Tutorial 8. Cavity Remeshing

Introduction

Cavity remeshing is useful in parametric studies as it allows you to add, remove, or replace different parts of an existing mesh. This tutorial demonstrates the procedure for replacing an object in the existing mesh with another by creating a cavity and remeshing it. This tutorial demonstrates how to do the following:

1. Create and remesh a cavity to replace the mirror in a tetrahedral mesh.

2. Create and remesh a cavity in a hybrid mesh (tetrahedra and prisms) having a single fluid zone.

3. Create and remesh a cavity in a hybrid mesh (tetrahedra and prisms) having multiple fluid zones.

4. Create and remesh a cavity in a hexcore mesh.

Prerequisites

This tutorial assumes that you have some experience with TGrid, and that you are familiar with the graphical user interface.

Preparation

1. Download `cavity.zip` from the FLUENT User Services Center to your working directory. This file can be found from the Documentation link on the TGrid product page.

<div align="center">

OR

</div>

Copy `cavity.zip` from the TGrid documentation CD to your working directory.

- For UNIX systems, insert the CD into your CD-ROM drive and go to the following directory:

<div align="center">

cdrom/`tgrid5.0/help/tutfiles`

</div>

where, *cdrom* must be replaced by the name of your CD-ROM drive.

- For Windows systems, insert the CD into your CD-ROM drive and go to the following folder:

    cdrom:\tgrid5.0\help\tutfiles

    where, *cdrom* must be replaced by the name of your CD-ROM drive (e.g., E).

2. Unzip cavity.zip.

    The files, sedan_tetra.msh.gz, sedan_hyb-1zone.msh.gz, sedan_hyb-2zones.msh.gz, sedan_hexcore.msh.gz, mirror.msh.gz, *and* sedan_hyb-2zones-cavity.jou *can be found in the* cavity *folder created on unzipping the file.*

3. Start the 3D (3d) version of TGrid.

Case A. For a Tetrahedral Mesh

Step 1: Read and Display Mesh

1. Read the mesh file.

    File ⟶ Read ⟶Mesh...

    (a) Select sedan_tetra.msh.gz in the Files list.

    (b) Click OK.

2. Examine the mesh.

    Display ⟶Grid...

    (a) Select car, mirror-old, wheel-arch-front, wheel-arch-rear, wheel-front, and wheel-rear, in the Face Zones selection list.

    (b) Click Display (Figure 8.1).

    (c) Click the Cells tab and enable All in the Options group box.

    (d) Select fluid in the Cell Zone Groups selection list.

    (e) Click the Bounds tab and enable Limit by X in the X Range group box.

    (f) Enter -0.37 for both Minimum and Maximum in the X Range group box.
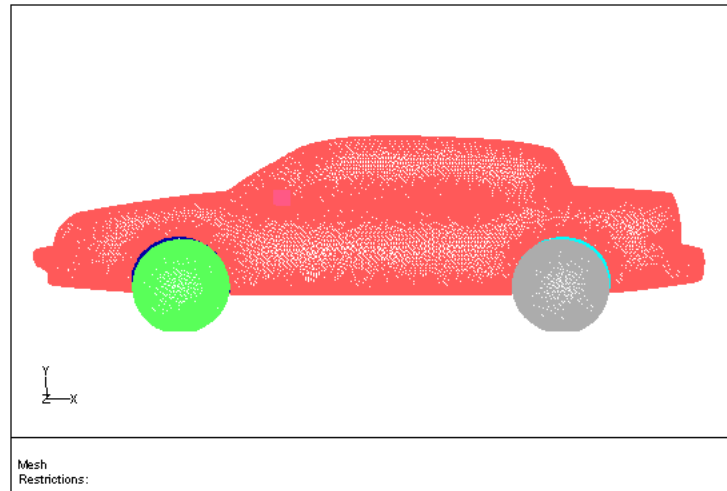
    (g) Click Display.

Figure 8.1: Boundary Mesh

(h) Display the left view.

Display ⟶Views...

    i. Select left in the Views list.

    ii. Click Apply and close the Views panel.

(i) Zoom in and examine the mesh around the mirror (Figure 8.2).
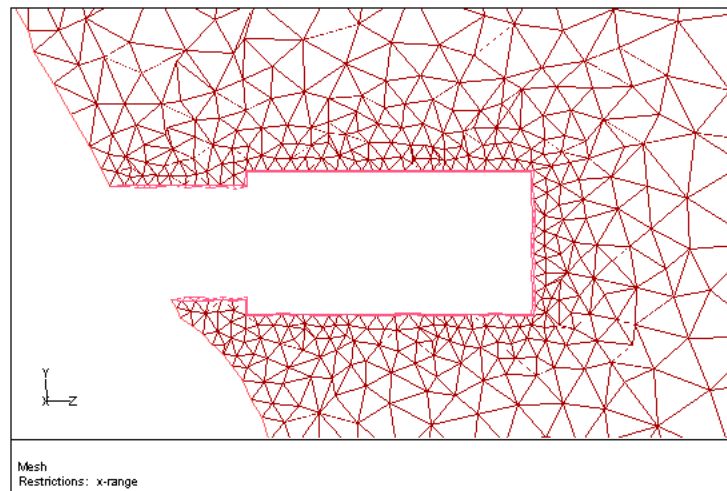
   The mesh comprises tetrahedral cells.

Figure 8.2: Tetrahedral Mesh Near the Mirror

Step 2: Import and Connect the New Mirror

*In this step, you will replace the mirror (*mirror-old*) by a modified geometry. The node distribution on the boundary on the two mirrors is identical.*

1. Read the mesh file (`mirror.msh.gz`).

   File ⟶ Read ⟶Mesh...

   (a) Select mirror.msh.gz in the Files list.

   (b) Enable Append File(s) and click OK.

2. Verify that the new mirror is appropriately positioned.

   Display ⟶Grid...

   (a) Select car, mirror, and mirror-old in the Face Zones selection list in the Faces tab.

   (b) Enable Free and Multi in the Options group box.

   Make sure that the fluid zone is deselected in the Cell Zones *selection list in the* Cells *tab. Click* Reset *in the* Bounds *tab.*

