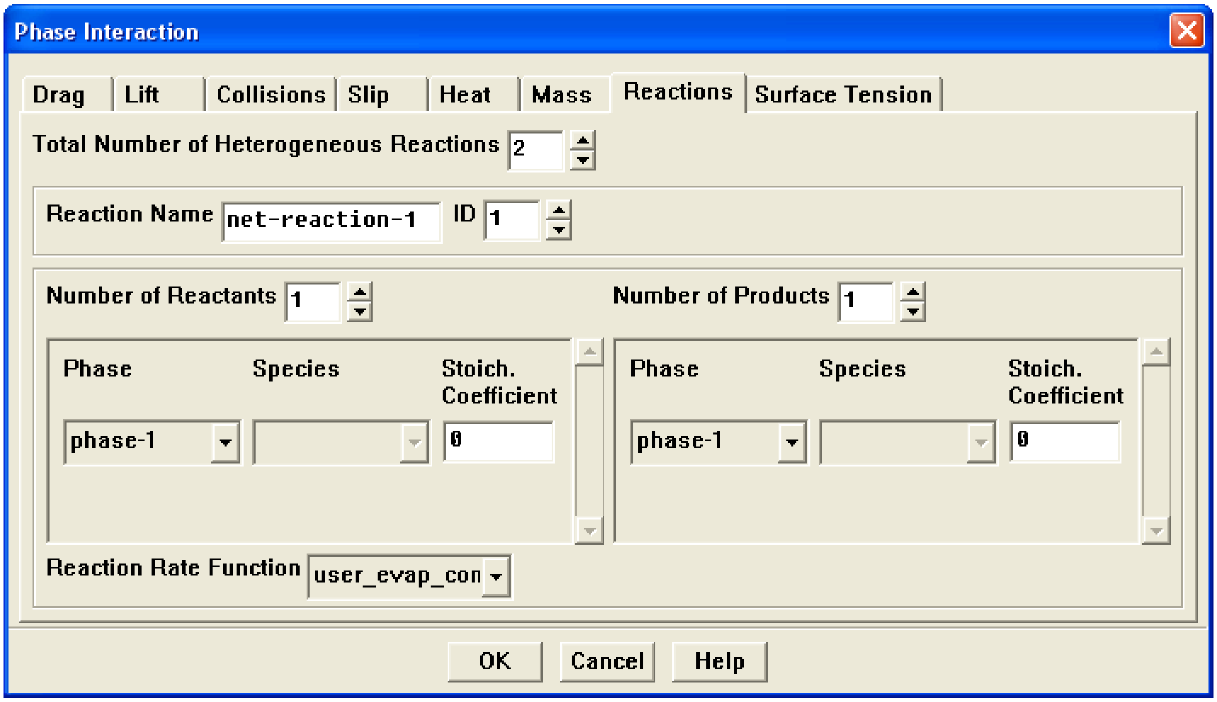
Finally, choose the function name (e.g., custom_drag) from the list of UDFs displayed in the User-Defined Functions panel, (Figure 6.3.3) and click OK. The function name (e.g., `custom_drag`) will then be displayed under the user-defined function for Drag Coefficient in the Phase Interaction panel.

See Section 2.4.2: `DEFINE_EXCHANGE_PROPERTY` for details about `DEFINE_EXCHANGE_PROPERTY` functions.

6.3.3 Hooking DEFINE_HET_RXN_RATE UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_HET_RXN_RATE UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable under Reaction Rate Function in the Reactions tab of the Phase Interaction panel. Note that the Reactions tab is enabled only when species transport is enabled and the Reaction Rate Function is accessible when the Total Number of Reactions is greater than 0. (Figure 6.3.4).

Define ⟶ Phases ⟶ Interaction...



Total Number of Heterogeneous Reactions 2

Reaction Name net-reaction-1 ID 1

Number of Reactants 1

Phase	Species	Stoich. Coefficient
phase-1		0

Number of Products 1

Phase	Species	Stoich. Coefficient
phase-1		0

Reaction Rate Function user_evap_con

Figure 6.3.4: The Phase Interaction Panel

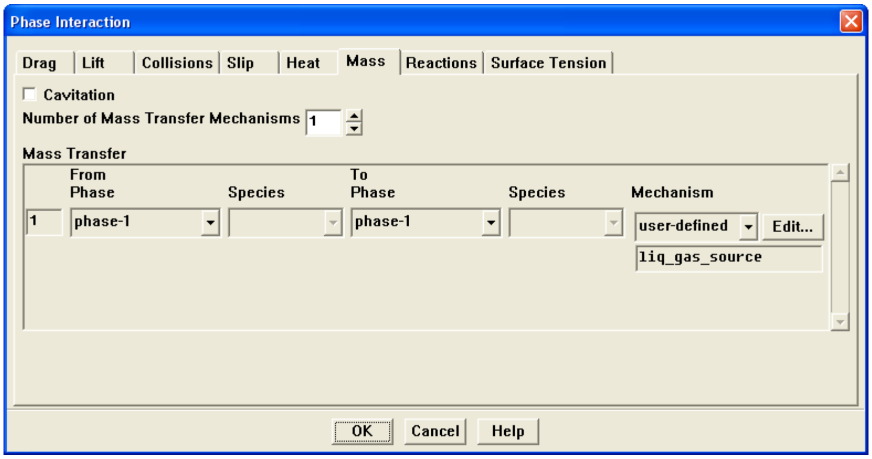
To hook the UDF to FLUENT, choose the function name (e.g., user_evap_con) in the Reaction Rate Function drop-down list under the Reaction tab (Figure 6.3.4), and click OK.

See Section 2.4.3: DEFINE_HET_RXN_RATE for details about writing DEFINE_HET_RXN_RATE functions.

6.3.4 Hooking DEFINE_MASS_TRANSFER UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_MASS_TRANSFER UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable from the Mass tab in the Phase Interaction panel (Figure 6.3.5).

Define ⟶ Phases ⟶Interaction...



□ Cavitation

Number of Mass Transfer Mechanisms 1

Mass Transfer

	From Phase	Species	To Phase	Species	Mechanism
1	phase-1		phase-1		user-defined liq_gas_source

Figure 6.3.5: The Phase Interaction Panel

To hook the UDF to FLUENT, click the Mass tab and then specify the Number of Mass Transfer Mechanisms greater than 0. The Mechanism drop-down list will appear. Next, choose user-defined from the Mechanism drop-down list to open the User-Defined Functions panel. Select the function name (e.g., liq_gas_source) from the UDF list and click OK. The UDF name will appear in the text entry box below the Mechanism drop-down list in the Phase Interaction panel.

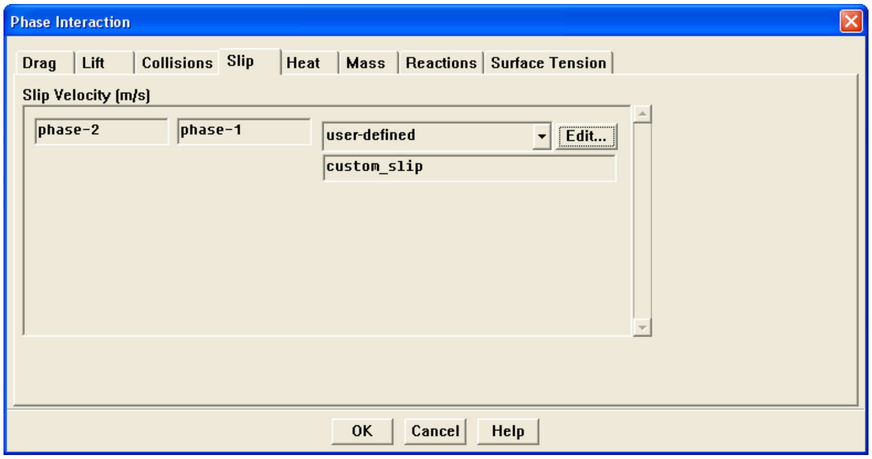
See Section 2.4.4: DEFINE_MASS_TRANSFER for details about writing DEFINE_MASS_TRANSFER functions.

6.3.5 Hooking DEFINE_VECTOR_EXCHANGE_PROPERTY UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_VECTOR_EXCHANGE_RATE UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Functions panel (Figure 6.3.7) in FLUENT.

To hook the UDF to FLUENT, you will first need to open the Phase Interaction panel (Figure 6.3.6) by clicking Interactions... in the Phases panel.

Define ⟶Phases...



Slip Velocity (m/s)

phase-2 phase-1 user-defined

custom_slip

Figure 6.3.6: The Phase Interaction Panel

Next, click on the Slip tab in the Phase Interaction panel, and choose user-defined in the drop-down list for the Slip Velocity. This will open the User-Defined Functions panel.

Slip velocity UDFs apply only to the multiphase Mixture model.

Finally, choose the function name (e.g., custom_slip) from the list of UDFs displayed in the User-Defined Functions panel, (Figure 6.3.3) and click OK.

See Section 2.4.5: DEFINE_VECTOR_EXCHANGE_PROPERTY for details about DEFINE_VECTOR_EXCHANGE_PROPERTY functions.

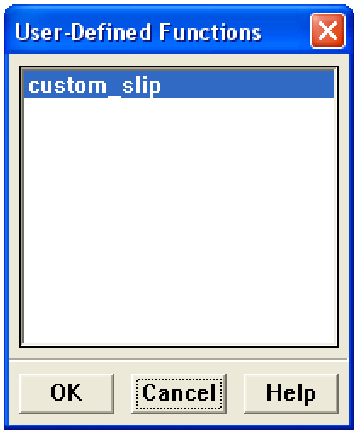


Figure 6.3.7: The User-Defined Functions Panel

6.4 Hooking Discrete Phase Model (DPM) UDFs

This section contains methods for hooking UDFs to FLUENT that have been

- defined using DEFINE macros described in Section 2.5: Discrete Phase Model (DPM) DEFINE Macros, and
- interpreted or compiled using methods described in Chapters 4 or 5, respectively.

6.4.1 Hooking DEFINE_DPM_BC UDFs

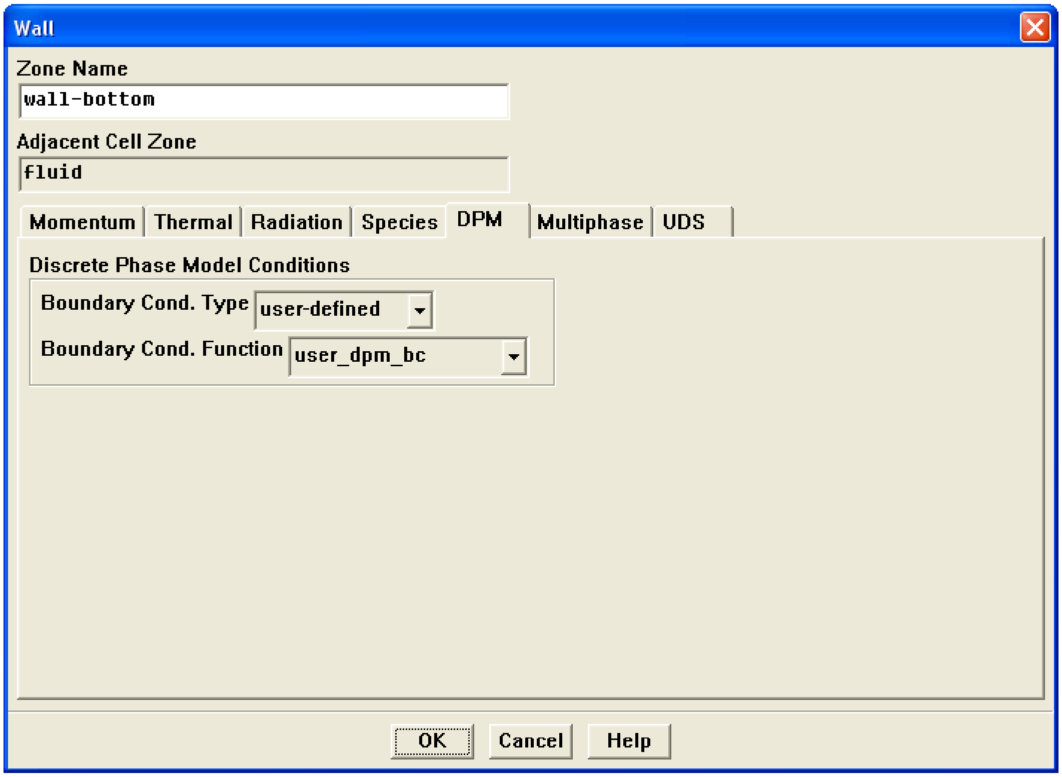
Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DPM_BC UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the appropriate boundary condition panel (Figure 6.4.1) in FLUENT.

Define ⟶Boundary Conditions...

Suppose that your UDF defines a particle velocity boundary condition at a wall. To hook the UDF to FLUENT, first open the Wall boundary condition panel and select the DPM tab (Figure 6.4.1)

Then choose user_defined as Boundary Cond. Type under Discrete Phase Model Conditions. This will expand the panel to allow you to choose the function name (e.g., user_dpm_bc) from the Boundary Cond. Function drop-down list (Figure 6.4.1). Click OK.

See Section 2.5.1: DEFINE_DPM_BC for details about DEFINE_DPM_BC functions.



Zone Name
wall-bottom

Adjacent Cell Zone
fluid

Discrete Phase Model Conditions

Boundary Cond. Type: user-defined

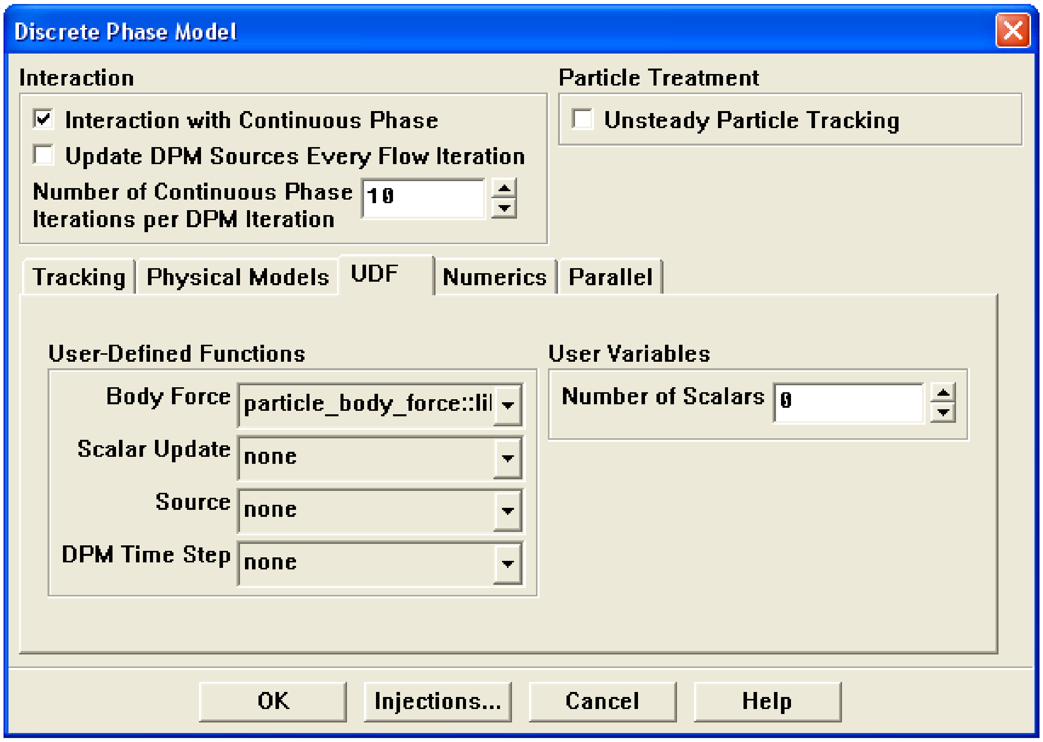
Boundary Cond. Function: user_dpm_bc

Figure 6.4.1: The Wall Panel

6.4.2 Hooking DEFINE_DPM_BODY_FORCE UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DPM_BODY_FORCE UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Discrete Phase Model panel (Figure 6.4.2) in FLUENT.

Define ⟶ Models ⟶ Discrete Phase...



Discrete Phase Model

Interaction

☑ Interaction with Continuous Phase

☐ Update DPM Sources Every Flow Iteration

Number of Continuous Phase Iterations per DPM Iteration: 10

Particle Treatment

☐ Unsteady Particle Tracking

User-Defined Functions

Body Force: particle_body_force::lil

Scalar Update: none

Source: none

DPM Time Step: none

User Variables

Number of Scalars: 0

Figure 6.4.2: The Discrete Phase Model Panel

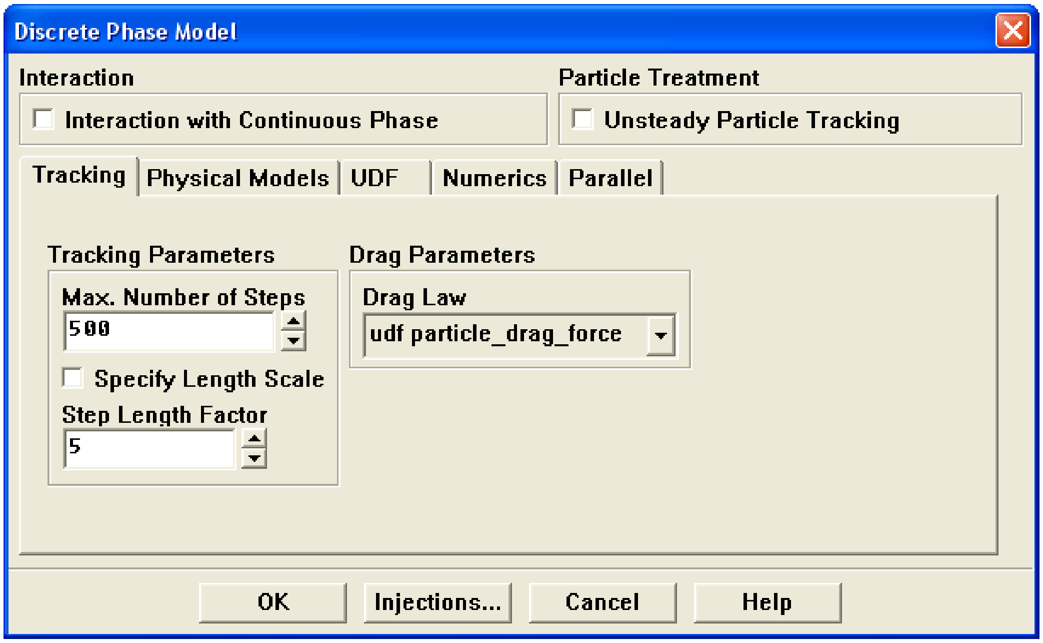
To hook the UDF to FLUENT, choose the function name (e.g., particle_body_force) in the Body Force drop-down list under User-Defined Functions, (Figure 6.4.2) and click OK.

See Section 2.5.2: DEFINE_DPM_BODY_FORCE for details about DEFINE_DPM_BODY_FORCE functions.

6.4.3 Hooking DEFINE_DPM_DRAG UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DPM_DRAG UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Discrete Phase Model panel (Figure 6.4.3) in FLUENT.

Define ⟶ Models ⟶ Discrete Phase...



Interaction

☐ Interaction with Continuous Phase

Particle Treatment

☐ Unsteady Particle Tracking

Tracking Parameters

Max. Number of Steps: 500

☐ Specify Length Scale

Step Length Factor: 5

Drag Parameters

Drag Law: udf particle_drag_force

Figure 6.4.3: The Discrete Phase Model Panel

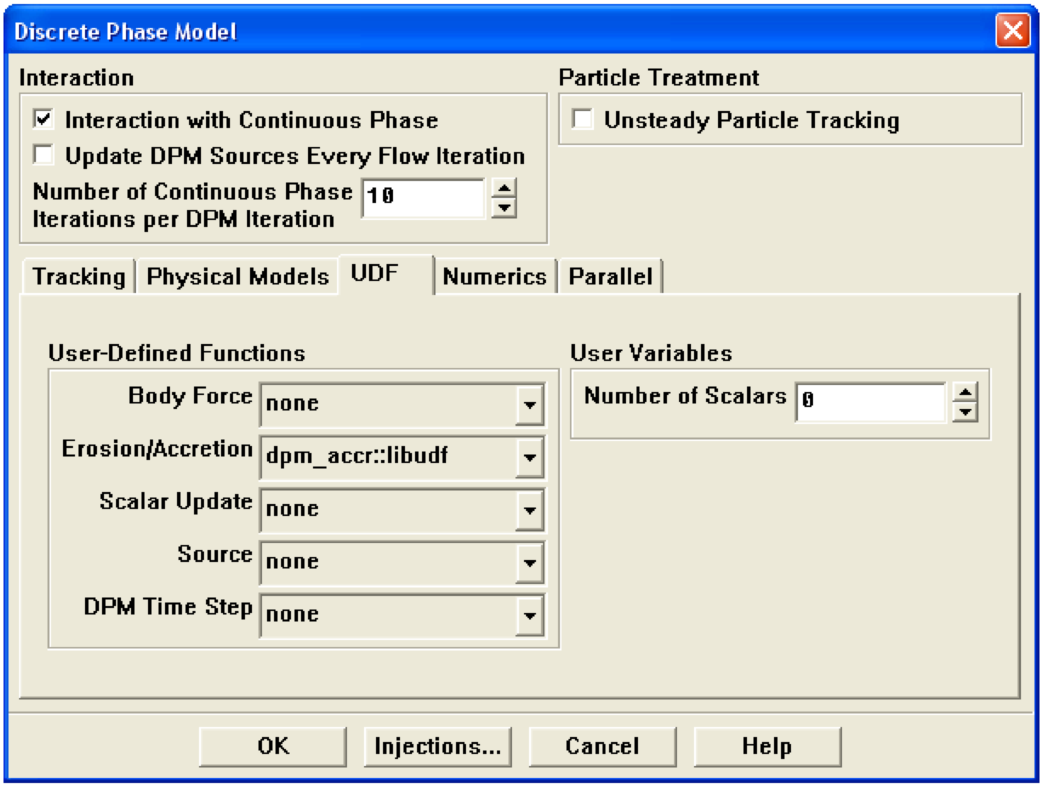
To hook the UDF to FLUENT, choose the function name (e.g., particle_drag_force) in the Drag Law drop-down list under Drag Parameters (Figure 6.4.3), and click OK. (Note, function names listed in the drop-down list are preceded by the word udf as in udf particle_drag_force.)

See Section 2.5.3: DEFINE_DPM_DRAG for details about DEFINE_DPM_DRAG functions.

6.4.4 Hooking DEFINE_DPM_EROSION UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DPM_EROSION UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Discrete Phase Model panel (Figure 6.4.4) in FLUENT.

Define ⟶ Models ⟶ Discrete Phase...



Discrete Phase Model

Interaction

☑ Interaction with Continuous Phase

□ Update DPM Sources Every Flow Iteration

Number of Continuous Phase Iterations per DPM Iteration: 10

Particle Treatment

□ Unsteady Particle Tracking

Tracking | Physical Models | UDF | Numerics | Parallel

User-Defined Functions

Body Force: none

Erosion/Accretion: dpm_accr::libudf

Scalar Update: none

Source: none

DPM Time Step: none

User Variables

Number of Scalars: 0

Figure 6.4.4: The Discrete Phase Model Panel

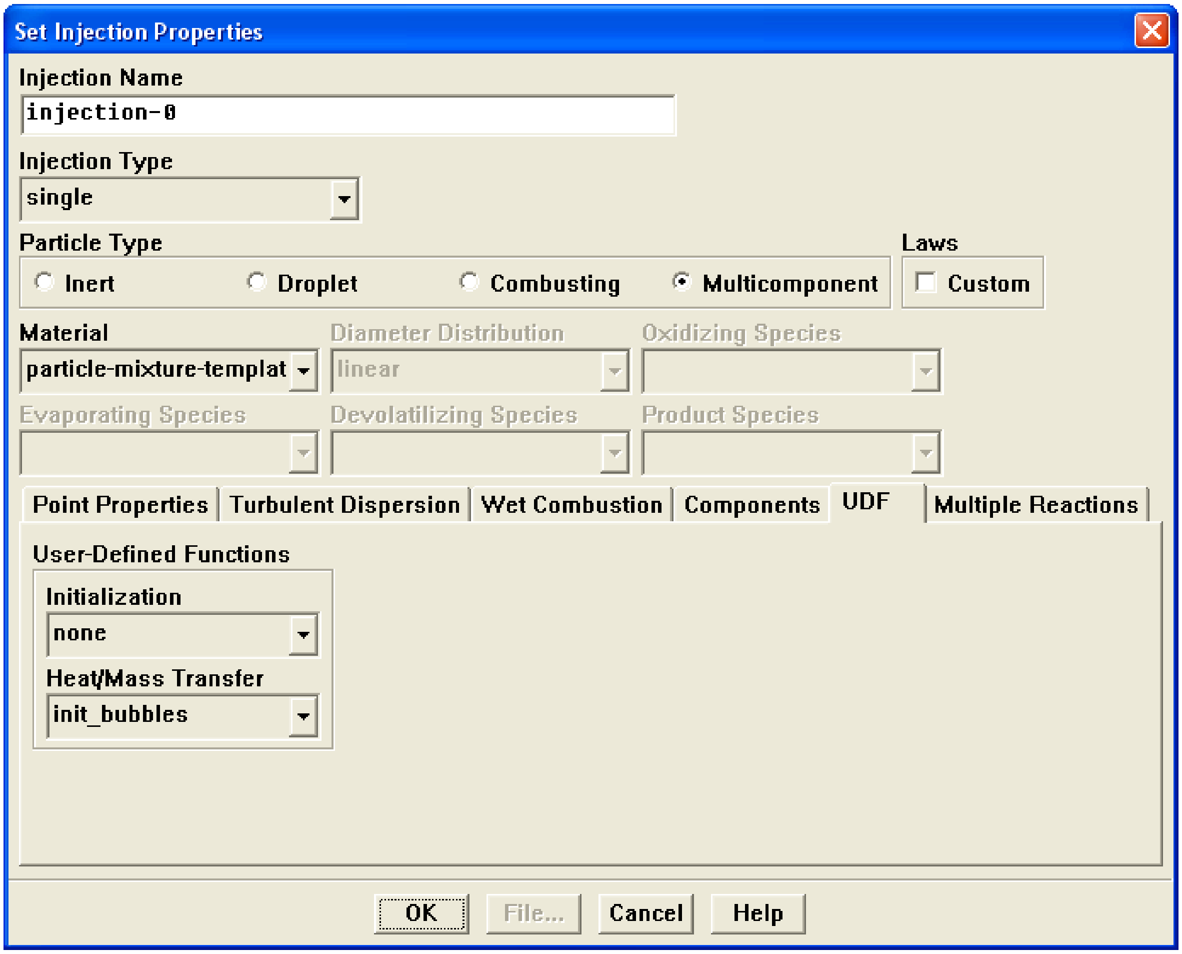
To hook the UDF to FLUENT, enable the Interaction with Continuous Phase option under Interaction (Figure 6.4.4), and then turn on Erosion/Accretion under Option. Finally, choose the function name (e.g., dpm_accr) in the Erosion/Accretion drop-down list under User-Defined Functions, and click OK.

See Section 2.5.4: DEFINE_DPM_EROSION for details about DEFINE_DPM_EROSION functions.

6.4.5 Hooking DEFINE_DPM_HEAT_MASS UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DPM_HEAT_MASS UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Set Injection Properties panel (Figure 6.4.5) in FLUENT. Before you hook the UDF, you'll need to create your particle injections in the Injections panel.

Define −→Injections...



Set Injection Properties

Injection Name: injection-0

Injection Type: single

Particle Type: ○ Inert ○ Droplet ○ Combusting ● Multicomponent

Laws: □ Custom

Material: particle-mixture-templat

Diameter Distribution: linear

Oxidizing Species

Evaporating Species

Devolatilizing Species

Product Species

User-Defined Functions

Initialization: none

Heat/Mass Transfer: init_bubbles

Figure 6.4.5: The Injections Panel

Click Create in the Injections panel to open the Set Injection Properties panel and set up your particle injections. Next, select the UDF tab in the Set Injection Properties panel (Figure 6.4.5), and choose the function name (e.g., init_bubbles) from the Heat/Mass Transfer drop-down list under User-Defined Functions. Click OK.

See Section 2.5.6: DEFINE_DPM_INJECTION_INIT for details about DEFINE_DPM_INJECTION_INIT functions.

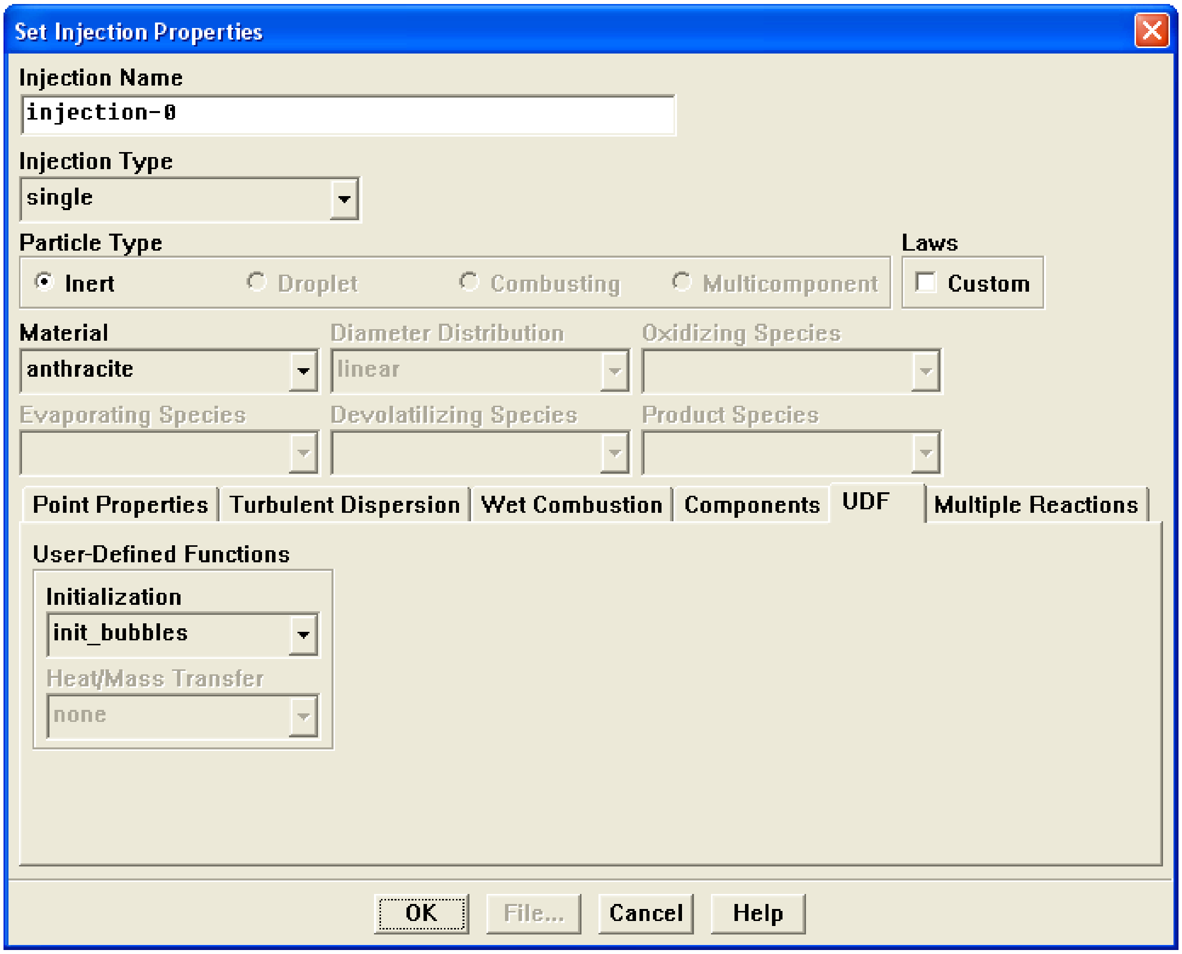
6.4.6 Hooking DEFINE_DPM_INJECTION_INIT UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DPM_INJECTION_INIT UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Set Injection Properties panel (Figure 6.4.6) in FLUENT. Before you hook the UDF, you'll need to create your particle injections in the Injections panel.

Define ⟶Injections...

Click Create in the Injections panel to open the Set Injection Properties panel and set up your particle injections. Next, select the UDF tab in the Set Injection Properties panel (Figure 6.4.6), and choose the function name (e.g., init_bubbles) from the Initialization drop-down list under User-Defined Functions. Click OK.

See Section 2.5.6: DEFINE_DPM_INJECTION_INIT for details about DEFINE_DPM_INJECTION_INIT functions.



Injection Name: injection-0

Injection Type: single

Particle Type: ● Inert ○ Droplet ○ Combusting ○ Multicomponent

Laws: □ Custom

Material: anthracite

Diameter Distribution: linear

Oxidizing Species

Evaporating Species

Devolatilizing Species

Product Species

User-Defined Functions

Initialization: init_bubbles

Heat/Mass Transfer: none

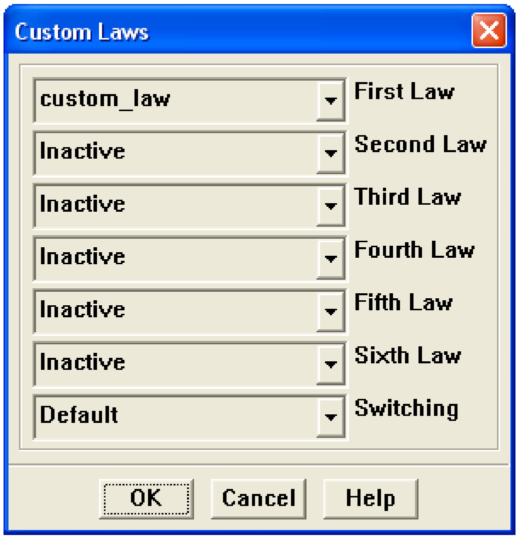
Figure 6.4.6: The Injections Panel

6.4.7 Hooking DEFINE_DPM_LAW UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DPM_LAW UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Custom Laws panel (Figure 6.4.7) in FLUENT. To hook the UDF to FLUENT, first click Create in the Injections panel to open the Set Injection Properties panel.

Define ⟶Injections...

Next, turn on the Custom option under Laws in the Set Injection Properties panel. This will open the Custom Laws panel.



custom_law First Law
Inactive Second Law
Inactive Third Law
Inactive Fourth Law
Inactive Fifth Law
Inactive Sixth Law
Default Switching

Figure 6.4.7: The Custom Laws Panel

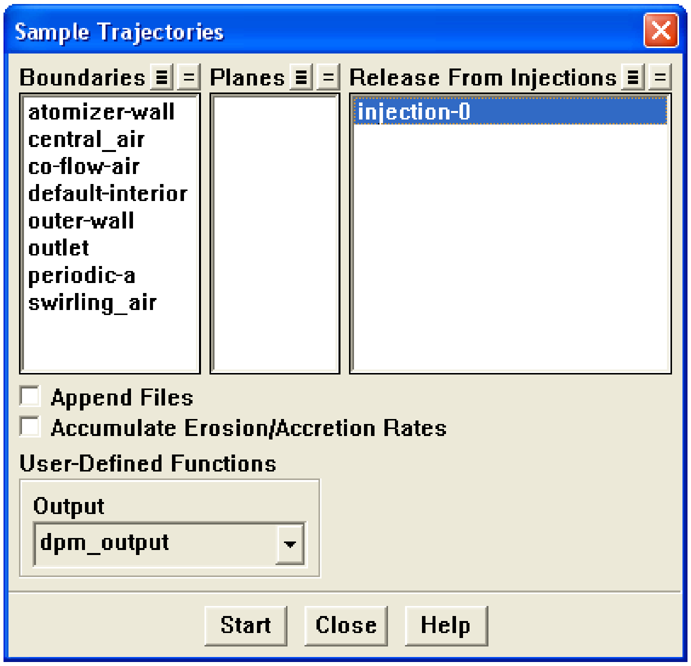
Finally, in the Custom Laws panel, (Figure 6.4.7) choose the function name (e.g., custom_law) in the appropriate drop-down list located to the left of each of the six particle laws (e.g., First Law), and click OK.

See Section 2.5.7: DEFINE_DPM_LAW for details about DEFINE_DPM_LAW functions.

6.4.8 Hooking DEFINE_DPM_OUTPUT UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DPM_OUTPUT UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Sample Trajectories panel (Figure 6.4.8) in FLUENT.

Report ⟶ Discrete Phase ⟶Sample...



Sample Trajectories

Boundaries: atomizer-wall, central_air, co-flow-air, default-interior, outer-wall, outlet, periodic-a, swirling_air

Planes

Release From Injections: injection-0

□ Append Files
□ Accumulate Erosion/Accretion Rates

User-Defined Functions

Output: dpm_output

Figure 6.4.8: The Sample Trajectories Panel

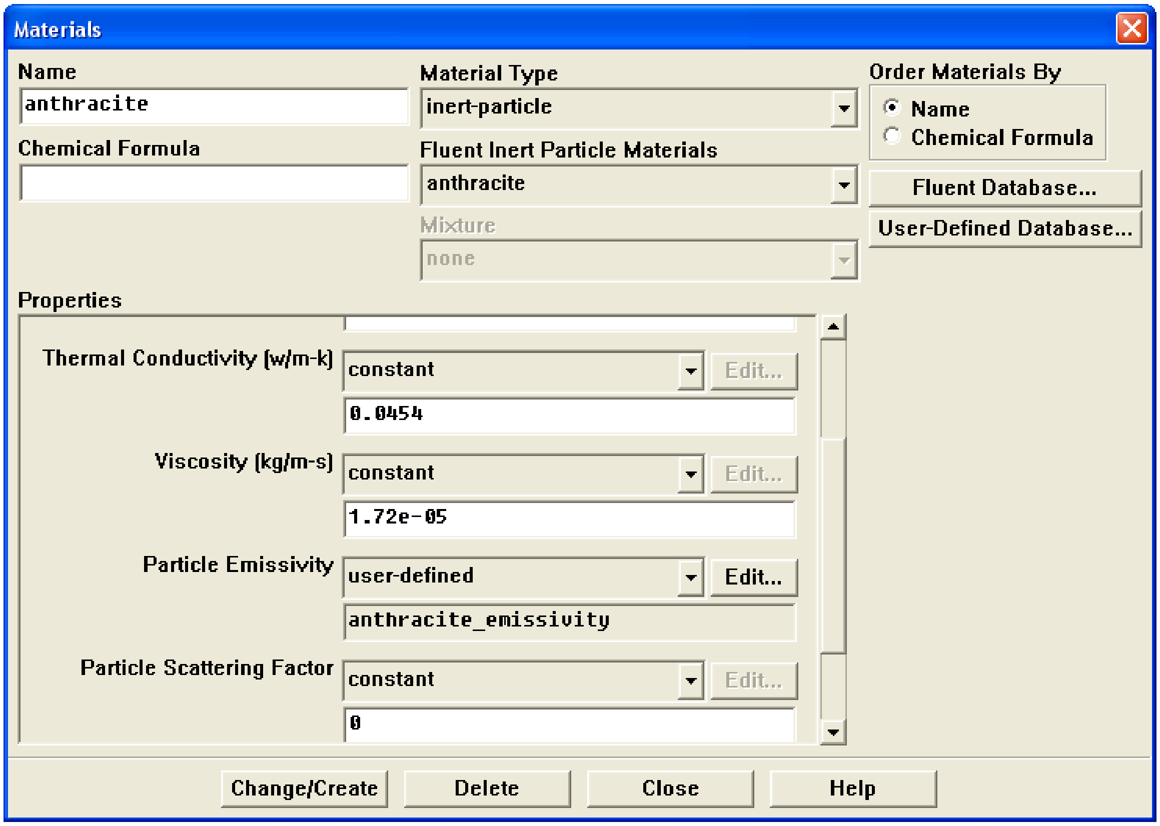
To hook the UDF to FLUENT, choose the function name (e.g., dpm_output) in the Output drop-down list under User-Defined Functions, and click Start and Close.

See Section 2.5.8: DEFINE_DPM_OUTPUT for details about DEFINE_DPM_OUTPUT functions.

6.4.9 Hooking DEFINE_DPM_PROPERTY UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DPM_PROPERTY UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the User-Defined Functions panel (Figure 6.4.10). To hook the UDF to FLUENT, you will first need to open the User-Defined Functions panel by choosing user-defined in the drop-down list for the appropriate property (e.g., Particle Emissivity) in the Materials panel (Figure 6.4.9).

Define ⟶Materials...



Materials

Name: anthracite

Chemical Formula:

Material Type: inert-particle

Fluent Inert Particle Materials: anthracite

Mixture: none

Order Materials By: ● Name ○ Chemical Formula

Properties

Thermal Conductivity (w/m-k): constant — 0.0454

Viscosity (kg/m-s): constant — 1.72e-05

Particle Emissivity: user-defined — anthracite_emissivity

Particle Scattering Factor: constant — 0

Figure 6.4.9: The Materials Panel

i In order for the Particle Emissivity property to be displayed in the sample panel shown above, you must enable a radiation model, turn on the Particle Radiation Interaction option in the Discrete Phase Model panel, and introduce a particle injection in the Injections panel.

