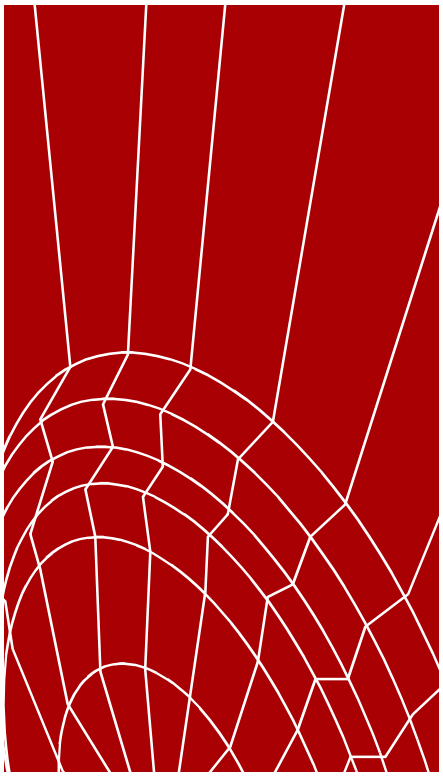

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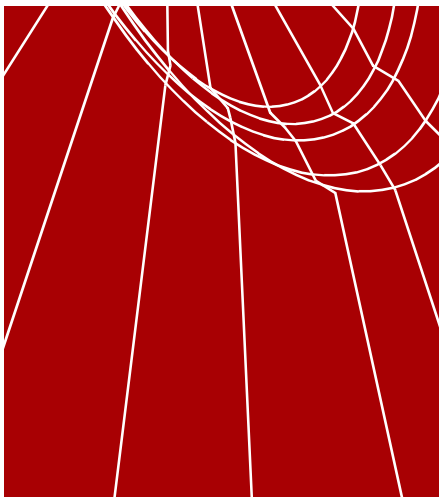
MARC/HexMesh™

User Guide



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Document Title: **MARC/HexMesh™: User Guide**
Part Number: UG-3013-1
Revision Date: May, 1998

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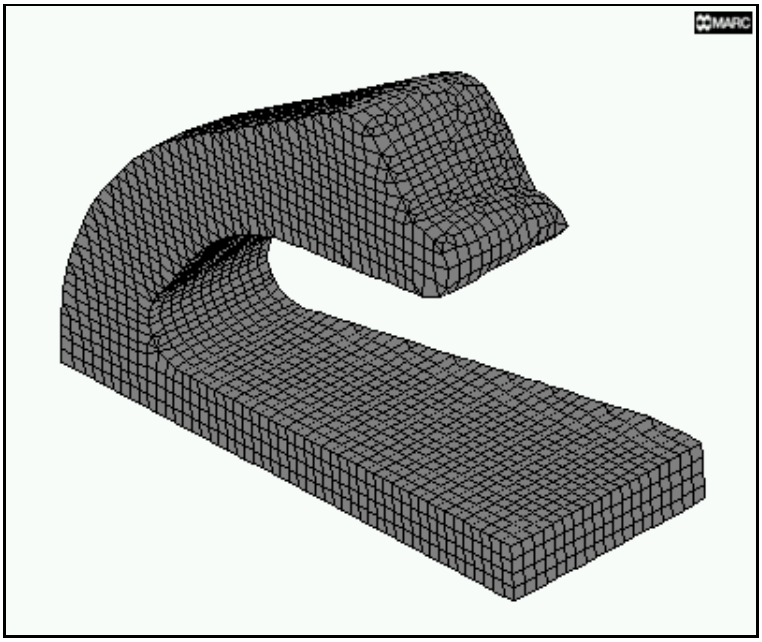
• Getting Started

About MARC/Hexmesh

Advantages of MARC/ HexMesh

MARC/Hexmesh generates a hexahedral mesh automatically from your CAD geometry enabling you to move rapidly from a CAD model to a finite element model of even the most complex shapes.

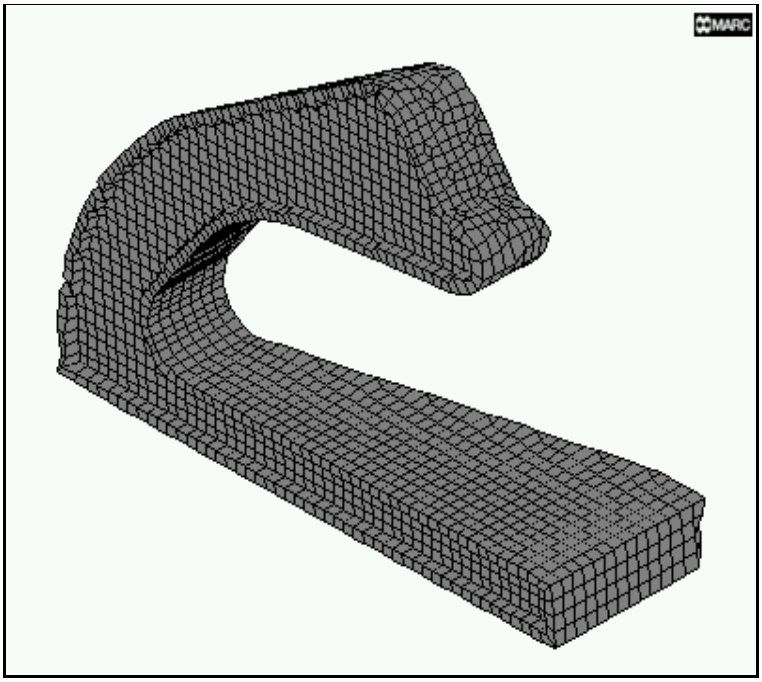
A model generated with MARC/Hexmesh allows you to perform linear and nonlinear finite element analyses and to achieve the kind of quality results associated with finite element models composed of hex elements.