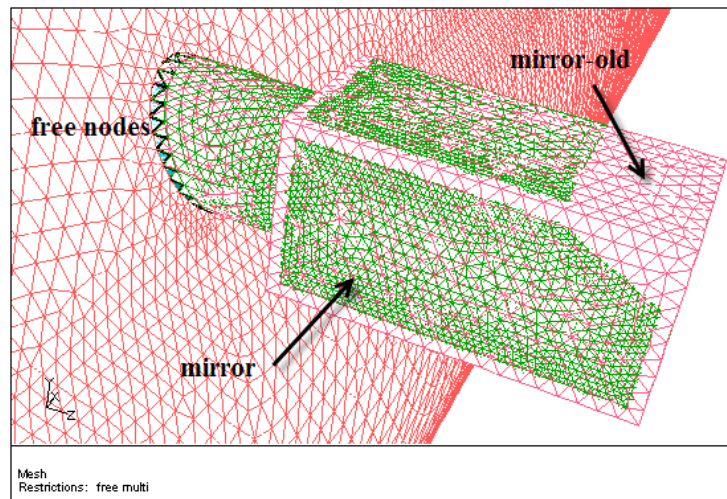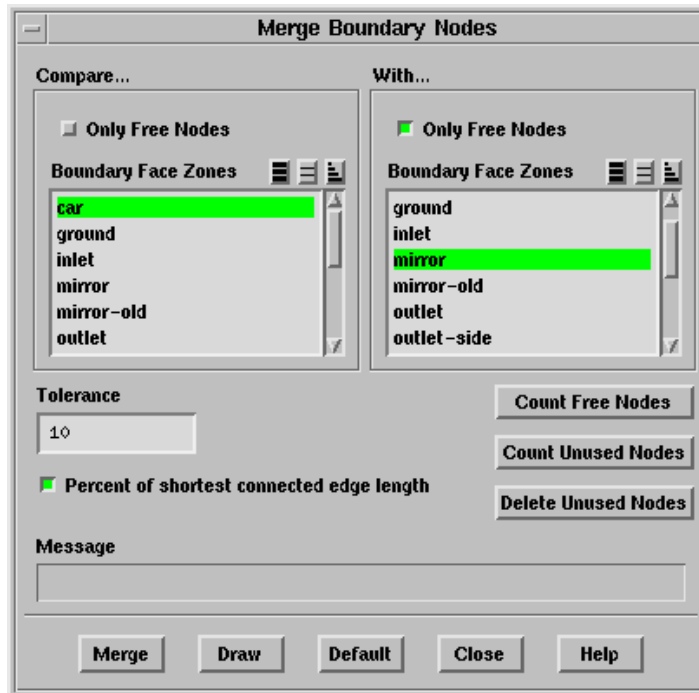   (c) Click Display (Figure 8.3).

Figure 8.3: Free Nodes on the Mirror

In Figure 8.3, you can see the free nodes on the boundary of mirror. *This indicates that the mirror is not connected to the car.*

3. Connect the mirror to the car.

   Boundary ⟶Merge Nodes...

(a) Select only car in the Boundary Face Zones selection list in the Compare... group box and disable Only Free Nodes.

(b) Select only mirror in the Boundary Face Zones selection list in the With... group box and retain Only Free Nodes.

(c) Enable Percent of shortest connected edge length and enter 10 for Tolerance.

(d) Click Merge.

(e) Click Display in the Display Grid panel.

   In Figure 8.4, you can see that there is a multiple connection between the mirrors and the car.

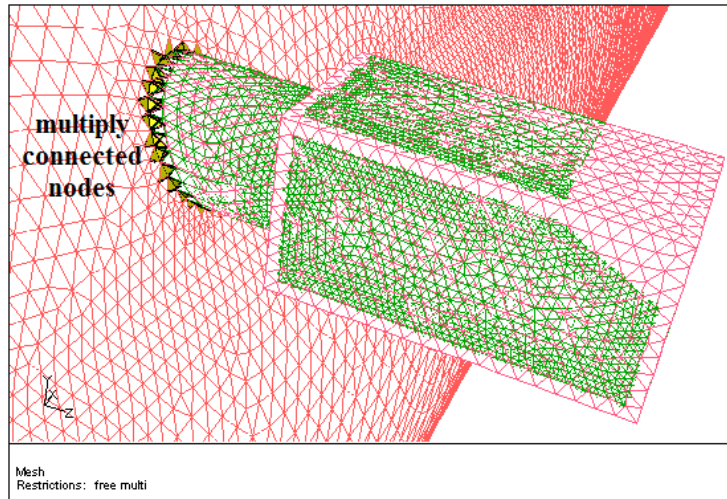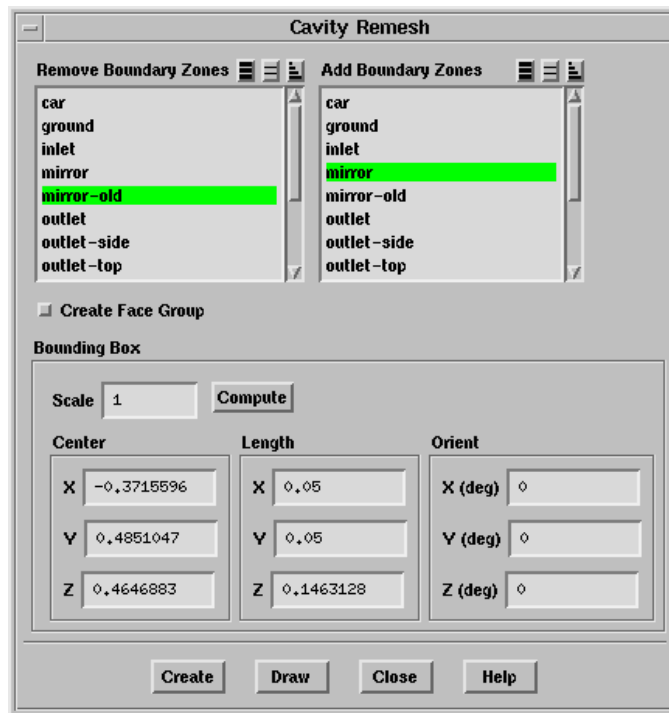(f) Close the Merge Boundary Nodes panel.

Figure 8.4: Multiply Connected Nodes on the Mirror

Step 3: Replace the Mirror

In this step, you will replace the existing mirror with a new one, without resetting the volume mesh. To do this, you will remove a portion of the mesh around the mirror.

1. Replace the mirror.

   Mesh ⟶ Tools ⟶Cavity Remesh...

(a) Select mirror-old in the Remove Boundary Zones selection list.

(b) Select mirror in the Add Boundary Zones selection list.

(c) Retain the value of 1 for Scale.

(d) Click Compute.

(e) Click Draw to verify that the cavity defined fits the mirror to be replaced.

(f) Click Create.

   TGrid *separates the car zone into two—one inside (*car:#*) and the other outside the cavity region, creates an interior surface (*interior-#:#*) at the boundary of the cavity, and defines and activates a domain for the cavity.*

(g) Select car:# and mirror in the Face Zones list in the Display Grid panel.

(h) Click Display and close the Display Grid panel.
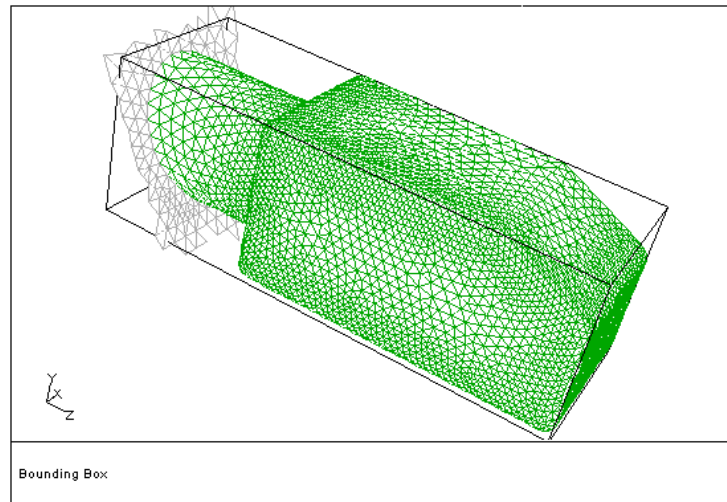
(i) Click Draw in the Cavity Remesh panel.