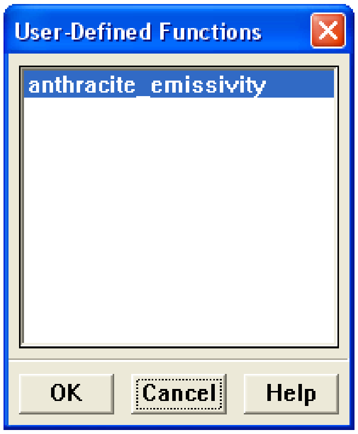


Figure 6.4.10: The User-Defined Functions Panel

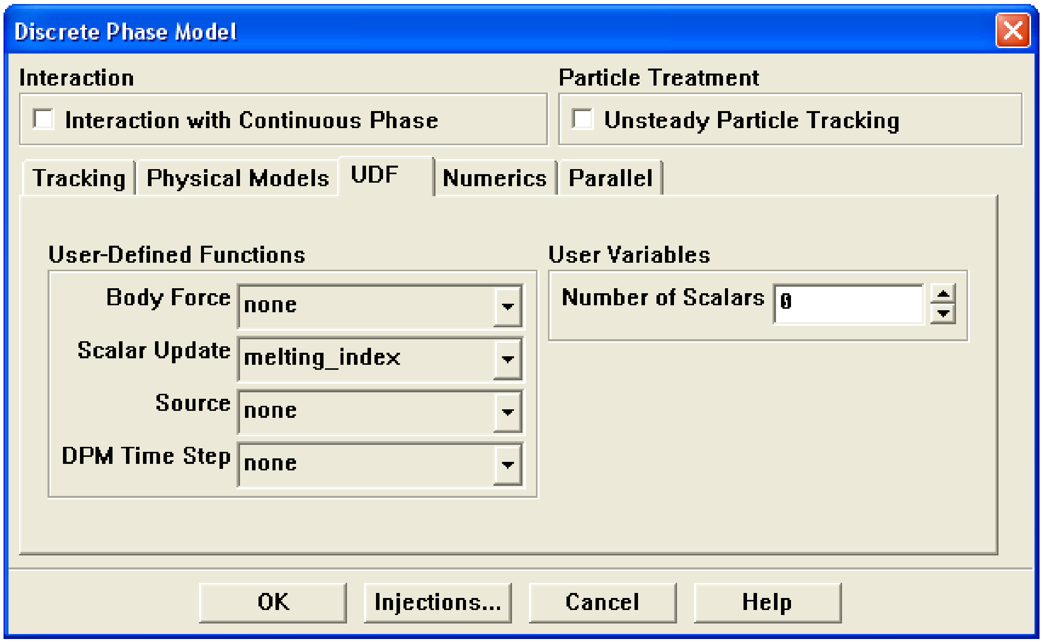
Next, choose the function name (e.g., anthracite_emissivity) from the list of UDFs displayed in the User-Defined Functions panel, (Figure 6.4.10) and click OK. The name of the function will subsequently be displayed under the selected property (e.g., Particle Emissivity) in the Materials panel.

See Section 2.3.14: DEFINE_PROPERTY UDFs for details about DEFINE_DPM_PROPERTY functions.

6.4.10 Hooking DEFINE_DPM_SCALAR_UPDATE UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DPM_SCALAR_UPDATE UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Discrete Phase Model panel (Figure 6.4.11) in FLUENT.

Define ⟶ Models ⟶ Discrete Phase...



Interaction

☐ Interaction with Continuous Phase

Particle Treatment

☐ Unsteady Particle Tracking

User-Defined Functions

Body Force	none
Scalar Update	melting_index
Source	none
DPM Time Step	none

User Variables

Number of Scalars 0

Figure 6.4.11: The Discrete Phase Model Panel

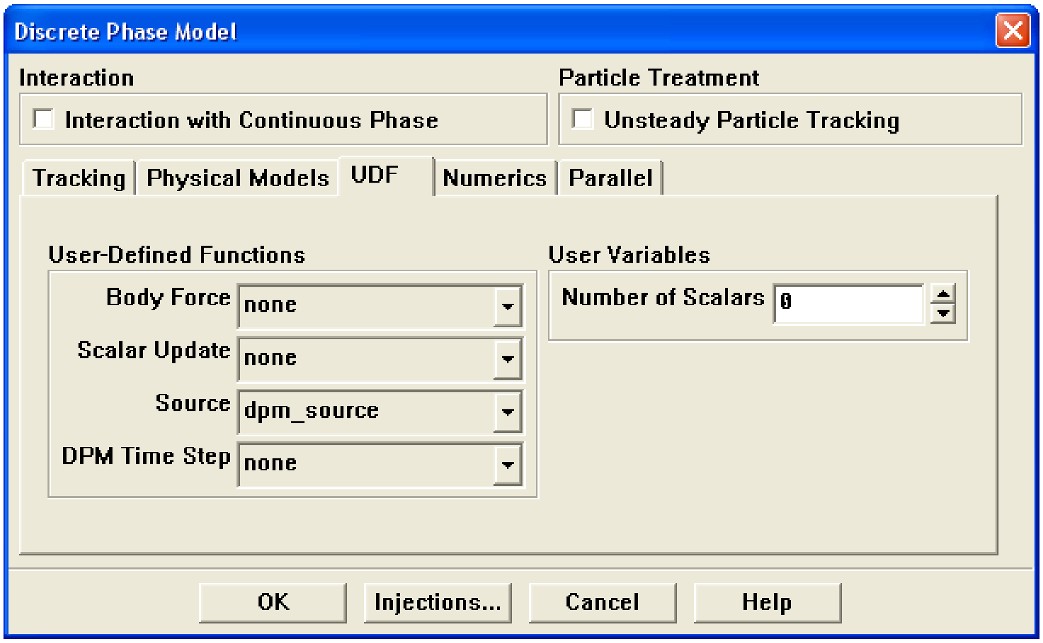
To hook the UDF to FLUENT, choose the function name (e.g., melting_index) in the Scalar Update drop-down list under User-Defined Functions (Figure 6.4.11), and click OK.

See Section 2.5.10: DEFINE_DPM_SCALAR_UPDATE for details about DEFINE_DPM_SCALAR_UPDATE functions.

6.4.11 Hooking DEFINE_DPM_SOURCE UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DPM_SOURCE UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Discrete Phase Model panel (Figure 6.4.12) in FLUENT.

Define ⟶ Models ⟶Discrete Phase...



Interaction

□ Interaction with Continuous Phase

Particle Treatment

□ Unsteady Particle Tracking

User-Defined Functions

Body Force: none

Scalar Update: none

Source: dpm_source

DPM Time Step: none

User Variables

Number of Scalars: 0

Figure 6.4.12: The Discrete Phase Model Panel

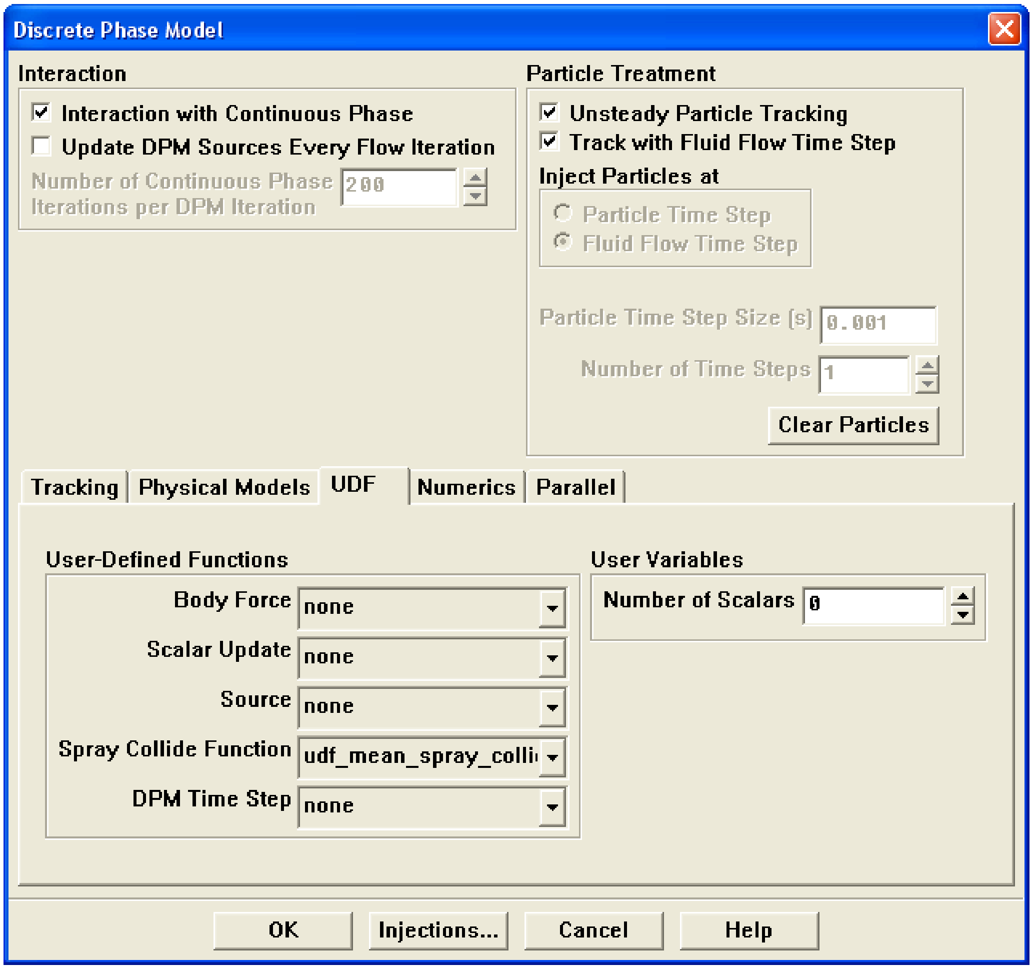
To hook the UDF to FLUENT, choose the function name (e.g., dpm_source) in the Source drop-down list under User-Defined Functions (Figure 6.4.12), and click OK.

See Section 2.5.11: DEFINE_DPM_SOURCE for details about DEFINE_DPM_SOURCE functions.

6.4.12 Hooking DEFINE_DPM_SPRAY_COLLIDE UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DPM_SPRAY_COLLIDE UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Discrete Phase Model panel (Figure 6.4.13) in FLUENT.

Define ⟶ Models ⟶ Discrete Phase...



Discrete Phase Model

Interaction

☑ Interaction with Continuous Phase

□ Update DPM Sources Every Flow Iteration

Number of Continuous Phase Iterations per DPM Iteration: 200

Particle Treatment

☑ Unsteady Particle Tracking

☑ Track with Fluid Flow Time Step

Inject Particles at

○ Particle Time Step

● Fluid Flow Time Step

Particle Time Step Size (s): 0.001

Number of Time Steps: 1

User-Defined Functions

Body Force: none

Scalar Update: none

Source: none

Spray Collide Function: udf_mean_spray_colli

DPM Time Step: none

User Variables

Number of Scalars: 0

Figure 6.4.13: The Discrete Phase Model Panel

> You will need to enable a discrete phase model in the Discrete Phase Model panel before you can hook the UDF.

To hook the UDF to FLUENT, choose the function name (e.g., udf_mean_spray) in the Spray Collide Function drop-down list in the User-Defined Function Hooks panel, (Figure 6.4.13) and click OK.

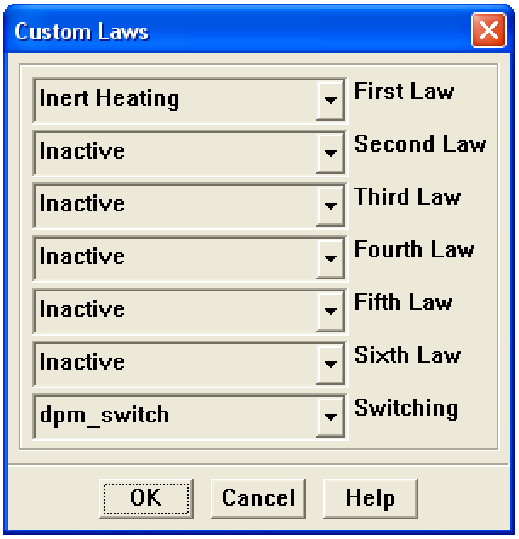
See Section 2.5.12: DEFINE_DPM_SPRAY_COLLIDE for details about DEFINE_DPM_SPRAY_COLLIDE functions.

6.4.13 Hooking DEFINE_DPM_SWITCH UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DPM_SWITCH UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Custom Laws panel (Figure 6.4.14) in FLUENT. To hook the UDF to FLUENT, first click Create in the Injections panel to open the Set Injection Properties panel.

Define ⟶Injections...

Next, turn on the Custom option under Laws in the Set Injection Properties panel. This will open the Custom Laws panel.



First Law: Inert Heating
Second Law: Inactive
Third Law: Inactive
Fourth Law: Inactive
Fifth Law: Inactive
Sixth Law: Inactive
Switching: dpm_switch

Figure 6.4.14: The Custom Laws Panel

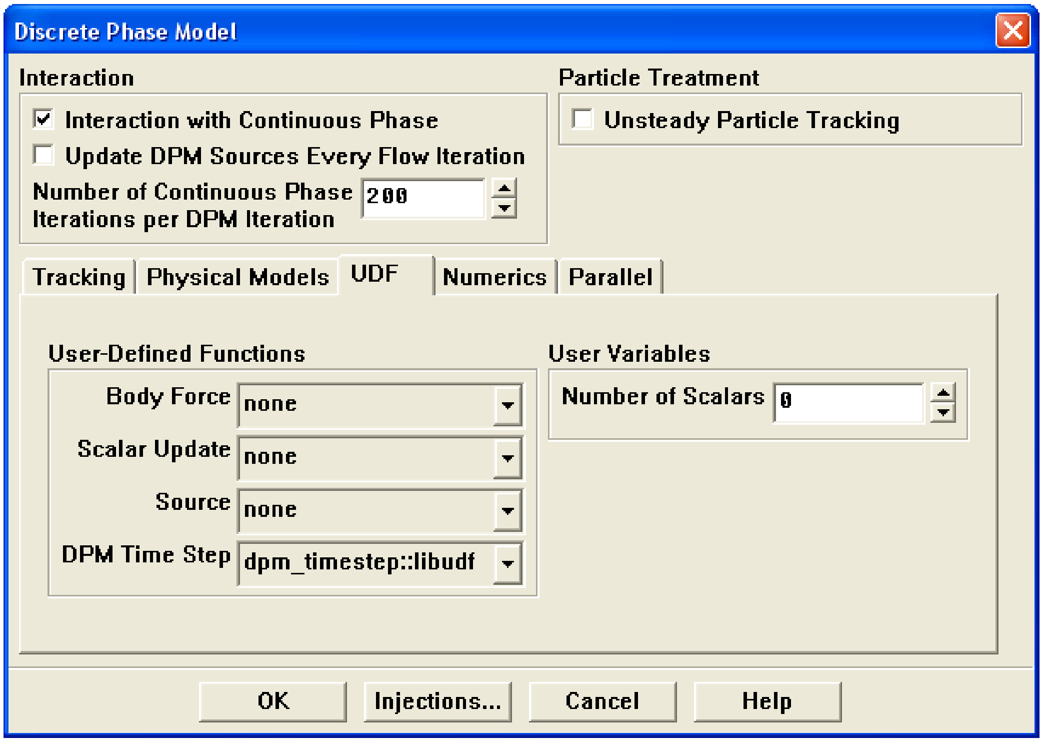
Finally, in the Custom Laws panel (Figure 6.4.14) choose the function name (e.g., dpm_switch) from the last drop-down list labeled Switching, (Figure 6.4.14) and click OK.

See Section 2.5.13: DEFINE_DPM_SWITCH for details about DEFINE_DPM_SWITCH functions.

6.4.14 Hooking DEFINE_DPM_TIMESTEP UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DPM_TIMESTEP UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Discrete Phase Model panel under the UDF tab for DPM Timestep (Figure 6.4.15).

Define ⟶ Models ⟶Discrete Phase...



Interaction

☑ Interaction with Continuous Phase

□ Update DPM Sources Every Flow Iteration

Number of Continuous Phase Iterations per DPM Iteration: 200

Particle Treatment

□ Unsteady Particle Tracking

User-Defined Functions

Body Force: none

Scalar Update: none

Source: none

DPM Time Step: dpm_timestep::libudf

User Variables

Number of Scalars: 0

Figure 6.4.15: The Discrete Phase Model Panel

To hook the UDF to FLUENT, choose the function name (e.g., dpm_timestep) in the DPM Time Step drop-down list under the UDF tab (Figure 6.4.15), and click OK.

See Section 2.5.14: DEFINE_DPM_TIMESTEP for details about DEFINE_DPM_TIMESTEP functions.

6.4.15 Hooking DEFINE_DPM_VP_EQUILIB UDFs

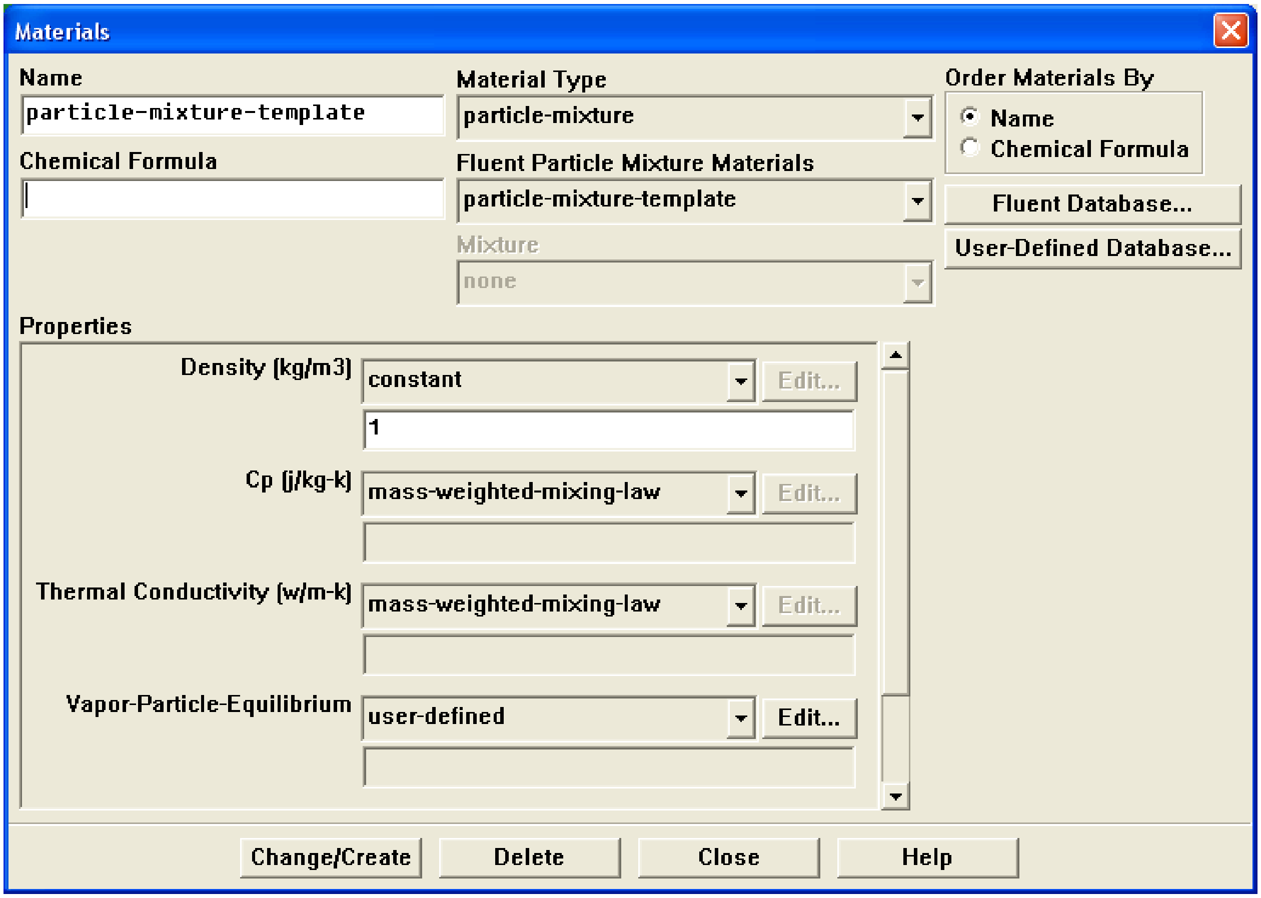
Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_DPM_VP_EQUILIB UDF, the name of the function you supplied as a DEFINE macro argument (e.g., raoult_vp) will become visible and selectable from the Materials panel in FLUENT. Before you hook the UDF, you'll need to create your particle injections in the Injections panel with the Multicomponent option enabled. .

Define ⟶Injections...

Click Create in the Injections panel to open the Set Injection Properties panel and set up your particle injections.

Next, open the Materials panel (Figure 6.4.16),

Define ⟶Materials...



Materials

Name: particle-mixture-template

Chemical Formula:

Material Type: particle-mixture

Fluent Particle Mixture Materials: particle-mixture-template

Mixture: none

Order Materials By: ● Name ○ Chemical Formula

Properties

Density (kg/m3): constant — 1

Cp (j/kg-k): mass-weighted-mixing-law

Thermal Conductivity (w/m-k): mass-weighted-mixing-law

Vapor-Particle-Equilibrium: user-defined

Figure 6.4.16: The Materials Panel

Select your particle-mixture material and then choose user-defined from the drop-down list for Vapor-Particle-Equilibrium. This will open the User-Defined Functions panel. Choose the UDF name from the list of UDFs displayed and click OK.

See Section 2.5.15: DEFINE_DPM_VP_EQUILIB for details about DEFINE_DPM_VP_EQUILIBRIUM functions.

6.5 Hooking Dynamic Mesh UDFs

This section contains methods for hooking UDFs to FLUENT that have been defined using DEFINE macros described in Section 2.6: Dynamic Mesh DEFINE Macros, and interpreted or compiled using methods described in Chapters 4 or 5, respectively.

6.5.1 Hooking DEFINE_CG_MOTION UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_CG_MOTION UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Dynamic Mesh Zones panel (Figure 6.5.1). To hook the UDF to FLUENT, you will first need to enable the dynamic mesh model.

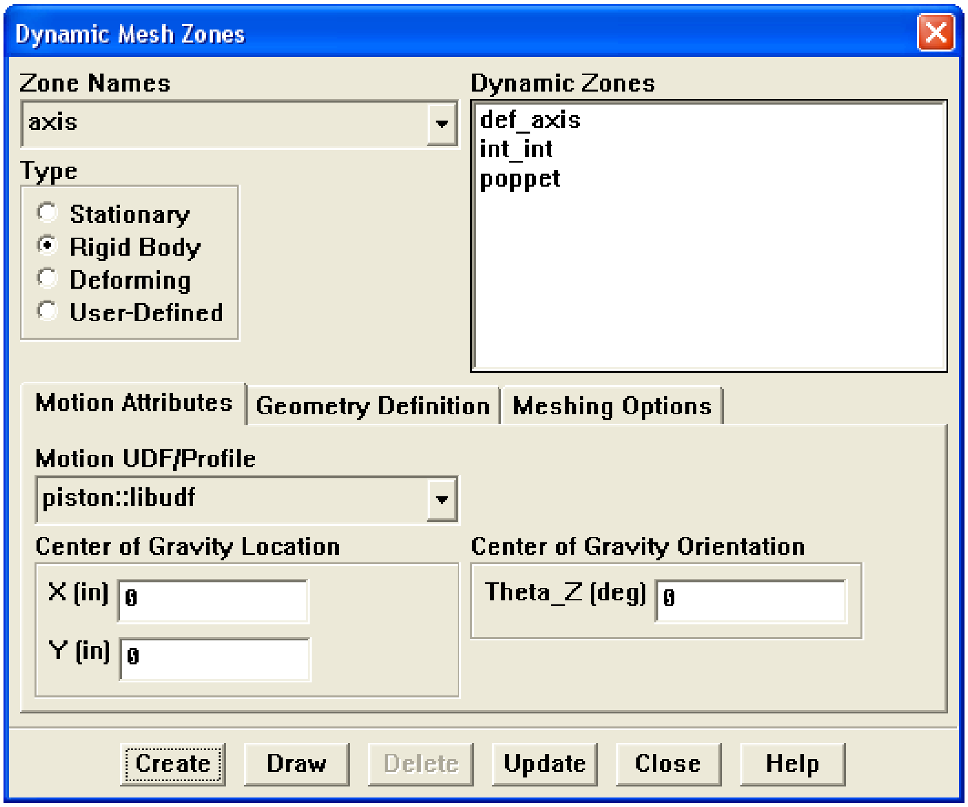
Define ⟶ Dynamic Mesh ⟶Parameters...

To enable the dymanic mesh model, select Dynamic Mesh under Model and click OK.

> *i* The Dynamic Mesh panel will be accessible only when you choose Unsteady as the time method in the Solver panel.

Next, open the Dynamic Mesh Zones panel.

Define ⟶ Dynamic Mesh ⟶Zones...



Dynamic Mesh Zones

Zone Names: axis

Type

○ Stationary
● Rigid Body
○ Deforming
○ User-Defined

Dynamic Zones

def_axis
int_int
poppet

Motion UDF/Profile: piston::libudf

Center of Gravity Location

X (in) 0

Y (in) 0

Center of Gravity Orientation

Theta_Z (deg) 0

Figure 6.5.1: The Dynamic Mesh Zones Panel

Select Rigid Body under Type in the Dynamic Mesh Zones panel (Figure 6.5.1) and click on the Motion Attributes tab. Finally, choose the function name (e.g., piston) from the Motion UDF/Profile drop-down list, and click Create then Close.

See Section 2.6.1: DEFINE_CG_MOTION for details about DEFINE_CG_MOTION functions.

6.5.2 Hooking DEFINE_GEOM UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_GEOM UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Dynamic Mesh Zones panel (Figure 6.5.2). To hook the UDF to FLUENT, you will first need to enable the Dynamic Mesh model.

Define ⟶ Dynamic Mesh ⟶Parameters...

To enable the model, select Dynamic Mesh under Model and click OK.

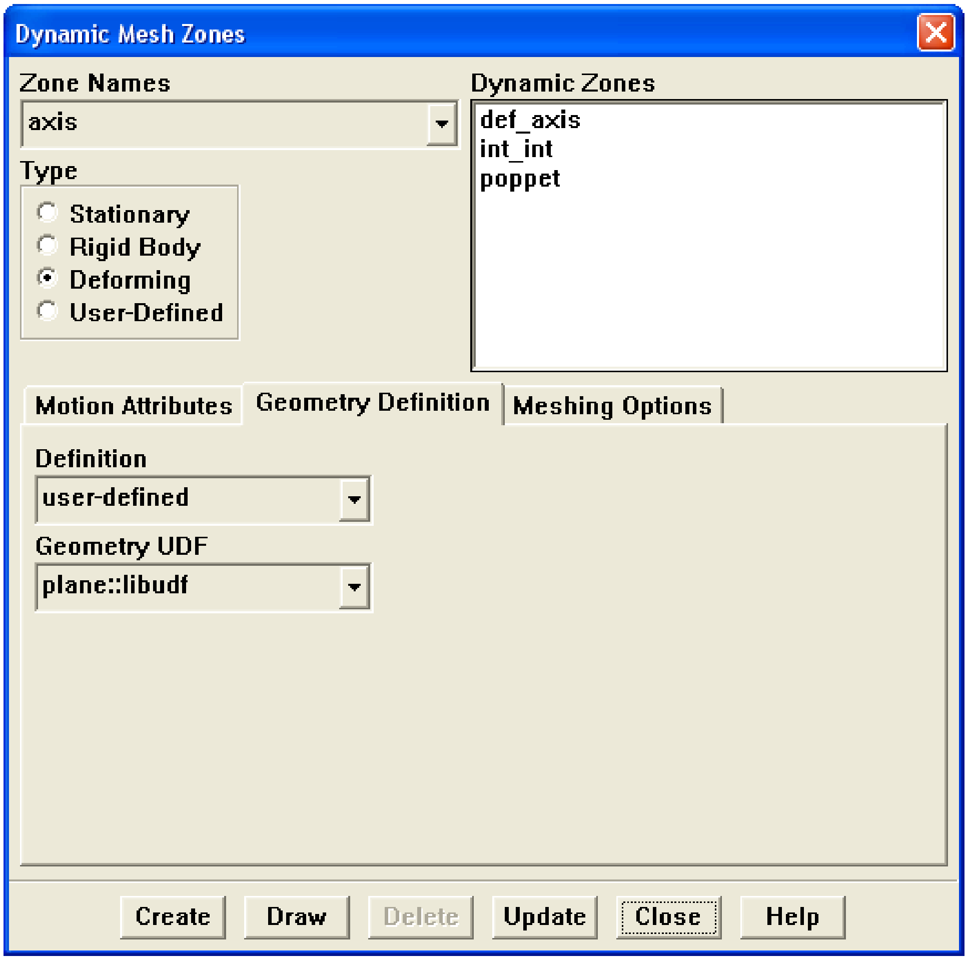
The Dynamic Mesh panel will be accessible only when you choose Unsteady as the time method in the Solver panel.

Next, open the Dynamic Mesh Zones panel.

Define ⟶ Dynamic Mesh ⟶Zones...

Select Deforming under Type in the Dynamic Mesh Zones panel (Figure 6.5.2) and click on the Geometry Definition tab. Select user-defined in the drop-down list under Definition, and choose the function name (e.g., plane) from the Geometry UDF drop-down list. Click Create and then Close.

See Section 2.6.2: DEFINE_GEOM for details about DEFINE_GEOM functions.



Dynamic Mesh Zones

Zone Names: axis

Type

○ Stationary
○ Rigid Body
● Deforming
○ User-Defined

Dynamic Zones

def_axis
int_int
poppet

Geometry Definition

Definition: user-defined

Geometry UDF: plane::libudf

Figure 6.5.2: The Dynamic Mesh Zones Panel

6.5.3 Hooking DEFINE_GRID_MOTION UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_GRID_MOTION UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Dynamic Mesh Zones panel (Figure 6.5.3). To hook the UDF to FLUENT, you will first need to enable the Dynamic Mesh model.

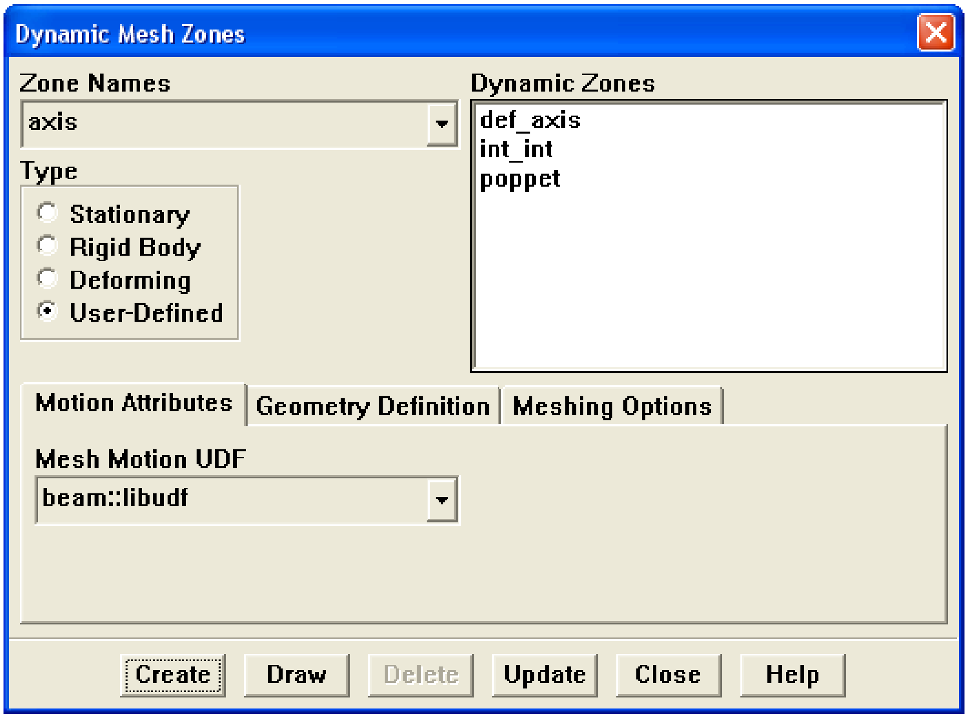
Define ⟶ Dynamic Mesh ⟶Parameters...

Select Dynamic Mesh under Model and click OK.

The Dynamic Mesh panel will be accessible only when you choose Unsteady as the time method in the Solver panel.

Next, open the Dynamic Mesh Zones panel.

Define ⟶ Dynamic Mesh ⟶Zones...



Dynamic Mesh Zones

Zone Names: axis

Dynamic Zones:
def_axis
int_int
poppet

Type:
○ Stationary
○ Rigid Body
○ Deforming
● User-Defined

Mesh Motion UDF: beam::libudf

Figure 6.5.3: Dynamic Mesh Zones

Select User-Defined under Type in the Dynamic Mesh Zones panel (Figure 6.5.3) and click on the Motion Attributes tab. Choose the function name (e.g., beam) from the Mesh Motion UDF drop-down list. Click Create then Close.

See Section 2.6.3: DEFINE_GRID_MOTION for details about DEFINE_GRID_MOTION functions.

6.5.4 Hooking DEFINE_SDOF_PROPERTIES UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_SDOF_PROPERTIES UDF, the name of the function you supplied as a DEFINE macro argument will become visible and selectable in the Dynamic Mesh Zones panel (Figure 6.5.4) in FLUENT. To hook the UDF to FLUENT, you will first need to enable the Dynamic Mesh model.

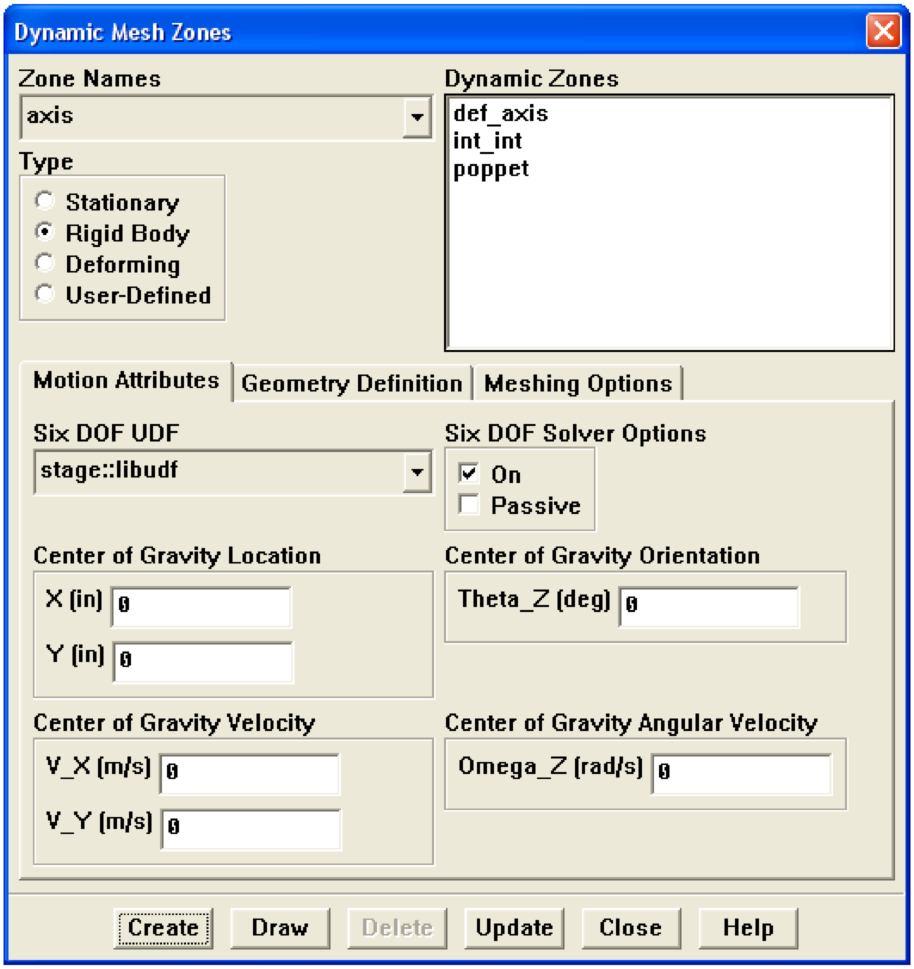
Define ⟶ Dynamic Mesh ⟶Parameters...

To enable the model, select Dynamic Mesh under Model and click OK.

> The Dynamic Mesh panel will be accessible only when you choose Unsteady as the time method in the Solver panel.

Next, open the Dynamic Mesh Zones panel.

Define ⟶ Dynamic Mesh ⟶Zones...



Dynamic Mesh Zones

Zone Names: axis

Type
○ Stationary
● Rigid Body
○ Deforming
○ User-Defined

Dynamic Zones
def_axis
int_int
poppet

Six DOF UDF: stage::libudf

Six DOF Solver Options
☑ On
□ Passive

Center of Gravity Location
X (in) 0
Y (in) 0

Center of Gravity Orientation
Theta_Z (deg) 0

Center of Gravity Velocity
V_X (m/s) 0
V_Y (m/s) 0

Center of Gravity Angular Velocity
Omega_Z (rad/s) 0

Figure 6.5.4: The Dynamic Mesh Zones Panel

Select Rigid Body under Type in the Dynamic Mesh Zones panel (Figure 6.5.4) and click on the Motion Attributes tab. Choose the function name (e.g., stage) from the Six DOF UDF drop-down list. Click Create then Close.

See Section 2.6.4: DEFINE_SDOF_PROPERTIES for details about DEFINE_SDOF_PROPERTIES functions.

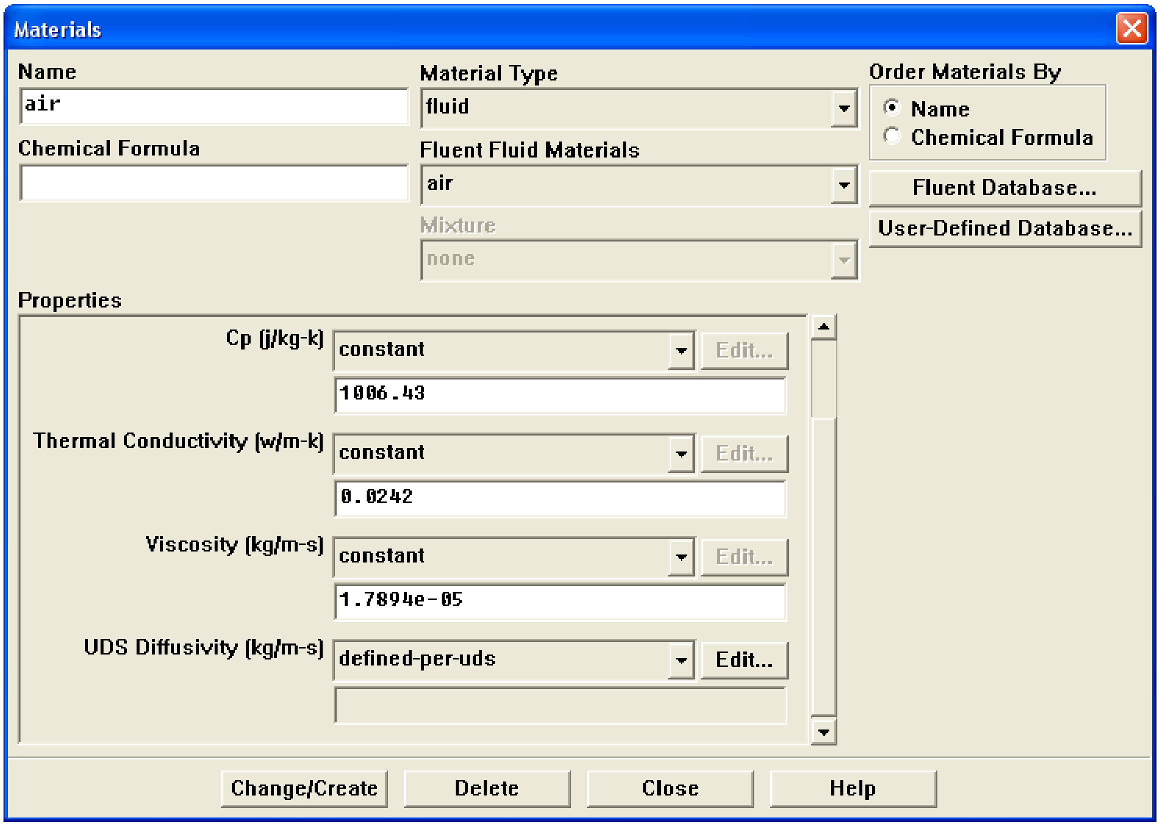
6.6 Hooking User-Defined Scalar (UDS) Transport Equation UDFs

This section contains methods for hooking anisotropic diffusion coeffient, fluex, and unsteady UDFs for scalar equations that have been defined using DEFINE macros described in Section 2.7: User-Defined Scalar (UDS) Transport Equation DEFINE Macros and interpreted or compiled using methods described in Chapters 4 or 5, respectively. See Section 6.2.13: Hooking DEFINE_PROFILE UDFs, Section 6.2.17: Hooking DEFINE_SOURCE UDFs, and Section 6.2.3: Hooking DEFINE_DIFFUSIVITY UDFs to hook scalar source term, profile, or isotropic diffusion coefficient UDFs.

6.6.1 Hooking DEFINE_ANISOTROPIC_DIFFUSIVITY UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_ANISOTROPIC_DIFFUSIVITY UDF, the name of the function you supplied as the first DEFINE macro argument (e.g., cyl_ortho_diff) will become visible and selectable in FLUENT. To hook the UDF to FLUENT, you will first need to open the Materials panel.

Define ⟶Materials...