hexahedral elements generated by MARC/HexMesh

Advantages of Hexahedral Elements

A mesh with hexahedral elements is generally more accurate and requires fewer elements than a meshes that contains tetrahedral elements. For complex geometries, hexahedral meshes are easier to visualize and edit than tetrahedral meshes.



interior of model meshed with MARC/HexMesh

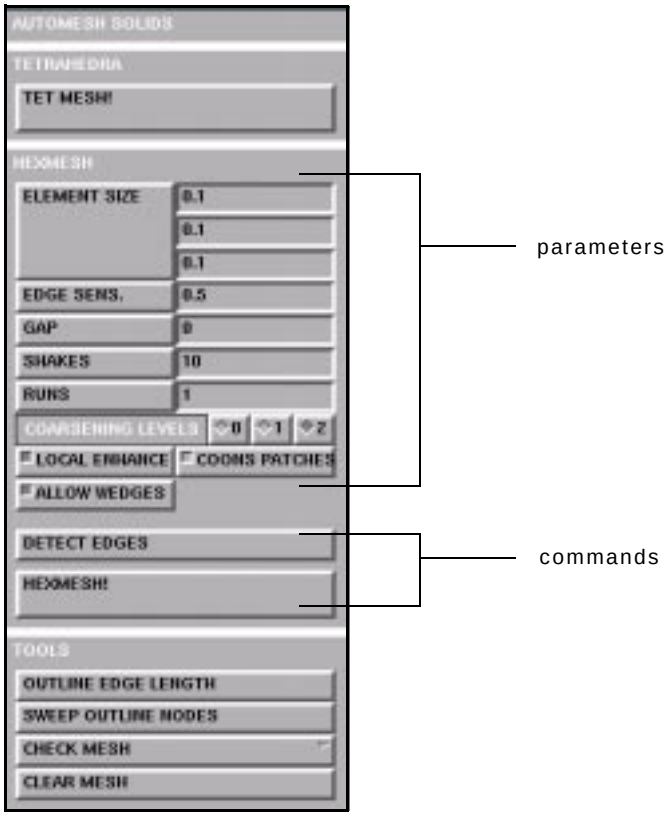
Activating the MARC/ HexMesh Feature

MARC/HexMesh is an add-on feature. If you purchased MARC/HexMesh with your original purchase or license renewal, your license file includes the feature line, **HEXMESH** which activates MARC/Hexmesh.

If you wish to purchase MARC/HexMesh for an existing license, contact your local MARC office. You will receive an additional feature line for your license file from license@marc.com.

About the Hexmesh Menu in Mentat

Use the Hexmesh menu in Mentat to define the parameters and apply the commands for the MARC/HexMesh. To display the Hexmesh menu, choose Mesh Generation>Automesh>Solid Meshing