Figure 8.5: Cavity Domain Before Meshing
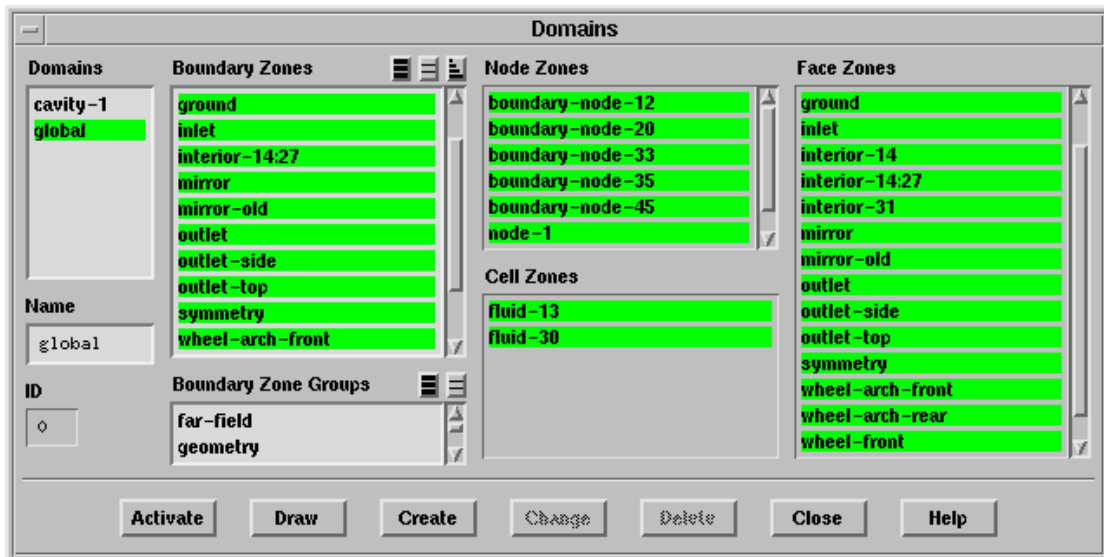
(j) Close the Cavity Remesh panel.

2. Mesh the cavity with tetrahedral cells.

   Mesh —→Tri/Tet...

(a) Retain the default settings and click Init&Refine.

(b) Close the Tri/Tet panel.

3. Activate the global domain.

   Mesh ⟶Domains...

(a) Select global in the Domains list.

(b) Click Activate and close the Domains panel.

4. Examine the mesh.
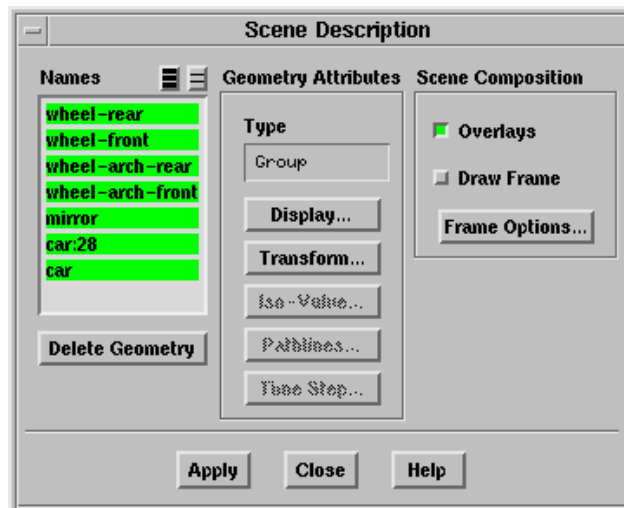
   Display ⟶Grid...

(a) Select car, car:#, mirror, wheel-arch-front, wheel-arch-rear, wheel-front, and wheel-rear in the Face Zones selection list in the Faces tab of the Display Grid panel.

(b) Disable Free and Multi in the Options group box.

(c) Click Display.

(d) Enable the overlaying of graphics.

   Display ⟶Scene...

   i. Select all the zones in the Names selection list.

   ii. Enable Overlays in the Scene Composition group box.

iii. Click Apply and close the Scene Description panel.

(e) Click the Cells tab in the Display Grid panel and enable All in the Options group box.

(f) Select the fluid zones in the Cell Zones selection list.

(g) Click the Bounds tab and enable Limit by X in the X Range group box.

(h) Enter -0.37 for both Minimum and Maximum in the X Range group box.

(i) Click Display.

(j) Click Draw in the Cavity Remesh panel (Figure 8.6).
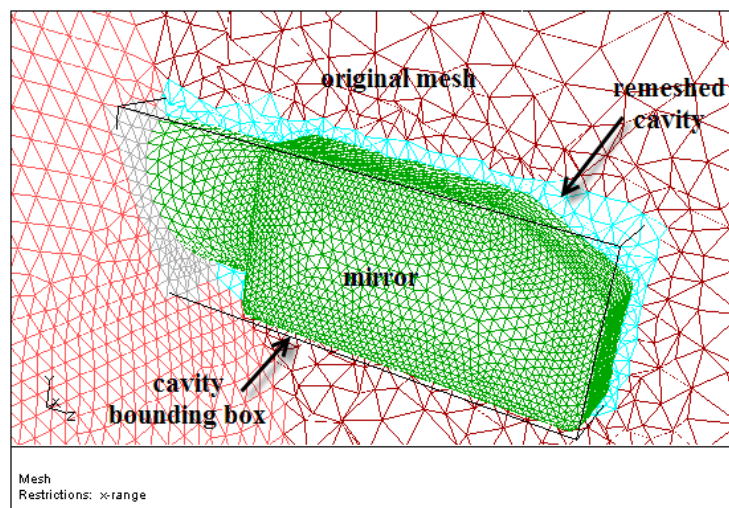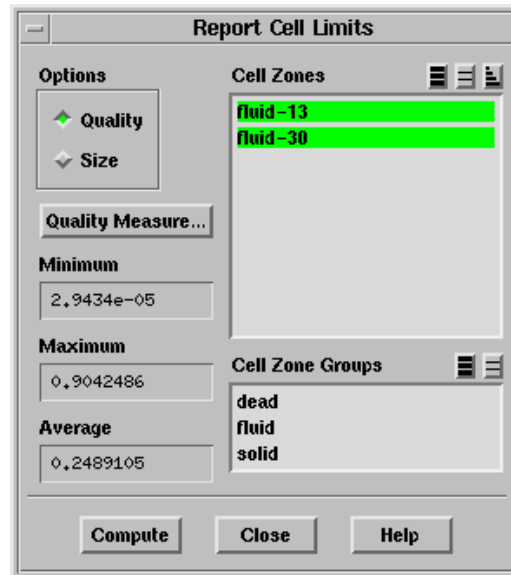
Mesh ⟶ Tools ⟶ Cavity Remesh...

Figure 8.6: Cavity Remeshed With Tetrahedral Cells

5. Check the mesh quality.

   Report ⟶Cell Limits...

   (a) Select all zones in the Cell Zones selection list.

   (b) Click Compute.

   The maximum skewness reported is around 0.904. The exact value may vary slightly on different platforms.

6. Merge the cavity domain with the original mesh.

```
> /mesh/cavity/merge-cavity
Insert domain name/id [cavity-1]   cavity-1   <Enter>
Into domain name/id [global]   global   <Enter>
Merging cell zone fluid-# (id #) with fluid-#
Merging face zone interior-#:# (id #) with interior-#
Merging face zone car:# (id #) with car
```

   where, # denotes the respective zone IDs.

7. Delete the old mirror.

   Boundary ⟶Manage...

   (a) Select mirror-old in the Face Zones selection list.

   (b) Select Delete in the Options list and retain the Delete Nodes option.