Name: air

Chemical Formula:

Material Type: fluid

Fluent Fluid Materials: air

Mixture: none

Order Materials By: ● Name ○ Chemical Formula

Properties

Cp (j/kg-k): constant
1006.43

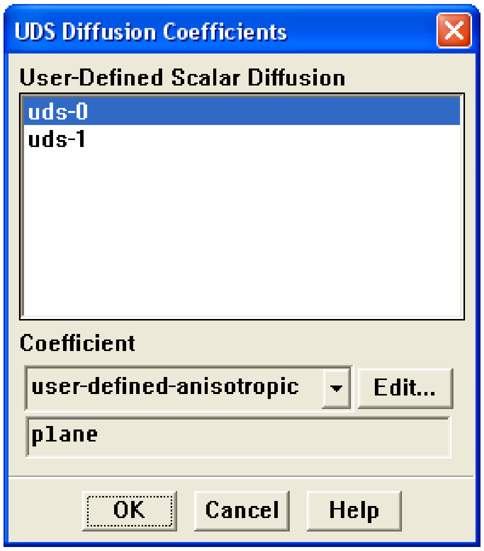
Thermal Conductivity (w/m-k): constant
0.0242

Viscosity (kg/m-s): constant
1.7894e-05

UDS Diffusivity (kg/m-s): defined-per-uds

Figure 6.6.1: The Materials Panel

Choose defined-per-uds from the drop-down list for UDS Diffusivity in the Materials panel (Figure 6.6.1). This will open the UDS Diffusion Coefficients panel (Figure 6.6.2).



UDS Diffusion Coefficients

User-Defined Scalar Diffusion

uds-0
uds-1

Coefficient

user-defined-anisotropic

plane

Figure 6.6.2: The UDS Diffusion Coefficients Panel

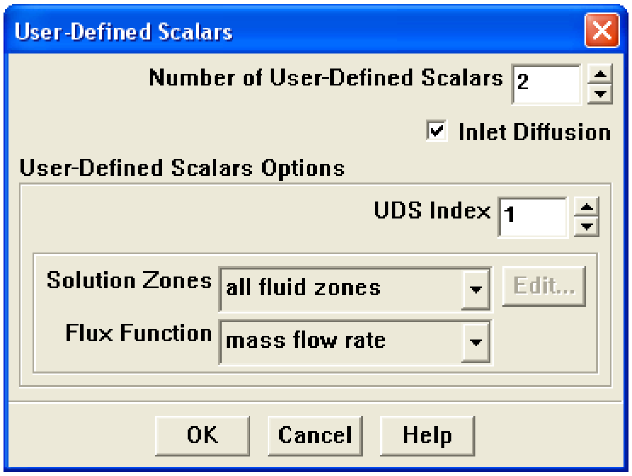
In the UDS Diffusion Coefficients panel, select a scalar equation (e.g., uds-0) and choose user-defined-anisotropic from the drop-down list under Coefficient. This will open the User-Defined Functions panel and allow you to select the UDF you wish to hook. Note that you will get an error if you have neglected to previously interpret or compile a `DEFINE_ANISOTROPIC_DIFFUSIVITY` UDF. Note that you can hook a unique diffusion coefficient UDF for each scalar tranpsport equation you have defined in your model.

See Section 2.7.2: `DEFINE_ANISOTROPIC_DIFFUSIVITY` for details about defining `DEFINE_ANISOTROPIC_DIFFUSIVITY` UDFs and the User's Guide for general information about UDS anisotropic diffusivity.

6.6.2 Hooking `DEFINE_UDS_FLUX` UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your `DEFINE_UDS_FLUX` UDF, the name of the argument that you supplied as the first `DEFINE` macro argument (e.g., `my_uds_flux`) will become visible and selectable in the User-Defined Scalars panel (Figure 6.6.3) in FLUENT.

Define ⟶ User-Defined ⟶Scalars...



Number of User-Defined Scalars 2

☑ Inlet Diffusion

User-Defined Scalars Options

UDS Index 1

Solution Zones all fluid zones

Flux Function mass flow rate

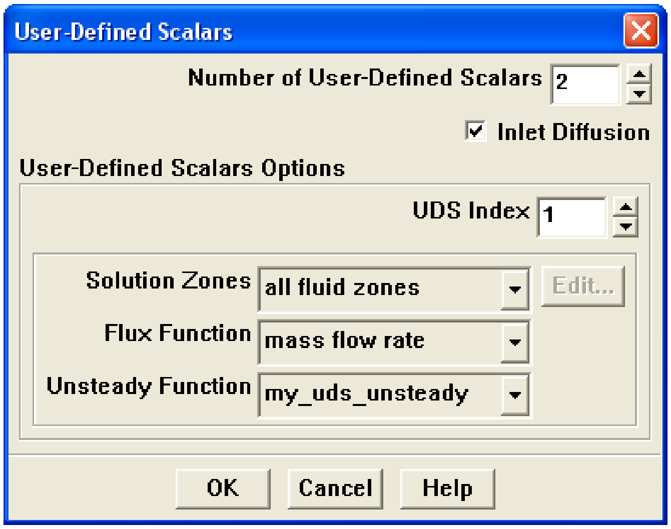
Figure 6.6.3: The User-Defined Scalars Panel

To hook the UDF to FLUENT, first specify the Number of User-Defined Scalars (e.g., 2) in the User-Defined Scalars panel (Figure 6.6.3). As you enter the number of user-defined scalars, the panel will expand to show the Flux Function settings. Next, for each scalar you have defined, increment the UDS Index and choose the Zone Type (e.g., all fluid zones), select the function (e.g., `my_uds_flux`) from the Flux Function drop-down list, and click OK.

6.6.3 Hooking DEFINE_UDS_UNSTEADY UDFs

Once you have interpreted (Chapter 4: Interpreting UDFs) or compiled (Chapter 5: Compiling UDFs) your DEFINE_UDS_UNSTEADY UDF, the name of the argument that you supplied as the first DEFINE macro argument (e.g., my_uds_unsteady) will become visible and selectable in the User-Defined Scalars panel (Figure 6.6.4) in FLUENT.

Define ⟶ User-Defined ⟶Scalars...



Number of User-Defined Scalars 2

☑ Inlet Diffusion

User-Defined Scalars Options

UDS Index 1

Solution Zones all fluid zones

Flux Function mass flow rate

Unsteady Function my_uds_unsteady

Figure 6.6.4: The User-Defined Scalars Panel

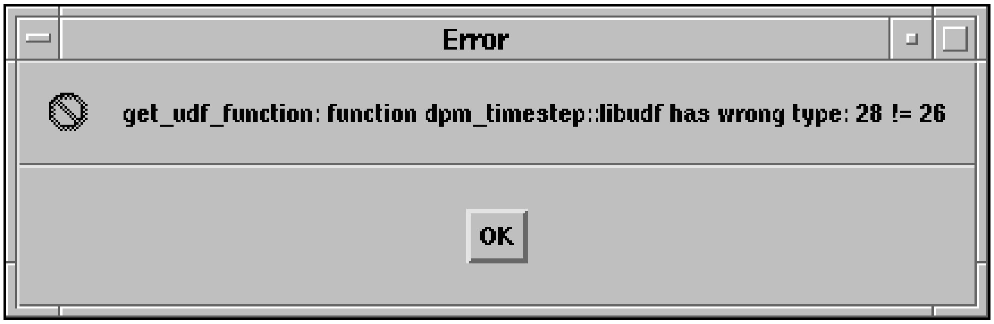
To hook the UDF to FLUENT, first specify the Number of User-Defined Scalars (e.g., 2) in the User-Defined Scalars panel (Figure 6.6.4). As you enter the number of user-defined scalars, the panel will expand to show the Unsteady Function settings. Next, for each scalar you have defined, increment the UDS Index and choose the Zone Type (e.g., all fluid zones), select the function (e.g., my_uds_unsteady) from the Unsteady Function drop-down list, and click OK.

6.7 Common Errors While Hooking a UDF to FLUENT

In some cases, if you select user-defined as an option in a graphics panel but have not previously interpreted or compiled/loaded a UDF, you will get an error message.

In other graphics panels, the user-defined option will only become visible as an option for a parameter *after* you have interpreted or compiled the UDF. Once you have interpreted or compiled the UDF, you can then select user-defined option and the list of interpreted and compiled/loaded UDFs will be displayed.

If you inadvertently hook a UDF to the wrong parameter in a FLUENT graphics panel (e.g., profile UDF for a material property), you will either get a real-time error message, or when you go to initialize or iterate the solution, FLUENT will report an error in the dialog box (Figure 6.7.1).



get_udf_function: function dpm_timestep::libudf has wrong type: 28 != 26

Figure 6.7.1: The Error Dialog

A message will also be reported to the console (and log file):

```
Error: get_udf_function: function dpm_timestep::libudf has wrong type: 28 != 26
Error Object: #f
```

Chapter 7. Parallel Considerations

This chapter contains an overview of user-defined functions (UDFs) for parallel FLUENT and their usage. Details about parallel UDF functionality can be found in the following sections:

7.1 Overview of Parallel FLUENT

Fluent Inc.'s parallel solver computes a solution to a large problem by simultaneously using multiple processes that may be executed on the same machine, or on different machines in a network. It does this by splitting up the computational domain into multiple partitions (Figure 7.1.1) and assigning each data partition to a different compute process, referred to as a compute node (Figure 7.1.2.) Each compute node executes the same program on its own data set, simultaneously, with every other compute node. The host process, or simply the host, does not contain grid cells, faces, or nodes (except when using the DPM shared-memory model). Its primary purpose is to interpret commands from Cortex (the FLUENT process responsible for user-interface and graphics-related functions) and in turn, to pass those commands (and data) to a compute node which distributes it to the other compute nodes.

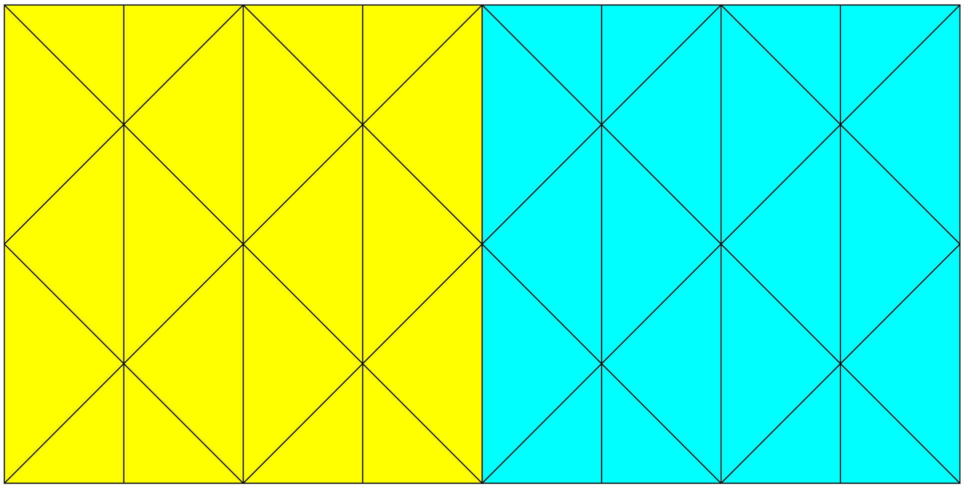


Figure 7.1.1: Partitioned Grid in Parallel FLUENT

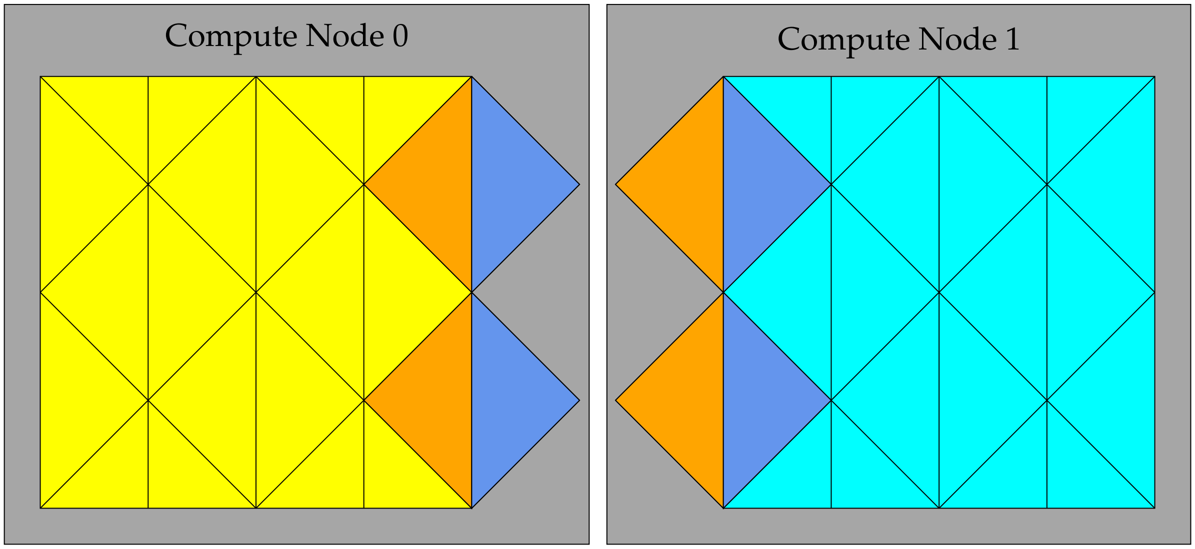


Figure 7.1.2: Partitioned Grid Distributed Between Two Compute Nodes

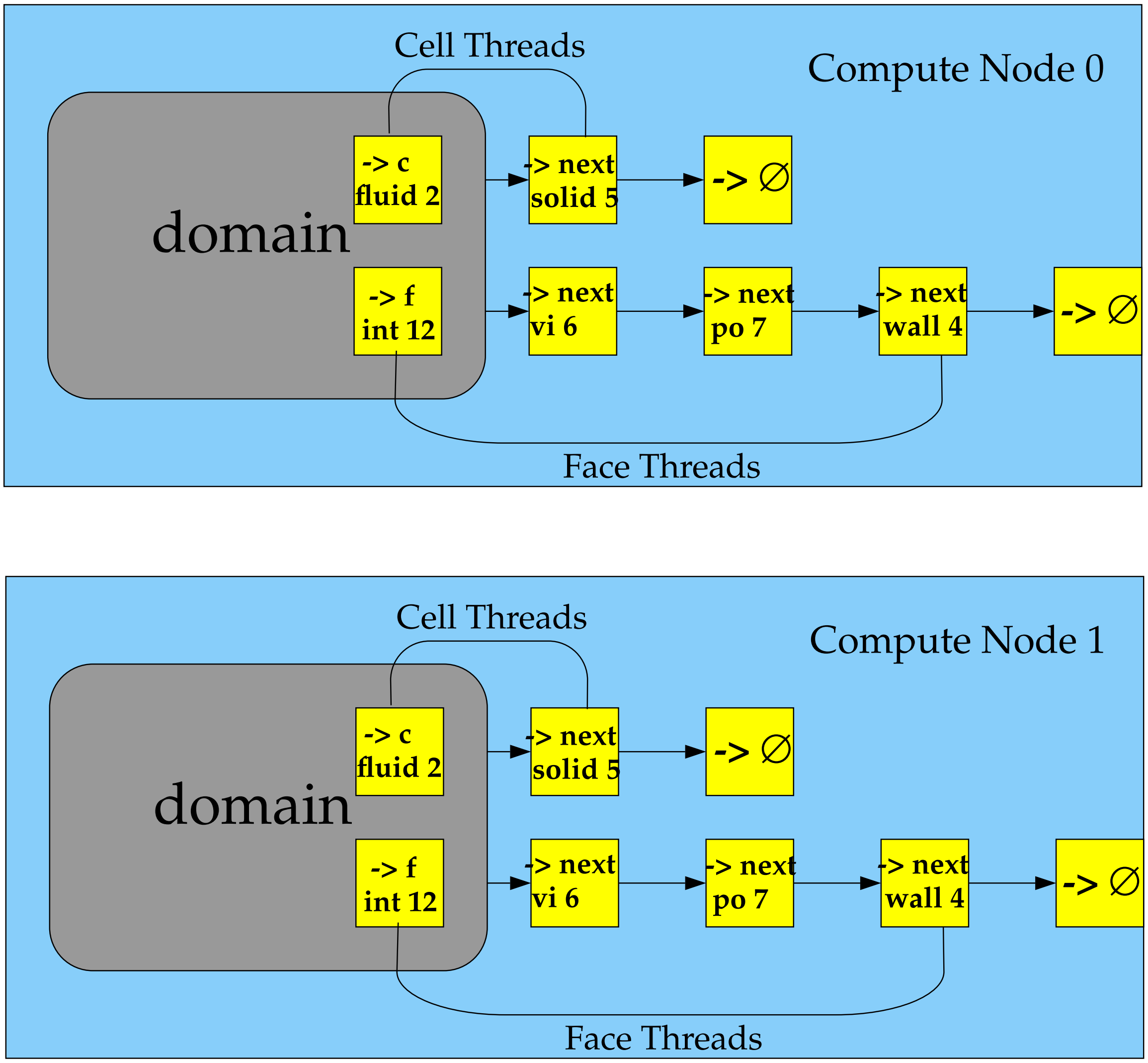


Figure 7.1.3: Domain and Thread Mirroring in a Distributed Grid

Compute nodes store and perform computations on their portion of the mesh while a single layer of overlapping cells along partition boundaries provides communication and continuity across the partition boundaries (Figure 7.1.2). Even though the cells and faces are partitioned, all of the domains and threads in a grid are mirrored on each compute node (Figure 7.1.3). The threads are stored as linked lists as in the serial solver. The compute nodes can be implemented on a massively parallel computer, a multiple-CPU workstation, or a network of workstations using the same or different operating systems.

7.1.1 Command Transfer and Communication

The processes that are involved in a FLUENT session running in parallel are defined by Cortex, a host process, and a set of n compute node processes (referred to as compute nodes), with compute nodes being labeled from 0 to n-1 (Figure 7.1.4). The host receives commands from Cortex and passes commands to compute node-0. Compute node-0, in turn, sends commands to the other compute nodes. All compute nodes (except 0) receive commands from compute node-0. Before the compute nodes pass messages to the host (via compute node-0), they synchronize with each other. Figure 7.1.4 shows the relationship of processes in parallel FLUENT.

Each compute node is 'virtually' connected to every other compute node and relies on its "communicator" to perform such functions as sending and receiving arrays, synchronizing, performing global reductions (such as summations over all cells), and establishing machine connectivity. A FLUENT communicator is a message-passing library. For example, it could be a vendor implementation of the Message Passing Interface (MPI) standard, as depicted in Figure 7.1.4.

All of the parallel FLUENT processes (as well as the serial process) are identified by a unique integer ID. The host process is assigned the ID `node_host(=999999)`. The host collects messages from compute node-0 and performs operation (such as printing, displaying messages, and writing to a file) on all of the data, in the same way as the serial solver. (Figure 7.1.5)

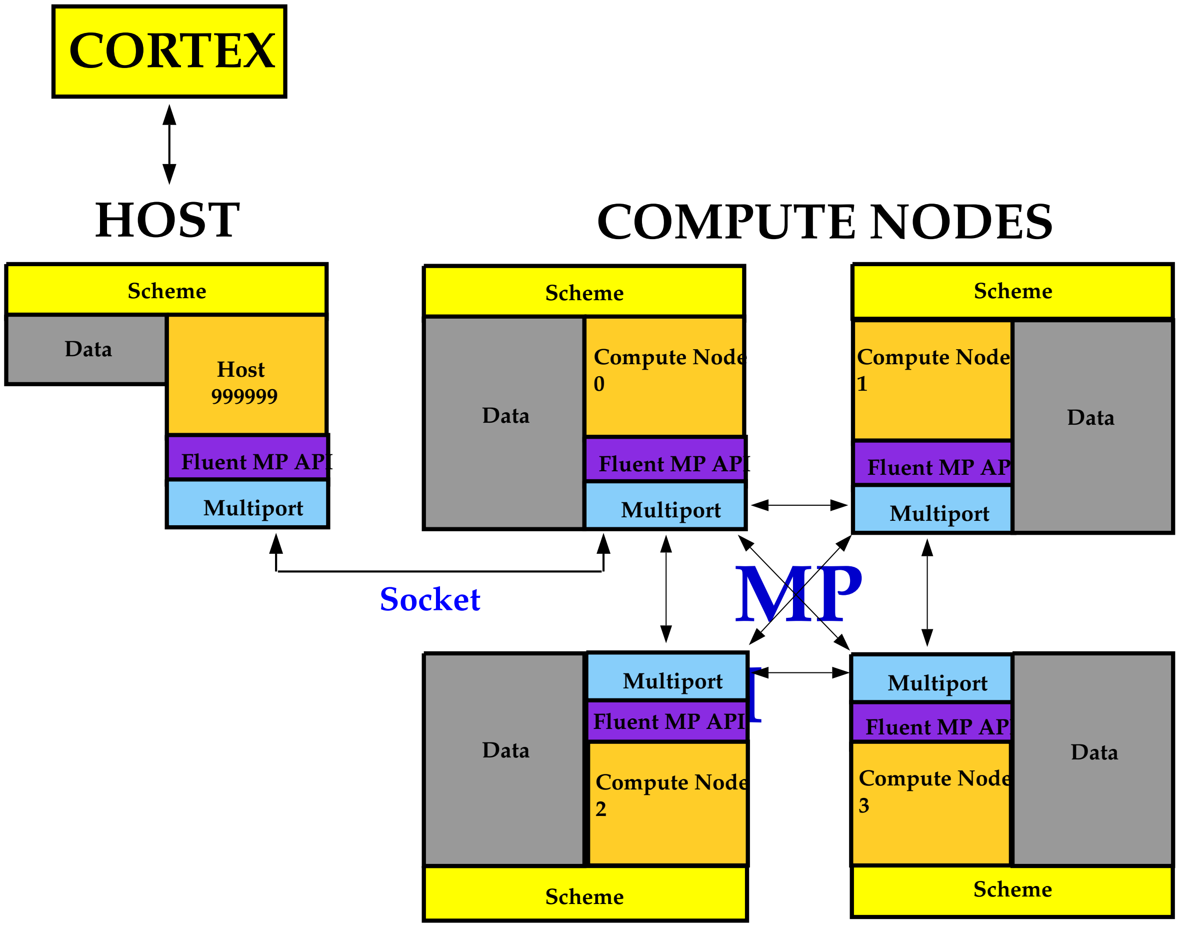


Figure 7.1.4: Parallel FLUENT Architecture

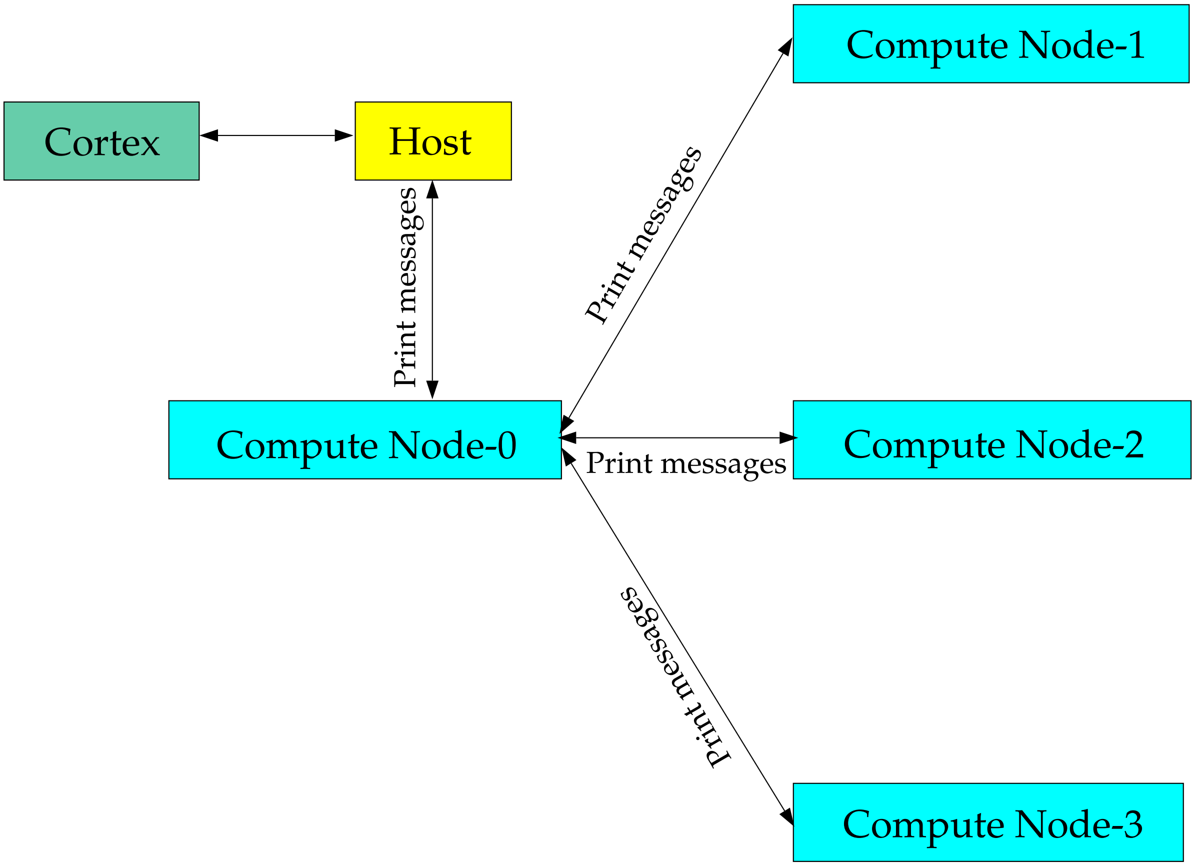


Figure 7.1.5: Example of Command Transfer in Parallel FLUENT

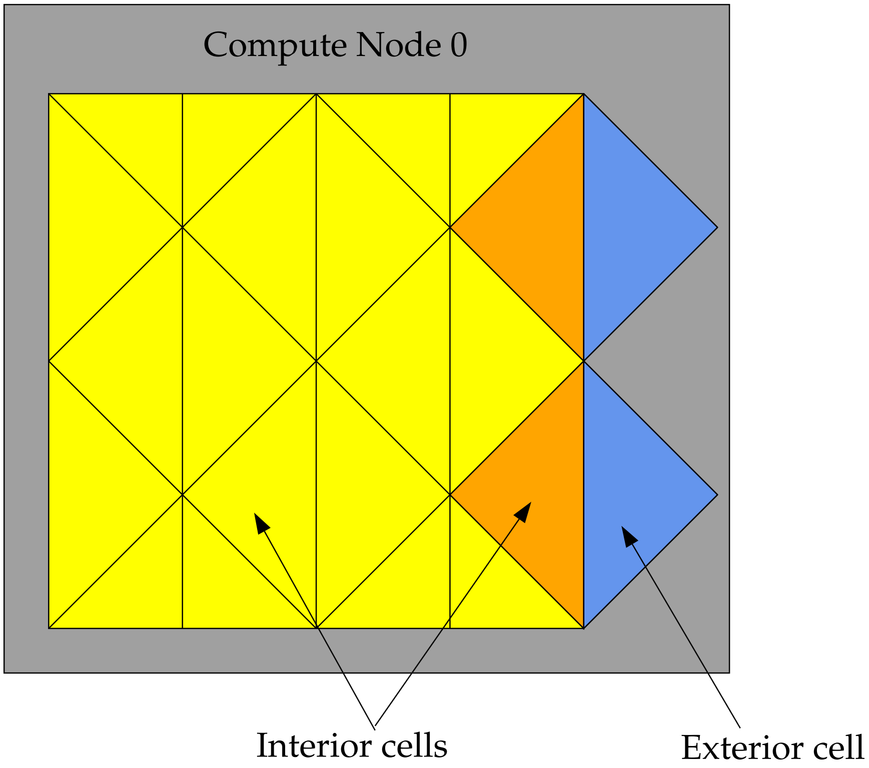


Figure 7.2.1: Partitioned Grid: Cells

7.2 Cells and Faces in a Partitioned Grid

Some terminology needs to be introduced to distinguish between different types of cells and faces in a partitioned grid. Note that this nomenclature applies only to parallel coding in FLUENT.

Cell Types in a Partitioned Grid

There are two types of cells in a partitioned grid: *interior cells* and *exterior cells* (Figure 7.2.1). Interior cells are fully contained within a grid partition. Exterior cells on one compute node correspond to the same interior cells in the adjacent compute node. (Figure 7.1.2). This duplication of cells at a partition boundary becomes important when you want to loop over cells in a parallel grid. There are separate macros for looping over interior cells, exterior cells, and all cells. See Section 7.5.5: Looping Macros for details.

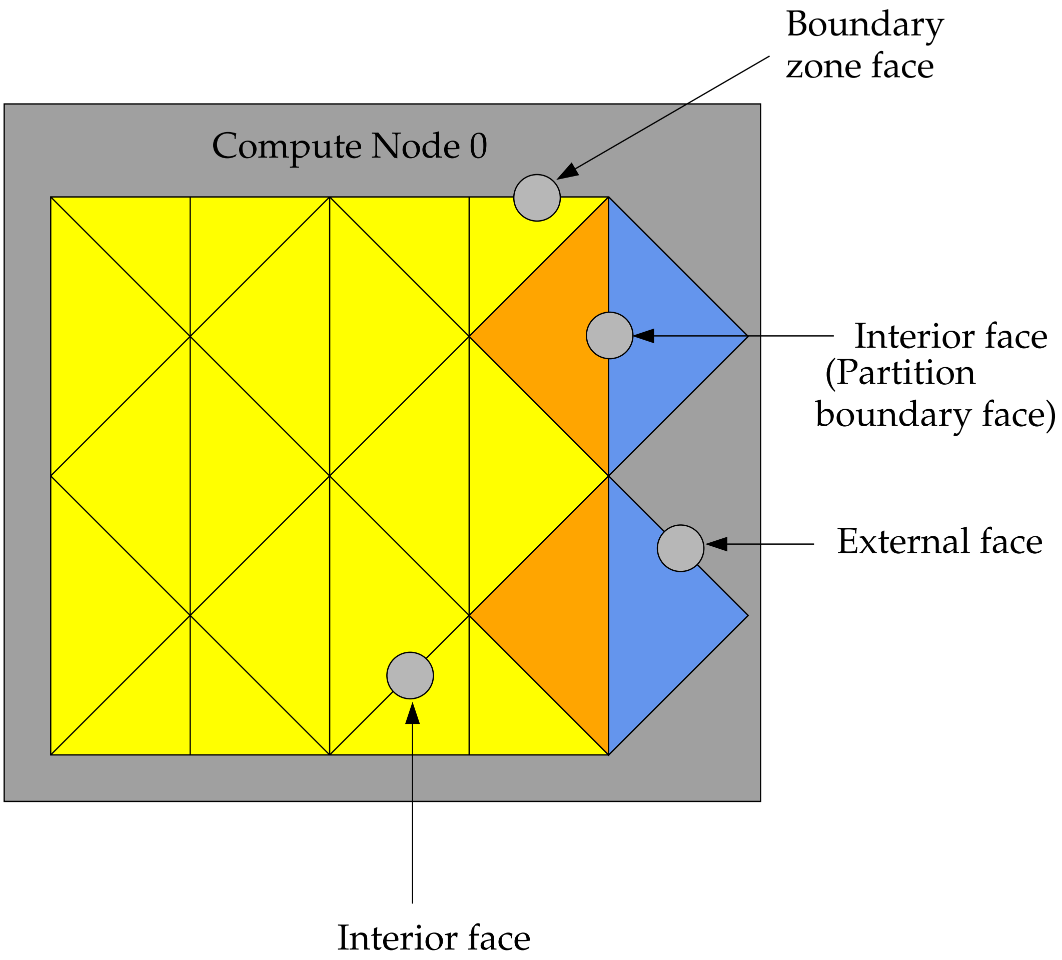


Figure 7.2.2: Partitioned Grid: Faces

Faces at Partition Boundaries

There are three classifications of faces in a partitioned grid: *interior*, *boundary zone*, and *external* (Figure 7.2.2). Interior faces have two neighboring cells. Interior faces that lie on a partition boundary are referred to as "partition boundary faces." Boundary zone faces lie on a physical grid boundary and have only one adjacent cell neighbor. External faces are non-partition boundary faces that belong to exterior cells. External faces are generally not used in parallel UDFs and, therefore, will not be discussed here.

Note that each partition boundary face is duplicated on adjacent compute nodes (Figure 7.1.2). This is necessary so that each compute node can calculate its own face values. However, this duplication can result in face data being counted twice when UDFs are involved in operations that involve summing data in a thread that contains partition boundary faces. For example, if your UDF is tasked with summing data over all of the faces in a grid, then as each node loops over its faces, duplicated partition boundary faces can be counted twice. For this reason, one compute node in every adjacent set is assigned by FLUENT as the ”principal” compute node, with respect to partition boundary faces. In other words, although each face can appear on one or two partitions, it can only “officially” belong to one of them. The boolean macro PRINCIPAL_FACE_P(f,t) returns TRUE if the face f is a principal face on the current compute node.

PRINCIPAL_FACE_P

You can use PRINCIPAL_FACE_P to test whether a given face is the principal face, before including it in a face loop summation. In the sample source code below, the area of a face is added to the total area only if it is the principal face. Note that PRINCIPAL_FACE_P is always TRUE for the serial version.

ℹ PRINCIPAL_FACE_P can be used *only* in compiled UDFs.

Example

```
begin_f_loop(f,t)
 if PRINCIPAL_FACE_P(f,t)  /* tests if the face is the principle face
                              FOR COMPILED UDFs ONLY */
 {
   F_AREA(area,f,t);   /* computes area of each face  */
   total_area +=NV_MAG(area);  /* computes total face area by
                                  accumulating  magnitude of each
                                  face's area  */
 }
end_f_loop(f,t)
```

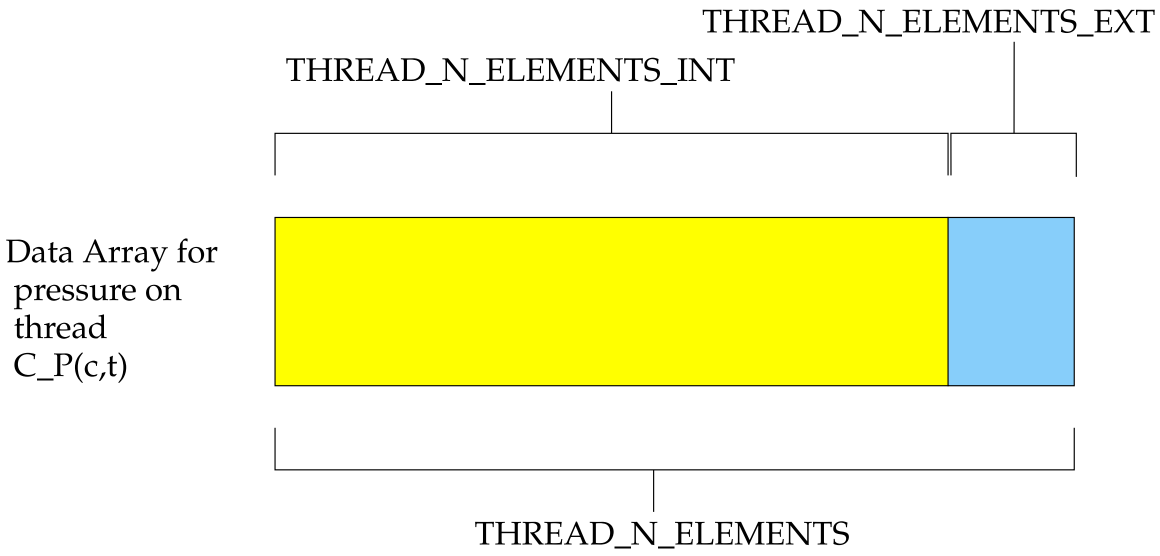


Figure 7.2.3: Exterior Thread Data Storage at End of a Thread Array

Exterior Thread Storage

Each thread stores the data associated with its cells or faces in a set of arrays. For example, pressure is stored in an array and the pressure for cell `c` is obtained by accessing element `c` of that array. Storage for exterior cell and face data occurs at the end of every thread data array, as shown in Figure 7.2.3.

7.3 Parallelizing Your Serial UDF

FLUENT's serial solver contains Cortex and only a single FLUENT process. The parallel solver, on the other hand, contains three types of executable: Cortex, host, and compute node (or simply "node" for short). When FLUENT runs in parallel, an instance of Cortex starts, followed by one host and `n` compute nodes, thereby giving a total of `n+2` running processes. For this reason, when you are running in parallel, you will need to make sure that your function will successfully execute as a host and a node process. At first it may appear that you should write three different versions of your UDF: one for serial, host, and node. Good programming practice, however, would suggest that you write a single UDF that, when compiled, can execute on any of the three versions. This process is referred to in this manual as "parallelizing" your serial UDF. You can do this by adding special macros for parallel as well as compiler directives to your UDF, as described below. Compiler directives, (e.g., `#if RP_NODE`, `RP_HOST`, `PARALLEL`) and their negated forms, direct the compiler to include only portions of the function that apply to a particular process, and ignore the rest (see Section 7.5.1: Compiler Directives).

A general rule of thumb is that your serial UDF needs to be "parallelized" if it performs an operation that is dependent on sending or receiving data from another compute node (or the host). UDFs that involve global reductions such as global sums, minimums or maximums, or ones that perform computations on data residing in adjacent compute nodes, for example, will need to be modified in order to run in parallel. Some other types of operations that require parallelization of serial source code include the following:

- Reading and Writing Files
- Global Reductions
- Global Sums
- Global Minimums and Maximums
- Global Logicals
- Certain Loops over Cells and Faces
- Displaying Messages on a Console
- Printing to a Host or Node Process

Once the source code for your "parallelized" UDF has been written, it can be compiled using the same methods for serial UDFs. Instructions for compiling UDFs can be found in Chapter 5: Compiling UDFs.

7.4 Parallelization of Discrete Phase Model (DPM) UDFs

The DPM model can be used for the following parallel options:

- Shared Memory
- Message Passing

When you are using a DPM-specific UDF (see Section 2.5: Discrete Phase Model (DPM) DEFINE Macros), it will be executed on the machine that is in charge of the considered particle, based on the above-mentioned parallel options. Since all fluid variables needed for DPM models are held in data structures of the tracked particles, no special care is needed when using DPM UDFs in parallel FLUENT with the exception of when you are writing in parallel to a sampling output file. In this case, you are not allowed to use the C function fprintf. Instead new functions are provided to enable the parallel file writing. Each node writes its information to separate files, which are put together and sorted upon closure of the file by FLUENT. The new functions can be used with the same parameter lists as the C function fprintf. The sorting of the files in parallel requires the specification of an extended parameter list. Information can be placed at the top of the file that will not sorted by using the function par_fprintf_head:

```
par_fprintf_head("x-coordinate y-coordinate z-coordinate\n")
```

This function will place the string "x-coordinate y-coordinate z-coordinate" at the top of the file.

Information is put on the nodes using the function par_fprintf:

```
par_fprintf("%d %d %e %e %e\n", p->injection->try_id, p->part_id,
P_POS(p)[0], P_POS(p)[1], P_POS(p)[2];
```

Here, the additional parameters p->injection->try_id and p->part_id are required for the sorting in parallel. The output written to the node-specific file of these two parameters will be removed. In serial, these sorting parameters are not required and the function call is instead the following:

```
par_fprintf("%e %e %e\n", P_POS(p)[0], P_POS(p)[1], P_POS(p)[2];
```

An example that utilizes these macros can be found in Section 2.5.8: DEFINE_DPM_OUTPUT.

Note that if you need to access other data such as cell values, then for the parallel options except Shared Memory, you will have access to all fluid and solver variables. When you choose the Shared Memory option, however, you will have access only to the variables defined in the macros SV_DPM_LIST and SV_DPMS_LIST. These macro definitions can be found in dpm.h.

7.5 Macros for Parallel UDFs

This section contains macros that you can use to parallelize your serial UDF. Where applicable, definitions for these macros can be found in the referenced header file (e.g., para.h).

7.5.1 Compiler Directives

When converting a UDF to run in parallel, some parts of the function may need to be done by the host and some by the compute nodes. This distinction is made when the UDF is compiled. By using Fluent-provided compiler directives, you can specify portions of your function to be assigned to the serial process, the host, or to the compute nodes. The UDF that you write will be written as a single file for the serial, parallel host and parallel node versions, but different parts of the function will be compiled to generate different versions of the dynamically linked shared object file libudf.so (libudf.dll on NT/Windows). Print tasks, for example, may be assigned exclusively to the host, while a task such as computing the total volume of a complete mesh will be assigned to the compute nodes. Since most operations are executed by the serial solver and either the host or compute nodes, negated forms of compiler directives are more commonly used.

Note that the primary purpose of the host is to interpret commands from Cortex and to pass those commands (and data) to compute node-0 for distribution. Since the host does not contain grid data, you will need to be careful not to include the host in any calculations that could, for example result in a division by zero. In this case, you will need to direct the compiler to ignore the host when it is performing grid-related calculations, by wrapping those operations around the #if !RP_HOST directive. For example, suppose that your UDF will compute the total area of a face thread, and then use that total area to compute a flux. If you do not exclude the host from these operations, the total area on the host will be zero and a floating point exception will occur when the function attempts to divide by zero to obtain the flux.

Example

```
#if !RP_HOST
avg_pres = total_pres_a / total_area;  /* if you don’t exclude the host
            this operation will result in a division by zero and error!
            Remember that host has no data so its total will be zero.*/
#endif
```

You will need to use the #if !RP_NODE directive when you want to exclude compute nodes from operations for which they do not have data.

Below is a list of parallel compiler directives and what they do. Note that if either RP_HOST or RP_NODE are true, then PARALLEL is also true.

```
/**********************************************************************/
/*   Compiler Directives                                               */
/**********************************************************************/

#if RP_HOST
    /*  only host process is involved */
#endif

#if RP_NODE
    /*  only compute nodes are involved */
#endif

#if PARALLEL
    /* both host and compute nodes are involved, but not serial
       equivalent to #if RP_HOST || RP_NODE  */
#endif


/*********************************************************************/
/*   Negated forms that are more commonly used                       */
/*********************************************************************/

#if !RP_HOST
    /*  either serial or compute node process is involved */
#endif

#if !RP_NODE
    /* either serial or host process is involved */
#endif

#if !PARALLEL
    /*  only serial process is involved */
#endif
```

The following simple UDF shows the use of compiler directives. The adjust function is used to define a function called `where_am_i`. This function queries to determine which type of process is executing and then displays a message on that computed node's monitor.