Mesh Generation>Automesh>Solid Meshing

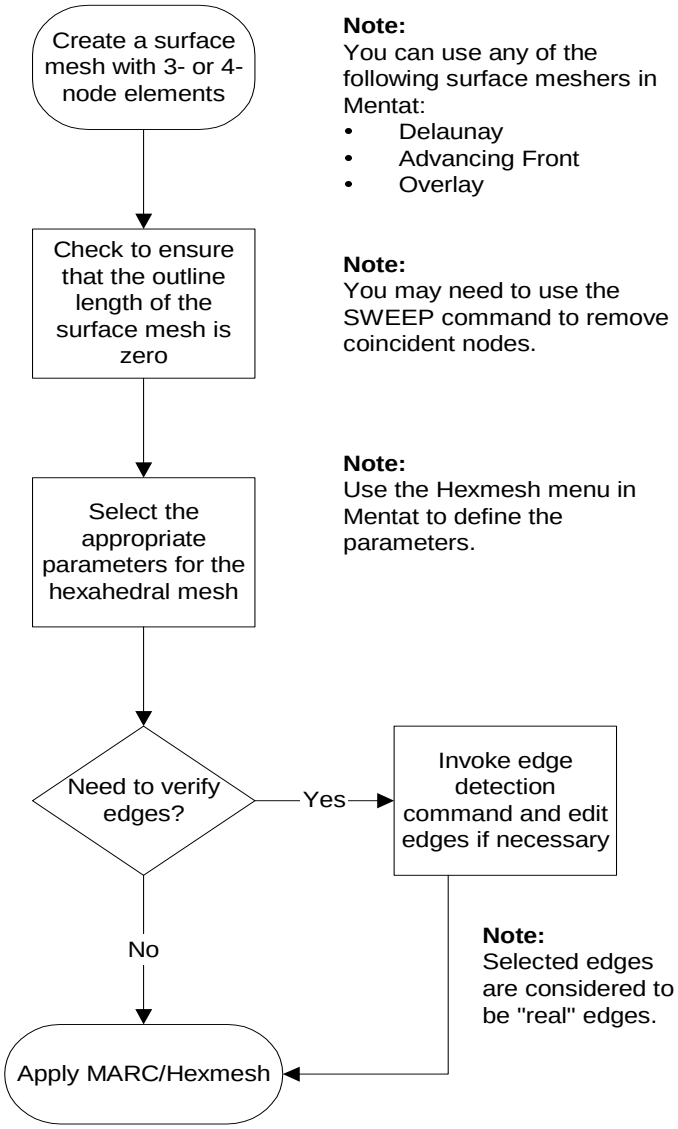
About the Input for MARC/HexMesh

The MARC/Hexmesh takes a description of a surface that is based on 3- or 4-node elements and performs an edge detection and a hexahedral mesh generation on that surface.

Before you apply the MARC/Hexmesh, you should create a surface mesh of the volume to be meshed. This volume should be totally enclosed with no free edges or ‘torn seams’. The surface mesh serves as a bounding surface of the volume to be meshed.

Key Steps in the Meshing Process

Here are the key steps in the meshing process:



You can regulate the accuracy and speed of the hexmeshing operations by specifying the different parameters and applying the Hexmesh commands in Mentat.

Questions or Comments About MARC/HexMesh

If you have questions and comments about MARC/HexMesh, or you need more information, use the following table to reach us:

for...	contact...
technical support information about MARC/HexMesh,	support@marc.com
questions and comments about this user guide,	document@marc.com
revisions of this user guide in Portable Document Format (you need Acrobat Reader 3.0 or higher),	http://www.marc.com/Support/Support.html

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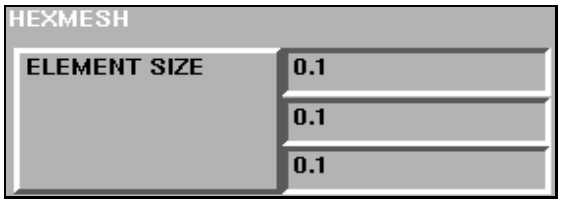
• MARC/HexMesh Parameters and Commands

Using Parameters and Commands

Specifying Element Size

Use the Element Size parameter to specify the sizes of hexahedral elements generated in the x, y, and z directions. The default element sizes for the x, y, and z directions are 0.1.



Mesh Generation>Automesh>Solid Meshing

The size of the element determines the number of resulting hexahedral elements. The following table demonstrates how element size affects the meshing process:

If you specify...	then...
smaller elements,	the quality of the mesh is better. However, since there are more elements, the meshing process is slower. Also, if you specify too small an element size, the meshing grid may become too large and the mesher may fail.
a large element size (in comparison to the object size),	meshing might fail.

To set the element size:

1. Click **ELEMENT SIZE**.
2. Type the element sizes in the x, y, and z directions. You must specify an element greater than zero.
3. Press Enter.

Specifying Edge Sensitivity

Use the Edge Sensitivity parameter to specify when, in the edge detection process, the shared edge between two input elements represents a "real" edge. The mesher uses these real edges to maintain the geometric representation of the model.

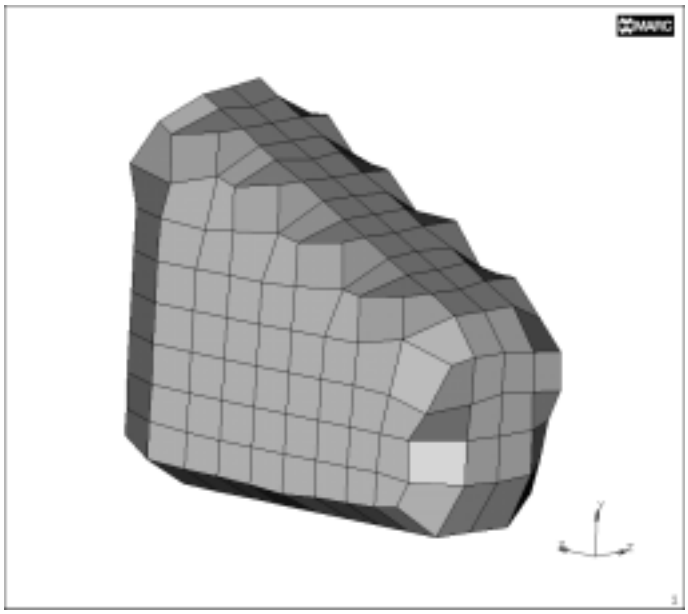
Mesh Generation>Automesh>Solid Meshing

A higher value of edge sensitivity makes the HexMesh more sensitive during the edge detection process. The default value of edge sensitivity is 0.5. The range of values is $0 \leq x \leq 1$.