   (c) Click Apply.

   A Question dialog box will appear, asking you to confirm if you want to delete the selected zone(s).

(d) Click Yes in the Question dialog box.

(e) Close the Manage Face Zones panel.

8. Check the mesh.

Mesh ⟶Check

9. Save the mesh (sedan-tet-cavity.msh.gz).

File ⟶ Write ⟶Mesh...

Case B. For a Hybrid Mesh (Tetrahedra and Prisms) Having a Single Fluid Zone

1. Read the mesh file (sedan_hyb-1zone.msh.gz).

File ⟶ Read ⟶Mesh...

(a) Select sedan_hyb-1zone.msh.gz in the Files list.

(b) Click OK.

2. Examine the mesh.

Display ⟶Grid...

(a) Click the Cells tab and enable All in the Options group box.

(b) Select fluid in the Cell Zone Groups selection list.

(c) Click the Bounds tab and enable Limit by X in the X Range group box.

(d) Enter -0.37 for both Minimum and Maximum in the X Range group box.

(e) Click Display.

(f) Display the left view.

Display ⟶Views...

(g) Zoom in and examine the mesh around the mirror (Figure 8.7).

3. Import and connect the mirror.

(a) Read the mesh file mirror.msh.gz with the Append File(s) option enabled.

File ⟶ Read ⟶Mesh...
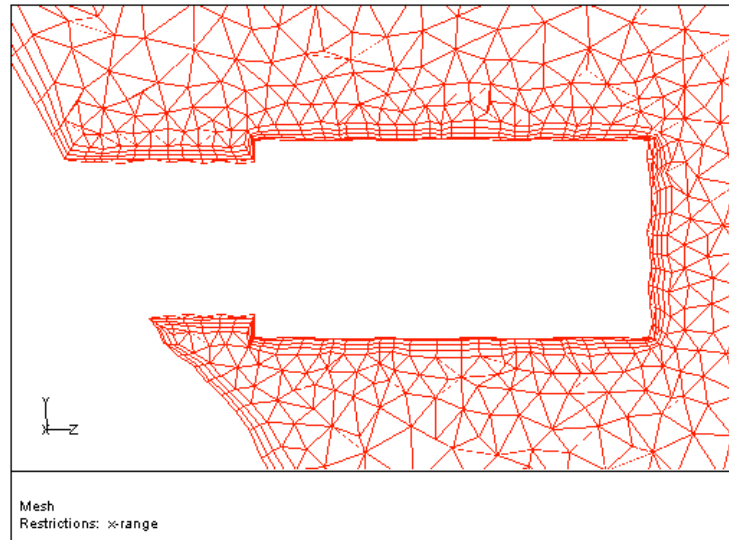
Figure 8.7: Hybrid Mesh Near the Mirror

(b) Verify that the mirror is appropriately positioned.

    i. Select car, mirror, and mirror-old in the Face Zones selection list in the Faces tab of the Display Grid panel.

        <u>Display</u> ⟶Grid...

    ii. Enable Free and Multi in the Options group box in the Faces tab.

        Make sure that the fluid zone is deselected in the Cell Zones *selection list in the* Cells *tab. Click* Reset *in the* Bounds *tab.*

    iii. Click Display.

        The presence of free nodes indicates that the mirror is not connected to the car.

(c) Connect the mirror to the car.

    <u>Boundary</u> ⟶Merge Nodes...

    i. Select only car in the Boundary Face Zones selection list in the Compare... group box and disable Only Free Nodes.

    ii. Select only mirror in the Boundary Face Zones selection list in the With... group box and enable Only Free Nodes.

    iii. Enable Percent of shortest connected edge length and enter 10 for Tolerance.

    iv. Click Merge.

    v. Click Display in the Display Grid panel.

        Both mirrors are now connected to the car.

    vi. Close the Merge Boundary Nodes panel.

4. Replace the mirror.

Mesh ⟶ Tools ⟶Cavity Remesh...

(a) Select mirror-old in the Remove Boundary Zones selection list.

(b) Select mirror in the Add Boundary Zones selection list.

(c) Enter 1 for Scale and click Compute.

(d) Click Draw.

The bounding box for the cavity fits the mirror. However, you need to generate prisms as well as tetrahedral cells in the cavity. Hence, you need to increase the scale.

(e) Enter 2 for Scale and click Compute.

(f) Click Draw.

(g) Click Create.

TGrid separates the car zone into two—one inside (car:#) and the other outside the cavity region, creates an interior surface (interior:#:#) at the boundary of the cavity, and defines and activates a domain for the cavity.

(h) Select all the zones in the Cavity Remesh panel.
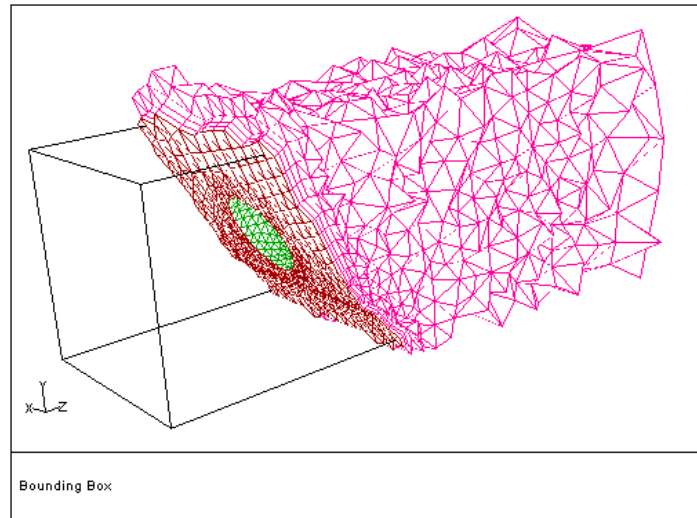
(i) Click Draw to view the domain (Figure 8.8).

Figure 8.8: Cavity Domain Before Meshing

Zoom in to the interior zone (as shown in Figure 8.9), to see the quad faces. When you remesh the cavity, the prisms created during the remeshing will connect to these quad faces.
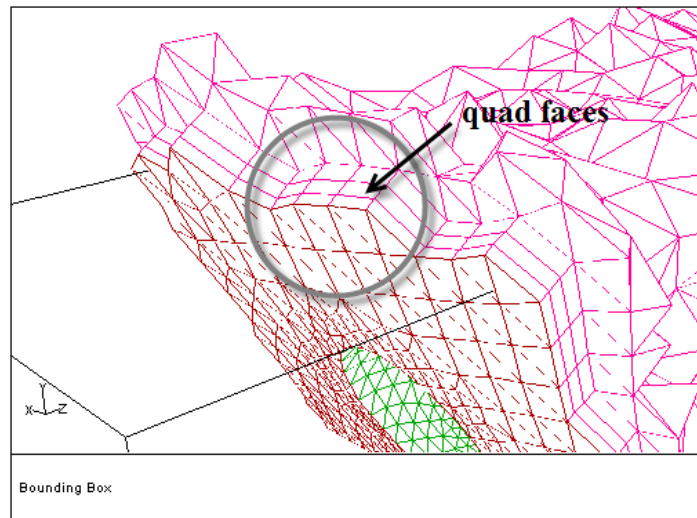

Figure 8.9: Quad Faces in the Interior

(j) Close the Cavity Remesh panel.

5. Specify the meshing parameters for meshing the cavity.

   Mesh ⟶Auto Mesh...