Example

```
/*****************************************************
  Simple UDF that uses compiler directives
*****************************************************/
#include "udf.h"
DEFINE_ADJUST(where_am_i, domain)
{
#if RP_HOST
  Message("I am in the host process\n");
#endif /* RP_HOST */

#if RP_NODE
  Message("I am in the node process with ID %d\n",myid);
  /* myid is a global variable which is set to the multiport ID for
     each node */
#endif /* RP_NODE */

#if !PARALLEL
  Message("I am in the serial process\n");
#endif /* !PARALLEL */
}
```

This simple allocation of functionality between the different types of processes is useful in a limited number of practical situations. For example, you may want to display a message on the compute nodes when a particular computation is being run (by using `RP_NODE` or `!RP_HOST`). Or, you can also choose to designate the host process to display messages (by using `RP_HOST` or `!RP_NODE`). Usually you want messages written only once by the host process (and the serial process). Simple messages such as “Running the Adjust Function” are straightforward. Alternatively, you may want to collect data from all the nodes and print the total once, from the host. To perform this type of operation your UDF will need some form of communication between processes. The most common mode of communication is between the host and the node processes.

7.5.2 Communicating Between the Host and Node Processes

There are two sets of similar macros that can be used to send data between the host and the compute nodes: `host_to_node_type_num` and `node_to_host_type_num`.

Host-to-Node Data Transfer

To send data from the host process to *all* the node processes (indirectly via compute node-0) we use macros of the form:

```
host_to_node_type_num(val_1,val_2,...,val_num);
```

where 'num' is the number of variables that will be passed in the argument list and 'type' is the data type of the variables that will be passed. The maximum number of variables that can be passed is 7. Arrays and strings can also be passed from host to nodes, one at a time, as shown in the examples below.

Examples

```
/*  integer and real variables passed from host to nodes  */
host_to_node_int_1(count);
host_to_node_real_7(len1, len2, width1, width2, breadth1, breadth2, vol);


/*  string and array variables passed from host to nodes  */
char wall_name[]="wall-17";
int thread_ids[10] = {1,29,5,32,18,2,55,21,72,14};

host_to_node_string(wall_name,8); /* remember terminating NUL character */
host_to_node_int(thread_ids,10);
```

Note that these `host_to_node` communication macros do not need to be "protected" by compiler directives for parallel UDFs, because all of these macros automatically do the following:

- send the variable value if compiled as the host version
- receive and then set the local variable if compiled as a compute node version
- do nothing in the serial version

The most common use for this set of macros is to pass parameters or boundary conditions from the host to the nodes processes. See the example UDF in Section 7.8: Parallel UDF Example for a demonstration of usage.

Node-to-Host Data Transfer

To send data from compute node-0 to the host process we use macros of the form:

```
node_to_host_type_num(val_1,val_2,...,val_num);
```

where 'num' is the number of variables that will be passed in the argument list and 'type' is the data type of the variables that will be passed. The maximum number of variables that can be passed is 7. Arrays and strings can also be passed from host to nodes, one at a time, as shown in the examples below.

Note that unlike the `host_to_node` macros which pass data from the host process to *all* of the compute nodes (indirectly via compute node-0), `node_to_host` macros pass data *only* from compute node-0 to the host.

Examples

```
/*  integer and real variables passed from compute node-0 to host  */
node_to_host_int_1(count);
node_to_host_real_7(len1, len2, width1, width2, breadth1, breadth2, vol);


/*  string and array variables passed from compute node-0 to host  */
char *string;
int string_length;
real vel[ND_ND];

node_to_host_string(string,string_length);
node_to_host_real(vel,ND_ND);
```

`node_to_host` macros do not need to be protected by compiler directives (e.g., `#if RP_NODE`) since they automatically do the following:

- send the variable value if the node is compute node-0 and the function is compiled as a node version
- do nothing if the function is compiled as a node version, but the node is not compute node-0
- receive and set variables if the function is compiled as the host version
- do nothing for the serial version

The most common usage for this set of macros is to pass global reduction results from compute node-0 to the host process. In cases where the value that is to be passed is computed by all of the compute nodes, there must be some sort of collection (such as a summation) of the data from all the compute nodes onto compute node-0 before the single collected (summed) value can be sent. Refer to the example UDF in Section 7.8: Parallel UDF Example for a demonstration of usage and Section 7.5.4: Global Reduction Macros for a full list of global reduction operations.

7.5.3 Predicates

There are a number of macros available in parallel FLUENT that expand to logical tests. These logical macros, referred to as "predicates", are denoted by the suffix P and can be used as test conditions in your UDF. The following predicates return TRUE if the condition in the parenthesis is met.

```
/*  predicate definitions from para.h header file */

# define MULTIPLE_COMPUTE_NODE_P (compute_node_count > 1)
# define ONE_COMPUTE_NODE_P (compute_node_count == 1)
# define ZERO_COMPUTE_NODE_P (compute_node_count == 0)
```

There are a number of predicates that allow you to test the identity of the node process in your UDF, using the compute node ID. A compute node's ID is stored as the global integer variable myid (see Section 7.7: Process Identification). Each of the macros listed below tests certain conditions of myid for a process. For example, the predicate I_AM_NODE_ZERO_P compares the value of myid with the compute node-0 ID and returns TRUE when they are the same. I_AM_NODE_SAME_P(n), on the other hand, compares the compute node ID that is passed in n with myid. When the two IDs are the same, the function returns TRUE. Node ID predicates are often used in conditional-if statements in UDFs.

```
/*  predicate definitions from para.h header file */

# define I_AM_NODE_HOST_P (myid == node_host)
# define I_AM_NODE_ZERO_P (myid == node_zero)
# define I_AM_NODE_ONE_P (myid == node_one)
# define I_AM_NODE_LAST_P (myid == node_last)
# define I_AM_NODE_SAME_P(n) (myid == (n))
# define I_AM_NODE_LESS_P(n) (myid < (n))
# define I_AM_NODE_MORE_P(n) (myid > (n))
```

Recall that from Section 7.2: Cells and Faces in a Partitioned Grid, a face may appear in one or two partitions but in order that summation operations don't count it twice, it is officially allocated to only one of the partitions. The tests above are used with the neighboring cell's partition ID to determine if it belongs to the current partition. The convention that is used is that the smaller-numbered compute node is assigned as the "principal" compute node for that face. PRINCIPAL_FACE_P returns TRUE if the face is located on its principal compute node. The macro can be used as a test condition when you want to perform a global sum on faces and some of the faces are partition boundary faces. (The macro returns TRUE for the serial process). Below is the definition of PRINCIPAL_FACE_P from para.h. See Section 7.2: Cells and Faces in a Partitioned Grid for more information about PRINCIPAL_FACE_P.

```
/*  predicate definitions from para.h header file */
# define PRINCIPAL_FACE_P(f,t) (!TWO_CELL_FACE_P(f,t) || \
       PRINCIPAL_TWO_CELL_FACE_P(f,t))

# define PRINCIPAL_TWO_CELL_FACE_P(f,t) \
    (!(I_AM_NODE_MORE_P(C_PART(F_C0(f,t),THREAD_T0(t))) || \
       I_AM_NODE_MORE_P(C_PART(F_C1(f,t),THREAD_T1(t)))))
```

7.5.4 Global Reduction Macros

Global reduction operations are those that collect data from all of the compute nodes, and reduce the data to a single value, or an array of values. These include operations such as global summations, global maximums and minimums, and global logicals. These macros begin with the prefix PRF_G and are defined in prf.h. Global summation macros are identified by the suffix SUM, global maximums by HIGH, and global minimums by LOW. The suffixes AND and OR identify global logicals.

The variable data types for each macro are identified in the macro name, where R denotes real data types, I denotes integers, and L denotes logicals. For example, the macro PRF_GISUM finds the summation of integers over the compute nodes.

Each of the global reduction macros discussed in the following sections has two different versions: one takes a single variable argument, while the other takes a variable array. Macros with a 1 appended to the end of the name take one argument, and return a single variable as the global reduction result. For example, the macro PRF_GIHIGH1(x) expands to a function that takes one argument x and computes the maximum of the variable x amongst all of the compute nodes, and returns it. The result can then be assigned to another variable (e.g., y) as shown below.

Example: Global Reduction Variable Macro

```
{
 int y;
 int x = myid;
 y = PRF_GIHIGH1(x); /* y now contains the same number (compute_node_count
                           - 1) on all the nodes */
}
```

Macros *without* a 1 suffix, on the other hand, compute global reduction variable arrays. These macros take three arguments: x, N, and iwork where x is an array, N is the number of elements in the array, and iwork is an array that is of the same type and size as x which is needed for temporary storage. Macros of this type are passed an array x and the elements of array x are filled with the new result after returning from the function. For example, the macro PRF_GIHIGH(x,N,iwork) expands to a function that computes the maximum of each element of the array x over all the compute nodes, uses the array iwork for temporary storage, and modifies array x by replacing each element with its resulting global maximum. The function does not return a value.

Example: Global Reduction Variable Array Macro

```
{
 real x[N], iwork[N];

 /* The elements of x are set in the working array here and will
    have different values on each compute node.

    In this case, x[0] could be the maximum cell temperature of all
    the cells on the compute node.  x[1] the maximum pressure, x[2]
    the maximum density, etc.
 */

  PRF_GRHIGH(x,N,iwork); /* The maximum value for each value over
                            all the compute nodes is found here */

  /* The elements of x on each compute node now hold the same
     maximum values over all the compute nodes for temperature,
     pressure, density, etc.  */

 }
```

Global Summations

Macros that can be used to compute global sums of variables are identified by the suffix SUM. PRF_GISUM1 and PRF_GISUM compute the global sum of integer variables and integer variable arrays, respectively.

PRF_GRSUM1(x) computes the global sum of a real variable x across all compute nodes. The global sum is of type float when running a single precision version of FLUENT and type double when running the double precision version. Alternatively, PRF_GRSUM(x,N,iwork) computes the global sum of a float variable array for single precision and double when running double precision.

Global Summations

Macro	Action
PRF_GISUM1(x)	Returns sum of integer x over all compute nodes.
PRF_GISUM(x,N,iwork)	Sets x to contain sums over all compute nodes.
PRF_GRSUM1(x)	Returns sum of x over all compute nodes; float if single precision, double if double precision.
PRF_GRSUM(x,N,iwork)	Sets x to contain sums over all compute nodes; float array if single precision, double array if double precision.

Global Maximums and Minimums

Macros that can be used to compute global maximums and minimums of variables are identified by the suffixes HIGH and LOW, respectively. PRF_GIHIGH1 and PRF_GIHIGH compute the global maximum of integer variables and integer variable arrays, respectively.

PRF_GRHIGH1(x) computes the global maximum of a real variable x across all compute nodes. The value of the global maximum is of type float when running the single precision version of FLUENT and type double when running the double precision version.

PRF_GRHIGH(x,N,iwork) computes the global maximum of a real variable array, similar to the description of PRF_GRSUM(x,N,iwork) on the previous page. The same naming convention used for PRF_GHIGH macros applies to PRF_GLOW.

Global Maximums

Macro	Action
PRF_GIHIGH1(x)	Returns maximum of integer x over all compute nodes.
PRF_GIHIGH(x,N,iwork)	Sets x to contain maximums over all compute nodes.
PRF_GRHIGH1(x)	Returns maximums of x over all compute nodes; float if single precision, double if double precision.
PRF_GRHIGH(x,N,iwork)	Sets x to contain maximums over all compute nodes; float array if single precision, double array if double precision.

Global Minimums

Macro	Action
PRF_GILOW1(x)	Returns minimum of integer x over all compute nodes.
PRF_GILOW(x,N,iwork)	Sets x to contain minimums over all compute nodes.
PRF_GRLOW1(x)	Returns minimum of x over all compute nodes; float if single precision, double if double precision.
PRF_GRLOW(x,N,iwork)	Sets x to contain minimums over all compute nodes; float array if single precision, double array if double precision.

Global Logicals

Macros that can be used to compute global logical ANDs and logical ORs are identified by the suffixes AND and OR, respectively. PRF_GLOR1(x) computes the global logical OR of variable x across all compute nodes. PRF_GLOR(x,N,iwork) computes the global logical OR of variable array x. The elements of x are set to TRUE if any of the corresponding elements on the compute nodes are TRUE.

By contrast, PRF_GLAND(x) computes the global logical AND across all compute nodes and PRF_GLAND(x,N,iwork) computes the global logical AND of variable array x. The elements of x are set to TRUE if any of the corresponding elements on the compute nodes are TRUE.

Global Logicals

Macro	**Action**
PRF_GLOR1(x)	TRUE when variable x is TRUE for *any* of the compute nodes
PRF_GLOR(x,N,work)	TRUE when *any* of the elements in variable array x is TRUE
PRF_GLAND1(x)	TRUE when variable x is TRUE for *all* compute nodes
PRF_GLAND(x,N,iwork)	TRUE when every element in variable array x is TRUE

Global Synchronization

PRF_GSYNC() can be used when you want to globally synchronize compute nodes before proceeding with the next operation. When you insert a PRF_GSYNC macro in your UDF, no commands beyond it will execute until the preceding commands in the source code have been completed on all of the compute nodes. Synchronization may also be useful when debugging your function.

7.5.5 Looping Macros

There are three types of cell looping macros that are available for parallel coding; one that loops over interior cells only, exterior cells only, and both interior and exterior cells.

Looping Over Cells

A partitioned grid in parallel FLUENT is made up of interior cells and exterior cells (see Figure 7.2.1). There is a set of cell-looping macros you can use to loop over interior cells only, exterior cells only, or both interior and exterior cells.

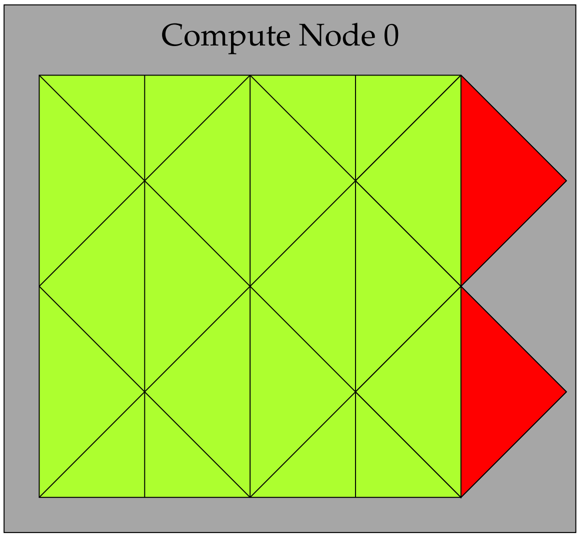


Figure 7.5.1: Looping Over Interior Cells in a Partitioned Grid Using `begin,end_c_loop_int` (indicated by the green cells)

Interior Cell Looping Macro

The macro `begin,end_c_loop_int` loops over interior cells in a partitioned grid (Figure 7.5.1) and is identified by the suffix `int`. This macro pair can also be used by the serial version of FLUENT to loop over all cells in the given thread. It contains a `begin` and `end` statement, and between these statements, operations can be performed on each of the thread's interior cells in turn. The macro is passed a cell index `c` and a cell thread pointer `tc`.

```
begin_c_loop_int(c, tc)
   {
    }
end_c_loop_int(c, tc)
```

Example

```
real total_volume = 0.0;
begin_c_loop_int(c,tc)
   {
    /*  C_VOLUME gets the cell volume and accumulates it.  The end
        result will be the total  volume of each compute node's
        respective grid   */
     total_volume += C_VOLUME(c,tc);
   }
end_c_loop_int(c,tc)
```

Exterior Cell Looping Macro

The macro `begin,end_c_loop_ext` loops over exterior cells in a partitioned grid (Figure 7.5.2) and is identified by the suffix `ext`. It contains a `begin` and `end` statement, and between these statements, operations can be performed on each of the thread's exterior cells in turn. The macro is passed a cell index `c` and cell thread pointer `tc`. In most situations, there is no need to use the exterior cell loop macros. They are only provided for convenience if you come across a special need in your UDF.

```
begin_c_loop_ext(c, tc)
   {
    }
end_c_loop_ext(c,tc)
```

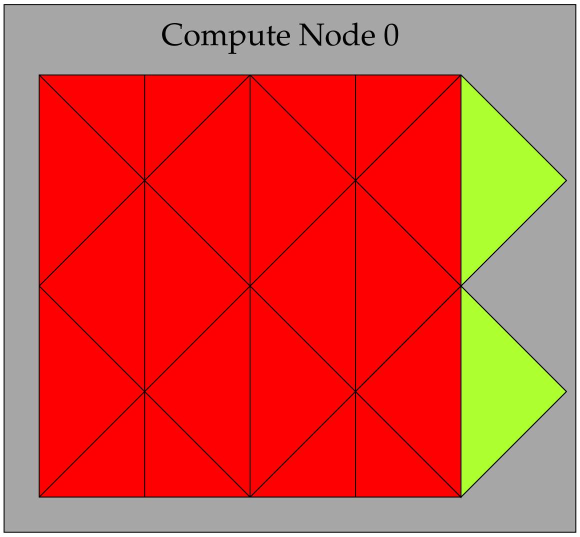


Figure 7.5.2: Looping Over Exterior Cells in a Partitioned Grid Using `begin,end_c_loop_ext` (indicated by the green cells)

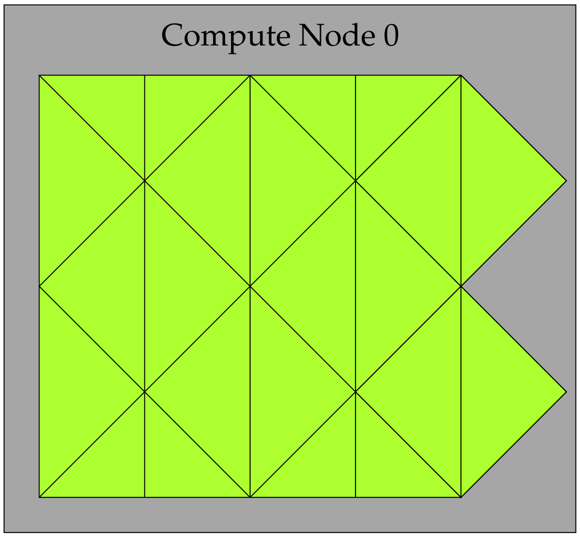


Figure 7.5.3: Looping Over Both Interior and Exterior Cells in a Partitioned Grid Using `begin,end_c_loop`

Interior and Exterior Cell Looping Macro

The macro `begin,end_c_loop` can be used in a serial or parallel UDF. In parallel, the macro will loop over all interior *and* exterior cells in a grid partition (Figure 7.5.3). Note that in serial, this pair of macros is equivalent to the `begin,end_c_loop_int` macros. It contains a `begin` and `end` statement, and between these statements, operations can be performed on each of the thread's interior and exterior cells in turn. The macro is passed a cell index `c` and a cell thread pointer `tc`.

```
begin_c_loop(c, tc)
   {
    }
end_c_loop(c ,tc)
```

Example

```
real temp;
begin_c_loop(c,tc)
   {
     /* get cell temperature, compute temperature function and store
        result in user-defined memory, location index 0.  */

     temp = C_T(c,tc);
     C_UDMI(c,tc,0) = (temp - tmin) / (tmax - tmin);
     /* assumes a valid tmax and tmin has already been computed */
   }
end_c_loop(c,tc)
```

Looping Over Faces

For the purpose of discussing parallel FLUENT, faces can be categorized into two types: interior faces and boundary zone faces (Figure 7.2.2). Partition boundary faces are interior faces that lie on the partition boundary of a compute node's grid.

begin,end_f_loop is a face looping macro available in parallel FLUENT that loops over all interior and boundary zone faces in a compute node. The macro begin,end_f_loop contains a begin and end statement, and between these statements, operations can be performed on each of the faces of the thread. The macro is passed a face index f and face thread pointer tf.

```
begin_f_loop(f, tf)
   {
    }
end_f_loop(f,tf)
```

begin_f_loop_int and begin_f_loop_ext are looping macros that loop around interior and exterior faces in a compute node, respectively. The _int form is equivalent to begin_f_loop_int. Although these macros exist, they do not have a practical application in UDFs and should not be used.

Recall that partition boundary faces lie on the boundary between two adjacent compute nodes and are represented on both nodes. Therefore, there are some computations (e.g., summations) when a partition boundary face will get counted twice in a face loop. This can be corrected by testing whether the current node is a face's principal compute node inside your face looping macro, using PRINCIPAL_FACE_P. This is shown in the example below. See Section 7.2: Cells and Faces in a Partitioned Grid for details.

Example

```
begin_f_loop(f,tf)
/*  each compute node checks whether or not it is the principal compute
    node with respect to the given face and thread   */

if PRINCIPAL_FACE_P(f,tf)
  /* face is on the principal compute node, so get the area and pressure
     vectors, and compute the total area and pressure for the thread
     from the magnitudes */
{
   F_AREA(area,f,tf);
   total_area += NV_MAG(area);
   total_pres_a += NV_MAG(area)*F_P(f,tf);
 }
end_f_loop(f,tf)

total_area = PRF_GRSUM1(total_area);
total_pres_a = PRF_GRSUM1(total_pres_a);
```

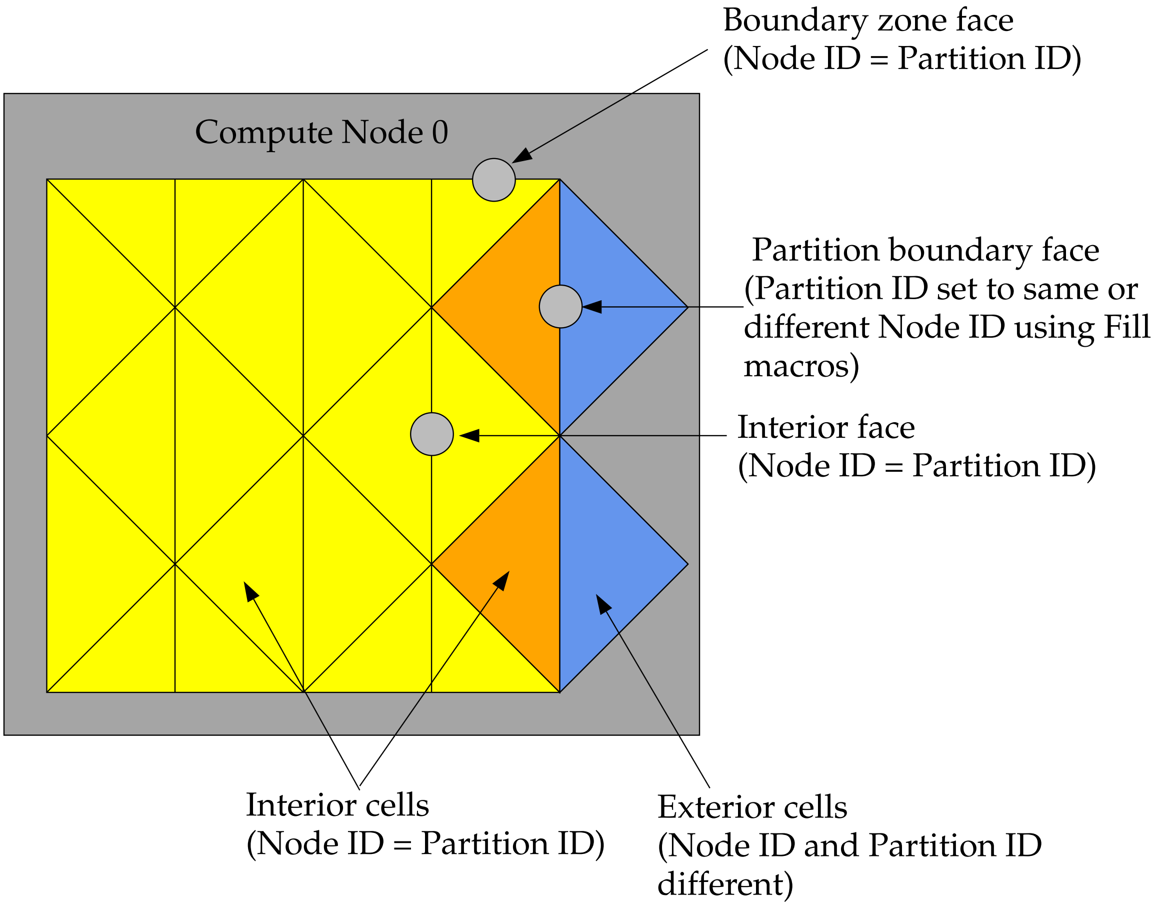


Figure 7.5.4: Partition Ids for Cells and Faces in a Compute Node

7.5.6 Cell and Face Partition ID Macros

In general, cells and faces have a partition ID that is numbered from `0` to `n-1`, where `n` is the number of compute nodes. The partition IDs of cells and faces are stored in the variables `C_PART` and `F_PART`, respectively. `C_PART(c,tc)` stores the integer partition ID of a cell and `F_PART(f,tf)` stores the integer partition ID of a face.

Note that `myid` can be used in conjunction with the partition ID, since the partition ID of an exterior cell is the ID of the neighboring compute node.

Cell Partition IDs

For interior cells, the partition ID is the same as the compute node ID. For exterior cells, the compute node ID and the partition ID are different. For example, in a parallel system with two compute nodes (0 and 1), the exterior cells of compute node-0 have a partition ID of `1`, and the exterior cells of compute node-1 have a partition ID of `0` (Figure 7.5.4).

Face Partition IDs

For interior faces and boundary zone faces, the partition ID is the same as the compute node ID. The partition ID of a partition boundary face, however, can be either the same as the compute node, or it can be the ID of the adjacent node, depending on what values F_PART is filled with (Figure 7.5.4). Recall that an exterior cell of a compute node has only partition boundary faces; the other faces of the cell belong to the adjacent compute node. Therefore, depending on the computation you want to do with your UDF, you may want to fill the partition boundary face with the same partition ID as the compute node (using Fill_Face_Part_With_Same) or with different IDs (using Fill_Face_Part_With_Different). Face partition IDs will need to be filled before you can access them with the F_PART macro. There is rarely a need for face partition IDs in parallel UDFs.

7.5.7 Message Displaying Macros

You can direct FLUENT to display messages on a host, node, or serial process using the Message utility. To do this, simply use a conditional if statement and the appropriate compiler directive (e.g., #if RP_NODE) to select the process(es) you want the message to come from. This is demonstrated in the following example:

Example

```
#if RP_NODE
  Message("Total Area Before Summing %f\n",total\_area);
#endif /* RP_NODE */
```

In this example, the message will be sent by the compute nodes. (It will not be sent by the host or serial process.)

Message0 is a specialized form of the Message utility. Message0 will send messages from compute node-0 only and is ignored on the other compute nodes, without having to use a compiler directive. Note that Message0 will also display messages on a serial process.

Example

```
/* Let Compute Node-0 display messages  */

Message0("Total volume = %f\n",total_volume);
```

7.5.8 Message Passing Macros

High-level communication macros of the form node_to_host... and host_to_node... that are described in Section 7.5.2: Communicating Between the Host and Node Processes are typically used when you want to send data from the host to all of the compute nodes, or from node-0 to the host. You cannot, however, use these high-level macros when you need to pass data between compute nodes, or pass data from all of the compute nodes to compute node-0. In these cases, you can use special message passing macros described in this section.

Note that the higher-level communication macros expand to functions that perform a number of lower-level message passing operations which send sections of data as single arrays from one process to another process. These lower-level message passing macros can be easily identified in the macro name by the characters SEND and RECV. Macros that are used to send data to processes have the prefix PRF_CSEND, whereas macros that are used to receive data from processes have the prefix PRF_CRECV. Data that is to be sent or received can belong to the following data types: character (CHAR), integer (INT), REAL and logical (BOOLEAN). BOOLEAN variables are TRUE or FALSE. REAL variables are assigned as float data types when running a single precision version of FLUENTand double when running double precision. Message passing macros are defined in the prf.h header file and are listed below.

```
/*  message passing macros  */

PRF_CSEND_CHAR(to, buffer, nelem, tag)
PRF_CRECV_CHAR (from, buffer, nelem, tag)
PRF_CSEND_INT(to, buffer, nelem, tag)
PRF_CRECV_INT(from, buffer, nelem, tag)
PRF_CSEND_REAL(to, buffer, nelem, tag)
PRF_CRECV_REAL(from, buffer, nelem, tag)
PRF_CSEND_BOOLEAN(to, buffer, nelem, tag)
PRF_CRECV_BOOLEAN(from, buffer, nelem, tag)
```

There are four arguments to the message passing macros. For ‘send’ messages, the argument to is the node ID of the process that data is being sent to. buffer is the name of an array of the appropriate type that will be sent. nelem is the number of elements in the array and tag is a user-defined message tag. The tag convention is to use myid when sending messages and to use the compute node ID of the sender when receiving messages.

For ‘receive’ messages, the argument from is the ID of the sending node. buffer is the name of an array of the appropriate type that will be received. nelem is the number of elements in the array and tag is the ID of the receiving node. The tag convention for receive messages is the ‘from’ node (same as the first argument).

Note that if variables that are to be sent or received are defined in your function as `real` variables, then you can use the message passing macros with the _REAL suffix. The compiler will then substitute PRF_CSENT_DOUBLE or PRF_CRECV_DOUBLE if you are running double precision and PRF_CSENT_FLOAT or PRF_CRECV_FLOAT, for single precision.

Because message-passing macros are low-level macros, you will need to make sure that when a message is sent from a node process, a corresponding receiving macro appears in the receiving-node process. Note that your UDF cannot directly send messages from a compute node (other than 0) to the host using message-passing macros. They can send messages indirectly to the host through compute node-0. For example, if you want your parallel UDF to send data from all of the compute nodes to the host for postprocessing purposes, the data will first have to be passed from each compute node to compute node-0, and then from compute node-0 to the host. In the case where the compute node processes send a message to compute node-0, compute node-0 must have a loop to receive the N messages from the N nodes.

Below is an example of a compiled parallel UDF that utilizes message passing macros PRF_CSEND and PRF_CRECV. Refer to the comments (*/) in the code, for details about the function.

Example: Message Passing

```
#include "udf.h"
#define WALLID 3

DEFINE_ON_DEMAND(face_p_list)
{
#if !RP_HOST  /* Host will do nothing in this udf. Serial will */
  face_t f;
  Thread *tf;
  Domain *domain;
  real *p_array;
  real x[ND_ND], (*x_array)[ND_ND];
  int n_faces, i, j;

  domain=Get_Domain(1); /* Each Node will be able to access
                                  its part of the domain */

  tf=Lookup_Thread(domain, WALLID); /* Get the thread from the domain */

  /* The number of faces of the thread on nodes 1,2... needs to be sent
     to compute node-0 so it knows the size of the arrays to receive
     from each */

  n_faces=THREAD_N_ELEMENTS_INT(tf);
```

```
    /* No need to check for Principal Faces as this UDF
       will be used for boundary zones only */

  #if RP_NODE
    if(! I_AM_NODE_ZERO_P) /* Nodes 1,2... send the number of faces */
      {
        PRF_CSEND_INT(node_zero, &n_faces, 1, myid);
      }
  #endif
  /* Allocating memory for arrays on each node */
    p_array=(real * )malloc(n_faces*sizeof(real));
    x_array=(real (*)[ND_ND])malloc(ND_ND*n_faces*sizeof(real));

    begin_f_loop(f, tf)
          /* Loop over interior faces in the thread, filling p_array
             with face pressure and x_array with centroid   */
      {
        p_array[f] = F_P(f, tf);
        F_CENTROID(x_array[f], f, tf);
      }
    end_f_loop(f, tf)

  /* Send data from node 1,2, ... to node 0 */
  Message0("\nstart\n");
  #if RP_NODE
    if(! I_AM_NODE_ZERO_P) /* Only SEND data from nodes 1,2... */
      {
        PRF_CSEND_REAL(node_zero, p_array, n_faces, myid);
        PRF_CSEND_REAL(node_zero, x_array[0], ND_ND*n_faces, myid);
      }
    else
  #endif
      {/* Node-0 and Serial processes have their own data,
           so list it out first */
        Message0("\n\nList of Pressures...\n");
                /* Same as Message() on SERIAL */

        for(j=0; j<n_faces; j++)
            /* n_faces is currently node-0/serial value */
          {
  # if RP_3D
           Message0("%12.4e %12.4e %12.4e %12.4e\n",
             x_array[j][0], x_array[j][1], x_array[j][2], p_array[j]);
  # else /* 2D */
           Message0("%12.4e %12.4e %12.4e\n",
             x_array[j][0], x_array[j][1], p_array[j]);
  # endif
          }
      }

  /* Node-0 must now RECV data from the other nodes and list that too */
  #if RP_NODE
    if(I_AM_NODE_ZERO_P)
      {
       compute_node_loop_not_zero(i)
             /* See para.h for definition of this loop */
       {
        PRF_CRECV_INT(i, &n_faces, 1, i);
                      /* n_faces now value for node-i */
        /* Reallocate memory for arrays for node-i */
        p_array=(real *)realloc(p_array, n_faces*sizeof(real));
        x_array=(real(*)[ND_ND])realloc(x_array,ND_ND*n_faces*sizeof(real));

        /* Receive data */
        PRF_CRECV_REAL(i, p_array, n_faces, i);
        PRF_CRECV_REAL(i, x_array[0], ND_ND*n_faces, i);
        for(j=0; j<n_faces; j++)
             {
  # if RP_3D
      Message0("%12.4e %12.4e %12.4e %12.4e\n",
              x_array[j][0], x_array[j][1], x_array[j][2], p_array[j]);
  # else /* 2D */
      Message0("%12.4e %12.4e %12.4e\n",
               x_array[j][0], x_array[j][1], p_array[j]);
  # endif
             }
          }
      }
  #endif /* RP_NODE */

    free(p_array); /* Each array has to be freed before function exit */
    free(x_array);

  #endif /* ! RP_HOST */
  }
```

7.5.9 Macros for Exchanging Data Between Compute Nodes

EXCHANGE_SVAR_MESSAGE and EXCHANGE_SVAR_FACE_MESSAGE can be used to exchange storage variables (SV_...) between compute nodes. EXCHANGE_SVAR_MESSAGE exchanges cell data between compute nodes, while EXCHANGE_SVAR_FACE_MESSAGE exchanges face data. Note that compute nodes are 'virtually' synchronized when an EXCHANGE macro is used; receiving compute nodes wait for data to be sent, before continuing.

```
/*  Compute Node Exchange Macros   */

EXCHANGE_SVAR_FACE_MESSAGE(domain, (SV_P, SV_NULL));
EXCHANGE_SVAR_MESSAGE(domain, (SV_P, SV_NULL));
```

EXCHANGE_SVAR_FACE_MESSAGE() is rarely needed in UDFs. You can exchange multiple storage variables between compute nodes. Storage variable names are separated by commas in the argument list and the list is ended by SV_NULL. For example, EXCHANGE_SVAR_MESSAGE(domain, (SV_P, SV_T, SV_NULL)) is used to exchange cell pressure and temperature variables. You can determine a storage variable name from the header file that contains the variable's definition statement. For example, suppose you want to exchange the cell pressure (C_P) with an adjacent compute node. You can look at the header file that contains the definition of C_P (mem.h) and determine that the storage variable for cell pressure is SV_P. You will need to pass the storage variable to the exchange macro.

7.6 Limitations of Parallel UDFs

The macro PRINCIPAL_FACE_P can be used *only* in compiled UDFs.

PRF_GRSUM1 and similar global reduction macros (Section 7.5.4: Global Reduction Macros cannot be used in DEFINE_SOURCE UDFs in parallel FLUENT. As a workaround, you can write a DEFINE_ADJUST UDF that calculates a global sum value in the adjust function, and then save the variable in user-defined memory. You can subsequently retrieve the stored variable from user-defined memory and use it inside a DEFINE_SOURCE UDF. This is demonstrated below.

In the following example, the spark volume is calculated in the DEFINE_ADJUST function and the value is stored in user-defined memory using C_UDMI. The volume is then retrieved from user-defined memory and used in the DEFINE_SOURCE UDF.

```
#include "udf.h"

static real spark_center[ND_ND]={20e-3, 1e-3};
static int fluid_chamber_ID = 2;

DEFINE_ADJUST(adjust, domain)
{
 real vol, xc[ND_ND], dis[ND_ND], radius;
 cell_t c;
 Thread * tc;

 tc = Lookup_Thread(domain, fluid_chamber_ID);

 radius = RP_Get_Real("spark/radius");

 vol = 0;
 begin_c_loop_int (c, tc)
    {
     C_CENTROID(xc, c, tc);
     NV_VV(dis, =, xc, -, spark_center);

     if (NV_MAG(dis) < radius)
         {
          vol += C_VOLUME(c, tc);
          }
     }
 end_c_loop_int (c, tc)
 vol = PRF_GRSUM1(vol);

 begin_c_loop_int (c, tc)
```

```
      {
       C_UDMI(c, tc, 1) = vol;
      }
   end_c_loop_int (c, tc)
  }

  DEFINE_SOURCE(energy_source, c, t, dS, eqn)
  {
    #if !RP_HOST
      real xc[ND_ND], dis[ND_ND];
      real source, radius, vol, CA, rpm, start_CA;

      rpm        = RP_Get_Real("dynamesh/in-cyn/crank-rpm");
      start_CA   = RP_Get_Real("spark/start-ca");

      CA = rpm*CURRENT_TIME*6+RP_Get_Real("dynamesh/in-cyn/crank-start-angle");

      if(CA>=start_CA&&CA<(start_CA+RP_Get_Real("spark/duration")*rpm*6))
        {
           radius = RP_Get_Real("spark/radius");
           vol = C_UDMI(c, t, 1);

           C_CENTROID(xc, c, t);
           NV_VV(dis, =, xc, -, spark_center);
           if (NV_MAG(dis) < radius)
             {
              source  =
              RP_Get_Real("spark/energy")/RP_Get_Real("spark/duration")/vol;
             return source;
              }
           else
              {
               return 0;
               }
        }
      else
        {
         return 0;
        }
    #endif
  }
```

i Interpreted UDFs cannot be used while running in parallel with an Infiniband interconnect. The compiled UDF approach should be used in this case.

7.7 Process Identification

Each process in parallel FLUENT has a unique integer identifier that is stored as the global variable myid. When you use myid in your parallel UDF, it will return the integer ID of the current compute node (including the host). The host process has an ID of node_host(=999999) and is stored as the global variable node_host. Compute node-0 has an ID of 0 and is assigned to the global variable node_zero. Below is a list of global variables in parallel FLUENT.

Global Variables in Parallel FLUENT

```
int node_zero = 0;
int node_host = 999999;
int node_one = 1;
int node_serial = 1000000;

int node_last;  /* returns the id of the last compute node  */
int compute_node_count; /* returns the number of compute nodes */
int myid;  /*  returns the id of the current compute node (and host) */
```

myid is commonly used in conditional-if statements in parallel UDF code. Below is some sample code that uses the global variable myid. In this example, the total number of faces in a face thread is first computed by accumulation. Then, if myid is not compute node-0, the number of faces is passed from all of the compute nodes to compute node-0 using the message passing macro PRF_CSEND_INT. (See Section 7.5.8: Message Passing Macros for details on PRF_CSEND_INT.)

Example: Usage of myid

```
  int noface=0;
  begin_f_loop(f, tf)    /* loops over faces in a face thread and
                            computes number of faces */
    {
     noface++;
    }
  end_f_loop(f, tf)

/* Pass the number of faces from node 1,2, ... to node 0 */
```

```
#if RP_NODE
if(myid!=node_zero)
  {
   PRF_CSEND_INT(node_zero, &noface, 1, myid);
  }
#endif
```

7.8 Parallel UDF Example

The following is an example of a serial UDF that has been parallelized, so that it can run on any version of FLUENT(host, node, serial). Explanations for the various changes from the simple serial version are provided in the /* comments */ and discussed below. The UDF, named face_av, is defined using an adjust function, computes a global sum of pressure on a specific face zone, and computes its area average.

Example: Global Summation of Pressure on a Face Zone and its Area Average Computation

```
#include "udf.h"

DEFINE_ADJUST(face_av,domain)
{
/* Variables used by serial, host, node versions */
 int surface_thread_id=0;
 real total_area=0.0;
 real total_force=0.0;

/* "Parallelized" Sections */
#if !RP_HOST   /* Compile this section for computing processes only (serial
                  and node)  since these variables are not available
                  on the host */
 Thread* thread;
 face_t face;
 real area[ND_ND];
#endif /* !RP_HOST */



/* Get the value of the thread ID from a user-defined Scheme variable */
#if !RP_NODE /* SERIAL or HOST */
 surface_thread_id = RP_Get_Integer("pres_av/thread-id");
 Message("\nCalculating on Thread # %d\n",surface_thread_id);
#endif /* !RP_NODE */

 /*  To set up this user Scheme variable in cortex type */
 /* (rp-var-define 'pres_av/thread-id 2 'integer #f) */
 /* Once set up you can change it to another thread's ID using : */
 /* (rpsetvar 'pres_av/thread-id 7) */

 /* Send the ID value to all the nodes */
 host_to_node_int_1(surface_thread_id); /* Does nothing in serial */
#if RP_NODE
 Message("\nNode %d is calculating on thread # %d\n",myid,
          surface_thread_id);
#endif /* RP_NODE */

#if !RP_HOST  /* SERIAL or NODE */
 /* thread is only used on compute processes */
 thread = Lookup_Thread(domain,surface_thread_id);

 begin_f_loop(face,thread)

/* If this is the node to which face "officially" belongs,*/
/* get the area vector and pressure and increment         */
/* the total area and total force values for this node    */
  if (PRINCIPAL_FACE_P(face,thread)) /* Always TRUE in serial version */
  {
   F_AREA(area,face,thread);
   total_area += NV_MAG(area);
   total_force += NV_MAG(area)*F_P(face,thread);
  }
 end_f_loop(face,thread)

 Message("Total Area Before Summing %f\n",total_area);
 Message("Total Normal Force Before Summing %f\n",total_force);

# if RP_NODE /* Perform node synchronized actions here
                Does nothing in Serial */
  total_area = PRF_GRSUM1(total_area);
  total_force = PRF_GRSUM1(total_force);
# endif /* RP_NODE */

#endif /* !RP_HOST */

/* Pass the node's total area and pressure to the Host for averaging  */
 node_to_host_real_2(total_area,total_force); /* Does nothing in SERIAL */

#if !RP_NODE /* SERIAL or HOST */
Message("Total Area After Summing: %f (m2)\n",total_area);
Message("Total Normal Force After Summing %f (N)\n",total_force);
Message("Average pressure on Surface %d is %f (Pa)\n",
                 surface_thread_id,(total_force/total_area));
#endif /* !RP_NODE */
}
```

The function begins by initializing the variables surface_thread_id, total_area, and total_force for all processes. This is done because the variables are used by the serial, host, and node processes. The compute nodes use the variables for computation purposes and the host uses them for message-passing and displaying purposes. Next, the preprocessor is directed to compile thread, face, and area variables only on the serial and node versions (and not the host), since faces and threads are only defined in the serial and node versions of FLUENT. (Note that in general, the host will ignore these statements since its face and cell data are zero, but it is good programming practice to exclude the host. See Section 7.5: Macros for Parallel UDFs for details on compiler directives.)