How the Value of Edge Sensitivity Affects the Edge Detection Process

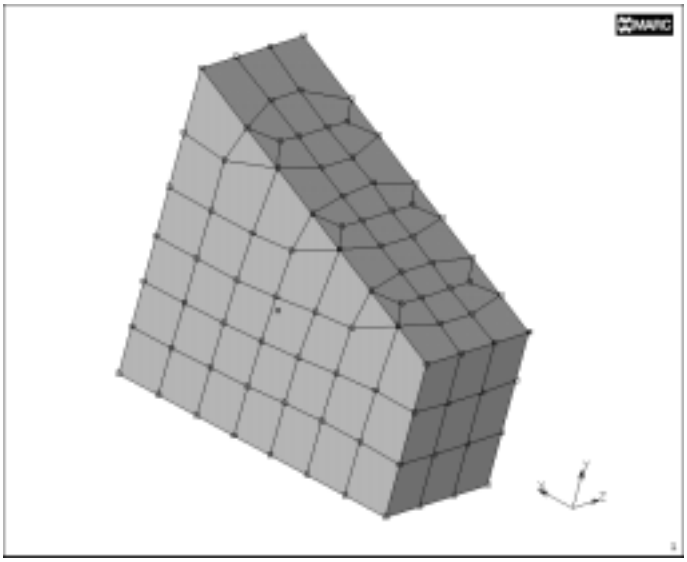
The following illustrations show how the value of edge sensitivity affects the edge detection process:

- Edge sensitivity = 0:



fewer edges detected

- Edge sensitivity = 1:



more edges detected

To specify edge sensitivity:

1. Click **EDGE SENSITIVITY** and type in a value.
2. Press Enter.

Specifying Gap

Use the Gap parameter to specify the size of the gap that is initially left between the inner hexahedral elements and the surface during mesh generation.

After the mesher creates the overlay grid it removes elements that are either close to or outside the surface mesh depending on the value of the gap that you specify. The mesher then meshes the gap area.

The range of values for the Gap parameter is -1 to 1. Negative values result in a smaller gap and can even result in mesh penetration.

To set the value of the Gap parameter:

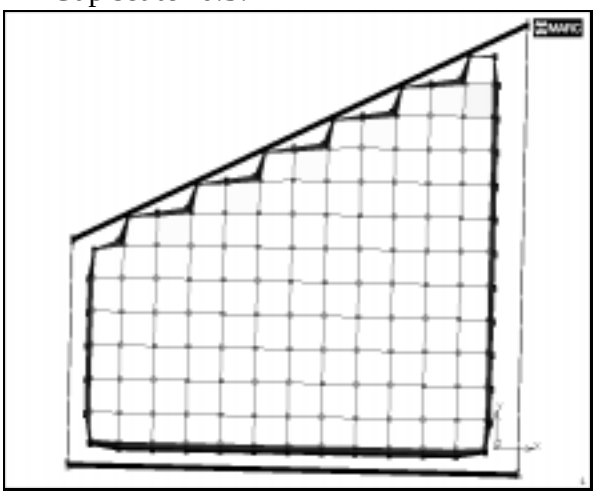
1. Click **GAP** and type in a value.

2. Press Enter.

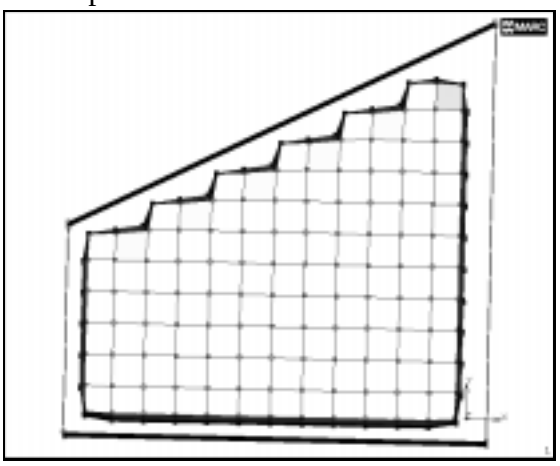
How the Value of Gap Affects the Mesh

The following figures demonstrate how the value of gap affects the mesh.

- Gap set to -0.3:

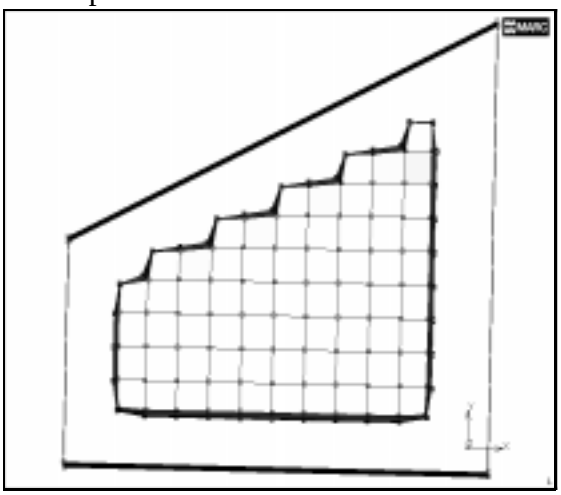


- Gap set to 0:



How the Value of Gap Affects the Mesh (Contd.)

- Gap set to 1:



Specifying the Number of Shakes

Shaking is a process of global mesh enhancement where the nodes tend to move to places of less potential energy. This has a relaxing effect on the nodes and often results in a better mesh quality.

Higher values of the Shakes parameter take up greater computing resources. Here are some guidelines for setting the values of the Shakes parameter for test and final meshes:

Situation	Suggested Value
Test mesh	10
Final mesh	100

To specify the number of shakes:

1. Click **SHAKES** and type in a value.
2. Press Enter.

Using the Runs Parameter

If the HexMesh does not produce a valid mesh, it can automatically run again with a smaller element size. Using the Runs parameter, you can specify the maximum number of reruns performed by the HexMesh.