(a) Specify the prism meshing parameters.

   i. Verify that the normals on the mirror are correctly oriented.

   Display ⟶Grid...

      A. Select mirror in the Face Zones selection list in the Faces tab.

      B. Enable Normals in the Options group box in the Attributes tab and enter 0.001 for Normal Scale.

      C. Click Display.

         The normals point outward and hence, are correctly oriented.

      D. Disable Normals and close the Display Grid panel.

  ii. Click the Set... button in the Boundary Layer Mesh group box in the Auto Mesh panel to open the Prisms panel.

 iii. Select car:# and mirror in the Boundary Zones selection list.

  iv. Select aspect-ratio in the Offset Method drop-down list and enter 5 for First Aspect Ratio.
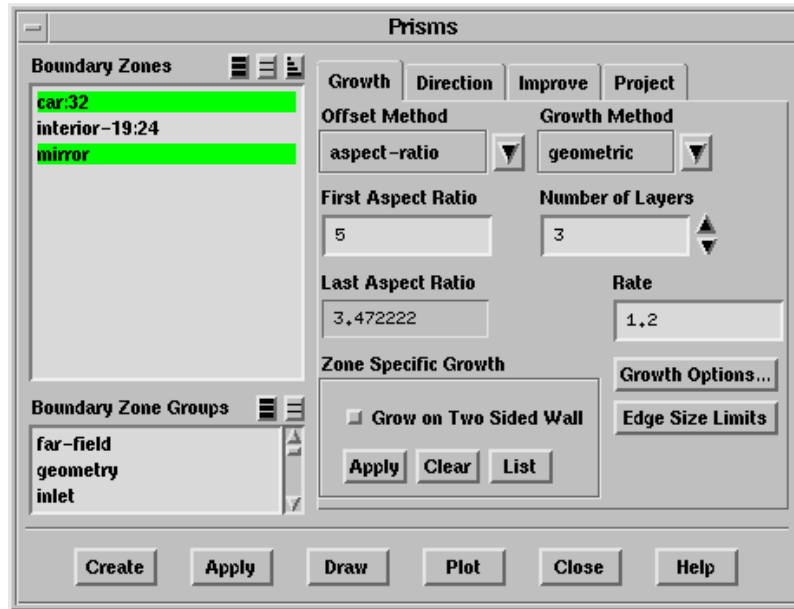
v. Select geometric in the Growth Method drop-down list and enter 1.2 for Rate.

vi. Set the Number of Layers to 3.

vii. Click the Growth Options... button to open the Prisms Growth Options panel.
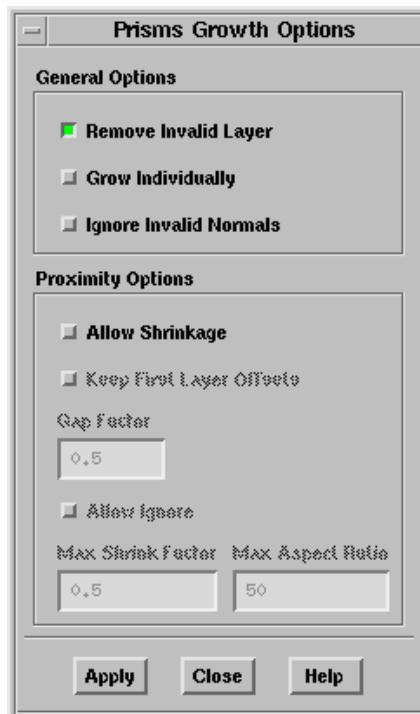
A. Make sure that Allow Shrinkage is disabled in the Proximity Options group box.

B. Click Apply and close the Prisms Growth Options panel.

viii. Click Apply in the Zone Specific Growth group box.

⚠ It is necessary to apply the prism growth parameters on specific zones for TGrid to retain the growth parameters in memory. The Prisms option in the Auto Mesh panel will be visible only after applying zone-specific growth.

ix. Close the Prisms panel.

x. Enable Prisms in the Auto Mesh panel.

(b) Specify the tetrahedral meshing parameters.

i. Retain the selection of Tri/Tet click the Set.... button in the Volume Fill group box to open the Tri/Tet panel.

A. Click the Refinement tab and retain the selection of adv-front in the Refine Method drop-down list.
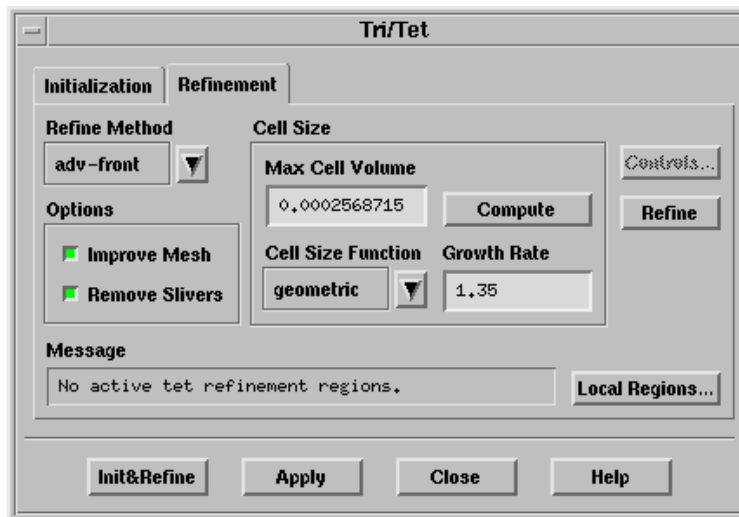
B. Retain the default value for Max Cell Volume.

C. Select geometric in the Cell Size Function drop-down list and enter 1.35 for Growth Rate.

D. Click Apply and close the Tri/Tet panel.

(c) Enable Merge Cell Zones.

(d) Click Mesh.

TGrid *will generate prism layers around the mirror and the car according to the defined parameters, automatically create a domain and fill it with tetrahedra, and finally merge the zones together.*

(e) Close the Auto Mesh panel.

(f) Examine the mesh.

Display ⟶Grid...

   i. Click the Cells tab and enable All in the Options group box.

  ii. Select fluid in the Cell Zone Groups selection list.

 iii. Click the Bounds tab and enable Limit by X in the X Range group box.

 iv. Enter -0.37 for both Minimum and Maximum in the X Range group box.

  v. Click Display (Figure 8.10).

In Figure 8.10, you can see the three prism layers generated around the mirror and car. The rest of the domain is filled with tetrahedra.

 vi. Activate the global domain.

Mesh ⟶Domains...

   A. Select global in the Domains list and click Activate.

   B. Close the Domains panel.
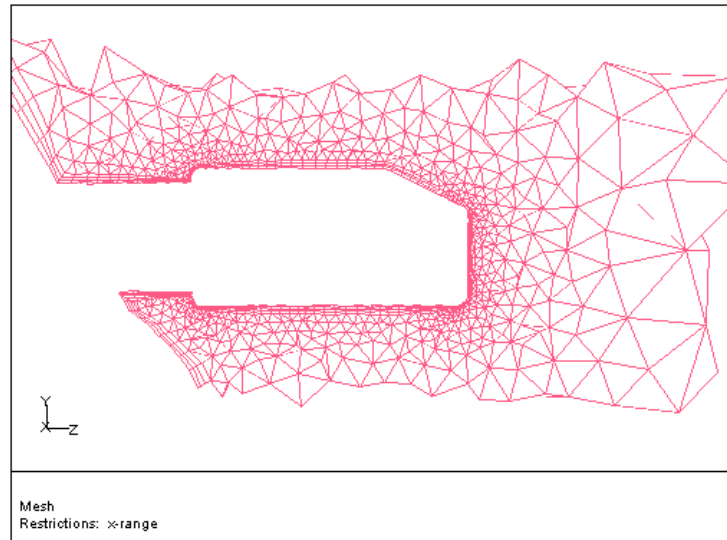
Figure 8.10: Remeshed Cavity

vii. Display the original mesh along with the remeshed cavity.