Next, a user-defined Scheme variable named pres_av/thread-id is obtained by the host (and serial) process using the RP_Get_Integer utility (see Section 3.6: Scheme Macros), and is assigned to the variable surface_thread_id. (Note that this user-defined Scheme variable was previously set up in Cortex and assigned a value of 2 by typing the text commands shown in the comments.) Once a Scheme-based variable is set up for the thread ID, it can be easily changed to another thread ID from the text interface, without the burden of modifying the source code and recompiling the UDF. Since the host communicates with Cortex and the nodes are not aware of Scheme variables, it is essential to direct the compiler to exclude the nodes from compiling them using #if !RP_NODE. Failure to do this will result in a compile error.

The surface_thread_id is then passed from the host to compute node-0 using the host_to_node macro. Compute node-0, in turn, automatically distributes the variable to the other compute nodes. The serial and node processes are directed to loop over all faces in the thread associated with the surface_thread_id, using #if !RP_HOST, and compute the total area and total force. Since the host does not contain any thread data, it will ignore these statements if you do not direct the compiler, but it is good programming practice to do so. The macro PRINCIPAL_FACE_P is used to ensure that faces at partition boundaries are not counted twice (see Section 7.2: Cells and Faces in a Partitioned Grid). The nodes display the total area and force on the monitors (using the Message utility) before the global summation. PRF_GRSUM1 (Section 7.5.4: Global Reduction Macros) is a global summation macro that is used to compute the total area and force of all the compute nodes. These operations are directed for the compute nodes using #if RP_NODE.

7.9 Writing Files in Parallel

Although compute nodes can perform computations on data simultaneously when FLUENT is running in parallel, when data is written to a single, common file, the writing operations have to be sequential. The file has to be opened and written to by processes that have access to the desired file system. It is often the case that the compute nodes are running on a dedicated parallel machine without disk space. This means that all of the data has to be written from the host process which always runs on a machine with access to a file system, since it reads and writes the case and data files. This implies that unlike the example in Section 7.5.8: Message Passing Macros, where data is only passed to compute node-0 to be collated, data must now be passed from all the compute nodes to compute node-0, which then passes it on to the host node which writes it to the file. This process is known as "marshalling".

Thus, file writing in parallel is done in the following stages:

1. The host process opens the file.
2. Compute node-0 sends its data to the host.
3. The other compute nodes send their data to compute node-0.
4. Compute node-0 receives the data from the other compute nodes and sends it to the host.
5. The host receives the data sent from *all* the compute nodes and writes it to the file.
6. The host closes the file.

Since the SERIAL, HOST, and NODE processes are performing different tasks, the example below appears long and utilizes a large number of compiler directives. If, however, as an exercise you make three copies of this example and in each copy delete the unused sections for either the SERIAL, HOST or NODE versions, then you will see that it is actually quite a simple routine.

Example: Writing Data to a Common File on the Host Process's File System

```
/*******************************************************************
   This function will write pressures and positions
    for a fluid zone to a file on the host machine
********************************************************************/
#include "udf.h"

# define FLUID_ID 2
```

```
DEFINE_ON_DEMAND(pressures_to_file)
{
  /* Different variables are needed on different nodes */
#if !RP_HOST
 Domain *domain=Get_Domain(1);
 Thread *thread;
 cell_t c;
#else
 int i;
#endif

#if !RP_NODE
 FILE *fp = NULL;
 char filename[]="press_out.txt";
#endif

#if PARALLEL
 int size;  /* data passing variables */
 real *array;
 int pe;
#endif

 /* Only Serial and Compute Nodes have data on threads */
#if !RP_HOST
 thread=Lookup_Thread(domain,FLUID_ID);
#endif

#if !RP_NODE /* SERIAL or HOST */
 if ((fp = fopen(filename, "w"))==NULL)
       Message("\n Warning: Unable to open %s for writing\n",filename);
 else
       Message("\nWriting Pressure to %s...",filename);
#endif

 /* UDF Now does 3 different things depending on SERIAL, NODE or HOST */

#if !PARALLEL /* SERIAL */
 begin_c_loop(c,thread)
   fprintf(fp, "%g\n", C_P(c,thread));/* Simply write out pressure data */
 end_c_loop(c,thread)
#endif /* !PARALLEL */

#if RP_NODE
```

```
 /* Each Node loads up its data passing array */
 size=THREAD_N_ELEMENTS_INT(thread);
 array = (real *)malloc(size * sizeof(real));

 begin_c_loop_int(c,thread)
   array[c]= C_P(c,thread);
 end_c_loop_int(c,thread)
   /* Set pe to destination node */
   /* If on node_0 send data to host */
   /* Else send to node_0 because */
   /*   compute nodes connect to node_0 & node_0 to host */
 pe = (I_AM_NODE_ZERO_P) ? node_host : node_zero;

 PRF_CSEND_INT(pe, &size, 1, myid);
 PRF_CSEND_REAL(pe, array, size, myid);

 free(array);/* free array on nodes once data sent */

 /* node_0 now collect data sent by other compute nodes */
 /*   and sends it straight on to the host */
 if (I_AM_NODE_ZERO_P)
   compute_node_loop_not_zero (pe)
   {
     PRF_CRECV_INT(pe, &size, 1, pe);
     array = (real *)malloc(size * sizeof(real));
     PRF_CRECV_REAL(pe, array, size, pe);

     PRF_CSEND_INT(node_host, &size, 1, myid);
     PRF_CSEND_REAL(node_host, array, size, myid);

     free((char *)array);
   }
#endif /* RP_NODE */

#if RP_HOST
 compute_node_loop (pe) /* only acts as a counter in this loop */
   {
     /* Receive data sent by each node and write it out to the file */
     PRF_CRECV_INT(node_zero, &size, 1, node_zero);
     array = (real *)malloc(size * sizeof(real));
     PRF_CRECV_REAL(node_zero, array, size, node_zero);
     for (i=0; i<size; i++)
       fprintf(fp, "%g\n", array[i]);

     free(array);
   }
#endif /* RP_HOST */


#if !RP_NODE /* SERIAL or HOST */
 fclose(fp); /* Close the file that was only opened if on SERIAL or HOST */
 Message("Done\n");
#endif

}
```

Chapter 8. Examples

This chapter provides examples of UDFs that range from simple to complex. It begins with a step-by-step process that takes you through the seven basic steps of programming and using a UDF in FLUENT. Some examples for commonly-used types of applications are subsequently presented.

- Section 8.1: Step-By-Step UDF Example
- Section 8.2: Detailed UDF Examples

8.1 Step-By-Step UDF Example

The following 7-step process can be used to code a UDF and use it effectively in your FLUENT model.

8.1.1 Process Overview

1. Define your problem. (Section 8.1.2: Step 1: Define Your Problem)
2. Create a C source code file. (Section 8.1.3: Step 2: Create a C Source File)
3. Start FLUENT and read in (or set up) the case file. (Section 8.1.4: Step 3: Start FLUENT and Read (or Set Up) the Case File)
4. Interpret or compile the source file. (Section 8.1.5: Step 4: Interpret or Compile the Source File)
5. Hook the UDF to FLUENT. (Section 8.1.6: Step 5: Hook the UDF to FLUENT)
6. Run the calculation. (Section 8.1.7: Step 6: Run the Calculation)
7. Analyze the numerical solution and compare it to expected results. (Section 8.1.8: Step 7: Analyze the Numerical Solution and Compare to Expected Results)

To begin the process, you'll need to define the problem you wish to solve using a UDF (Step 1). For example, suppose you want to use a UDF to define a custom boundary profile for your model. You will first need to define the set of mathematical equations that describes the profile.

Next you will need to translate the mathematical equation (conceptual design) into a function written in the C programming language (Step 2). You can do this using any text editor. Save the file with a `.c` suffix (e.g., `udfexample.c`) in your working directory. (See Appendix A for some basic information on C programming.)

Once you have written the C function, you are ready to start FLUENT and read in (or set up) your case file (Step 3). You will then need to interpret or compile the source code, debug it (Step 4), and then hook the function to FLUENT (Step 5). Finally you'll run the calculation (Step 6), analyze the results from your simulation, and compare them to expected results (Step 7). You may loop through this entire process more than once, depending on the results of your analysis. Follow the step-by-step process in the sections below to see how this is done.

8.1.2 Step 1: Define Your Problem

The first step in creating a UDF and using it in your FLUENT model involves defining your model equation(s).

Consider the turbine vane illustrated in Figure 8.1.1. An unstructured grid is used to model the flow field surrounding the vane. The domain extends from a periodic boundary on the bottom to an identical one on the top, a velocity inlet on the left, and a pressure outlet on the right.

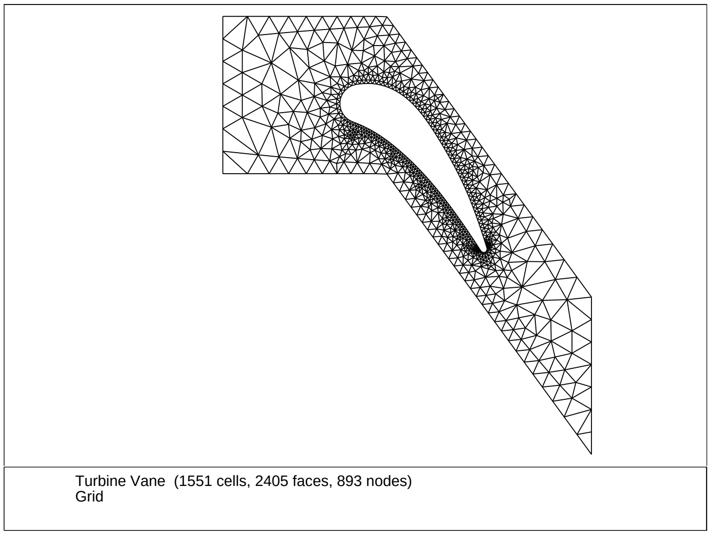


Figure 8.1.1: The Grid for the Turbine Vane Example

A flow field in which a constant x velocity is applied at the inlet will be compared with one where a parabolic x velocity profile is applied. The results of a constant-velocity applied field (of 20 m/s) at the inlet are shown in Figures 8.1.2 and 8.1.3. The initial constant-velocity field is distorted as the flow moves around the turbine vane.

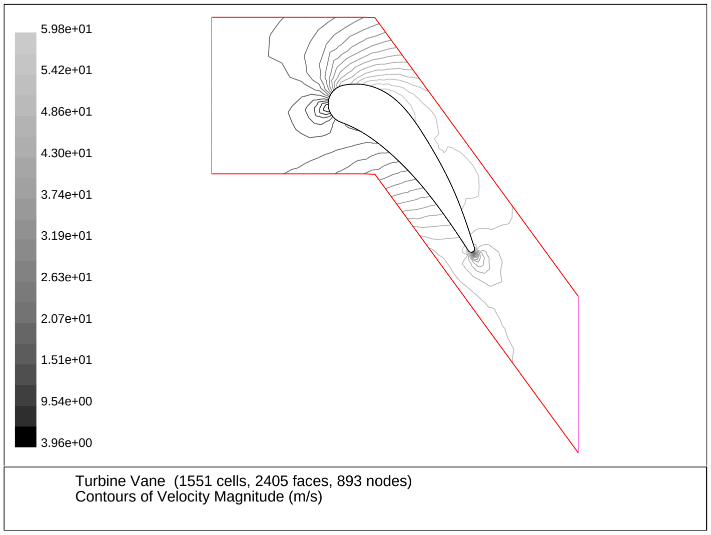


Figure 8.1.2: Velocity Magnitude Contours for a Constant Inlet x Velocity

Now suppose that you want to impose a non-uniform x velocity to the turbine vane inlet, which is described by the profile

$$v_x = 20 - 20\left(\frac{y}{0.0745}\right)^2 \qquad (8.1\text{-}1)$$

where the variable y is 0.0 at the center of the inlet, and extends to values of ± 0.0745 m at the top and bottom. Thus the x velocity will be 20 m/s at the center of the inlet, and 0 at the edges.

To solve this type of problem, you can write a custom profile UDF and apply it to your FLUENT model.

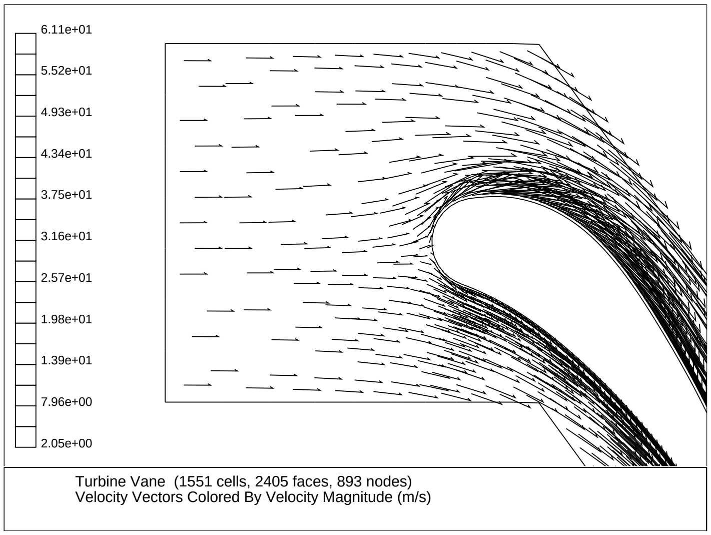


Figure 8.1.3: Velocity Vectors for a Constant Inlet x Velocity

8.1.3 Step 2: Create a C Source File

Now that you have determined the equation that defines the UDF (Equation 8.1-1), you can use any text editor to create a file containing C code that implements the function. Save the source code file with a `.c` extension (e.g., `udfexample.c`) in your working directory. The following UDF source code listing contains a single function, only. Your source file can contain multiple concatenated functions. (Refer to Appendix A for basic information on C programming.)

Below is an example of how the equation derived in Step 1 (Equation 8.1-1) can be implemented in a UDF. The functionality of the UDF is designated by the leading `DEFINE` macro. Here, the `DEFINE_PROFILE` macro is used to indicate to the solver that the code proceeding it will provide profile information at boundaries. Other `DEFINE` macros will be discussed later in this manual. (See Chapter 2: `DEFINE` Macros for details about `DEFINE` macro usage.)

```
/**********************************************************************
  udfexample.c
  UDF for specifying a steady-state velocity profile boundary condition
 **********************************************************************/

#include "udf.h"  /* must be at the beginning of every UDF you write */

DEFINE_PROFILE(x_velocity,thread,index)
{
  real x[ND_ND]; /* this will hold the position vector */
  real y;
  face_t f;

  begin_f_loop(f,thread)  /* loops over all faces in the thread passed
                              in the DEFINE macro argument  */
    {
      F_CENTROID(x,f,thread);
      y = x[1];
      F_PROFILE(f,thread,index) = 20. - y*y/(.0745*.0745)*20.;
    }
  end_f_loop(f,thread)
}
```

The first argument of the DEFINE_PROFILE macro, x_velocity, is the name of the UDF that you supply. The name will appear in the boundary condition panel once the function is interpreted or compiled, enabling you to hook the function to your model. Note that the UDF name you supply cannot contain a number as the first character. The equation that is defined by the function will be applied to all cell faces (identified by f in the face loop) on a given boundary zone (identified by thread). The thread is defined automatically when you hook the UDF to a particular boundary in the FLUENT graphical user-interface. The index is defined automatically through the begin_f_loop utility. In this UDF, the begin_f_loop macro (Section 3.3: Looping Macros) is used to loop through all cell faces in the boundary zone. For each face, the coordinates of the face centroid are accessed by F_CENTROID (Section 3.2.4: Face Centroid (F_CENTROID)). The *y* coordinate y is used in the parabolic profile equation and the returned velocity is assigned to the face through F_PROFILE. begin_f_loop and F_PROFILE (Section 3.2.6: Set Boundary Condition Value (F_PROFILE)) are Fluent-supplied macros. Refer to Chapter 3: Additional Macros for Writing UDFs for details on how to utilize predfined macros and functions supplied by Fluent Inc. to acccess FLUENT solver data and perform other tasks.

8.1.4 Step 3: Start FLUENT and Read (or Set Up) the Case File

Once you have created the source code for your UDF, you are ready to begin the problem setup in FLUENT.

1. Start FLUENT from your working directory.
2. Read (or set up) your case file.

8.1.5 Step 4: Interpret or Compile the Source File

You are now ready to interpret or compile the profile UDF named x_velocity) that you created in Step 2 and is contained within the source file named udfexample.c. In general, you *must* compile your function as a compiled UDF if the source code contains structured reference calls or other elements of C that are not handled by the FLUENT interpreter. To determine whether you should compile or interpret your UDF, see Section 1.5.1: Differences Between Interpreted and Compiled UDFs.

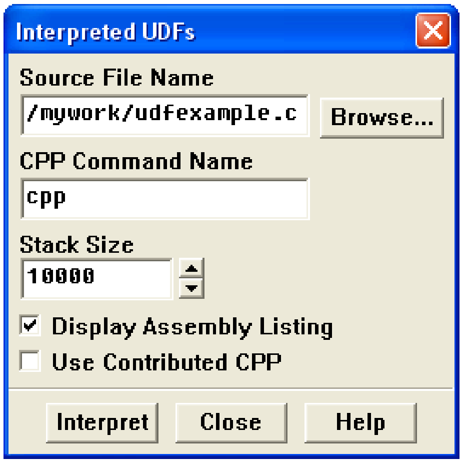
Interpret the Source File

Follow the procedure below to interpret your source file in FLUENT. For more information on interpreting UDFs, see Chapter 4: Interpreting UDFs.

Note that this step does not apply to Windows parallel networks. See Section 4.2: Interpreting a UDF Source File Using the Interpreted UDFs Panel for details.

1. Open the Interpreted UDFs panel.

   Define → User-Defined → Functions → Interpreted...



Interpreted UDFs

Source File Name: /mywork/udfexample.c

CPP Command Name: cpp

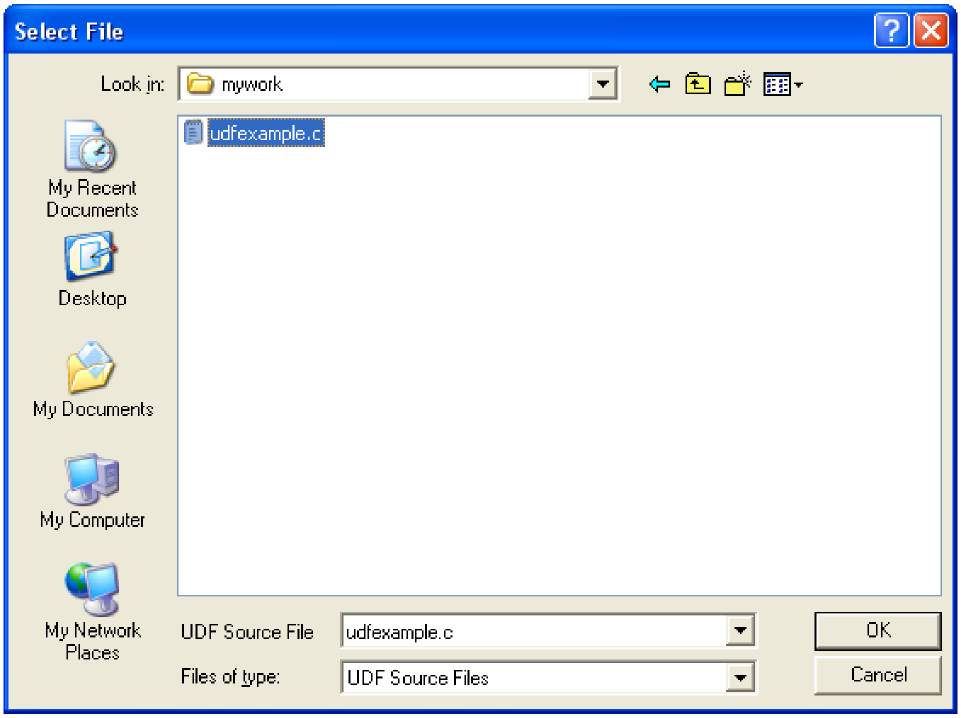
Stack Size: 10000

☑ Display Assembly Listing

□ Use Contributed CPP

Figure 8.1.4: The Interpreted UDFs Panel

2. In the Interpreted UDFs panel, select the UDF source file by either typing the complete path in the Source File Name field or click Browse... to use the browser. This will open the Select File panel (Figure 8.1.5).



Look in: mywork

UDF Source File: udfexample.c

Files of type: UDF Source Files

Figure 8.1.5: The Select File Panel

3. In the Select File panel, highlight the directory path under Directories (e.g., /nfs/homeserver/home/clb/mywork/), and the desired file (e.g., udfexample.c) under Files, and click OK. This will close the Select File panel and display the path to the selected source file in the Interpreted UDFs panel.

4. In the Interpreted UDFs panel, specify the C preprocessor to be used in the CPP Command Name field. You can keep the default cpp or you can select Use Contributed CPP to use the preprocessor supplied by Fluent Inc.

   If you installed the `/contrib` component from the "PrePost" CD, then by default, the cpp preprocessor will appear in the panel. For Windows NT users, the standard Windows NT installation of the FLUENT product includes the cpp preprocessor.

   For Windows NT systems, if you are using the Microsoft compiler, then use the command `cl -E`.

   Note that the default CPP Command Name is different for 2d and 3d cases. The default preprocessor is cpp and `cc -E` for a 2d and 3d case, respectively.

5. Keep the default Stack Size setting of 10000, unless the number of local variables in your function will cause the stack to overflow. In this case, set the Stack Size to a number that is greater than the number of local variables used.

6. Keep the Display Assembly Listing option on if you want a listing of assembly language code to appear in your console window when the function interprets. This option will be saved in your case file, so that when you read the case in a subsequent FLUENT session, the assembly code will be automatically displayed.

7. Click Interpret to interpret your UDF. If the Display Assembly Listing option was chosen, then the assembly code will appear in the console window when the UDF is interpreted, as shown below.

```
x_velocity:
                .local.pointer thread (r0)
                .local.int nv (r1)
    0           .local.end
    0           save
                .local.int f (r3)
    1           push.int 0
                .local.pointer x (r4)
    3           begin.data 8 bytes, 0 bytes initialized:
    7           save
    .             .
    .             .
    .             .
  156           pre.inc.int f (r3)
  158           pop.int
  159           b .L3 (22)
      .L2:
  161           restore
  162           restore
  163           ret.v
```

Note that if your compilation is unsuccessful, then FLUENT will report an error and you will need to debug your program. See Section 4.3: Common Errors Made While Interpreting A Source File for details.

8. Click Close when the interpreter has finished.

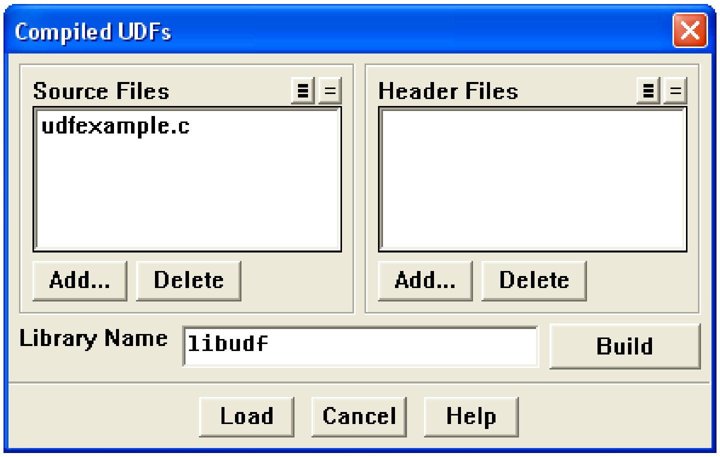
9. Write the case file. The interpreted UDF, named x_velocity, will be saved with the case file so that the function will be automatically interpreted whenever the case is subsequently read.

Compile the Source File

You can compile your UDF using the text user interface (TUI) or the graphical user interface (GUI) in FLUENT. The GUI option for compiling a source file on a UNIX system is discussed below. For details about compiling on other platforms (e.g., Windows) using the TUI to compile your function, or for general questions about compiling UDFs in FLUENT see Chapter 5: Compiling UDFs.

1. Make sure that the UDF source file (e.g., `udfexample.c`) is in the same directory that contains your case and data file.
2. Start FLUENT from your working directory.
3. Read (or set up) your case file.
4. Open the Compiled UDFs panel (Figure 8.1.6).

   Define ⟶ User-Defined ⟶ Functions ⟶ Compiled...

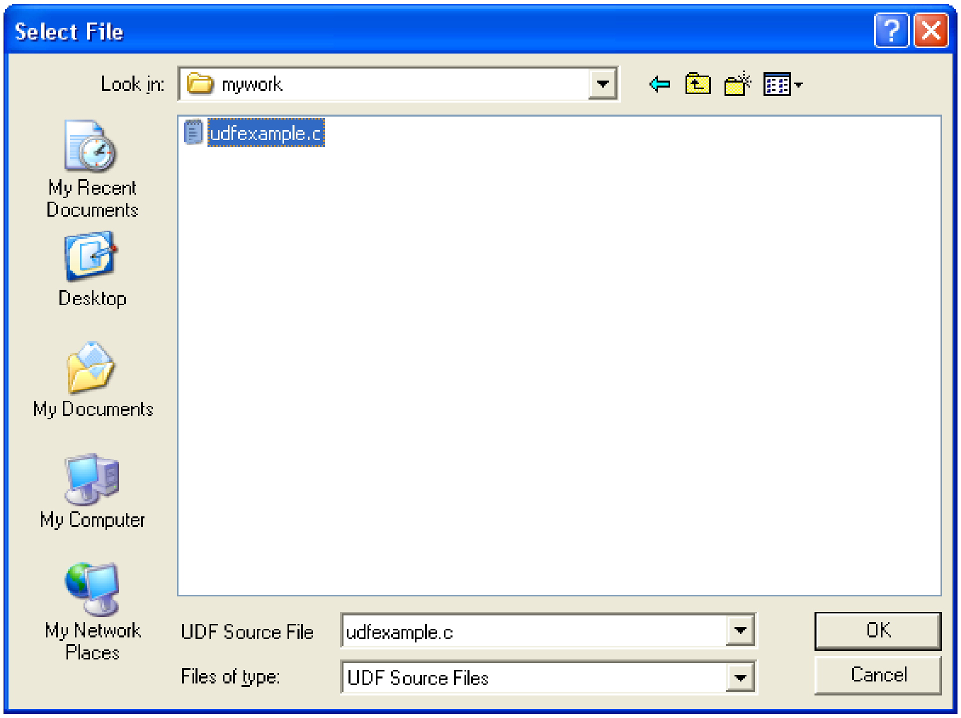


Source Files: udfexample.c

Library Name: libudf

Figure 8.1.6: The Compiled UDFs Panel

5. Click Add... under Source Files in the Compiled UDFs panel. This will open the Select File panel (Figure 8.1.7).



UDF Source File: udfexample.c

Files of type: UDF Source Files

Figure 8.1.7: The Select File Panel

6. In the Select File panel under Directories, choose the directory path that contains the C source file, and then under Files select the desired file (e.g., udfexample.c) you want to compile. (Once selected, the complete path to the source file will be displayed under Source File(s).) Click OK. The Select File panel will close and the file you added will appear in the Source Files list in the Compiled UDFs panel. Repeat the previous step to select the Header Files that need to be included in the compilation.

7. In the Compiled UDFs panel, select the file that is listed under Source Files and type the name of the shared library in the Library Name field (or leave the default name libudf). Click Build. This process will compile the code and will build a shared library in your working directory for the architecture you are running on.

As the compile/build process begins, a Warning dialog box will appear, reminding you that the UDF source file must be in the directory that contains your case and data files (i.e., your working directory). If you have an existing library directory (e.g., libudf) then you will need to remove it prior to the build, to ensure that the latest files are used. Click OK to close the dialog box and resume the compile/build process. The results of the build will be displayed on the console window. You can view the compilation history in the 'log' file that is saved in your working directory.

> *i* If the compile/build is unsuccessful, then FLUENT will report an error and you will need to debug your program before continuing. See Section 5.6: Common Errors When Building and Loading a UDF Library for a list of common errors.

8. Click Load to load the shared library into FLUENT. The console will report that the library has been opened and the function (e.g., x_velocity) loaded.

```
Opening library "libudf"...
Library "libudf/lnx86/2d/libudf.so" opened
        x_velocity
Done.
```

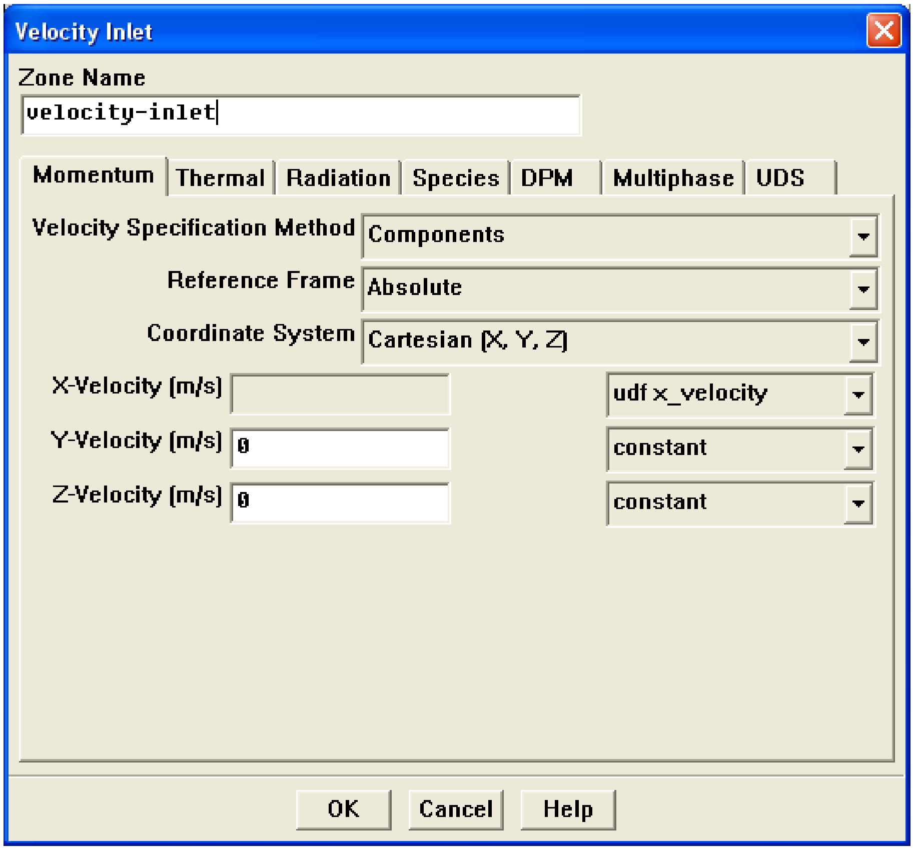
See Chapter 5: Compiling UDFs for more information on the compile/build process.

8.1.6 Step 5: Hook the UDF to FLUENT

Now that you have interpreted or compiled your UDF following the methods outlined in Step 4, you are ready to hook the profile UDF in this sample problem to the Velocity Inlet boundary condition panel (see Chapter 6: Hooking UDFs to FLUENT for details on how to hook UDFs). First click on the Momentum tab in the Velocity Inlet panel (Figure 8.1.8) and then choose the name of the UDF that was given in our sample problem with udf preceeding it (udf x_velocity) from the X Velocity drop-down list. Once selected, the default value will become grayed-out in the X-Velocity field. Click OK to accept the new boundary condition and close the panel. The user profile will be used in the subsequent solution calculation.

1. Open the Velocity Inlet panel.

   Define ⟶ Boundary Conditions...



Zone Name: velocity-inlet

Velocity Specification Method: Components

Reference Frame: Absolute

Coordinate System: Cartesian (X, Y, Z)

X-Velocity (m/s): udf x_velocity

Y-Velocity (m/s): 0 constant

Z-Velocity (m/s): 0 constant

Figure 8.1.8: The Velocity Inlet Panel

8.1.7 Step 6: Run the Calculation

Run the calculation as usual.

Solve ⟶Iterate...

8.1.8 Step 7: Analyze the Numerical Solution and Compare to Expected Results

Once the solution is run to convergence, obtain a revised velocity field. The velocity magnitude contours for the parabolic inlet x velocity are shown in Figure 8.1.9, and can be compared to the results of a constant-velocity field of 20 m/sec (Figure 8.1.2). For the constant velocity condition, the flow field is distorted as the flow moves around the turbine vane. The velocity field for the imposed parabolic profile, however, shows a maximum at the center of the inlet, which drops to zero at the edges.

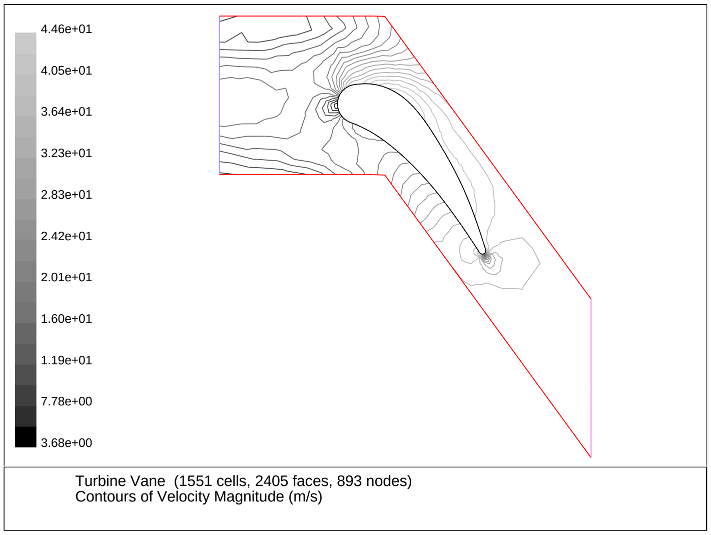


Figure 8.1.9: Velocity Magnitude Contours for a Parabolic Inlet x Velocity

8.2 Detailed UDF Examples

This section contains detailed examples of UDFs that are used in typical FLUENT applications.

- Section 8.2.1: Boundary Conditions
- Section 8.2.2: Source Terms
- Section 8.2.3: Physical Properties
- Section 8.2.4: Reaction Rates
- Section 8.2.5: User-Defined Scalars

8.2.1 Boundary Conditions

This section contains two applications of boundary condition UDFs.

- Parabolic Velocity Inlet Profile for a Turbine Vane
- Transient Velocity Inlet Profile for Flow in a Tube

Parabolic Velocity Inlet Profile in a Turbine Vane

Consider the turbine vane illustrated in Figure 8.2.1. An unstructured grid is used to model the flow field surrounding the vane. The domain extends from a periodic boundary on the bottom to an identical one on the top, a velocity inlet on the left, and a pressure outlet on the right.

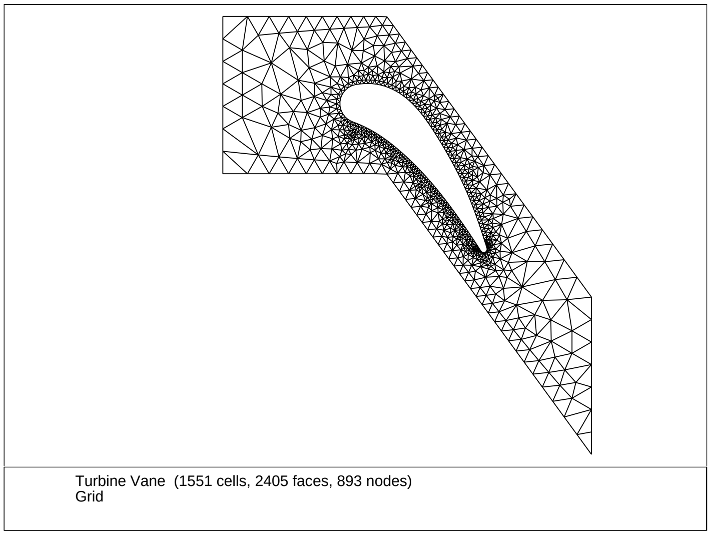


Figure 8.2.1: The Grid for the Turbine Vane Example

A flow field in which a constant x velocity is applied at the inlet will be compared with one where a parabolic x velocity profile is applied. While the application of a profile using a piecewise-linear profile is available with the boundary profiles option, the specification of a polynomial can only be accomplished by a user-defined function.

The results of a constant-velocity applied field (of 20 m/sec) at the inlet are shown in Figures 8.2.2 and 8.2.3. The initial constant velocity field is distorted as the flow moves around the turbine vane.

The inlet x velocity will now be described by the following profile:

$$v_x = 20 - 20\left(\frac{y}{0.0745}\right)^2$$

where the variable y is 0.0 at the center of the inlet, and extends to values of ± 0.0745 m at the top and bottom. Thus the x velocity will be 20 m/sec at the center of the inlet, and 0 at the edges.

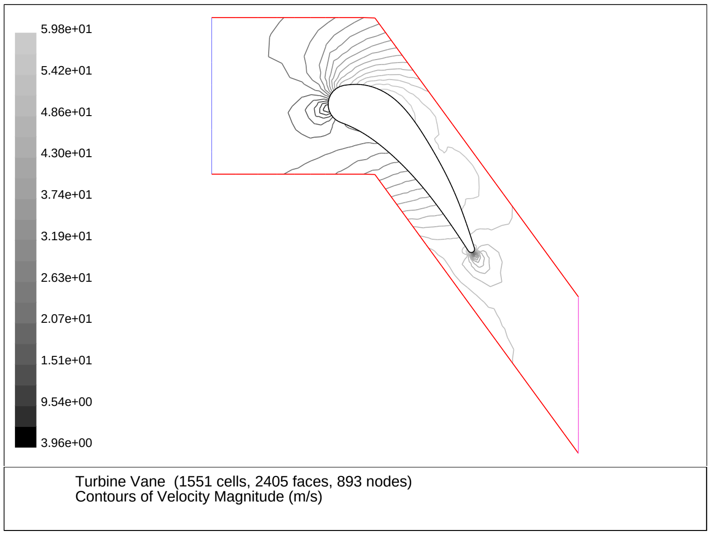


Figure 8.2.2: Velocity Magnitude Contours for a Constant Inlet x Velocity

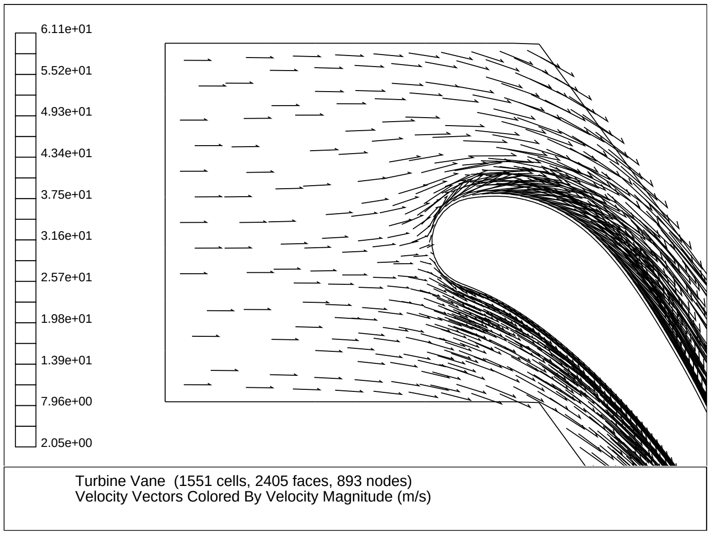


Figure 8.2.3: Velocity Vectors for a Constant Inlet x Velocity

A UDF is used to introduce this parabolic profile at the inlet. The C source code (`vprofile.c`) is shown below. The function makes use of Fluent-supplied solver functions that are described in Section 3.2.4: Face Macros.

The UDF, named `inlet_x_velocity`, is defined using `DEFINE_PROFILE` and has two arguments: `thread` and `position`. `Thread` is a pointer to the face's thread, and `position` is an integer that is a numerical label for the variable being set within each loop.