Mesh Generation>Automesh>Solid Meshing

To specify the number of runs:

1. Click **RUNS** and type in a value.
2. Press Enter.

To prevent reruns, type in the value, 1.

Using the Coarsening Parameter

Use the Coarsening parameter to specify a difference in size between the elements in the interior and the elements in the surface. This may reduce the overall number of elements generated.

Mesh Generation>Automesh>Solid Meshing

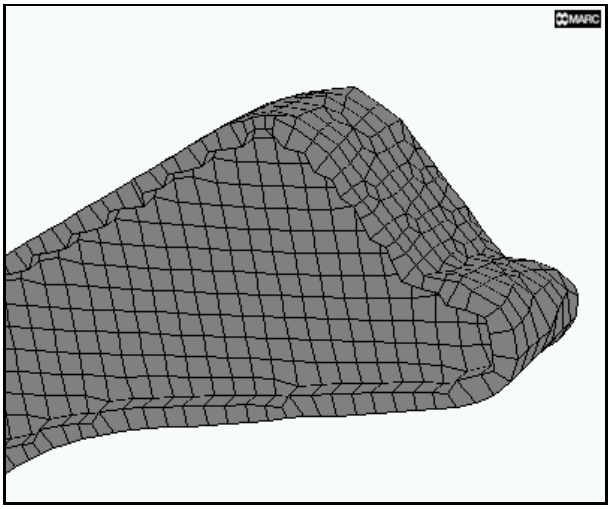
You can specify one of three levels of coarsening—0,1, or 2. A value, 0, indicates that there will be no coarsening. A value, 2, specifies that the elements in the interior can be up to four times larger on each side than the elements on the surface.

To specify a level of coarsening, click on the radio button next to the level.

How the Level of Coarsening Affects the Elements

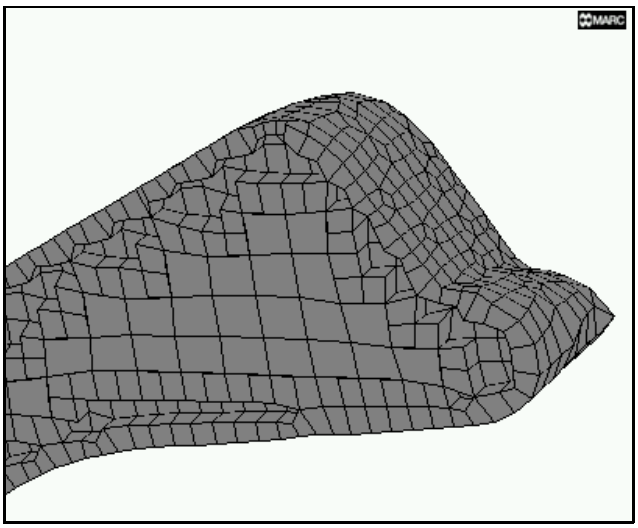
The following illustrations represent two different levels of coarsening.

- Coarsening set to 0:



interior elements of the model are uniform

- Coarsening set to 2:



interior elements are larger than the elements on the surface

About the Local Enhance Parameter

The Local Enhance parameter checks for inside-out elements in localized areas of the final mesh. If there are inside-out elements in certain localized areas, the mesher checks those elements for any additional constraints (for example, they may be mapped on to corner points or edges).

When it finds additional constraints in the inside-out elements, the mesher removes the constraints so that the resulting mesh in those areas has no inside-out elements.

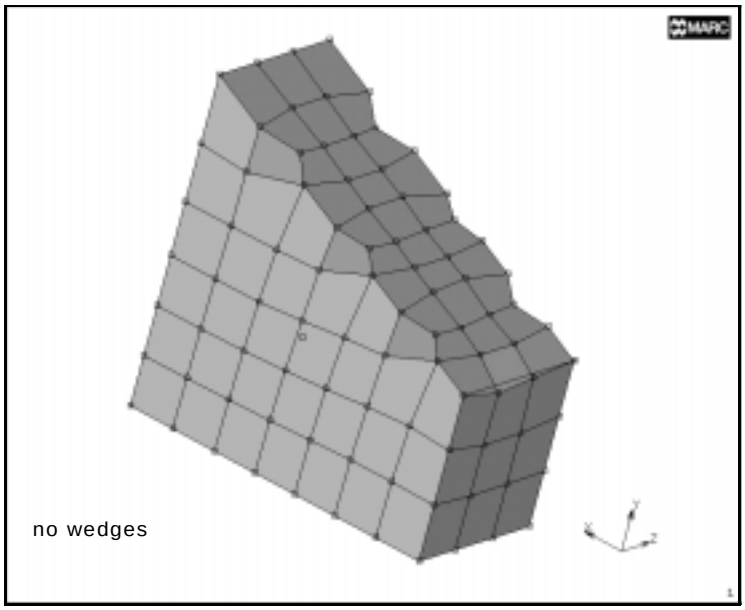
Mesh Generation>Automesh>Solid Meshing

The default setting of the Local Enhance parameter is ON.