A. Select car, car:#, mirror, wheel-arch-front, wheel-arch-rear, wheel-front, and wheel-rear in the Face Zones selection list in the Faces tab of the Display Grid panel.

B. Make sure the fluid zone is deselected in the Cells tab and the display bounds are reset in the Bounds tab.

C. Click Display.

D. Enable the overlaying of graphics.

   | Display | ⟶Scene...

E. Select all the zones in the Names selection list and enable Overlays in the Scene Compostition group box.

F. Click Apply and close the Scene Description panel.

G. Select the fluid zones in the Cell Zones selection list in the Cells tab of the Display Grid panel.

H. Enable All in the Options group box.

 I. Click the Bounds tab and enable Limit by X in the X Range group box.

 J. Enter -0.37 for both Minimum and Maximum in the X Range group box.

K. Click Display.

L. Click Draw in the Cavity Remesh panel (Figure 8.11).
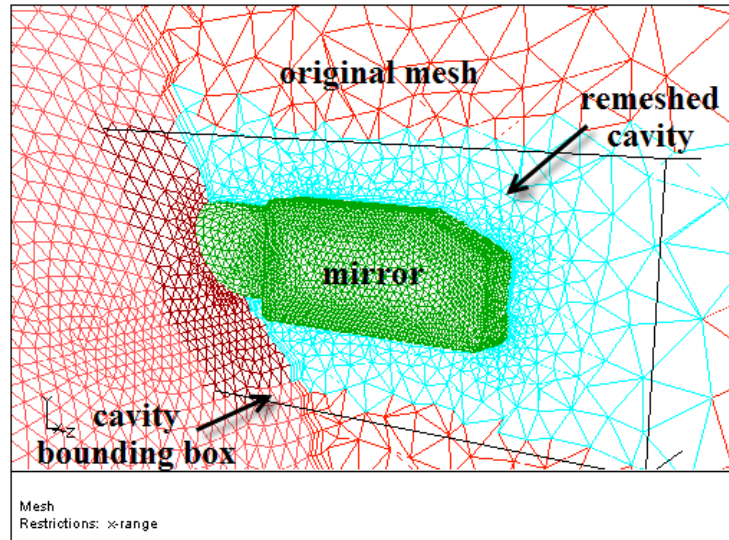
   | Mesh | ⟶ | Tools | ⟶Cavity Remesh...

Figure 8.11: Cavity Remeshed With Hybrid Mesh

In Figure 8.10, you can see that the mesh outside the cavity has not been modified. The mesh inside the cavity is connected in a conformal manner with the original mesh.

6. Merge the cavity domain with the original mesh.

```
> /mesh/cavity/merge-cavity
Insert domain name/id [tet]  cavity-2  <Enter>

Into domain name/id [cavity-2]  global  <Enter>
Merging cell zone fluid-# (id #) with fluid-#
Merging face zone interior-#:# (id #) with interior-#
Merging face zone car:# (id #) with car
```

where, # denotes the respective zone IDs.

7. Delete the old mirror.

Boundary ⟶ Manage...

   (a) Select mirror-old in the Face Zones selection list.

   (b) Select Delete in the Options list and retain the Delete Nodes option.

   (c) Click Apply.

   A Question dialog box will open asking you to confirm if you want to delete the selected zone(s).

   (d) Click Yes to close the Question dialog box.

   (e) Close the Manage Face Zones panel.

8. Check the mesh quality.

Report —→Cell Limits...

The maximum skewness reported is around 0.92. The exact value may vary slightly on different platforms.

9. Check the mesh.

Mesh —→Check

10. Save the mesh (`sedan-hyb-1-cavity.msh.gz`).

File —→ Write —→Mesh...

Case C. For a Hybrid Mesh (Tetrahedra and Prisms) Having Multiple Fluid Zones

This section demonstrates the use of a journal file to remesh a cavity in a mesh having two different fluid zones (prism and tetrahedral cells).

1. View the contents of the journal file (`sedan_hyb-2zones-cavity.jou`) in a viewer.

   All lines starting with a semi-colon (;) indicate comments.

```
;Read the hybrid mesh and the new mirror
/file/read-multiple-mesh "sedan_hyb-2zones.msh.gz" "mirror.msh.gz"

;Display the cells in the plane x=-0.37
/display/set-grid/x-range -0.37 -0.37
/display/set-grid/all-cells? yes
/display/all-grid * ,

;Set the view
/display/view/camera/target -0.37 0.486 0.48
/display/view/camera/position -1 0.486 0.48
/display/view/camera/field 0.35 0.35
/display/view/camera/up-vector 0 1 0

;Merge the free nodes of the imported mirror with 10% edge tolerance
/boundary/merge-nodes car , mirror , no yes yes 10

;Replace the mirror by creating a cavity with a scale of 2
/mesh/cavity/replace-zones mirror-old , mirror , 2 , , , no
/display/all-grid * ,

;Specify prism growth parameters
```

```
/mesh/prism/controls/zone-specific-growth/apply-growth mirror car:* ,
aspect-ratio geometric 3 5 1.2 no
;Disable shrinkage of prism layers
/mesh/prism/controls/proximity/allow-shrinkage? no

;Mesh the cavity with prisms and tetrahedra
/mesh/tritet/controls/refine-method adv-front
/mesh/tritet/controls/cell-size-function geometric 1.35
/mesh/auto-mesh yes pyramids tritet no
/display/all-grid * ,

;Activate the global domain
/mesh/domain/activate global

;Merge the fluid zones together
/mesh/manage/merge * , yes

;Display the cells in the plane x = -0.37
/display/all-grid fluid* ,

;Delete the old mirror
/boundary/manage/delete mirror-old , yes
```

2. Start a new TGrid session.

3. Read the journal file `sedan_hyb-2zones-cavity.jou`.

   File $\longrightarrow$ Read $\longrightarrow$ Journal...