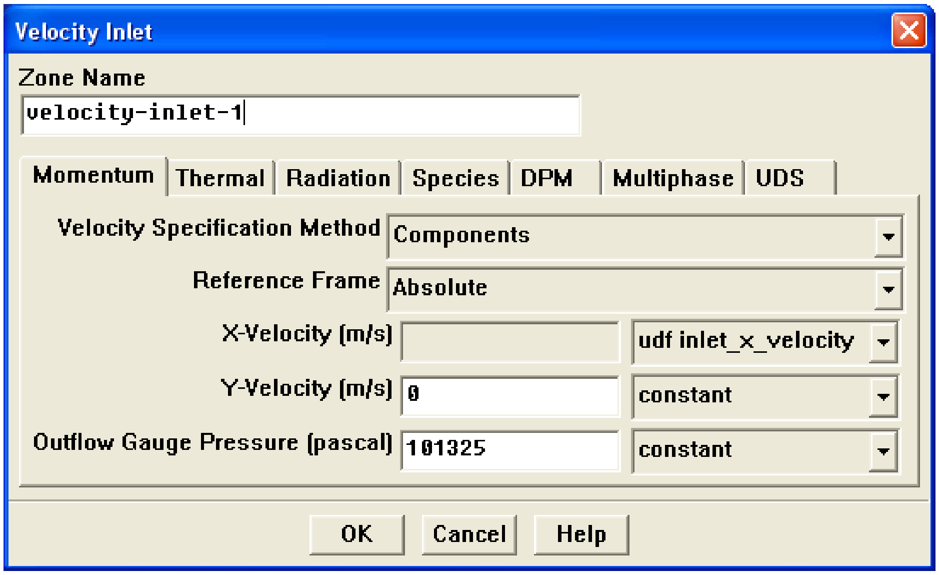
The function begins by declaring variable `f` as a `face_t` data type. A one-dimensional array `x` and variable `y` are declared as `real` data types. A looping macro is then used to loop over each face in the zone to create a profile, or an array of data. Within each loop, `F_CENTROID` outputs the value of the face centroid (array `x`) for the face with index `f` that is on the thread pointed to by `thread`. The y coordinate stored in `x[1]` is assigned to variable `y`, and is then used to calculate the x velocity. This value is then assigned to `F_PROFILE`, which uses the integer `position` (passed to it by the solver based on your selection of the UDF as the boundary condition for x velocity in the Velocity Inlet panel) to set the x velocity face value in memory.

```
/***********************************************************************
   vprofile.c
   UDF for specifying steady-state velocity profile boundary condition
************************************************************************/
#include "udf.h"

DEFINE_PROFILE(inlet_x_velocity, thread, position)
{
  real x[ND_ND]; /* this will hold the position vector */
  real y;
  face_t f;

  begin_f_loop(f, thread)
    {
      F_CENTROID(x,f,thread);
      y = x[1];
      F_PROFILE(f, thread, position) = 20. - y*y/(.0745*.0745)*20.;
    }
  end_f_loop(f, thread)
}
```

To make use of this UDF in FLUENT, you will first need to interpret (or compile) the function, and then hook it to FLUENT using the graphical user interface. Follow the procedure for interpreting source files using the Interpreted UDFs panel (Section 4.2: Interpreting a UDF Source File Using the Interpreted UDFs Panel), or compiling source files using the Compiled UDFs panel (Section 5.2: Compile a UDF Using the GUI).

To hook the UDF to FLUENT as the velocity boundary condition for the zone of choice, open the Velocity Inlet panel and click on the Momentum tab (Figure 8.2.4).

Define ⟶Boundary Conditions...


Zone Name: velocity-inlet-1

Velocity Specification Method: Components

Reference Frame: Absolute

X-Velocity (m/s): udf inlet_x_velocity

Y-Velocity (m/s): 0 constant

Outflow Gauge Pressure (pascal): 101325 constant

Figure 8.2.4: The Velocity Inlet Panel

In the X-Velocity drop-down list, select udf inlet_x_velocity, the name that was given to the function above (with udf preceeding it). Once selected, the default value will become grayed-out in the X-Velocity field. Click OK to accept the new boundary condition and close the panel. The user profile will be used in the subsequent solution calculation.

After the solution is run to convergence, a revised velocity field is obtained as shown in Figures 8.2.5 and 8.2.6. The velocity field shows a maximum at the center of the inlet, which drops to zero at the edges.

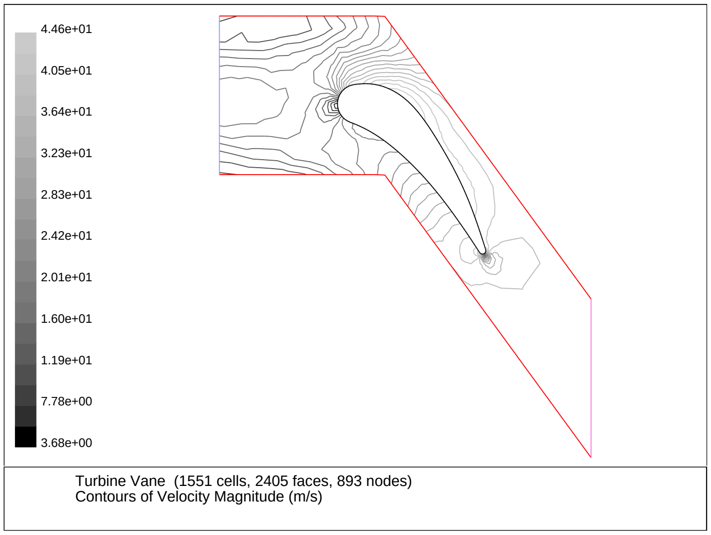


Figure 8.2.5: Velocity Magnitude Contours for a Parabolic Inlet x Velocity

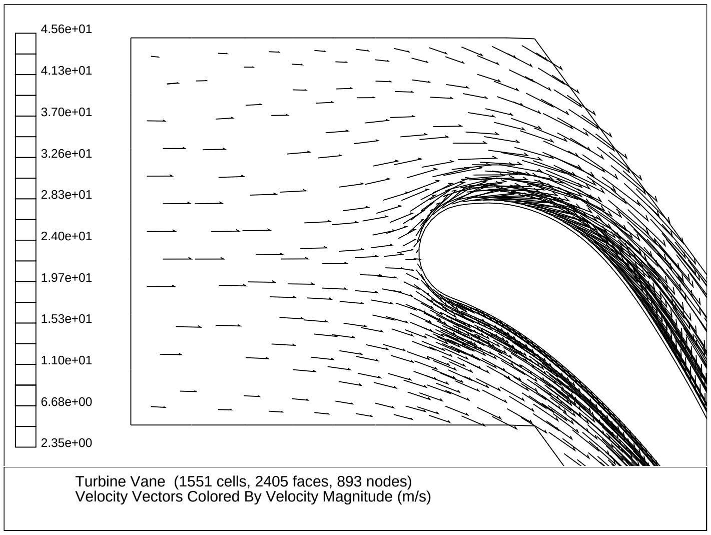


Figure 8.2.6: Velocity Vectors for a Parabolic Inlet x Velocity

Transient Velocity Inlet Profile for Flow in a Tube

In this example, a temporally periodic velocity boundary condition will be applied to the inlet of a tube using a UDF. The velocity has the form

$$v_x = v_0 + A\sin(\omega t)$$

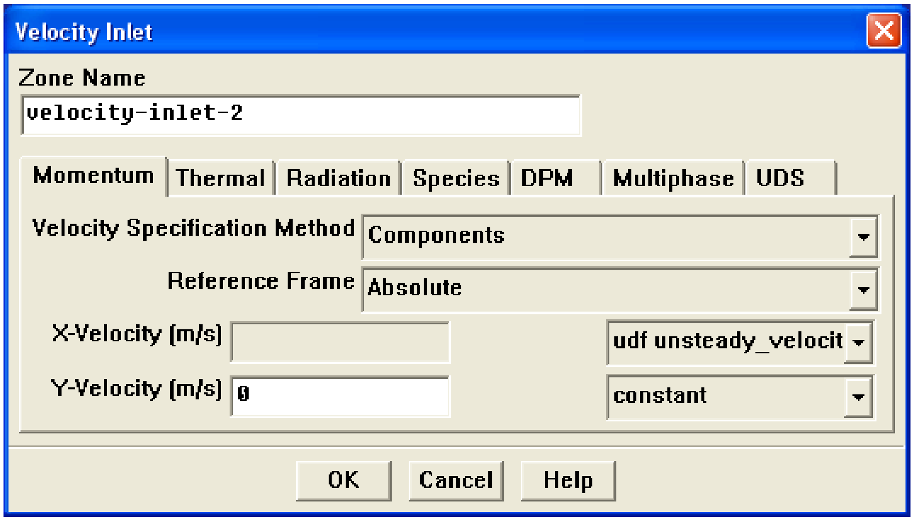
The tube is 1 m long with a radius of 0.2 m. It is assumed to be filled with air with a density of 1 kg/m^3 and a viscosity of 2×10^{-5} kg/m-s. The velocity of the air fluctuates about an equilibrium value, v_0, of 20 m/s, with an amplitude of 5 m/s and at a frequency of 10 rad/s.

The source file listing for the UDF that describes the transient inlet profile is shown below. The function, named `unsteady_velocity`, is defined using the `DEFINE_PROFILE` macro. The utility `CURRENT_TIME` is used to look up the `real` flow time, which is assigned to the variable `t`. (See Section 3.5: Time-Dependent Macros for details on `CURRENT_TIME`).

```
/**********************************************************************
   unsteady.c
   UDF for specifying a transient velocity profile boundary condition
**********************************************************************/

#include "udf.h"

DEFINE_PROFILE(unsteady_velocity, thread, position)
{
  face_t f;
  real t = CURRENT_TIME;

  begin_f_loop(f, thread)
    {
      F_PROFILE(f, thread, position) = 20. + 5.0*sin(10.*t);
    }
  end_f_loop(f, thread)
}
```

Before you can interpret or compile the UDF, you must specify an unsteady flow calculation in the Solver panel. Then, follow the procedure for interpreting source files using the Interpreted UDFs panel (Section 4.2: Interpreting a UDF Source File Using the Interpreted UDFs Panel), or compiling source files using the Compiled UDFs panel (Section 5.2: Compile a UDF Using the GUI).

The sinusoidal velocity boundary condition defined by the UDF can now be hooked to the inlet zone for the X-Velocity. In the Velocity Inlet panel, simply select the name of the UDF given in this example with the word udf preceeding it (udf unsteady_velocity) from the drop-down list to the right of the X-Velocity field. Once selected, the default value will become grayed-out in the X-Velocity field. Click OK to accept the new boundary condition and close the panel. The user profile will be used in the subsequent solution calculation.


Velocity Inlet

Zone Name: velocity-inlet-2

Velocity Specification Method: Components

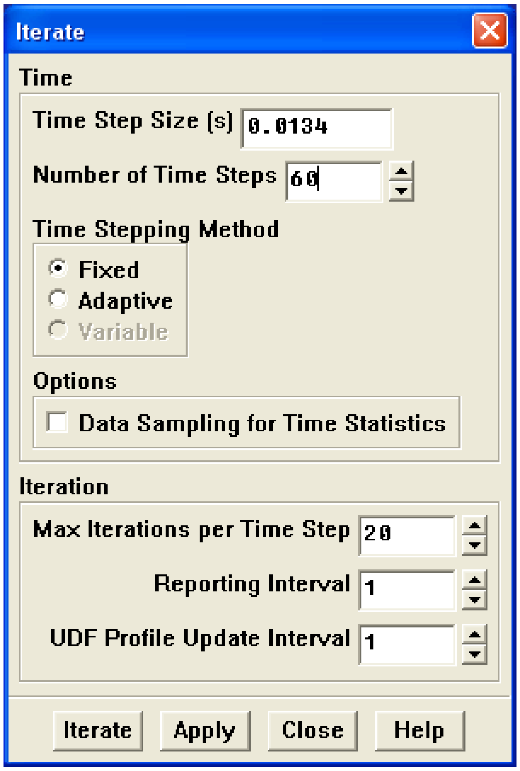
Reference Frame: Absolute

X-Velocity (m/s): udf unsteady_velocit

Y-Velocity (m/s): 0 constant

The time-stepping parameters are set in the Iterate panel.

Solve ⟶Iterate...



Time

Time Step Size (s) 0.0134

Number of Time Steps 60

Time Stepping Method

● Fixed
○ Adaptive
○ Variable

Options

□ Data Sampling for Time Statistics

Iteration

Max Iterations per Time Step 20

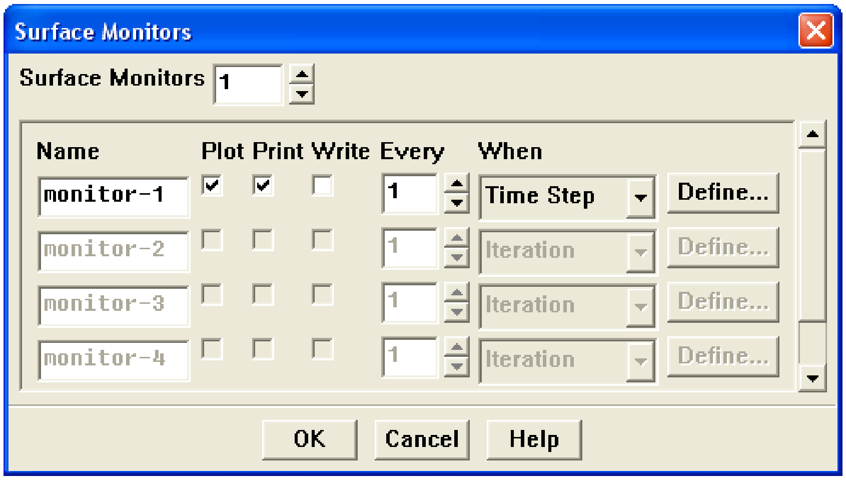
Reporting Interval 1

UDF Profile Update Interval 1

In this example, a Time Step Size of `0.0314` s is used so that 20 time steps will complete a full period of oscillation in the inlet velocity. The UDF Profile Update Interval is set to `1` so that the velocity will be updated every iteration. After `60` time steps (or 3 periods) are complete, you can examine the velocity magnitude across the pressure outlet for its response to the oscillating inlet condition.

To collect this information during the calculation, open the Surface Monitors panel before beginning to iterate.

Solve ⟶ Monitors ⟶Surface...



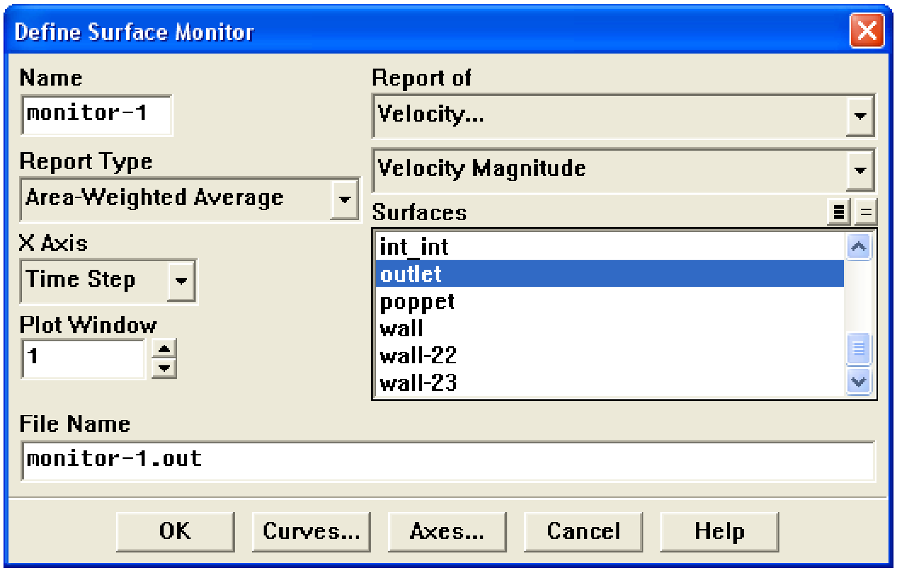
Surface Monitors

Surface Monitors 1

Name	Plot	Print	Write	Every	When
monitor-1	☑	☑	□	1	Time Step
monitor-2	□	□	□	1	Iteration
monitor-3	□	□	□	1	Iteration
monitor-4	□	□	□	1	Iteration

Increase the Surface Monitors index to 1. This will enable you to define the parameters of `monitor-1` (which you could rename, if desired, in the text entry box under Name). Select Plot so that the selected quantity will be plotted as the calculation proceeds. Select Print to see the changing values of the selected quantity in the console window. Select Write so that the information will be written to a file, which will be given the name `monitor-1.out`. (If you change the name of the monitor, that name will be used as the prefix for the output file.)

Under Every, you can choose Iteration, Time Step, or Flow Time. To monitor the result of each time step, you should choose the Time Step option. By clicking on Define... you can specify the quantity to be monitored in the Define Surface Monitor panel.


Define Surface Monitor

Name: monitor-1

Report of: Velocity...

Velocity Magnitude

Report Type: Area-Weighted Average

X Axis: Time Step

Plot Window: 1

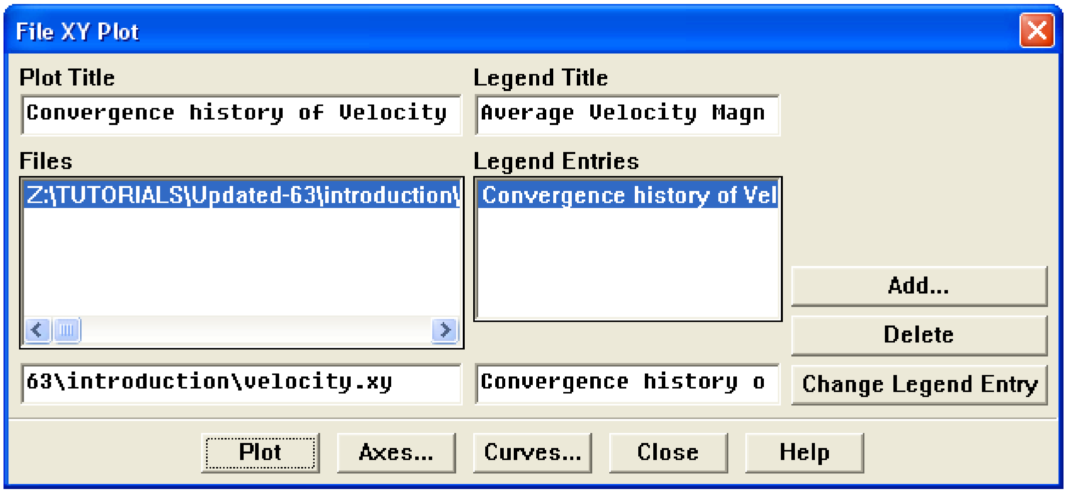
Surfaces: int_int, outlet, poppet, wall, wall-22, wall-23

File Name: monitor-1.out

In this example, Velocity... and Velocity Magnitude are chosen in the drop-down lists under Report of. The location of the report is pressure-outlet-5, which is selected in the Surfaces list. A simple Area-Weighted Average is chosen in the Report Type drop-down list, with the Flow Time chosen in the X Axis drop-down list.

Once the first time step has been completed, the monitor should appear in the chosen plot window. Alternatively, you can read the file by opening the File XY Plot panel.

Plot ⟶File...


File XY Plot

Plot Title: Convergence history of Velocity

Legend Title: Average Velocity Magn

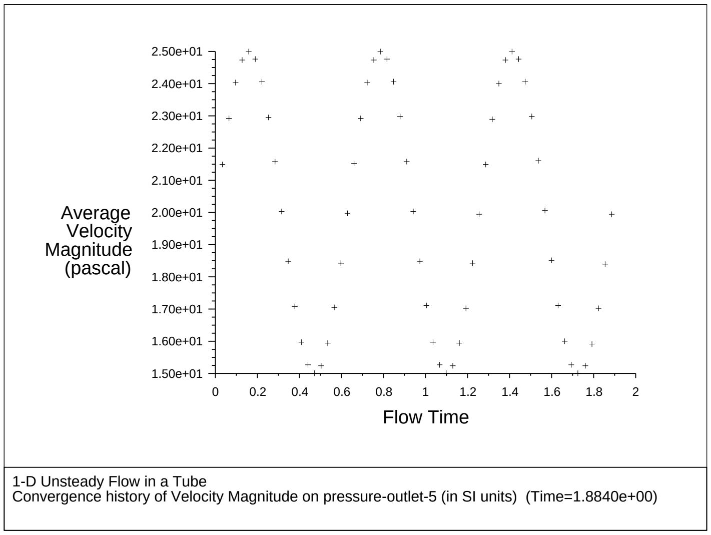
Files: Z:\TUTORIALS\Updated-63\introduction\

Legend Entries: Convergence history of Vel

63\introduction\velocity.xy

Convergence history o

You can read the output file by typing its name in the text entry box under Files and clicking on Add.... By selecting this file and clicking on Plot, you can obtain the plot shown in Figure 8.2.7.



1-D Unsteady Flow in a Tube
Convergence history of Velocity Magnitude on pressure-outlet-5 (in SI units) (Time=1.8840e+00)

Figure 8.2.7: Average Velocity Magnitude at the Pressure Outlet

The figure nicely illustrates that the velocity oscillates around the equilibrium value, 20 m/s, with an amplitude of 5 m/s, as expected.

8.2.2 Source Terms

This section contains an application of a source term UDF. It is executed as an interpreted UDF in FLUENT.

Adding a Momentum Source to a Duct Flow

When a source term is being modeled with a UDF, it is important to understand the context in which the function is called. When you add a source term, FLUENT will call your function as it performs a global loop on cells. Your function should compute the source term and return it to the solver.

In this example, a momentum source will be added to a 2D Cartesian duct flow. The duct is 4 m long and 2 m wide, and will be modeled with a symmetry boundary through the middle. Liquid metal (with properties listed in Table 8.2.1) enters the duct at the left with a velocity of 1 mm/s at a temperature of 290 K. After the metal has traveled 0.5 m along the duct, it is exposed to a cooling wall, which is held at a constant temperature of 280 K. To simulate the freezing of the metal, a momentum source is applied to the metal as soon as its temperature falls below 288 K. The momentum source is proportional to the x component of the velocity, v_x, and has the opposite sign:

$$S_x = -Cv_x \tag{8.2-1}$$

where C is a constant. As the liquid cools, its motion will be reduced to zero, simulating the formation of the solid. (In this simple example, the energy equation will not be customized to account for the latent heat of freezing. The velocity field will be used only as an indicator of the solidification region.)

The solver linearizes source terms in order to enhance the stability and convergence of a solution. To allow the solver to do this, you need to specify the dependent relationship between the source and solution variables in your UDF, in the form of derivatives. The source term, S_x, depends only on the solution variable, v_x. Its derivative with respect to v_x is

$$\frac{\partial S_x}{\partial v_x} = -C \tag{8.2-2}$$

The following UDF specifies a source term and its derivative. The function, named `cell_x_source`, is defined on a cell using `DEFINE_SOURCE`. The constant C in Equation 8.2-1 is called `CON` in the function, and it is given a numerical value of 20 kg/m^3-s, which will result in the desired units of N/m^3 for the source. The temperature at the cell is returned by `C_T(cell,thread)`. The function checks to see if the temperature is below (or equal to) 288 K. If it is, the source is computed according to Equation 8.2-1 (`C_U` returns the value of the x velocity of the cell). If it is not, the source is set to 0.0. At the end of the function, the appropriate value for the source is returned to the FLUENT solver.

Table 8.2.1: Properties of the Liquid Metal

Property	**Value**
Density	8000 kg/m^3
Viscosity	5.5 $\times 10^{-3}$ kg/m-s
Specific Heat	680 J/kg-K
Thermal Conductivity	30 W/m-K

```
/*****************************************************************
   UDF that adds momentum source term and derivative to duct flow
******************************************************************/

#include "udf.h"

#define CON 20.0

DEFINE_SOURCE(cell_x_source, cell, thread, dS, eqn)
{
  real source;

  if (C_T(cell,thread) <= 288.)
    {
      /* source term */
      source = -CON*C_U(cell,thread);

      /* derivative of source term w.r.t. x-velocity. */
      dS[eqn] = -CON;
    }
  else
    source = dS[eqn] = 0.;

  return source;
}
```

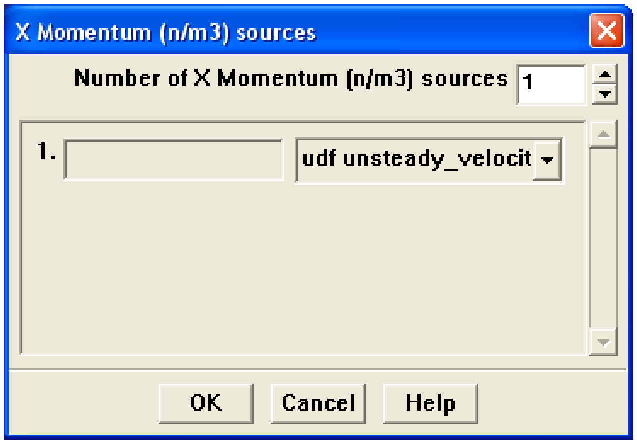
To make use of this UDF in FLUENT, you will first need to interpret (or compile) the function, and then hook it to FLUENT using the graphical user interface. Follow the procedure for interpreting source files using the Interpreted UDFs panel (Section 4.2: Interpreting a UDF Source File Using the Interpreted UDFs Panel), or compiling source files using the Compiled UDFs panel (Section 5.2: Compile a UDF Using the GUI).

To include source terms in the calculation you will first need to turn on the Source Terms option in the Fluid or Solid panel and click the Source Terms tab. This will display the momentum source term parameters in the scrollable window.

Define ⟶Boundary Conditions...

Next, click the Edit... button next to the X Momentum source term. This will open the X Momentum Sources panel where you will select the number of terms you wish to model (Figure 6.2.23). Increment the Number of Momentum sources counter to 1 and then choose the function namefor the UDF in this example (udf cell_x_source from the drop-down list.(Note that the UDF name that is displayed in the drop-down lists is preceeded by the word udf.) Click OK to accept the new boundary condition and close the panel.

The X Momentum parameter in the Fluid panel will now display 1 source. Click OK to close the Fluid panel and fix the new momentum source term for the solution calculation.



X Momentum (n/m3) sources

Number of X Momentum (n/m3) sources 1

1. udf unsteady_velocit

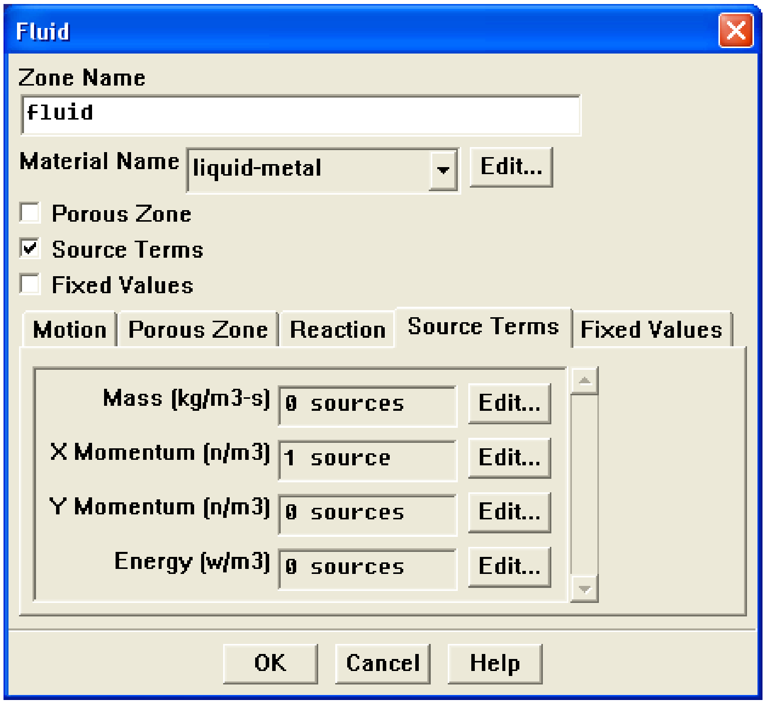
Figure 8.2.8: The Fluid Panel

Once the solution has converged, you can view contours of static temperature to see the cooling effects of the wall on the liquid metal as it moves through the duct (Figure 8.2.10).

Contours of velocity magnitude (Figure 8.2.11) show that the liquid in the cool region near the wall has indeed come to rest to simulate solidification taking place.

The solidification is further illustrated by line contours of stream function (Figure 8.2.12).

To more accurately predict the freezing of a liquid in this manner, an energy source term would be needed, as would a more accurate value for the constant appearing in Equation 8.2-1.



Fluid

Zone Name: fluid

Material Name: liquid-metal

□ Porous Zone

☑ Source Terms

□ Fixed Values

Source Terms

Mass (kg/m3-s): 0 sources

X Momentum (n/m3): 1 source

Y Momentum (n/m3): 0 sources

Energy (w/m3): 0 sources

Figure 8.2.9: The Fluid Panel

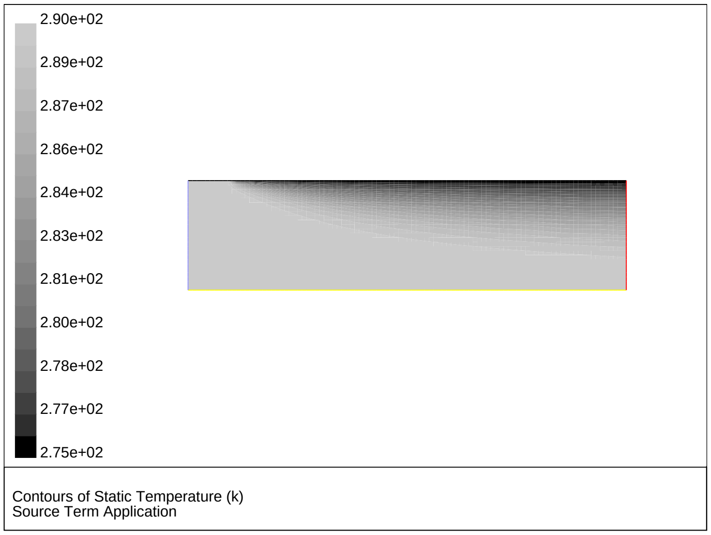


Figure 8.2.10: Temperature Contours Illustrating Liquid Metal Cooling

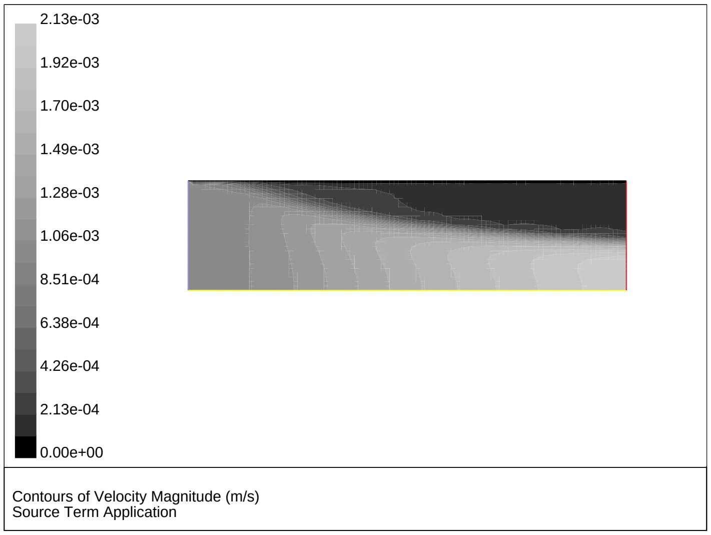


Figure 8.2.11: Velocity Magnitude Contours Suggesting Solidification

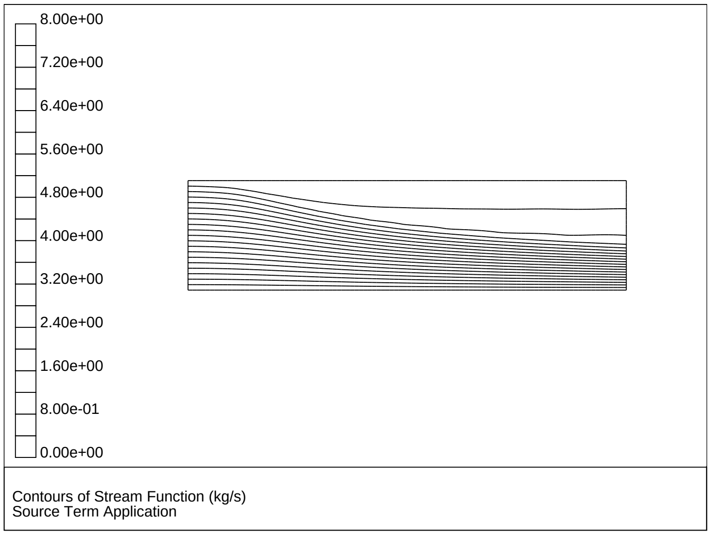


Figure 8.2.12: Stream Function Contours Suggesting Solidification

8.2.3 Physical Properties

This section contains an application of a physical property UDF. It is executed as an interpreted UDF in FLUENT.

Solidification via a Temperature-Dependent Viscosity

UDFs for properties (as well as sources) are called from within a loop on cells. For this reason, functions that specify properties are only required to compute the property for a single cell, and return the value to the FLUENT solver.

The UDF in this example generates a variable viscosity profile to simulate solidification, and is applied to the same problem that was presented in Section 8.2.2: Adding a Momentum Source to a Duct Flow. The viscosity in the warm ($T > 288$ K) fluid has a molecular value for the liquid (5.5×10^{-3} kg/m-s), while the viscosity for the cooler region ($T < 286$ K) has a much larger value (1.0 kg/m-s). In the intermediate temperature range ($286 \text{ K} \leq T \leq 288$ K), the viscosity follows a linear profile (Equation 8.2-3) that extends between the two values given above:

$$\mu = 143.2135 - 0.49725T \tag{8.2-3}$$

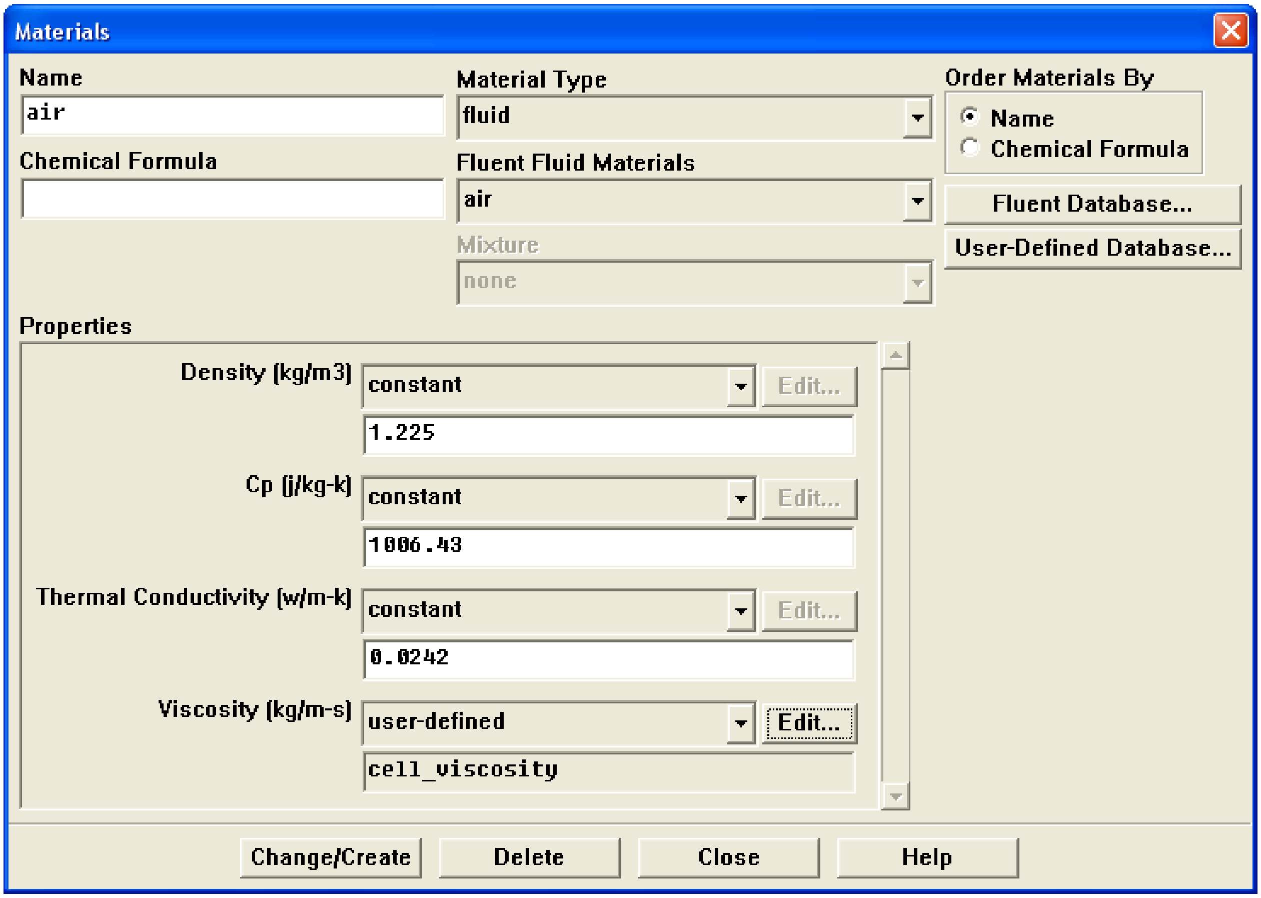
This model is based on the assumption that as the liquid cools and rapidly becomes more viscous, its velocity will decrease, thereby simulating solidification. Here, no correction is made for the energy field to include the latent heat of freezing. The C source code for the UDF is shown below.

The function, named `cell_viscosity`, is defined on a cell using `DEFINE_PROPERTY`. Two `real` variables are introduced: `temp`, the value of `C_T(cell,thread)`, and `mu_lam`, the laminar viscosity computed by the function. The value of the temperature is checked, and based upon the range into which it falls, the appropriate value of `mu_lam` is computed. At the end of the function, the computed value for `mu_lam` is returned to the solver.

```
/*********************************************************************
   UDF for specifying a temperature-dependent viscosity property
**********************************************************************/

#include "udf.h"

DEFINE_PROPERTY(cell_viscosity, cell, thread)
{
  real mu_lam;
  real temp = C_T(cell, thread);

  if (temp > 288.)
    mu_lam = 5.5e-3;
  else if (temp > 286.)
    mu_lam = 143.2135 - 0.49725 * temp;
  else
    mu_lam = 1.;

  return mu_lam;
}
```

This function can be executed as an interpreted or compiled UDF in FLUENT. Follow the procedure for interpreting source files using the Interpreted UDFs panel (Section 4.2: Interpreting a UDF Source File Using the Interpreted UDFs Panel), or compiling source files using the Compiled UDFs panel (Section 5.2: Compile a UDF Using the GUI)

To make use of the user-defined property in FLUENT, you will use the Materials panel. In the drop-down list for Viscosity, select the user-defined option.



Name: air

Chemical Formula:

Material Type: fluid

Fluent Fluid Materials: air

Mixture: none

Order Materials By: ● Name ○ Chemical Formula

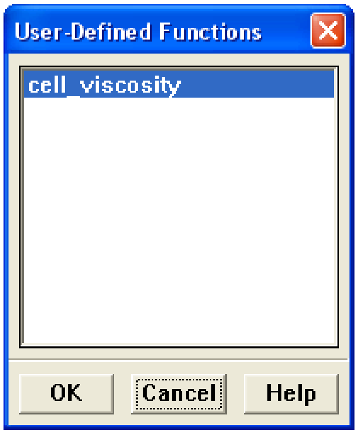
Density (kg/m3): constant
1.225

Cp (j/kg-k): constant
1006.43

Thermal Conductivity (w/m-k): constant
0.0242

Viscosity (kg/m-s): user-defined
cell_viscosity

Once you select this option, the User-Defined Functions panel opens, from which you can select the appropriate function name. In this example, only one option is available, but in other examples, you may have several functions from which to choose. (Recall that if you need to compile more than one interpreted UDF, the functions can be concatenated in a single source file prior to compiling.)



The results of this model are similar to those obtained in Section 8.2.2: Adding a Momentum Source to a Duct Flow. Figure 8.2.13 shows the viscosity field resulting from the application of the user-defined function. The viscosity varies rapidly over a narrow spatial band from a constant value of 0.0055 to 1.0 kg/m-s.

The velocity field (Figure 8.2.14) demonstrates that the liquid slows down in response to the increased viscosity, as expected. In this model, there is a large “mushy” region, in which the motion of the fluid gradually decreases. This is in contrast to the first model, in which a momentum source was applied and a more abrupt change in the fluid motion was observed.