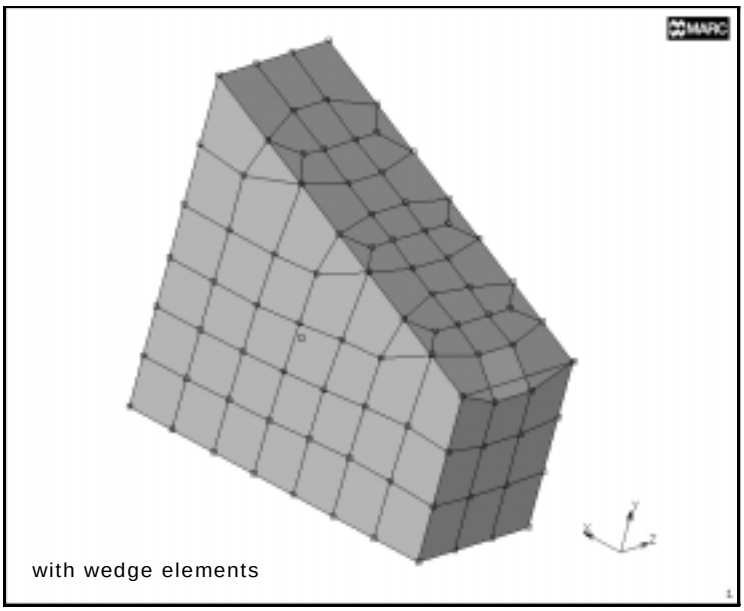
Using the Allow Wedges Parameter

Use the Allow Wedges parameter to create wedge elements if an edge crosses the diagonal of a face of the hexahedral element. This improves the quality of the resulting mesh.

- Allow Wedges parameter OFF:



- Allow Wedges parameter ON.



About the Coons Patches Parameter

Use the Coons Patches parameter to reduce the loss of volume while meshing regions with curved surfaces. This results in a smoother representation of the input surfaces and a better approximation of the input geometry. However, this parameter consumes greater CPU resources.

The default setting for the Coons Patches parameter is OFF.

Using the Detect Edges Command

Use the Detect Edges command to automatically select geometric edges from an input list of triangular and quadrilateral elements that enclose the volume to be meshed. These detected edges help define the input geometry for the MARC/HexMesh.

DETECT EDGES

Mesh Generation>Automesh>Solid Meshing

The elements in the input list should be oriented with their tops facing outward and there must not be any free edges or holes in the list.

To apply the Detect Edges command:

1. Click **EDGE SENSITIVITY** and specify a value other than 0.
2. Click **DETECT EDGES** and enter a list of triangular or quadrilateral elements.
3. Press Enter.

When you apply the Detect Edges command, the detected element edges are automatically included in the list of selected edges. However, you can modify this list by selecting (or deselecting) edges before applying the HexMesh command.

Selecting Edges

To select edges:

1. Choose Mesh Generation>Select.
2. Choose the select mode, **AND**.
3. Enter a list of edges.
4. Press Enter.

Any element edges that you select using the Detect Edges command are considered to be real edges.

To remove these edges, clear them from the selection list using the Select menu options in Mentat (see Deselecting Edges).

Deselecting Edges

To deselect edges:

1. Choose Mesh Generation>Select.

2. Choose the select mode, **EXCEPT**.
3. Enter a list of edges.
4. Press Enter.

Checklist for the Hexmesh Command

Before you apply the Hexmesh command you should ensure that:

- the input list of triangular and quadrilateral elements enclose the volume to be meshed.
- there are no free edges or holes in the input list.
- the elements are oriented with their tops facing outward
- the length assigned to the element edges does not exceed the thickness of geometry to be meshed (a good rule-of-thumb is: edge length = 1/3 thickness of the smallest section)

Applying the Hexmesh Command

To apply the HexMesh command:

1. Click **HEXMESH**

.

Mesh Generation>Automesh>Solid Meshing

2. Specify a list of triangular and quadrilateral elements.
3. Press Enter.

About the Meshing Tools

The following table describes the operations supported by meshing tools available for the hexmesher:

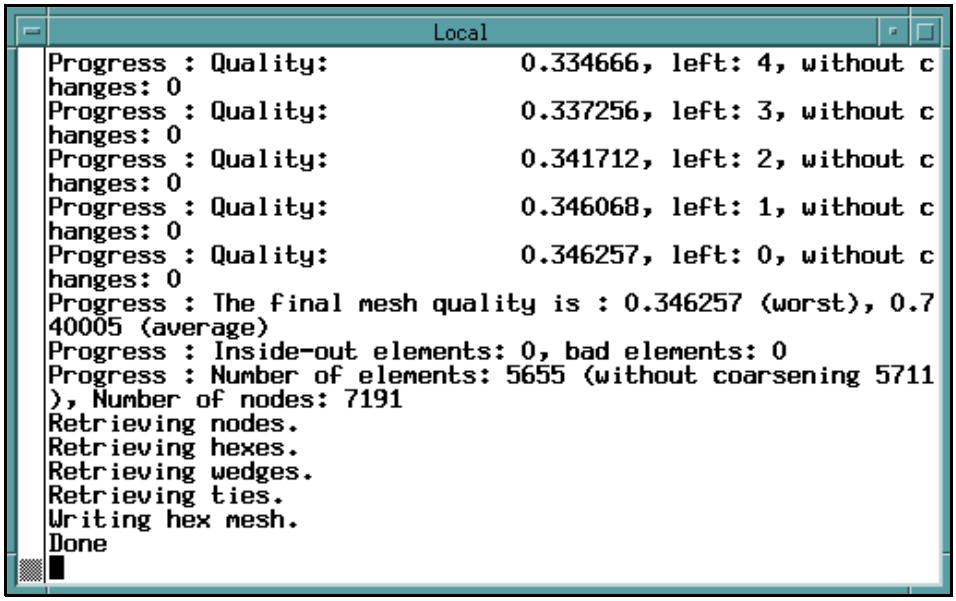
Tool	Operation
Outline Edge Length	Computes the outline edge length. A value, 0, signifies that there are: • no free edges • all elements have the same orientation
Sweep Outline Nodes	Removes coincident nodes on the outline.
Check Mesh	Checks mesh for distorted, upside-down, or inside-out elements. Reverses the orientation of elements, curves, and surfaces.
Clear Mesh	Removes the entire mesh leaving the geometry intact.