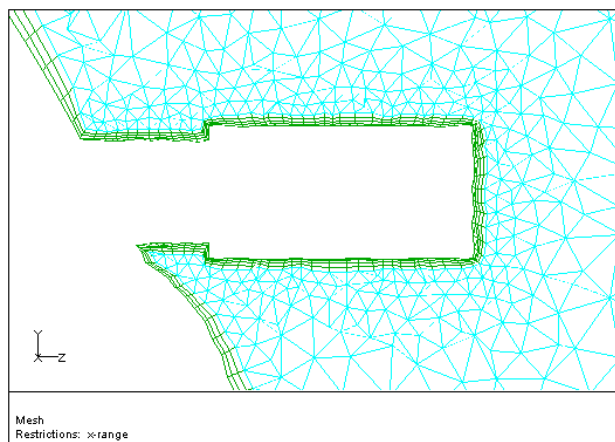   *Figures 8.12—8.14 show the mesh at intermediate stages.*
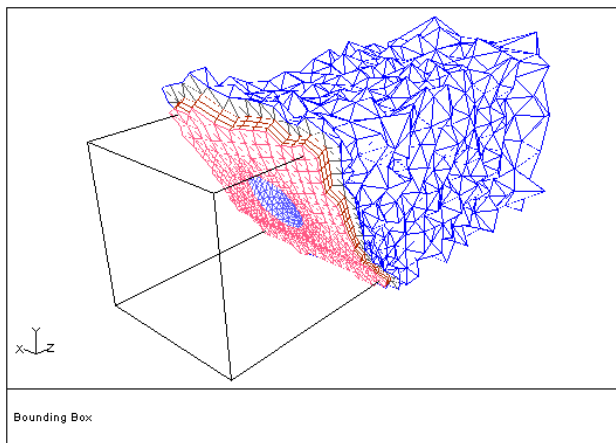

Figure 8.12: Hybrid Mesh Near the Mirror

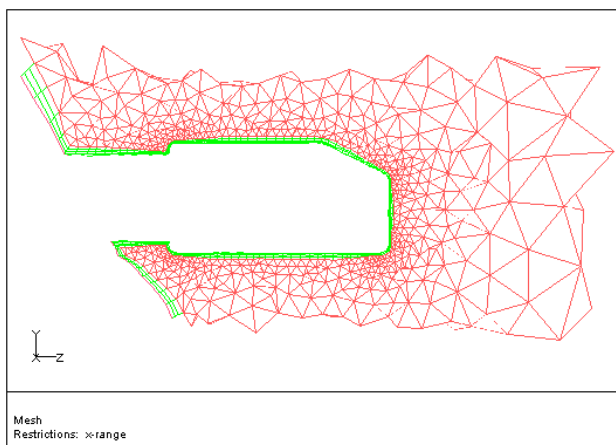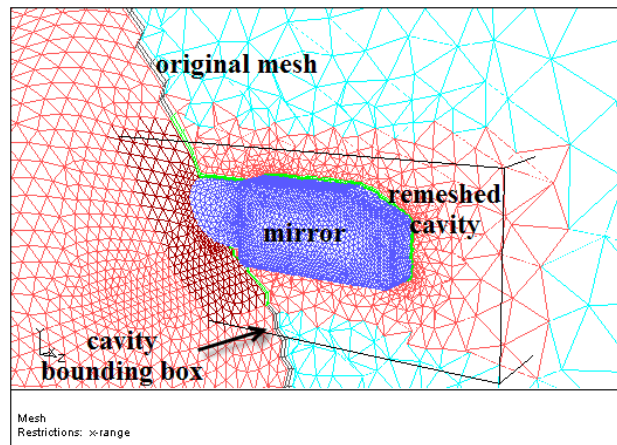Figure 8.13: Cavity Domain Before Meshing

Figure 8.14: Remeshed Cavity

Figure 8.15: Cavity Remeshed With Hybrid Mesh

Case D. For a Hexcore Mesh

The steps in this section are similar to those described in previous sections, and hence are less explicit.

1. Read the mesh files `sedan_hexcore.msh.gz` and `mirror.msh.gz`.

   File ⟶ Read ⟶Mesh...

2. Examine the mesh.

   Display ⟶Grid...

   (a) Enable All in the Options group box and select the fluid zone in the Cell Zones selection list in the Cells tab.

   (b) Enable Limit by X and enter -0.37 for both Minimum and Maximum in the X Range group box in the Bounds tab.

   (c) Click Display.

   (d) Display the left view.

      Display ⟶Views...

   (e) Zoom in and examine the mesh around the mirror (Figure 8.16).

3. Verify that the mirror is appropriately positioned.

   Enable the display of free nodes to check whether the mirror is connected to the car. The presence of free nodes indicates that the mirror is not connected to the car.
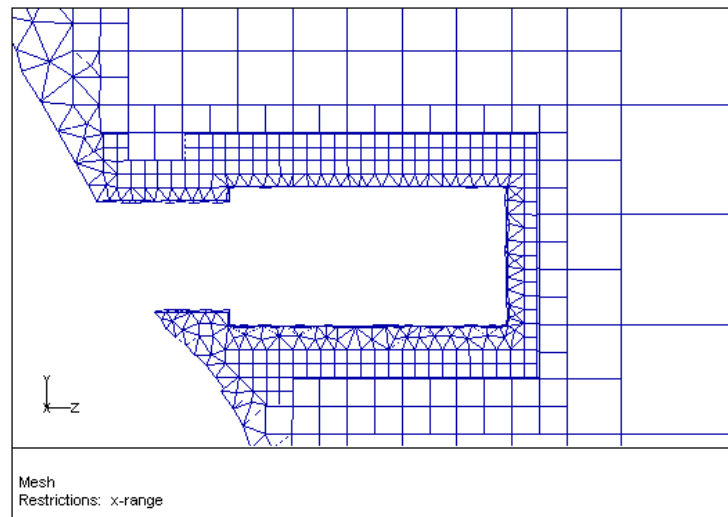
Figure 8.16: Hexcore Mesh Near the Mirror

4. Connect the new mirror.

 Boundary ⟶Merge Nodes...

 (a) Select only car in the Boundary Face Zones selection list in the Compare... group box and disable Only Free Nodes.

 (b) Select only mirror in the Boundary Face Zones selection list in the With... group box and retain the Only Free Nodes option.

 (c) Enable Percent of shortest connected edge length and enter 10 for Tolerance.

 (d) Click Merge.

 (e) Close the Merge Boundary Nodes panel.

5. Replace the old mirror with the new one.

 Mesh ⟶ Tools ⟶Cavity Remesh...

 Only the tetrahedral cells of the Hexcore mesh will be deleted. Hence, the new geometry must not be larger than the original one.

 (a) Select mirror-old in the Remove Boundary Zones selection list and mirror in the Add Boundary Zones selection list, respectively.

 (b) Enter 1.5 for Scale and click Compute.

 (c) Click Create.