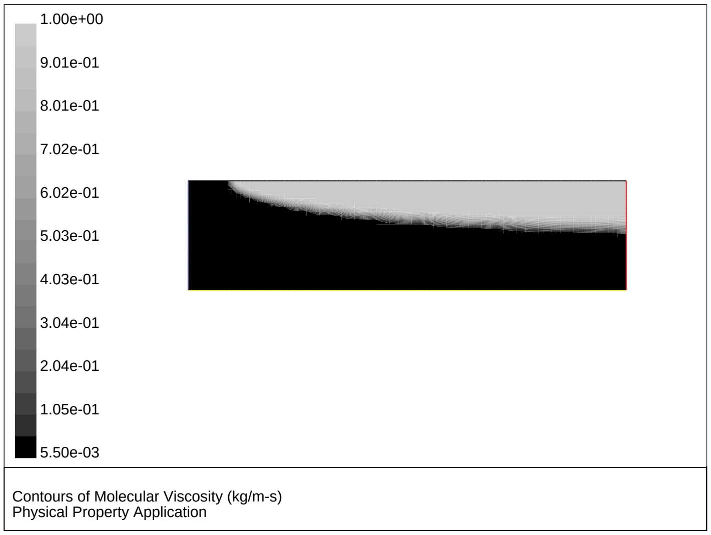


Figure 8.2.13: Laminar Viscosity Generated by a User-Defined Function

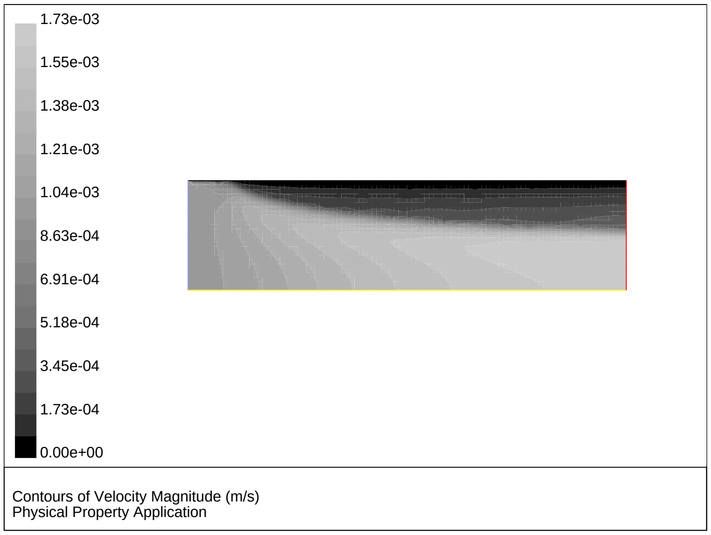


Figure 8.2.14: Contours of Velocity Magnitude Resulting from a User-Defined Viscosity

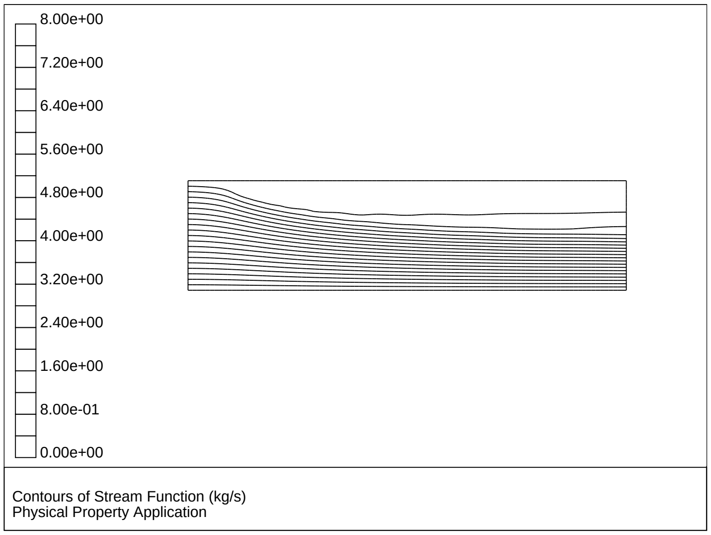


Figure 8.2.15: Stream Function Contours Suggesting Solidification

8.2.4 Reaction Rates

This section contains an example of a custom reaction rate UDF. It is executed as a compiled UDF in FLUENT.

Volume Reaction Rate

A custom volume reaction rate for a simple system of two gaseous species is considered. The species are named `species-a` and `species-b`. The reaction rate is one that converts `species-a` into `species-b` at a rate given by the following expression:

$$R = \frac{K_1 X_a}{(1 + K_2 X_a)^2} \tag{8.2-4}$$

where X_a is the mass fraction of `species-a`, and K_1 and K_2 are constants.

The 2D (planar) domain consists of a 90-degree bend. The duct is 16 inches wide and approximately 114 inches long. A 6-inch-thick porous region covers the bottom and right-hand wall, and the reaction takes place in the porous region only. The species in the duct have identical properties. The density is 1.0 kg/m^3, and the viscosity is 1.72×10^{-5} kg/m-s.

The outline of the domain is shown in Figure 8.2.16. The porous medium is the region below and to the right of the line that extends from the inlet on the left to the pressure outlet at the top of the domain.

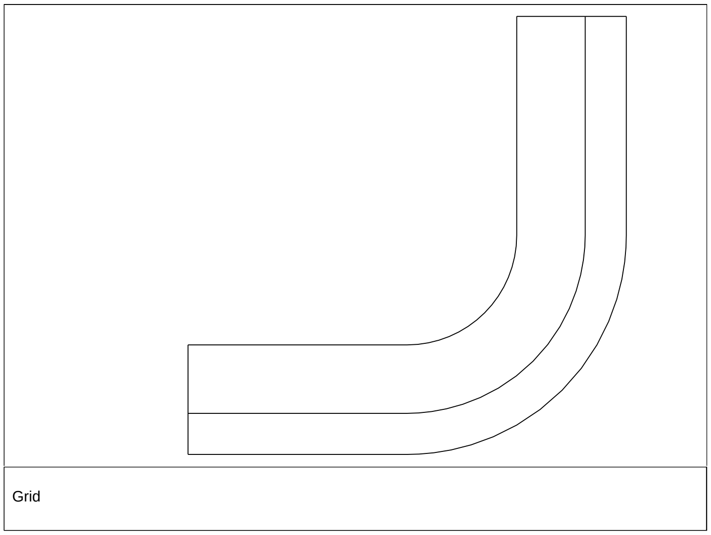


Figure 8.2.16: The Outline of the 2D Duct

Through the inlet on the left, gas that is purely `species-a` enters with an x velocity of 0.1 m/s. The gas enters both the open region on the top of the porous medium and the porous medium itself, where there is an inertial resistance of 5 m^{-1} in each of the two coordinate directions. The laminar flow field (Figure 8.2.17) shows that most of the gas is diverted from the porous region into the open region.

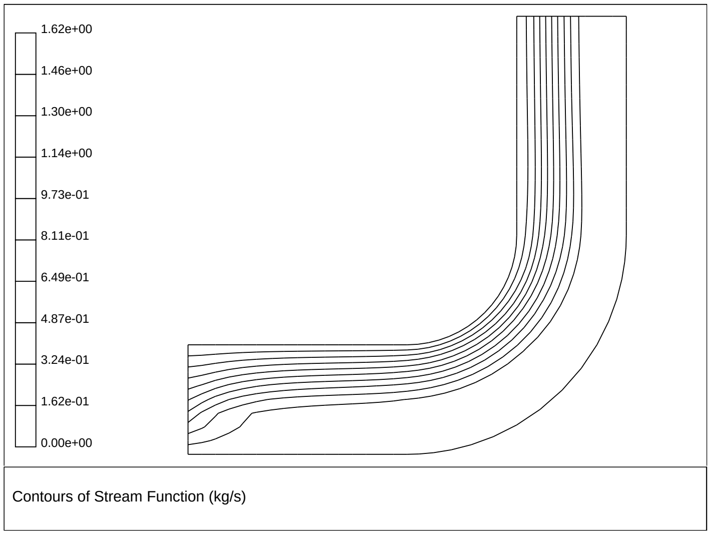


Figure 8.2.17: Streamlines for the 2D Duct with a Porous Region

The flow pattern is further substantiated by the vector plot shown in Figure 8.2.18. The flow in the porous region is considerably slower than that in the open region.

The source code (`rate.c`) that contains the UDF used to model the reaction taking place in the porous region is shown below. The function, named `vol_reac_rate`, is defined on a cell for a given species mass fraction using `DEFINE_VR_RATE`. The UDF performs a test to check for the porous region, and only applies the reaction rate equation to the porous region. The macro `FLUID_THREAD_P(t)` is used to determine if a cell thread is a fluid (rather than a solid) thread. The variable `THREAD_VAR(t).fluid.porous` is used to check if a fluid cell thread is a porous region.

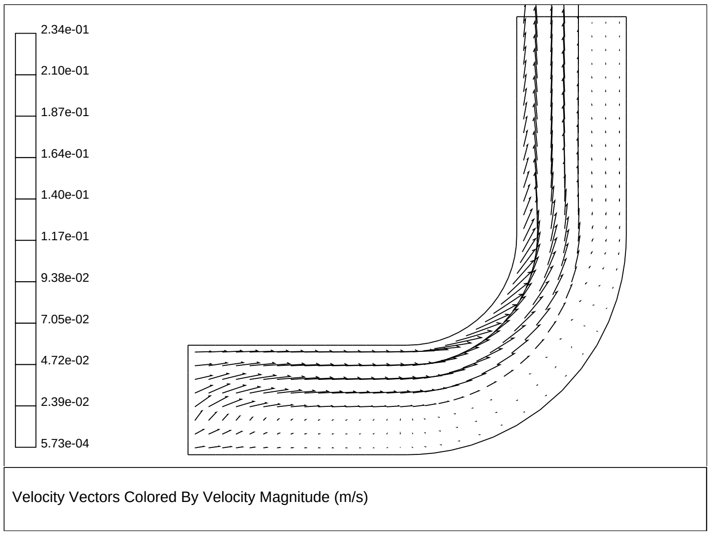


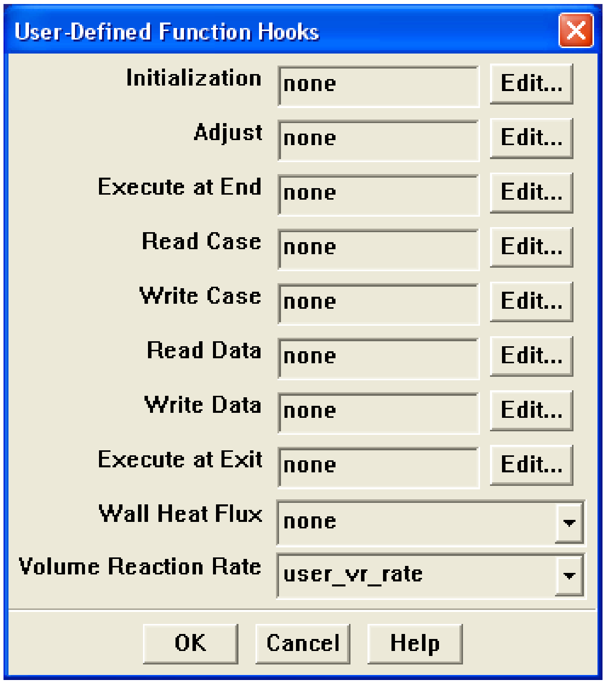
Figure 8.2.18: Velocity Vectors for the 2D Duct with a Porous Region

```
/*******************************************************************
   rate.c
   Compiled UDF for specifying a reaction rate in a porous medium
*******************************************************************/

#include "udf.h"

#define K1 2.0e-2
#define K2 5.

DEFINE_VR_RATE(user_rate,c,t,r,mole_weight,species_mf,rate,rr_t)
{
   real s1 = species_mf[0];
   real mw1 = mole_weight[0];

   if (FLUID_THREAD_P(t) && THREAD_VAR(t).fluid.porous)
       *rate = K1*s1/pow((1.+K2*s1),2.0)/mw1;
   else
       *rate = 0.;

   *rr_t = *rate;
}
```

This UDF is executed as a compiled UDF in FLUENT. Follow the procedure for compiling source files using the Compiled UDFs panel that is described in Section 5.2: Compile a UDF Using the GUI.

Once the function vol_reac_rate is compiled and loaded, you can hook the reaction rate UDF to FLUENT by selecting the function's name in the Volume Reaction Rate Function drop-down list in the User-Defined Function Hooks panel (Figure 6.2.28).

Define ⟶ User-Defined ⟶ Function Hooks...



Initialization none

Adjust none

Execute at End none

Read Case none

Write Case none

Read Data none

Write Data none

Execute at Exit none

Wall Heat Flux none

Volume Reaction Rate user_vr_rate

Initialize and run the calculation. The converged solution for the mass fraction of `species-a` is shown in Figure 8.2.19. The gas that moves through the porous region is gradually converted to `species-b` in the horizontal section of the duct. No reaction takes place in the fluid region, although some diffusion of `species-b` out of the porous region is suggested by the wide transition layer between the regions of 100% and 0% `species-a`.

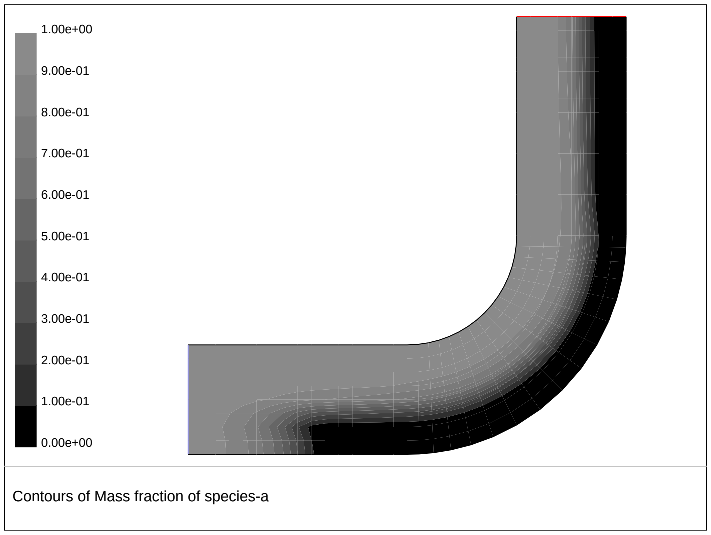


Figure 8.2.19: Mass Fraction for species-a Governed by a Reaction in a Porous Region

8.2.5 User-Defined Scalars

This section contains examples of UDFs that can be used to customize user-defined scalar (UDS) transport equations. See Section 2.7: User-Defined Scalar (UDS) Transport Equation DEFINE Macros in the UDF Manual for information on how you can define UDFs in FLUENT. Refer to Section 9.3: User-Defined Scalar (UDS) Transport Equations of the User's Guide for UDS equation theory and details on how to set up scalar equations.

Postprocessing Using User-Defined Scalars

Below is an example of a compiled UDF that computes the gradient of temperature to the fourth power, and stores its magnitude in a user-defined scalar. The computed temperature gradient can, for example, be subsequently used to plot contours. Although the practical application of this UDF is questionable, its purpose here is to show the methodology of computing gradients of arbitrary quantities that can be used for postprocessing.

```
/***********************************************************************/
/* UDF for computing the magnitude of the gradient of T^4             */
/***********************************************************************/

#include "udf.h"

/* Define which user-defined scalars to use. */
enum
{
  T4,
  MAG_GRAD_T4,
  N_REQUIRED_UDS
};

DEFINE_ADJUST(adjust_fcn, domain)
{
  Thread *t;
  cell_t c;
  face_t f;


  /* Make sure there are enough user-defined scalars. */
  if (n_uds < N_REQUIRED_UDS)
    Internal_Error("not enough user-defined scalars allocated");
```

```
/* Fill first UDS with temperature raised to fourth power. */
thread_loop_c (t,domain)
  {
    if (NULL != THREAD_STORAGE(t,SV_UDS_I(T4)))
      {
        begin_c_loop (c,t)
          {
            real T = C_T(c,t);
            C_UDSI(c,t,T4) = pow(T,4.);
          }
        end_c_loop (c,t)
      }
  }


thread_loop_f (t,domain)
  {
    if (NULL != THREAD_STORAGE(t,SV_UDS_I(T4)))
      {
        begin_f_loop (f,t)
          {
            real T = 0.;
            if (NULL != THREAD_STORAGE(t,SV_T))
              T = F_T(f,t);
            else if (NULL != THREAD_STORAGE(t->t0,SV_T))
              T = C_T(F_C0(f,t),t->t0);
            F_UDSI(f,t,T4) = pow(T,4.);
          }
        end_f_loop (f,t)
      }
  }

/* Fill second UDS with magnitude of gradient. */
thread_loop_c (t,domain)
  {
    if (NULL != THREAD_STORAGE(t,SV_UDS_I(T4)) &&
        NULL != T_STORAGE_R_NV(t,SV_UDSI_G(T4)))
     {
        begin_c_loop (c,t)
          {
            C_UDSI(c,t,MAG_GRAD_T4) = NV_MAG(C_UDSI_G(c,t,T4));
          }
        end_c_loop (c,t)
    }
  }

 thread_loop_f (t,domain)
  {
   if (NULL != THREAD_STORAGE(t,SV_UDS_I(T4)) &&
     NULL != T_STORAGE_R_NV(t->t0,SV_UDSI_G(T4)))
    {
     begin_f_loop (f,t)
      {
       F_UDSI(f,t,MAG_GRAD_T4)=C_UDSI(F_C0(f,t),t->t0,MAG_GRAD_T4);
      }
     end_f_loop (f,t)
    }
  }
}
```

The conditional statement `if (NULL != THREAD_STORAGE(t,SV_UDS_I(T4)))` is used to check if the storage for the user-defined scalar with index `T4` has been allocated, while `NULL != T_STORAGE_R_NV(t,SV_UDSI_G(T4))` checks whether the storage of the gradient of the user-defined scalar with index `T4` has been allocated.

In addition to compiling this UDF, as described in Chapter 5: Compiling UDFs, you will need to enable the solution of a user-defined scalar transport equation in FLUENT.

Define ⟶ User-Defined ⟶Scalars...

Refer to Section 9.3: User-Defined Scalar (UDS) Transport Equations of the User's Guide for UDS equation theory and details on how to setup scalar equations.

Implementing FLUENT's P-1 Radiation Model Using User-Defined Scalars

This section provides an example that demonstrates how the P1 radiation model can be implemented as a UDF, utilizing a user-defined scalar transport equation. In the P1 model, the variation of the incident radiation, G, in the domain can be described by an equation that consists of a diffusion and source term.

The transport equation for incident radiation, G, is given by Equation 8.2-5. The diffusion coefficient, Γ, is given by Equation 8.2-6 and the source term is given by Equation 8.2-7. Refer to the equations discussed in Section 13.3.3: P-1 Radiation Model Theory of the User's Guide for more details.

$$\nabla \cdot (\Gamma \nabla G) + S^G = 0 \tag{8.2-5}$$

$$\Gamma = \frac{1}{3a + (3 - C)\,\sigma_s} \tag{8.2-6}$$

$$S^G = a\left(4\sigma T^4 - G\right) \tag{8.2-7}$$

As shown in Section 13.3.3: P-1 Radiation Model Theory of the User's Guide manual, the boundary condition for G at the walls is equal to the negative of the radiative wall heat flux, $q_{r,w}$ (Equation 8.2-8), where $\vec{n}$ is the outward normal vector. The radiative wall heat flux can be given by Equation 8.2-9.

$$q_r \cdot \vec{n} = -\Gamma \nabla G \cdot \vec{n} \tag{8.2-8}$$

$$q_{r,w} = -\frac{\epsilon_w}{2\,(2 - \epsilon_w)}\left(4\sigma T_w^4 - G_w\right) \tag{8.2-9}$$

This form of the boundary condition is unfortunately specified in terms of the incident radiation at the wall, G_w. This mixed boundary condition can be avoided by solving first for G_w using Equations 8.2-8 and 8.2-9, resulting in Equation 8.2-10. Then, this expression for G_w is substituted back into Equation 8.2-9 to give the radiative wall heat flux $q_{r,w}$ as Equation 8.2-11.

$$G_w = \frac{4\sigma T_w^4 E_w + \frac{\alpha_0 \Gamma_0}{A}\left[G_0 - \beta_0(G)\right]}{E_w + \frac{\alpha_0 \Gamma_0}{A}} \tag{8.2-10}$$

$$q_r = -\frac{\alpha_0 \Gamma_0 E_w}{A\left(E_w + \frac{\alpha_0 \Gamma_0}{A}\right)}\left[4\pi I_b(T_{iw}) - G_0 + \beta_0(G)\right] \tag{8.2-11}$$

The additional β_0 and G_0 terms that appear in Equations 8.2-10 and 8.2-11 are a result of the evaluation of the gradient of incident radiation in Equation 8.2-8.

In FLUENT, the component of a gradient of a scalar directed normal to a cell boundary (face), $\nabla G \cdot \mathtt{n}$, is estimated as the sum of primary and secondary components. The primary component represents the gradient in the direction defined by the cell centroids, and the secondary component is in the direction along the face separating the two cells. From this information, the face normal component can be determined. The secondary component of the gradient can be found using the Fluent macro BOUNDARY_SECONDARY_GRADIENT_SOURCE. The use of this macro first requires that cell geometry information be defined, which can be readily obtained by the use of a second macro, BOUNDARY_FACE_GEOMETRY (see Section 3.2.5: Boundary Face Geometry (BOUNDARY_FACE_GEOMETRY)). You will see these macros called in the UDF that defines the wall boundary condition for G.

To complete the implementation of the P1 model, the radiation energy equation must be coupled with the thermal energy equation. This is accomplished by modifying the source term and wall boundary condition of the energy equation. Consider first how the energy equation source term must be modified. The gradient of the incident radiation is proportional to the radiative heat flux. A local increase (or decrease) in the radiative heat flux is attributable to a local decrease (or increase) in thermal energy via the absorption and emission mechanisms. The gradient of the radiative heat flux is therefore a (negative) source of thermal energy. As shown in Section 13.3.3: P-1 Radiation Model Theory of the User's Guide manual, the source term for the incident radiation Equation 8.2-7 is equal to the gradient of the radiative heat flux and hence its negative specifies the source term needed to modify the energy equation.

Now consider how the energy boundary condition at the wall must be modified. Locally, the only mode of energy transfer from the wall to the fluid that is accounted for by default is conduction. With the inclusion of radiation effects, radiative heat transfer to and from the wall must also be accounted for. (This is done automatically if you use FLUENT's built-in P1 model.) The DEFINE_HEAT_FLUX macro allows the wall boundary condition to be modified to accommodate this second mode of heat transfer by specifying the coefficients of the *qir* equation discussed in Section 2.3.8: DEFINE_HEAT_FLUX. The net radiative heat flux to the wall has already been given as Equation 8.2-9. Comparing this equation with that for *qir* in Section 2.3.8: DEFINE_HEAT_FLUX will result in the proper coefficients for $cir[]$.

In this example, the implementation of the P1 model can be accomplished through six separate UDFs. They are all included in a single source file, which can be executed as a compiled UDF. The single user-defined scalar transport equation for incident radiation, G, uses a DEFINE_DIFFUSIVITY UDF to define Γ of Equation 8.2-6, and a UDF to define the source term of Equation 8.2-7. The boundary condition for G at the walls is handled by assigning, in DEFINE_PROFILE, the negative of Equation 8.2-11 as the specified flux. A DEFINE_ADJUST UDF is used to instruct FLUENT to check that the proper number of user-defined scalars has been defined (in the solver). Lastly, the energy equation must be assigned a source term equal to the negative of that used in the incident radiation equation and the DEFINE_HEAT_FLUX UDF is used to alter the boundary conditions at the walls for the energy equation.

In the solver, at least one user-defined scalar (UDS) equation must be enabled. The scalar diffusivity is assigned in the Materials panel for the scalar equation. The scalar source and energy source terms are assigned in the boundary condition panel for the fluid zones. The boundary condition for the scalar equation at the walls is assigned in the boundary condition panel for the wall zones. The DEFINE_ADJUST and DEFINE_HEAT_FLUX functions are assigned in the User-Defined Function Hooks panel.

Note that the residual monitor for the UDS equation should be reduced from $1e-3$ to $1e-6$ before running the solution. If the solution diverges, then it may be due to the large source terms. In this case, the under-relaxation factor should be reduced to 0.99 and the solution re-run.

```
/**************************************************************/
/* Implementation of the P1 model using user-defined scalars  */
/**************************************************************/

#include "udf.h"
#include "sg.h"

/* Define which user-defined scalars to use. */
enum
{
  P1,
  N_REQUIRED_UDS
};


static real abs_coeff = 0.2;    /* absorption coefficient */
static real scat_coeff = 0.0;   /* scattering coefficient */
static real las_coeff = 0.0;    /* linear-anisotropic     */
                                /* scattering coefficient */
static real epsilon_w = 1.0;    /* wall emissivity */
```

```
DEFINE_ADJUST(p1_adjust, domain)
{
  /* Make sure there are enough user defined-scalars. */
  if (n_uds < N_REQUIRED_UDS)
    Internal_Error("not enough user-defined scalars allocated");
}


DEFINE_SOURCE(energy_source, c, t, dS, eqn)
{
  dS[eqn] = -16.*abs_coeff*SIGMA_SBC*pow(C_T(c,t),3.);
  return -abs_coeff*(4.*SIGMA_SBC*pow(C_T(c,t),4.) - C_UDSI(c,t,P1));
}


DEFINE_SOURCE(p1_source, c, t, dS, eqn)
{
  dS[eqn] = 16.*abs_coeff*SIGMA_SBC*pow(C_T(c,t),3.);
  return abs_coeff*(4.*SIGMA_SBC*pow(C_T(c,t),4.) - C_UDSI(c,t,P1));
}


DEFINE_DIFFUSIVITY(p1_diffusivity, c, t, i)
{
  return 1./(3.*abs_coeff + (3. - las_coeff)*scat_coeff);
}


DEFINE_PROFILE(p1_bc, thread, position)

{
  face_t f;
  real A[ND_ND],At;
  real dG[ND_ND],dr0[ND_ND],es[ND_ND],ds,A_by_es;
  real aterm,alpha0,beta0,gamma0,Gsource,Ibw;
  real Ew = epsilon_w/(2.*(2. - epsilon_w));
  Thread *t0=thread->t0;

  /* Do nothing if areas aren't computed yet or not next to fluid. */
  if (!Data_Valid_P() || !FLUID_THREAD_P(t0)) return;
```

```
    begin_f_loop (f,thread)
      {
        cell_t c0 = F_C0(f,thread);

        BOUNDARY_FACE_GEOMETRY(f,thread,A,ds,es,A_by_es,dr0);
        At = NV_MAG(A);

        if (NULLP(T_STORAGE_R_NV(t0,SV_UDSI_G(P1))))
          Gsource = 0.;   /* if gradient not stored yet */
        else
          BOUNDARY_SECONDARY_GRADIENT_SOURCE(Gsource,SV_UDSI_G(P1),
                                             dG,es,A_by_es,1.);

        gamma0 = C_UDSI_DIFF(c0,t0,P1);
        alpha0 = A_by_es/ds;
        beta0  = Gsource/alpha0;
        aterm  = alpha0*gamma0/At;

        Ibw = SIGMA_SBC*pow(WALL_TEMP_OUTER(f,thread),4.)/M_PI;

        /* Specify the radiative heat flux. */
        F_PROFILE(f,thread,position) =
          aterm*Ew/(Ew + aterm)*(4.*M_PI*Ibw - C_UDSI(c0,t0,P1) + beta0);
      }
    end_f_loop (f,thread)
  }


  DEFINE_HEAT_FLUX(heat_flux, f, t, c0, t0, cid, cir)
  {

       real Ew = epsilon_w/(2.*(2. - epsilon_w));

       cir[0] = Ew * F_UDSI(f,t,P1);
       cir[3] = 4.0 * Ew * SIGMA_SBC;

  }
```

Appendix A. C Programming Basics

This chapter contains an overview of C programming basics for UDFs.

A.1 Introduction

This chapter contains some basic information about the C programming language that may be helpful when writing UDFs in FLUENT. It is not intended to be used as a primer on C and assumes that you are an experienced programmer in C. There are many topics and details that are *not* covered in this chapter including, for example, while and do-while control statements, unions, recursion, structures, and reading and writing files.

If you are unfamiliar with C, please consult a C language reference guide (e.g., [2, 3]) before you begin the process of writing UDFs for your FLUENT model.

A.2 Commenting Your C Code

It is good programming practice to document your C code with comments that are useful for explaining the purpose of the function. In a single line of code, your comments must begin with the /* identifier, followed by text, and end with the */ identifier as shown by the following:

```
/* This is how I put a comment in my C program  */
```

Comments that span multiple lines are bracketed by the same identifiers:

```
/* This is how I put a comment in my C program
   that spans more
   than one line.     */
```

Do not include a DEFINE macro name (e.g., DEFINE_PROFILE) within a comment in your source code. This will cause a compilation error.

A.3 C Data Types in FLUENT

The UDF interpreter in FLUENT supports the following standard C data types:

int	integer number
long	integer number of increased range
float	floating point (real) number
double	double-precision floating point (real) number
char	single byte of memory, enough to hold a character

Note that in FLUENT, real is a typedef that switches between float for single-precision arithmetic, and double for double-precision arithmetic. Since the interpreter makes this assignment automatically, it is good programming practice to use the real typedef when declaring all float and double data type variables in your UDF.

A.4 Constants

Constants are absolute values that are used in expressions and need to be defined in your C program using #define. Simple constants are decimal integers (e.g., 0, 1, 2). Constants that contain decimal points or the letter e are taken as floating point constants. As a convention, constants are typically declared using all capitals. For example, you may set the ID of a zone, or define constants YMIN and YMAX as shown below:

```
#define WALL_ID 5
#define YMIN 0.0
#define YMAX 0.4064
```

A.5 Variables

A variable (or object) is a place in memory where you can store a value. Every variable has a type (e.g., real), a name, and a value, and may have a storage class identifier (static or extern). All variables must be declared before they can be used. By declaring a variable ahead of time, the C compiler knows what kind of storage to allocate for the value.

Global variables are variables that are defined outside of any single function and are visible to all function(s) within a UDF source file. Global variables can also be used by other functions outside of the source file unless they are declared as static (see Section A.5.3: Static Variables). Global variables are typically declared at the beginning of a file, after preprocessor directives as in

```
#include "udf.h"

real volume;  /* real variable named volume is declared globally */

DEFINE_ADJUST(compute_volume, domain)
{
   /* code that computes volume of some zone  */
   volume = ....
}
```

Local variables are variables that are used in a single function. They are created when the function is called, and are destroyed when the function returns unless they are declared as static (see Section A.5.3: Static Variables). Local variables are declared within the body of a function (inside the curly braces {}). In the example below, mu_lam and temp are local variables. The value of these variables is not preserved once the function returns.

```
DEFINE_PROPERTY(cell_viscosity, cell, thread)
{
  real mu_lam;                     /* local variable  */
  real temp = C_T(cell, thread);   /* local variable  */

  if (temp > 288.)
    mu_lam = 5.5e-3;
  else if (temp > 286.)
    mu_lam = 143.2135 - 0.49725 * temp;
  else
    mu_lam = 1.;

  return mu_lam;
}
```

A.5.1 Declaring Variables

A variable declaration begins with the data type (e.g., int), followed by the name of one or more variables of the same type that are separated by commas. A variable declaration can also contain an initial value, and always ends with a semicolon (;). Variable names must begin with a letter in C. A name can include letters, numbers, and the underscore (_) character. Note that the C preprocessor is case-sensitive (recognizes uppercase and lowercase letters as being different). Below are some examples of variable declarations.

```
int n;                    /* declaring variable n as an integer       */
int i1, i2;               /* declaring variables i1 and i2 as integers */
float tmax = 0.;          /* tmax is a floating point real number
                             that is initialized to 0                 */
real average_temp = 0.0; /* average_temp is a real number initialized
                             to 0.0                                   */
```

A.5.2 External Variables

If you have a global variable that is declared in one source code file, but a function in another source file needs to use it, then it must be defined in the other source file as an external variable. To do this, simply precede the variable declaration by the word `extern` as in

```
extern real volume;
```

If there are several files referring to that variable then it is convenient to include the `extern` definition in a header (`.h`) file, and include the header file in all of the `.c` files that want to use the external variable. Only one `.c` file should have the declaration of the variable without the `extern` keyword. Below is an example that demonstrates the use of a header file.

i `extern` can be used only in compiled UDFs.

Example

Suppose that there is a global variable named volume that is declared in a C source file named file1.c

```
#include "udf.h"
real volume;      /* real variable named volume is declared globally */

DEFINE_ADJUST(compute_volume, domain)
{
   /* code that computes volume of some zone  */
   volume = ....
}
```

If multiple source files want to use volume in their computations, then volume can be declared as an external variable in a header file (e.g., extfile.h)

```
/* extfile.h
   Header file that contains the external variable declaration for
   volume  */

extern real volume;
```

Now another file named file2.c can declare volume as an external variable by simply including extfile.h.

```
/* file2.c

#include "udf.h"
#include "extfile.h"  /* header file containing extern declaration
                         is included */

DEFINE_SOURCE(heat_source,c,t,ds,eqn)
{
   /* code that computes the per unit volume source using the total
      volume computed in the compute_volume function from file1.c   */

   real total_source = ...;
   real source;

   source = total_source/volume;
   return source;
}
```

A.5.3 Static Variables

The static operator has different effects depending on whether it is applied to local or global variables. When a local variable is declared as static the variable is prevented from being destroyed when a function returns from a call. In other words, the value of the variable is preserved. When a global variable is declared as static the variable is "file global". It can be used by any function within the source file in which it is declared, but is prevented from being used outside the file, even if is declared as external. Functions can also be declared as static. A static function is visible only to the source file in which it is defined.

i static variables and functions can be declared *only* in compiled UDF source files.

Example - Static Global Variable

```
/*  mysource.c  /*

#include "udf.h"

static real abs_coeff = 1.0;  /* static global variable */
     /* used by both functions in this source file but is
        not visible to the outside  */

DEFINE_SOURCE(energy_source, c, t, dS, eqn)
{
 real source;    /* local variable
 int P1 = ....;  /* local variable
                    value is not preserved when function returns */

 dS[eqn] = -16.* abs_coeff * SIGMA_SBC * pow(C_T(c,t),3.);
 source =-abs_coeff *(4.* SIGMA_SBC * pow(C_T(c,t),4.) - C_UDSI(c,t,P1));
 return source;
}

DEFINE_SOURCE(p1_source, c, t, dS, eqn)
{
 real source;
 int P1 = ...;
 dS[eqn] = -abs_coeff;
 source = abs_coeff *(4.* SIGMA_SBC * pow(C_T(c,t),4.) - C_UDSI(c,t,P1));
 return source;
}
```

A.6 User-Defined Data Types

C also allows you to create user-defined data types using structures and `typedef`. (For information about structures in C, see [2].) An example of a structured list definition is shown below.

`typedef` can only be used for compiled UDFs.

Example

```
typedef struct list{int a;
                    real b;
                    int c;} mylist; /* mylist is type structure list
mylist x,y,z;                          x,y,z are type structure list */
```

A.7 Casting

You can convert from one data type to another by casting. A cast is denoted by type, where the type is `int`, `float`, etc., as shown in the following example:

```
int x = 1;
real y = 3.14159;
int z = x+((int) y);       /* z = 4 */
```

A.8 Functions

Functions perform tasks. Tasks may be useful to other functions defined within the same source code file, or they may be used by a function external to the source file. A function has a name (that you supply) and a list of zero or more arguments that are passed to it. Note that your function name cannot contain a number in the first couple of characters. A function has a body enclosed within curly braces that contains instructions for carrying out the task. A function may return a value of a particular type. C functions pass data by value.

Functions either return a value of a particular data type (e.g., `real`), or do not return any value if they are of type `void`. To determine the return data type for the `DEFINE` macro you will use to define your UDF, look at the macro's corresponding `#define` statement in the `udf.h` file or see Appendix B for a listing.

C functions cannot alter their arguments. They can, however, alter the variables that their arguments point to.

A.9 Arrays

Arrays of variables can be defined using the notation name[size], where name is the variable name and size is an integer that defines the number of elements in the array. The index of a C array always begins at 0.

Arrays of variables can be of different data types as shown below.

Examples

```
int a[10], b[10][10];
real radii[5];

a[0] = 1;                    /* a 1-Dimensional array of variable a     */
radii[4] = 3.14159265;       /* a 1-Dimensional array of variable radii */
b[10][10] = 4;               /* a 2-Dimensional array of variable b     */
```

A.10 Pointers

A pointer is a variable that contains an address in memory where the value referenced by the pointer is stored. In other words, a pointer is a variable that points to another variable by referring to the other variable's address. Pointers contain memory addresses, not values. Pointer variables must be declared in C using the * notation. Pointers are widely used to reference data stored in structures and to pass data among functions (by passing the addresses of the data).

For example,

```
int *ip;
```

declares a pointer named ip that points to an integer variable. Now suppose you want to assign an address to pointer ip. To do this, you can use the & notation. For example,

```
ip = &a;
```

assigns the address of variable a to pointer ip.

You can retrieve the value of variable a that pointer ip is pointing to by

```
*ip
```

Alternatively, you can set the value of the variable that pointer ip points. For example,

```
*ip = 4;
```

assigns a value of 4 to the variable that pointer ip is pointing. The use of pointers is demonstrated by the following:

```
int a = 1;
int *ip;
ip = &a;                /* &a returns the address of variable a */
printf("content of address pointed to by ip = %d\n", *ip);
*ip = 4;                /* a = 4  */
printf("now a = %d\n", a);
```

Here, an integer variable a is initialized to 1. Next, ip is declared as a pointer to an integer variable. The address of variable a is then assigned to pointer ip. Next, the integer value of the address pointed to by ip is printed using *ip. (This value is 1.) The value of variable a is then indirectly set to 4 using *ip. The new value of a is then printed. Pointers can also point to the beginning of an array, and are strongly connected to arrays in C.

Pointers as Function Arguments

C functions can access and modify their arguments through pointers. In FLUENT, thread and domain pointers are common arguments to UDFs. When you specify these arguments in your UDF, the FLUENT solver automatically passes data that the pointers are referencing to your UDF so that your function can access solver data. (You do not have to declare pointers that are passed as arguments to your UDF from the solver.) For example, one of the arguments passed to a UDF that specifies a custom profile (defined by the DEFINE_PROFILE macro) is the pointer to the thread applied to by the boundary condition. The DEFINE_PROFILE function accesses the data pointed to by the thread pointer.

A.11 Control Statements

You can control the order in which statements are executed in your C program using control statements like `if`, `if-else`, and `for` loops. Control statements make decisions about what is to be executed next in the program sequence.

A.11.1 `if` Statement

An `if` statement is a type of conditional control statement. The format of an `if` statement is:

```
 if (logical-expression)
     {statements}
```

where `logical-expression` is the condition to be tested, and `statements` are the lines of code that are to be executed if the condition is met.

Example

```
if (q != 1)
     {a = 0; b = 1;}
```

A.11.2 `if-else` Statement

`if-else` statements are another type of conditional control statement. The format of an `if-else` statement is:

```
if (logical-expression)
  {statements}
else
  {statements}
```

where `logical-expression` is the condition to be tested, and the first set of `statements` are the lines of code that are to be executed if the condition is met. If the condition is not met, then the statements following `else` are executed.

Example

```
if (x < 0.)
  y = x/50.;
else
  {
   x = -x;
   y = x/25.;
  }
```

The equivalent FORTRAN code is shown below for comparison.

```
       IF (X.LT.0.) THEN
         Y = X/50.
       ELSE
         X = -X
         Y = X/25.
       ENDIF
```

A.11.3 `for` Loops

`for` loops are control statements that are a basic looping construct in C. They are analogous to `do` loops in FORTRAN. The format of a `for` loop is

```
for (begin ; end ; increment)
    {statements}
```

where `begin` is the expression that is executed at the beginning of the loop; `end` is the logical expression that tests for loop termination; and `increment` is the expression that is executed at the end of the loop iteration (usually incrementing a counter).

Example

```
/* Print integers 1-10 and their squares */

int i, j, n = 10;

for (i = 1 ; i <= n ; i++)
   { j = i*i;
     printf("%d %d\n",i,j);
   }
```

The equivalent FORTRAN code is shown below for comparison.

```
INTEGER I,J
N = 10
DO I = 1,10
J = I*I
WRITE (*,*) I,J
ENDDO
```

A.12 Common C Operators

Operators are internal C functions that, when they are applied to values, produce a result. Common types of C operators are arithmetic and logical.

A.12.1 Arithmetic Operators

Some common arithmetic operators are listed below.

`=`	assignment
`+`	addition
`-`	subtraction
`*`	multiplication
`/`	division
`%`	modulo reduction
`++`	increment
`--`	decrement

Note that multiplication, division, and modulo reduction (%) operations will be performed before addition and subtraction in any expression. When division is performed on two integers, the result is an integer with the remainder discarded. Modulo reduction is the remainder from integer division. The ++ operator is a shorthand notation for the increment operation.

A.12.2 Logical Operators

Some common logical operators are listed below.

`<`	less than
`<=`	less than or equal to
`>`	greater than
`>=`	greater than or equal to
`==`	equal to
`!=`	not equal to

A.13 C Library Functions

C compilers include a library of standard mathematical and I/O functions that you can use when you write your UDF code. Lists of standard C library functions are presented in the following sections. Definitions for standard C library functions can be found in various header files (e.g., `global.h`). These header files are all included in the `udf.h` file.

A.13.1 Trigonometric Functions

The trigonometric functions shown below are computed (with one exception) for the variable `x`. Both the function and the argument are double-precision `real` variables. The function `acos(x)` is the arccosine of the argument `x`, $\cos^{-1}(x)$. The function `atan2(x,y)` is the arctangent of `x/y`, $\tan^{-1}(x/y)$. The function `cosh(x)` is the hyperbolic cosine function, etc.

`double acos (double x);`	returns the arcosine of x
`double asin (double x);`	returns the arcsine of x
`double atan (double x);`	returns the arctangent of x
`double atan2 (double x, double y);`	returns the arctangent of x/y
`double cos (double x);`	returns the cosine of x
`double sin (double x);`	returns the sine of x
`double tan (double x);`	returns the tangent of x
`double cosh (double x);`	returns the hyperbolic cosine of x
`double sinh (double x);`	returns the hyperbolic sine of x
`double tanh (double x);`	returns the hyperbolic tangent of x

A.13.2 Miscellaneous Mathematical Functions

The C functions shown on the left below correspond to the mathematical functions shown on the right.

`double sqrt (double x);`	$\sqrt{x}$
`double pow(double x, double y);`	x^y
`double exp (double x);`	e^x
`double log (double x);`	$\ln(x)$
`double log10 (double x);`	$\log_{10}(x)$
`double fabs (double x);`	$\mid x \mid$
`double ceil (double x);`	smallest integer not less than x
`double floor (double x);`	largest integer not greater than x

A.13.3 Standard I/O Functions

A number of standard input and output (I/O) functions are available in C and in FLUENT. They are listed below. All of the functions work on a specified file except for `printf`, which displays information that is specified in the argument of the function. The format string argument is the same for `printf`, `fprintf`, and `fscanf`. Note that all of these standard C I/O functions are supported by the interpreter, so you can use them in either interpreted or compiled UDFs. For more information about standard I/O functions in C, you should consult a reference guide (e.g., [2]).