Rectifying an Unsuccessful Hexmeshing Operation

If your hexmeshing operation is unsuccessful, here are some measures that you can take before running the operation again:

- In the static menu area, click **UNDO** to return to the input mesh.
- Check the detected edges and edit them if necessary (*See "Using the Detect Edges Command" on page 21*).
- Select a gap parameter value other than 0 (*See "Specifying Gap" on page 15*).
- Specify a different element size (*See "Specifying Element Size" on page 13*).
- Modify the input list.

- Check the Mentat shell window for any status, warning, and error messages:



Mentat shell window

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• Using MARC/ HexMesh—Example

Using MARC/HexMesh

About the Example

The meshing example in this chapter demonstrates the steps in meshing a solid model with MARC/HexMesh. The example is a procedure file, **hexmesh.proc**, and uses the model, **hexmesh.mfd.**

The procedure file and the model are located in the Mentat directory, **examples/userguide**.

Example Overview

The key stages in this example are:

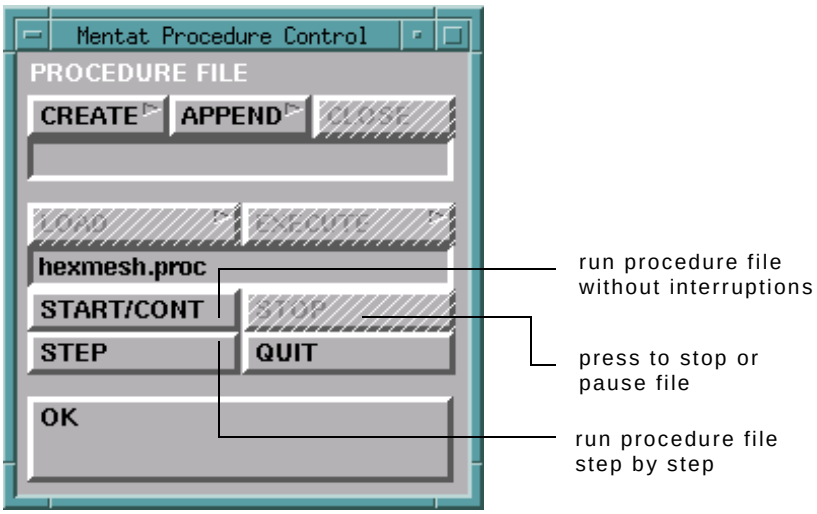
- **Stage1**: Run the procedure file.
- **Stage 2**: Prepare the input model for surface-meshing using the Delaunay surface tri-mesh.
- **Stage 3**: Apply the Delaunay tri-mesh
- **Stage 4**: Prepare the input list for MARC/HexMesh using the HexMesh parameters
- **Stage 5**: Apply MARC/HexMesh

Running the Procedure File

To run the procedure file, **hexmesh.proc**:

1. Choose Utils>Procedures.
2. In the Mentat Procedure Control window, click **LOAD**.
3. In the Mentat Procedure Files window, locate the file, **hexmesh.proc**, in the directory, **examples/userguide**.
4. Click **OK**. The procedure file appears in the Mentat Procedure Control window.
5. Use one of the following options to run the procedure file:

- To run the procedure file without interruptions, click **START/CONT**.
- To run the procedure file step by step, click **STEP**.



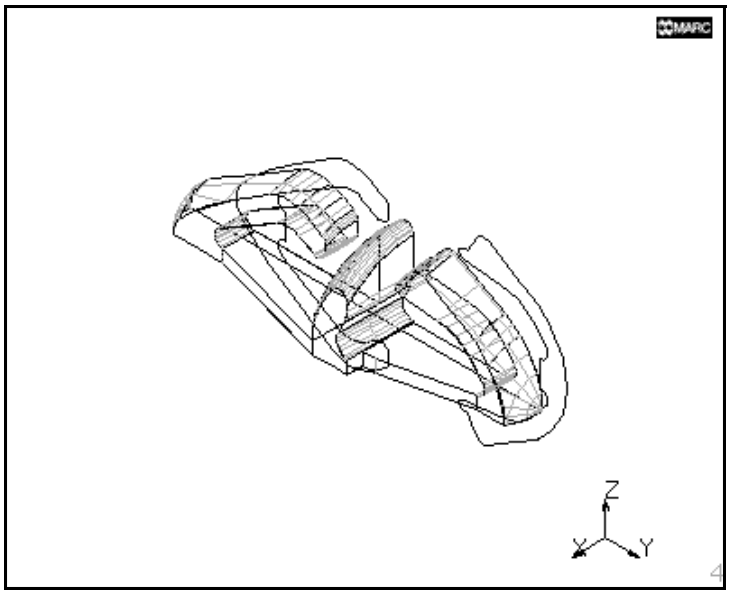
Preparing the Model for Surface Meshing

To prepare the model for surface-meshing using the Delaunay surface tri-mesh:

1. Click **FILL** to make the entire model visible.
2. Click **DRAW** and turn the drawing of nodes and points to OFF.

Preparing the Model for Surface Meshing (Contd.)