 (d) Select all the zones in the Cavity Remesh panel and click Draw to display the cavity boundaries (Figure 8.17).
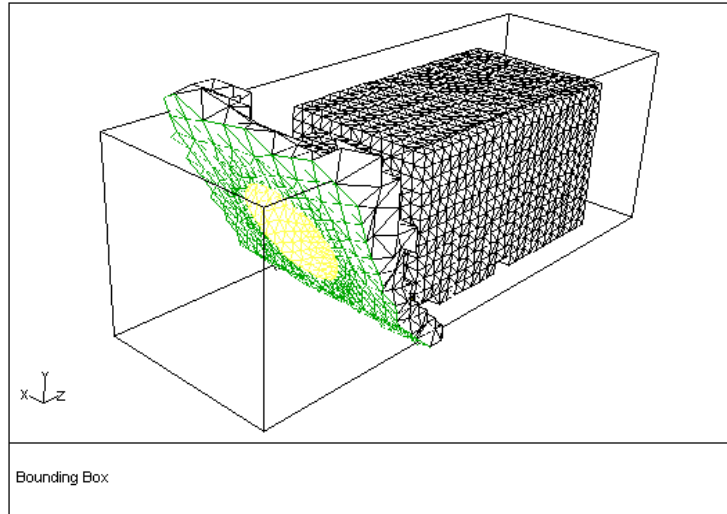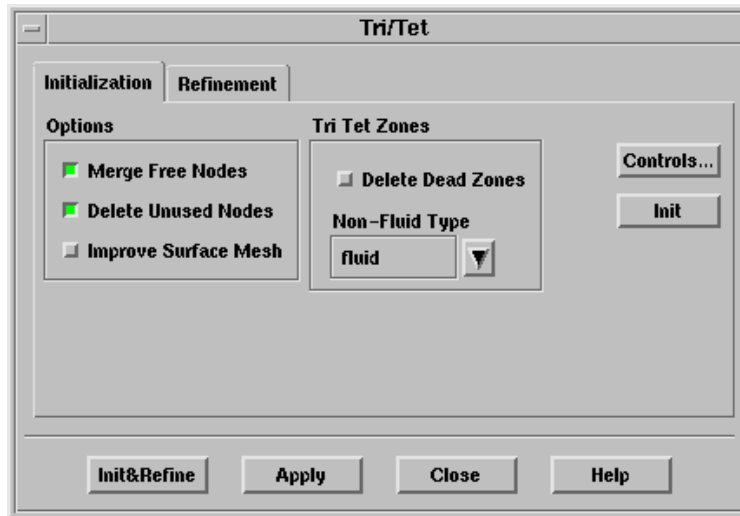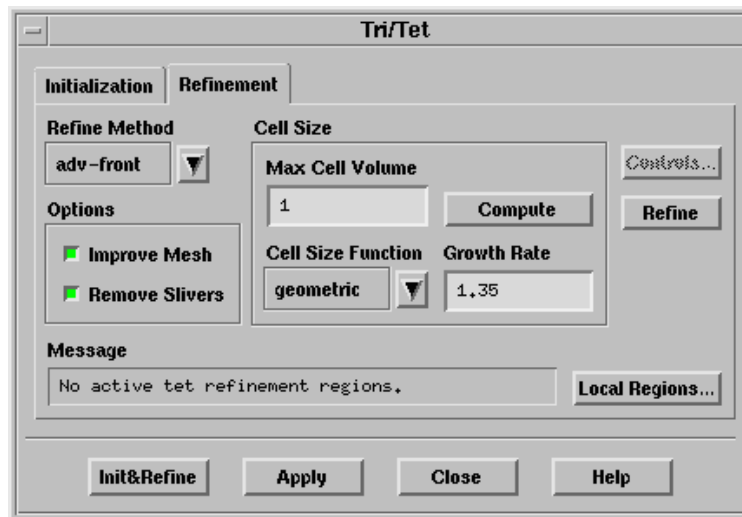
 (e) Close the Cavity Remesh panel.

Figure 8.17: Cavity Domain Before Meshing

6. Mesh the cavity using tetrahedra.

Mesh ⟶Tri/Tet...

(a) Select fluid in the Non-Fluid Type drop-down list in the Tri Tet Zones group box in the Initialization tab.

(b) Click the Refinement tab and enter 1.35 for Growth Rate.

(c) Click Init&Refine.

(d) Close the Tri/Tet panel.

7. Check the mesh quality.

Report ⟶Cell Limits...

The maximum and average skewness values are approximately 0.817 and 0.308, respectively.

8. Examine the remeshed cavity by displaying the cells in the plane x = -0.37 (Figure 8.18).
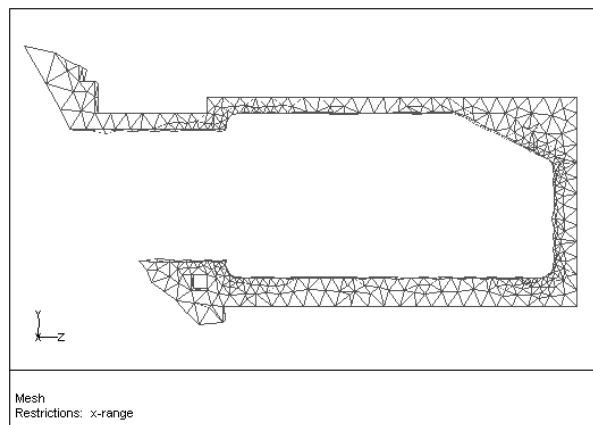
Display ⟶Grid...

Figure 8.18: Remeshed Cavity

In Figure 8.18, you can see that the cavity has been remeshed with tetrahedra.

9. Activate the global domain.

  Mesh ⟶Domains...

10. Display the original mesh along with the remeshed cavity (Figure 8.19).

 (a) Select car, car:#, mirror, wheel-arch-front, wheel-arch-rear, wheel-front, and wheel-rear in the Face Zones selection list in the Display Grid panel.

 (b) Make sure the fluid zone is deselected in the Cells tab and the display bounds are reset in the Bounds tab.

 (c) Click Display.

 (d) Enable the overlaying of graphics in the Scene Description panel.

   Display ⟶Scene...

 (e) Select the fluid zones in the Cell Zones selection list and enable All in the Options group box in the Cells tab of the Display Grid panel.

 (f) Enable Limit by X and enter -0.37 for both Minimum and Maximum in the X Range group box in the Bounds tab.

 (g) Click Display.

 (h) Click Draw in the Cavity Remesh panel.
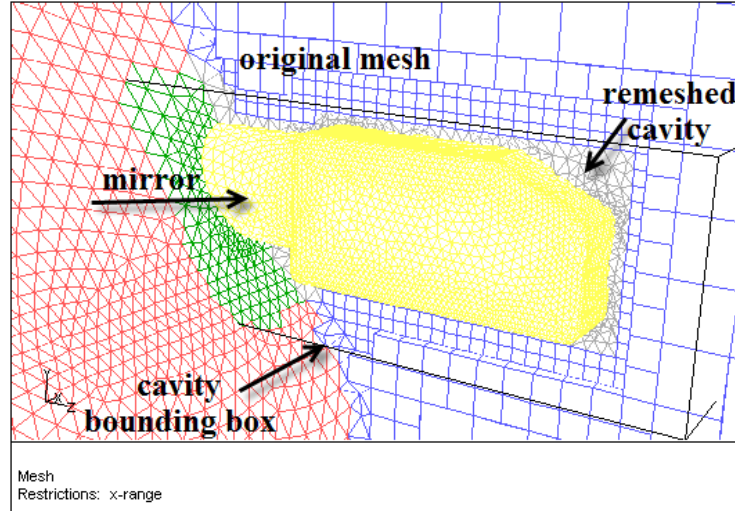
   Mesh ⟶ Tools ⟶Cavity Remesh...

Figure 8.19: Cavity Remeshed With Tetrahedral Cells

11. Merge the cavity with the global domain.

```
> /mesh/cavity/merge-cavity
Insert domain name/id [cavity-1] <Enter>
Into domain name/id [global] <Enter>
Merging cell zone fluid-# (id #) with fluid-#
Merging face zone interior-#:# (id #) with interior-#
Merging face zone car:# (id #) with car
```

where, # denotes the respective IDs.

12. Delete the old mirror.

Boundary —→Manage...

13. Check the mesh.

Mesh —→Check

14. Save the mesh (sedan-hexcore-cavity.msh.gz).

File —→ Write —→Mesh...

15. Exit TGrid.

File —→Exit

Summary

This tutorial demonstrated the creation of a cavity in an existing mesh to replace an object, and then remeshing the cavity as appropriate. The procedure for creating and remeshing the cavity was demonstrated for a tetrahedral mesh (Case A), hybrid mesh with a single fluid zone (Case B), hybrid mesh with multiple fluid zones (Case C), and a hexcore mesh (Case D).