Common C I/O Functions

`fopen("filename", "mode");`	opens a file
`fclose(fp);`	closes a file
`printf("format", ...);`	formatted print to the console
`fprintf(fp, "format", ...);`	formatted print to a file
`fscanf(fp, "format", ...);`	formatted read from a file

It is not possible to use the `scanf` C function in FLUENT.

fopen

```
FILE *fopen(char *filename, char *mode);
```

The function `fopen` opens a file in the mode that you specify. It takes two arguments: `filename` and `mode`. `filename` is a pointer to the file you want to open. `mode` is the mode in which you want the file opened. The options for `mode` are read `"r"`, write `"w"`, and append `"a`”. Both arguments must be enclosed in quotes. The function returns a pointer to the file that is to be opened.

Before using `fopen`, you will first need to define a local pointer of type `FILE` that is defined in `stdio.h` (e.g., `fp`). Then, you can open the file using `fopen`, and assign it to the local pointer as shown below. Recall that `stdio.h` is included in the `udf.h` file, so you don’t have to include it in your function.

```
FILE *fp;    /*  define a local pointer fp of type FILE  */
fp = fopen("data.txt","r");   /*  open a file named data.txt in
                                  read-only mode and assign it to fp */
```

fclose

```
int fclose(FILE *fp);
```

The function `fclose` closes a file that is pointed to by the local pointer passed as an argument (e.g., `fp`).

```
 fclose(fp);   /* close the file pointed to by fp */
```

printf

```
int printf(char *format, ...);
```

The function `printf` is a general-purpose printing function that prints to the console in a format that you specify. The first argument is the format string. It specifies how the remaining arguments are to be displayed in the console window. The format string is defined within quotes. The value of the replacement variables that follow the format string will be substituted in the display for all instances of `%type`. The `%` character is used to designate the character type. Some common format characters are: `%d` for integers, `%f` for floating point numbers, and `%e` for floating point numbers in exponential format (with `e` before the exponent). The format string for `printf` is the same as for `fprintf` and `fscanf`.

In the example below, the text `Content of variable a is:` will be displayed in the console window, and the value of the replacement variable, `a`, will be substituted in the message for all instances of `%d`.

Example:

```
int a = 5;
printf("Content of variable a is: %d\n", a); /* \n denotes a new line */
```

(UNIX only) It is recommended that you use the Fluent Inc. `Message` utility instead of `printf` for compiled UDFs. See Section 3.7: `Message` for details on the `Message` macro.

fprintf

```
int fprintf(FILE *fp, char *format, ...);
```

The function `fprintf` writes to a file that is pointed to by `fp`, in a format that you specify. The first argument is the format string. It specifies how the remaining arguments are to be written to the file. The format string for `fprintf` is the same as for `printf` and `fscanf`.

Example:

```
FILE *fp;
fprintf(fp,"%12.4e %12.4e %5d\n",x_array[j][0], x_array[j][1], noface);

int data1 = 64.25;
int data2 = 97.33;
fprintf(fp, "%4.2d %4.2d\n", data1, data2);
```

fscanf

`int fscanf(FILE *fp, char *format, ...);`

The function `fscanf` reads from a file that is pointed to by `fp`, in a format that you specify. The first argument is the format string. It specifies how the data that is to be read is to be interpreted. The replacement variables that follow the format string are used to store values that are read. The replacement variables are preceded by the `&` character. Note that the format string for `fscanf` is the same as for `fprintf` and `printf`.

In the example below, two floating point numbers are read from the file pointed to by `fp`, and are stored in the variables `f1` and `f2`.

Example:

```
FILE *fp;
fscanf(fp, "%f %f", &f1, &f2);
```

i You cannot use the `scanf` I/O function in FLUENT. You must use `fscanf` instead.

A.14 Preprocessor Directives

The UDF interpreter supports C preprocessor directives including `#define` and `#include`.

Macro Substitution Directive Using `#define`

When you use the `#define` macro substitution directive, the C preprocessor (e.g., `cpp`) performs a simple substitution and expands the occurrence of each argument in *macro* using the *replacement-text.*

`#define` *macro* *replacement-text*

For example, the macro substitution directive given by

```
#define RAD 1.2345
```

will cause the preprocessor to replace all instances of the variable `RAD` in your UDF with the number `1.2345`. There may be many references to the variable `RAD` in your function, but you only have to define it once in the macro directive; the preprocessor does the work of performing the substitution throughout your code.

In another example

```
#define AREA_RECTANGLE(X,Y) ((X)*(Y))
```

all of the references to `AREA_RECTANGLE(X,Y)` in you UDF are replaced by the product of `(X)` and `(Y)`.

File Inclusion Directive Using `#include`

When you use the `#include` file inclusion directive, the C preprocessor replaces the line `#include` *filename* with the contents of the named file.

`#include "`*filename*`"`

The file you name must reside in your current directory. The only exception to this rule is the `udf.h` file, which is read automatically by the FLUENT solver.

For example, the file inclusion directive given by

```
#include "udf.h"
```

will cause the `udf.h` file to be included with your source code. The FLUENT solver automatically reads the `udf.h` file from the `Fluent.Inc/fluent6.x/src/` directory.

A.15 Comparison with FORTRAN

Many simple C functions are similar to FORTRAN function subroutines as shown in the example below:

```
A simple C function    An equivalent FORTRAN function

int myfunction(int x)  INTEGER FUNCTION MYFUNCTION(X)
{
int x,y,z;             INTEGER X,Y,Z
y = 11;                Y = 11
z = x+y;               Z = X+Y
printf("z = %d",z);    WRITE (*,100) Z
return z;              MYFUNCTION = Z
}                      END
```

Appendix B. DEFINE Macro Definitions

B.1 General Solver DEFINE Macros

The following definitions for general solver DEFINE macros (see Section 2.2: General Purpose DEFINE Macros) are taken from the udf.h header file.

```
#define DEFINE_ADJUST(name, domain) void name(Domain *domain)

#define DEFINE_EXECUTE_AT_END(name) void name(void)

#define DEFINE_EXECUTE_AT_EXIT(name) void name(void)

#define DEFINE_EXECUTE_FROM_GUI(name, libname, mode) \
  void name(char *libname, int mode)

#define DEFINE_EXECUTE_ON_LOADING(name, libname) void name(char *libname)

#define DEFINE_INIT(name, domain) void name(Domain *domain)

#define DEFINE_ON_DEMAND(name) void name(void)

#define DEFINE_RW_FILE(name, fp) void name(FILE *fp)
```

B.2 Model-Specific DEFINE Macro Definitions

The following definitions for model-specific DEFINE macros (see Section 2.3: Model-Specific DEFINE Macros) are taken from the udf.h header file.

```
#define DEFINE_CHEM_STEP(name, c, t, p, num_p, n_spe, dt, pres, temp, yk) \
  void name(int cell_t c, Thread *t, Particle *p, int num_p, int n_spe, \
  double *dt, double *pres, double *temp, double *yk)

#define DEFINE_CPHI(name,c,t) \
  real name(cell_t c, Thread *t)

#define DEFINE_DIFFUSIVITY(name, c, t, i) \
  real name(cell_t c, Thread *t, int i)

#define DEFINE_DOM_DIFFUSE_REFLECTIVITY(name ,t, nb, n_a, n_b, diff_ ref_a, \
  diff_tran_a, diff_ref_b, diff_tran_b) \
  void name(Thread *t, int nb,  real n_a, real n_b, real *diff_ref_a, \
            real *diff_tran_a, real *diff_ref_b, real *diff_tran_b)

#define DEFINE_DOM_SPECULAR_REFLECTIVITY(name, f, t, nb, n_a, n_b, \
  ray_direction,  e_n, total_internal_reflection, \
  specular_reflectivity, specular_transmissivity) \
  void name(face_t f, Thread *t, int nb,  real n_a, real n_b , \
            real ray_direction[], real e_n[], \
            int *total_internal_reflection, real *specular_reflectivity,\
            real *specular_transmissivity)

#define DEFINE_DOM_SOURCE(name, c, t, ni, nb, emission, in_scattering, \
  abs_coeff,scat_coeff) \
  void name(cell_t c, Thread* t, int ni, int nb, real *emission, \
            real *in_scattering, real *abs_coeff, real *scat_coeff)

#define DEFINE_GRAY_BAND_ABS_COEFF(name, c, t, nb)  \
   real name(cell_t c, Thread *t, int nb)

#define DEFINE_HEAT_FLUX(name, f, t, c0, t0, cid, cir) \
  void name(face_t f, Thread *t, cell_t c0, Thread *t0, \
            real cid[], real cir[])

#define DEFINE_NET_REACTION_RATE(name, c, t, particle, pressure, \
  temp, yi, rr, jac) \
  void name(cell_t c, Thread *t, Particle *particle, \
  double *pressure, double *temp, double *yi, double *rr, \
  double *jac)

#define DEFINE_NOX_RATE(name, c, t, Pollut, Pollut_Par, NOx) \
  void name(cell_t c, Thread *t, Pollut_Cell *Pollut, \
  Pollut_Parameter *Poll_Par, NOx_Parameter *NOx)


#define DEFINE_PRANDTL_K(name, c, t) real name(cell_t c, Thread *t)

#define DEFINE_PRANDTL_D(name, c, t) real name(cell_t c, Thread *t)

#define DEFINE_PRANDTL_O(name, c, t) real name(cell_t c, Thread *t)

#define DEFINE_PRANDTL_T(name, c, t) real name(cell_t c, Thread *t)

#define DEFINE_PRANDTL_T_WALL(name, c, t) real name(cell_t c, Thread *t)

#define DEFINE_PROFILE(name, t, i) void name(Thread *t, int i)

#define DEFINE_PROPERTY(name, c, t) real name(cell_t c, Thread *t)

#define DEFINE_PR_RATE(name, c, t, r, mw, ci, p, sf, dif_index, \
  cat_index, rr) \
  void name(cell_t c, Thread *t, Reaction *r, real *mw, real *ci, \
            Tracked_Particle *p, real *sf , int dif_index, \
            int cat_index, real *rr)

#define DEFINE_SCAT_PHASE_FUNC(name, c, f) \
  real name(real c, real *f)

#define DEFINE_SOLAR_INTENSITY(name, sun_x, sun_y, sun_z, S_hour, S_minute) \
   real name(real sun_x, real sun_y, real sun_z, int S_hour,int S_minute)

#define DEFINE_SOURCE(name, c, t, dS, i) \
  real name(cell_t c, Thread *t, real dS[], int i)

#define DEFINE_SOX_RATE(name, c, t, Pollut, Pollut_Par, SOx) \
  void name(cell_t c, Thread *t, Pollut_Cell *Pollut, \
  Pollut_Parameter *Poll_Par, SOx_Parameter *SOx)


#define DEFINE_SR_RATE(name, f, t, r, mw, yi, rr) \
  void name(face_t f, Thread *t, \
    Reaction *r, real *mw, real *yi, real *rr)

#define DEFINE_TURB_PREMIX_SOURCE(name, c, t, \
  turbulent_flame_speed, source) \
  void name(cell_t c, Thread *t, real *turbulent_flame_speed, \
            real *source)

#define DEFINE_TURBULENT_VISCOSITY(name, c, t) \
  real name(cell_t c, Thread *t)

#define DEFINE_VR_RATE(name, c, t, r, mw, yi, rr, rr_t) \
  void name(cell_t c, Thread *t, \
    Reaction *r, real *mw, real *yi, real *rr, real *rr_t)

#define DEFINE_WALL_FUNCTIONS(name, f, t, c0, t0, wf_ret, yPlus, Emod) \
  real name(face_t f, Thread *t, cell_t c0, Thread *t0, int wf_ret \
  real yPlus, real Emod)
```

B.3 Multiphase DEFINE Macros

The following definitions for multiphase DEFINE macros (see Section 2.4: Multiphase DEFINE Macros) are taken from the udf.h header file.

```
#define DEFINE_CAVITATION_RATE(name, c, t, p, rhoV, rhoL, vofV, p_v, \
  cigma, f_gas, m_dot) \
  void name(cell_t c, Thread *t, real *p, real *rhoV, real *rhoL, \
            real *vofV, real *p_v, real *cigma, real *f_gas, real *m_dot)

#define DEFINE_EXCHANGE_PROPERTY(name, c, mixture_thread, \
  second_column_phase_index, first_column_phase_index) \
  real name(cell_t c, Thread *mixture_thread, \
            int second_column_phase_index, int first_column_phase_index)

#define DEFINE_HET_RXN_RATE(name, c, t, hr, mw, yi, rr, rr_t) \
  void name(cell_t c, Thread *t, \
    Hetero_Reaction *hr, real mw[MAX_PHASES][MAX_SPE_EQNS],  \
            real yi[MAX_PHASES][MAX_SPE_EQNS], real *rr, real *rr_t)

#define DEFINE_MASS_TRANSFER(name, c, mixture_thread, from_phase_index, \
  from_species_index, to_phase_index, to_species_index) \
  real name(cell_t c, Thread *mixture_thread, int from_phase_index, \
  int from_species_index, int to_phase_index, int to_species_index)


#define DEFINE_VECTOR_EXCHANGE_PROPERTY(name, c, mixture_thread, \
  second_column_phase_index, first_column_phase_index, vector_result) \
  void name(cell_t c, Thread *mixture_thread, \
            int second_column_phase_index, \
            int first_column_phase_index, real *vector_result)
```

B.4 Dynamic Mesh Model DEFINE Macros

The following definitions for dynamic mesh model DEFINE macros (see Section 2.6: Dynamic Mesh DEFINE Macros) are taken from the udf.h header file.

```
#define DEFINE_CG_MOTION(name, dt, vel, omega, time, dtime) \
  void name(Dynamic_Thread *dt, real vel[], real omega[], real time,\
            real dtime)

#define DEFINE_GEOM(name, d, dt, position) \
  void name(Domain *d, Dynamic_Thread *dt, real *position)

#define DEFINE_GRID_MOTION(name, d, dt, time, dtime) \
  void name(Domain *d, Dynamic_Thread *dt, real time, real dtime)

#define DEFINE_SDOF_PROPERTIES(name, properties, dt, time, dtime) \
  void name(real *properties, Dynamic_Thread *dt, real time, real dtime)
```

B.5 Discrete Phase Model DEFINE Macros

The following definitions for DPM DEFINE macros (see Section 2.5: Discrete Phase Model (DPM) DEFINE Macros) are taken from the dpm.h header file. Note that dpm.h is included in the udf.h header file.

```
#define DEFINE_DPM_BC(name, p, t, f, normal, dim) \
  int name(Tracked_Particle *p, Thread *t, face_t f, \
           real normal[], int dim)

#define DEFINE_DPM_BODY_FORCE(name, p, i) \
  real name(Tracked_Particle *p, int i)

#define DEFINE_DPM_DRAG(name, Re, p) \
  real name(real Re, Tracked_Particle *p)

#define DEFINE_DPM_EROSION(name, p, t, f, normal, alpha, Vmag, mdot) \
  void name(Tracked_Particle *p, Thread *t, face_t f, real normal[], \
    real alpha, real Vmag, real mdot)

#define DEFINE_DPM_HEAT_MASS(name, p, Cp, hgas, hvap, cvap_surf, dydt, dzdt) \
  void name(Tracked_Particle *p, real Cp, \
            real *hgas, real *hvap, real *cvap_surf, real *dydt, dpms_t *dzdt)

#define DEFINE_DPM_INJECTION_INIT(name, I) void name(Injection *I)

#define DEFINE_DPM_LAW(name, p, ci) \
  void name(Tracked_Particle *p, int ci)

#define DEFINE_DPM_OUTPUT(name, header, fp, p, t, plane) \
  void name(int header, FILE *fp, Tracked_Particle *p, \
            Thread *t, Plane *plane)

#define DEFINE_DPM_PROPERTY(name, c, t, p) \
  real name(cell_t c, Thread *t, Tracked_Particle *p)

#define DEFINE_DPM_SCALAR_UPDATE(name, c, t, initialize, p) \
  void name(cell_t c, Thread *t, int initialize, Tracked_Particle *p)

#define DEFINE_DPM_SOURCE(name, c, t, S, strength, p) \
  void name(cell_t c, Thread *t, dpms_t *S, real strength,\
            Tracked_Particle *p)

#define DEFINE_DPM_SPRAY_COLLIDE(name, tp, p) \
  void name(Tracked_Particle *tp, Particle *p)

#define DEFINE_DPM_SWITCH(name, p, ci) \
  void name(Tracked_Particle *p, int ci)

#define DEFINE_DPM_TIMESTEP(name, p, ts) \
  real name(Tracked_Particle *p,real ts)

#define DEFINE_DPM_VP_EQUILIB(name, p, cvap_surf) \
  void name(Tracked_Particle *p, real *cvap_surf)
```

B.6 User-Defined Scalar (UDS) DEFINE Macros

The following definitions for UDS DEFINE macros (see Section 2.7: User-Defined Scalar (UDS) Transport Equation DEFINE Macros) are taken from the udf.h header file.

```
#define DEFINE_ANISOTROPIC_DIFFUSIVITY(name, c, t, ns, dmatrix) \
   void name(cell_t c, Thread *t, int ns, real dmatrix[ND_ND][ND_ND])

#define DEFINE_UDS_FLUX(name, f, t, i) real name(face_t f, Thread *t, int i)

#define DEFINE_UDS_UNSTEADY(name, c, t, i, apu, su) \
  void name(cell_t c, Thread *t, int i, real *apu, real *su)
```

Appendix C. Quick Reference Guide for Multiphase DEFINE Macros

This appendix is a reference guide that contains a list of general purpose DEFINE macros (Section 2.3: Model-Specific DEFINE Macros) and multiphase-specific DEFINE macros (Section 2.4: Multiphase DEFINE Macros) that can be used to define multiphase model UDFs.

See Section 1.10: Special Considerations for Multiphase UDFs for information on special considerations for multiphase UDFs.

C.1 VOF Model

Tables C.1.1–C.1.2 list the variables that can be customized using UDFs for the VOF multiphase model, the DEFINE macros that are used to define the UDFs, and the phase that the UDF needs to be hooked to for the given variable.

Table C.1.1: DEFINE Macro Usage for the VOF Model

Variable	Macro	Phase Specified On
Boundary Conditions		
Inlet/Outlet		
volume fraction	DEFINE_PROFILE	secondary phase(s)
velocity magnitude	DEFINE_PROFILE	mixture
pressure	DEFINE_PROFILE	mixture
temperature	DEFINE_PROFILE	mixture
mass flux	DEFINE_PROFILE	primary and secondary phase(s)
species mass fractions	DEFINE_PROFILE	phase-dependent
internal emissivity	DEFINE_PROFILE	mixture
user-defined scalar boundary value	DEFINE_PROFILE	mixture
discrete phase boundary condition	DEFINE_PROFILE	mixture
Fluid		
mass source	DEFINE_SOURCE	primary and secondary phase(s)
momentum source	DEFINE_SOURCE	mixture
energy source	DEFINE_SOURCE	mixture

Table C.1.2: DEFINE Macro Usage for the VOF Model

Variable	Macro	Phase Specified On
Fluid - continued		
turbulence kinetic energy source	DEFINE_SOURCE	mixture
turbulence dissipation rate source	DEFINE_SOURCE	mixture
user-defined scalar source	DEFINE_SOURCE	mixture
species source	DEFINE_SOURCE	phase-dependent
velocity	DEFINE_PROFILE	mixture
temperature	DEFINE_PROFILE	mixture
user-defined scalar	DEFINE_PROFILE	mixture
turbulence kinetic energy	DEFINE_PROFILE	mixture
turbulence dissipation rate	DEFINE_PROFILE	mixture
species mass fraction	DEFINE_PROFILE	phase-dependent
porosity	DEFINE_PROFILE	mixture
Boundary Conditions		
Wall		
species boundary condition	DEFINE_PROFILE	phase-dependent
internal emissivity	DEFINE_PROFILE	mixture
irradiation	DEFINE_PROFILE	mixture
roughness height	DEFINE_PROFILE	mixture
roughness constant	DEFINE_PROFILE	mixture
shear stress components	DEFINE_PROFILE	mixture
swirl components	DEFINE_PROFILE	mixture
moving velocity components	DEFINE_PROFILE	mixture
heat flux	DEFINE_PROFILE	mixture
heat generation rate	DEFINE_PROFILE	mixture
heat transfer coefficient	DEFINE_PROFILE	mixture
external emissivity	DEFINE_PROFILE	mixture
external radiation temperature	DEFINE_PROFILE	mixture
free stream temperature	DEFINE_PROFILE	mixture
user scalar boundary value	DEFINE_PROFILE	mixture
discrete phase boundary value	DEFINE_DPM_BC	mixture
Other		
surface tension coefficient	DEFINE_PROPERTY	phase interaction
mass transfer coefficient	DEFINE_MASS_TRANSFER	phase interaction
heterogeneous reaction rate	DEFINE_HET_RXN_RATE	phase interaction

C.2 Mixture Model

Tables C.2.1–C.2.2 list the variables that can be customized using UDFs for the Mixture multiphase model, the DEFINE macros that are used to define the UDFs, and the phase that the UDF needs to be hooked to for the given variable.

Table C.2.1: DEFINE Macro Usage for the Mixture Model

Variable	Macro	Phase Specified On
Boundary Conditions		
Inlet/Outlet		
volume fraction	DEFINE_PROFILE	secondary phase(s)
mass flux	DEFINE_PROFILE	primary and secondary phase(s)
velocity magnitude	DEFINE_PROFILE	primary and secondary phases(s)
pressure	DEFINE_PROFILE	mixture
temperature	DEFINE_PROFILE	mixture
species mass fractions	DEFINE_PROFILE	phase-dependent
user-defined scalar boundary value	DEFINE_PROFILE	mixture
discrete phase boundary condition	DEFINE_PROFILE	mixture
Fluid		
mass source	DEFINE_SOURCE	primary and secondary phase(s)
momentum source	DEFINE_SOURCE	mixture
energy source	DEFINE_SOURCE	mixture
turbulence kinetic energy source	DEFINE_SOURCE	mixture
turbulence dissipation rate source	DEFINE_SOURCE	mixture
granular temperature source	DEFINE_SOURCE	secondary phase(s)
user scalar source	DEFINE_SOURCE	mixture
species source	DEFINE_SOURCE	phase-dependent
species mass fractions	DEFINE_PROFILE	phase-dependent
velocity	DEFINE_PROFILE	mixture
temperature	DEFINE_PROFILE	mixture
turbulence kinetic energy	DEFINE_PROFILE	mixture
turbulence dissipation rate	DEFINE_PROFILE	mixture
porosity	DEFINE_PROFILE	mixture
granular temperature	DEFINE_PROFILE	secondary phase(s)

Table C.2.2: DEFINE Macro Usage for the Mixture Model

Variable	Macro	Phase Specified On
Fluid - continued		
viscous resistance	DEFINE_PROFILE	primary and secondary phase(s)
inertial resistance	DEFINE_PROFILE	primary and secondary phase(s)
Wall		
roughness height	DEFINE_PROFILE	mixture
roughness constant	DEFINE_PROFILE	mixture
internal emissivity	DEFINE_PROFILE	mixture
shear stress components	DEFINE_PROFILE	mixture
moving velocity components	DEFINE_PROFILE	mixture
heat flux	DEFINE_PROFILE	mixture
heat generation rate	DEFINE_PROFILE	mixture
heat transfer coefficient	DEFINE_PROFILE	mixture
external emissivity	DEFINE_PROFILE	mixture
external radiation temperature	DEFINE_PROFILE	mixture
free stream temperature	DEFINE_PROFILE	mixture
granular flux	DEFINE_PROFILE	secondary phase(s)
granular temperature	DEFINE_PROFILE	secondary phase(s)
user scalar boundary value	DEFINE_PROFILE	mixture
discrete phase boundary value	DEFINE_DPM_BC	mixture
species boundary condition	DEFINE_PROFILE	phase-dependent
Material Properties		
cavitation surface tension coefficient	DEFINE_PROPERTY	phase interaction
cavitation vaporization pressure	DEFINE_PROPERTY	phase interaction
particle or droplet diameter	DEFINE_PROPERTY	secondary phase(s)
granular diameter	DEFINE_PROPERTY	secondary phase(s)
granular solids pressure	DEFINE_PROPERTY	secondary phase(s)
granular radial distribution	DEFINE_PROPERTY	secondary phase(s)
granular elasticity modulus	DEFINE_PROPERTY	secondary phase(s)
granular viscosity	DEFINE_PROPERTY	secondary phase(s)
granular temperature	DEFINE_PROPERTY	secondary phase(s)
Other		
slip velocity	DEFINE_VECTOR_EXCHANGE_PROPERTY	phase interaction
drag coefficient	DEFINE_EXCHANGE	phase interaction
mass transfer coefficient	DEFINE_MASS_TRANSFER	phase interaction
heterogeneous reaction rate	DEFINE_HET_RXN_RATE	phase interaction

C.3 Eulerian Model - Laminar Flow

Tables C.3.1–C.3.3 list the variables that can be customized using UDFs for the laminar flow Eulerian multiphase model, the DEFINE macros that are used to define the UDFs, and the phase that the UDF needs to be hooked to for the given variable.

Table C.3.1: DEFINE Macro Usage for the Eulerian Model - Laminar Flow

Variable	Macro	Phase Specified On
Boundary Conditions		
Inlet/Outlet		
volume fraction	DEFINE_PROFILE	secondary phase(s)
species mass fractions	DEFINE_PROFILE	phase-dependent
mass flux	DEFINE_PROFILE	primary and secondary phase(s)
flow direction components	DEFINE_PROFILE	primary and secondary phase(s)
velocity magnitude	DEFINE_PROFILE	primary and secondary phase(s)
temperature	DEFINE_PROFILE	primary and secondary phase(s)
pressure	DEFINE_PROFILE	mixture
user-defined scalar boundary value	DEFINE_PROFILE	mixture
discrete phase boundary value	DEFINE_DPM_BC	mixture
Fluid		
mass source	DEFINE_SOURCE	primary and secondary phase(s)
momentum source	DEFINE_SOURCE	primary and secondary phase(s)
energy source	DEFINE_SOURCE	primary and secondary phase(s)
species source	DEFINE_SOURCE	phase-dependent
granular temperature source	DEFINE_SOURCE	secondary phase(s)
user-defined scalar source	DEFINE_SOURCE	mixture
velocity	DEFINE_PROFILE	primary and secondary phase(s)
temperature	DEFINE_PROFILE	primary and secondary phase(s)

Table C.3.2: DEFINE Macro Usage for the Eulerian Model - Laminar Flow

Variable	Macro	Phase Specified On
Boundary Conditions		
Fluid		
species mass fraction	DEFINE_PROFILE	phase-dependent
granular temperature	DEFINE_PROFILE	secondary phase(s)
porosity	DEFINE_PROFILE	mixture
user-defined scalar	DEFINE_PROFILE	mixture
viscous resistance	DEFINE_PROFILE	primary and secondary phase(s)
inertial resistance	DEFINE_PROFILE	primary and secondary phase(s)
Wall		
species boundary condition	DEFINE_PROFILE	phase-dependent
shear stress components	DEFINE_PROFILE	primary and secondary phase(s)
moving velocity components	DEFINE_PROFILE	mixture
temperature	DEFINE_PROFILE	mixture
heat flux	DEFINE_PROFILE	mixture
heat generation rate	DEFINE_PROFILE	mixture
heat transfer coefficient	DEFINE_PROFILE	mixture
external emissivity	DEFINE_PROFILE	mixture
external radiation temperature	DEFINE_PROFILE	mixture
free stream temperature	DEFINE_PROFILE	mixture
user-defined scalar boundary value	DEFINE_PROFILE	mixture
discrete phase boundary value	DEFINE_DPM_BC	mixture
Material Properties		
granular diameter	DEFINE_PROPERTY	secondary phase(s)
granular solids pressure	DEFINE_PROPERTY	secondary phase(s)
granular radial distribution	DEFINE_PROPERTY	secondary phase(s)
granular elasticity modulus	DEFINE_PROPERTY	secondary phase(s)
granular viscosity	DEFINE_PROPERTY	secondary phase(s)
granular temperature	DEFINE_PROPERTY	secondary phase(s)

Table C.3.3: DEFINE Macro Usage for the Eulerian Model - Laminar Flow

Variable	**Macro**	**Phase Specified On**
Other		
drag coefficient	DEFINE_EXCHANGE	phase interaction
lift coefficient	DEFINE_EXCHANGE	phase interaction
heat transfer coefficient	DEFINE_PROPERTY	phase interaction
mass transfer coefficient	DEFINE_MASS_TRANSFER	phase interaction
heterogeneous reaction rate	DEFINE_HET_RXN_RATE	phase interaction

C.4 Eulerian Model - Mixture Turbulence Flow

Tables C.4.1–C.4.3 list the variables that can be customized using UDFs for the mixed turbulence flow Eulerian multiphase model, the DEFINE macros that are used to define the UDFs, and the phase that the UDF needs to be hooked to for the given variable.

Table C.4.1: DEFINE Macro Usage for the Eulerian Model - Mixture Turbulence Flow

Variable	Macro	Phase Specified On
Boundary Conditions		
Inlet/Outlet		
volume fraction	DEFINE_PROFILE	secondary phase(s)
species mass fractions	DEFINE_PROFILE	phase-dependent
mass flux	DEFINE_PROFILE	primary and secondary phases
velocity magnitude	DEFINE_PROFILE	primary and secondary phases(s)
temperature	DEFINE_PROFILE	primary and secondary phases(s)
pressure	DEFINE_PROFILE	mixture
user-defined scalar boundary value	DEFINE_PROFILE	mixture
discrete phase boundary condition	DEFINE_PROFILE	mixture
Fluid		
mass source	DEFINE_SOURCE	primary and secondary phase(s)
momentum source	DEFINE_SOURCE	primary and secondary phase(s)
energy source	DEFINE_SOURCE	primary and secondary phase(s)
turbulence dissipation rate source	DEFINE_SOURCE	mixture
turbulence kinetic energy source	DEFINE_SOURCE	mixture
user-defined scalar source	DEFINE_SOURCE	mixture
user-defined scalar	DEFINE_PROFILE	mixture
turbulence kinetic energy	DEFINE_PROFILE	mixture
turbulence dissipation rate	DEFINE_PROFILE	mixture

Table C.4.2: DEFINE Macro Usage for the Eulerian Model - Mixture Turbulence Flow

Variable	Macro	Phase Specified On
Fluid		
velocity	DEFINE_PROFILE	primary and secondary phase(s)
temperature	DEFINE_PROFILE	primary and secondary phase(s)
porosity	DEFINE_PROFILE	mixture
user-defined scalar	DEFINE_PROFILE	mixture
viscous resistance	DEFINE_PROFILE	primary and secondary phase(s)
inertial resistance	DEFINE_PROFILE	primary and secondary phase(s)
Wall		
species boundary condition	DEFINE_PROFILE	phase-dependent
shear stress components	DEFINE_PROFILE	primary and secondary phase(s)
moving velocity components	DEFINE_PROFILE	mixture
temperature	DEFINE_PROFILE	mixture
heat flux	DEFINE_PROFILE	mixture
heat generation rate	DEFINE_PROFILE	mixture
heat transfer coefficient	DEFINE_PROFILE	mixture
external emissivity	DEFINE_PROFILE	mixture
external radiation temperature	DEFINE_PROFILE	mixture
free stream temperature	DEFINE_PROFILE	mixture
granular flux	DEFINE_PROFILE	secondary phase(s)
granular temperature	DEFINE_PROFILE	secondary phase(s)
discrete phase boundary condition	DEFINE_DPM_BC	secondary phase(s)
user-defined scalar boundary value	DEFINE_PROFILE	secondary phase(s)
Material Properties		
granular diameter	DEFINE_PROPERTY	secondary phase(s)
granular viscosity	DEFINE_PROPERTY	secondary phase(s)
granular bulk viscosity	DEFINE_PROPERTY	secondary phase(s)
granular frictional viscosity	DEFINE_PROPERTY	secondary phase(s)
granular conductivity	DEFINE_PROPERTY	secondary phase(s)
granular solids pressure	DEFINE_PROPERTY	secondary phase(s)
granular radial distribution	DEFINE_PROPERTY	secondary phase(s)
granular elasticity modulus	DEFINE_PROPERTY	secondary phase(s)
turbulent viscosity	DEFINE_TURBULENT_VISCOSITY	mixture, primary, and secondary phase(s)

Table C.4.3: DEFINE Macro Usage for the Eulerian Model - Mixture Turbulence Flow

Variable	Macro	Phase Specified On
Other		
drag coefficient	DEFINE_EXCHANGE	phase interaction
lift coefficient	DEFINE_EXCHANGE	phase interaction
heat transfer coefficient	DEFINE_PROPERTY	phase interaction
mass transfer coefficient	DEFINE_MASS_TRANSFER	phase interaction
heterogeneous reaction rate	DEFINE_HET_RXN_RATE	phase interaction

C.5 Eulerian Model - Dispersed Turbulence Flow

Tables C.5.1–C.5.3 list the variables that can be customized using UDFs for the dispersed turbulence flow Eulerian multiphase model, the DEFINE macros that are used to define the UDFs, and the phase that the UDF needs to be hooked to for the given variable.

Table C.5.1: DEFINE Macro Usage for the Eulerian Model - Dispersed Turbulence Flow

Variable	Macro	Phase Specified On
Boundary Conditions		
Inlet/Outlet		
volume fraction	DEFINE_PROFILE	secondary phase(s)
species mass fractions	DEFINE_PROFILE	phase-dependent
mass flux	DEFINE_PROFILE	primary and secondary phases
velocity magnitude	DEFINE_PROFILE	primary and secondary phases(s)
temperature	DEFINE_PROFILE	primary and secondary phases(s)
pressure	DEFINE_PROFILE	mixture
user-defined scalar boundary value	DEFINE_PROFILE	mixture
discrete phase boundary condition	DEFINE_PROFILE	mixture
Fluid		
mass source	DEFINE_SOURCE	primary and secondary phase(s)
momentum source	DEFINE_SOURCE	primary and secondary phase(s)
energy source	DEFINE_SOURCE	primary and secondary phase(s)
turbulence dissipation rate source	DEFINE_SOURCE	primary and secondary phase(s)
turbulence kinetic energy source	DEFINE_SOURCE	primary and secondary phase(s)
species source	DEFINE_SOURCE	phase-dependent
user-defined scalar source	DEFINE_SOURCE	mixture
turbulence dissipation rate	DEFINE_PROFILE	primary and secondary phase(s)
turbulence kinetic energy	DEFINE_PROFILE	primary and secondary phase(s)

Table C.5.2: DEFINE Macro Usage for the Eulerian Model - Dispersed Turbulence Flow

Variable	Macro	Phase Specified On
Fluid		
velocity	DEFINE_PROFILE	primary and secondary phase(s)
temperature	DEFINE_PROFILE	primary and secondary phase(s)
species mass fraction	DEFINE_PROFILE	primary and secondary phase(s)
porosity	DEFINE_PROFILE	mixture
viscous resistance	DEFINE_PROFILE	primary and secondary phase(s)
inertial resistance	DEFINE_PROFILE	primary and secondary phase(s)
user-defined scalar	DEFINE_PROFILE	mixture
Wall		
species mass fraction	DEFINE_PROFILE	mixture
shear stress components	DEFINE_PROFILE	primary and secondary phase(s)
moving velocity components	DEFINE_PROFILE	mixture
heat flux	DEFINE_PROFILE	mixture
temperature	DEFINE_PROFILE	mixture
heat generation rate	DEFINE_PROFILE	mixture
heat transfer coefficient	DEFINE_PROFILE	mixture
external emissivity	DEFINE_PROFILE	mixture
external radiation temperature	DEFINE_PROFILE	mixture
free stream temperature	DEFINE_PROFILE	mixture
granular flux	DEFINE_PROFILE	secondary phase(s)
granular temperature	DEFINE_PROFILE	secondary phase(s)
user-defined scalar boundary value	DEFINE_PROFILE	mixture
discrete phase boundary value	DEFINE_DPM_BC	mixture
Material Properties		
granular diameter	DEFINE_PROPERTY	secondary phase(s)
granular viscosity	DEFINE_PROPERTY	secondary phase(s)
granular bulk viscosity	DEFINE_PROPERTY	secondary phase(s)
granular frictional viscosity	DEFINE_PROPERTY	secondary phase(s)
granular conductivity	DEFINE_PROPERTY	secondary phase(s)
granular solids pressure	DEFINE_PROPERTY	secondary phase(s)
granular radial distribution	DEFINE_PROPERTY	secondary phase(s)
granular elasticity modulus	DEFINE_PROPERTY	secondary phase(s)
turbulent viscosity	DEFINE_TURBULENT_ VISCOSITY	mixture, primary, and secondary phase(s)

Table C.5.3: DEFINE Macro Usage for the Eulerian Model - Dispersed Turbulence Flow

Variable	Macro	Phase Specified On
Other		
drag coefficient	DEFINE_EXCHANGE	phase interaction
lift coefficient	DEFINE_EXCHANGE	phase interaction
heat transfer coefficient	DEFINE_PROPERTY	phase interaction
mass transfer coefficient	DEFINE_MASS_TRANSFER	phase interaction
heterogeneous reaction rate	DEFINE_HET_RXN_RATE	phase interaction

C.6 Eulerian Model - Per Phase Turbulence Flow

Tables C.6.1–C.6.3 list the variables that can be customized using UDFs for the per phase turbulence flow Eulerian multiphase model, the DEFINE macros that are used to define the UDFs, and the phase that the UDF needs to be hooked to for the given variable.

Table C.6.1: DEFINE Macro Usage for the Eulerian Model - Per Phase Turbulence Flow

Variable	Macro	Phase Specified On
Boundary Conditions		
Inlet/Outlet		
volume fraction	DEFINE_PROFILE	secondary phase(s)
species mass fractions	DEFINE_PROFILE	phase-dependent
mass flux	DEFINE_PROFILE	primary and secondary phases
velocity magnitude	DEFINE_PROFILE	primary and secondary phases(s)
temperature	DEFINE_PROFILE	primary and secondary phases(s)
pressure	DEFINE_PROFILE	mixture
user-defined scalar boundary value	DEFINE_PROFILE	mixture
Fluid		
mass source	DEFINE_SOURCE	primary and secondary phase(s)
momentum source	DEFINE_SOURCE	primary and secondary phase(s)
energy source	DEFINE_SOURCE	primary and secondary phase(s)
turbulence dissipation rate source	DEFINE_SOURCE	primary and secondary phase(s)
turbulence kinetic energy source	DEFINE_SOURCE	primary and secondary phase(s)
user-defined scalar source	DEFINE_SOURCE	mixture
velocity	DEFINE_PROFILE	primary and secondary phase(s)
temperature	DEFINE_PROFILE	primary and secondary phase(s)

Table C.6.2: DEFINE Macro Usage for the Eulerian Model - Per Phase Turbulence Flow

Variable	Macro	Phase Specified On
Fluid		
turbulence kinetic energy	DEFINE_PROFILE	primary and secondary phase(s)
turbulence dissipation rate	DEFINE_PROFILE	primary and secondary phase(s)
granular flux	DEFINE_PROFILE	secondary phase(s)
granular temperature	DEFINE_PROFILE	secondary phase(s)
porosity	DEFINE_PROFILE	mixture
viscous resistance	DEFINE_PROFILE	primary and secondary phase(s)
inertial resistance	DEFINE_PROFILE	primary and secondary phase(s)
user-defined scalar	DEFINE_PROFILE	mixture
Wall		
species boundary condition	DEFINE_PROFILE	phase-dependent
shear stress components	DEFINE_PROFILE	primary and secondary phase(s)
moving velocity components	DEFINE_PROFILE	mixture
temperature	DEFINE_PROFILE	mixture
heat flux	DEFINE_PROFILE	mixture
heat generation rate	DEFINE_PROFILE	mixture
heat transfer coefficient	DEFINE_PROFILE	mixture
external emissivity	DEFINE_PROFILE	mixture
external radiation temperature	DEFINE_PROFILE	mixture
free stream temperature	DEFINE_PROFILE	mixture
granular flux	DEFINE_PROFILE	secondary phase(s)
granular temperature	DEFINE_PROFILE	secondary phase(s)
user-defined scalar boundary value	DEFINE_PROFILE	mixture
discrete phase boundary value	DEFINE_DPM_BC	mixture
Material Properties		
granular diameter	DEFINE_PROPERTY	secondary phase(s)
granular viscosity	DEFINE_PROPERTY	secondary phase(s)
granular bulk viscosity	DEFINE_PROPERTY	secondary phase(s)
granular frictional viscosity	DEFINE_PROPERTY	secondary phase(s)
granular conductivity	DEFINE_PROPERTY	secondary phase(s)
granular solids pressure	DEFINE_PROPERTY	secondary phase(s)
granular radial distribution	DEFINE_PROPERTY	secondary phase(s)
granular elasticity modulus	DEFINE_PROPERTY	secondary phase(s)
turbulent viscosity	DEFINE_TURBULENT_VISCOSITY	mixture, primary, and secondary phase(s)

Table C.6.3: DEFINE Macro Usage for the Eulerian Model - Per Phase Turbulence Flow

Variable	Macro	Phase Specified On
Other		
drag coefficient	DEFINE_EXCHANGE	phase interaction
lift coefficient	DEFINE_EXCHANGE	phase interaction
heat transfer coefficient	DEFINE_PROPERTY	phase interaction
mass transfer coefficient	DEFINE_MASS_TRANSFER	phase interaction
heterogeneous reaction rate	DEFINE_HET_RXN_RATE	phase interaction

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Index