3. Choose View>View Status>Show View 4.



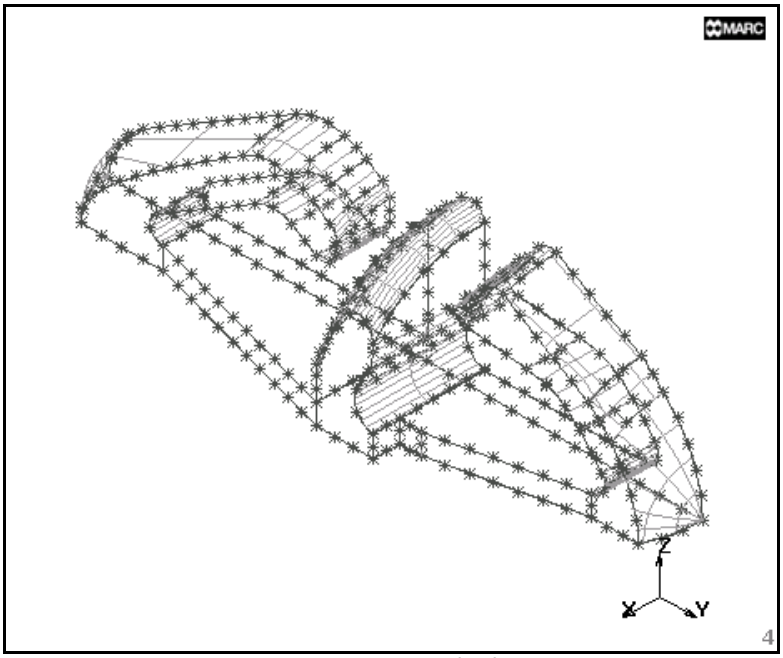
view 4

4. Click Mesh Generation>Automesh>Remove Free Curves to remove curves not attached to the surface.
5. Click **BREAK CURVES** and specify:
   - a vertex tolerance (0.5)
   - a list of curves (all existing)
6. Clean the surface geometry by specifying the following tolerance settings:
   - minimum tolerance (.01)
   - surface parametric space tolerance (.01)
7. Click **CLEAN SURFACE LOOPS** and specify a list of surfaces (all existing).
8. Click **CHECK SURFACES** and specify a list of surfaces (all existing).
9. Choose Automesh>Curve Divisions>Type
10. Specify a curve division with fixed average length (1).

Preparing the Model for Surface Meshing (Contd.)

11. Click **APPLY CURVE DIVISIONS** and specify a list of curves (all existing).
12. Click **MATCH CURVES** and specify:

- a vertex tolerance (.05)
- a list of curves (all existing)

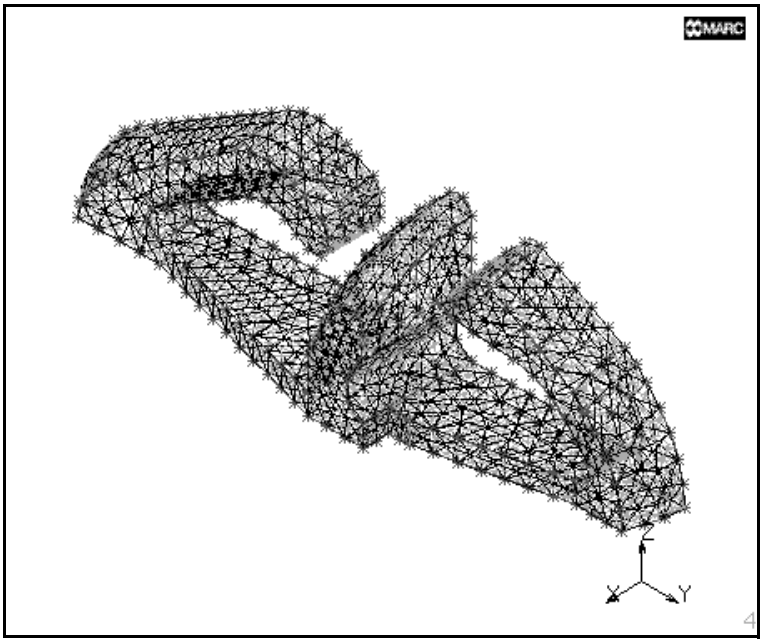


curves matched

Applying the Delaunay Tri-mesh

To apply the Delaunay tri-mesh to the model:

1. Choose Surface Meshing>Surface Tri Mesh.
2. Specify a list of curves (all existing).



surface tri mesh applied

Preparing the Input List for MARC/ HexMesh

To prepare the input list for MARC/HexMesh:

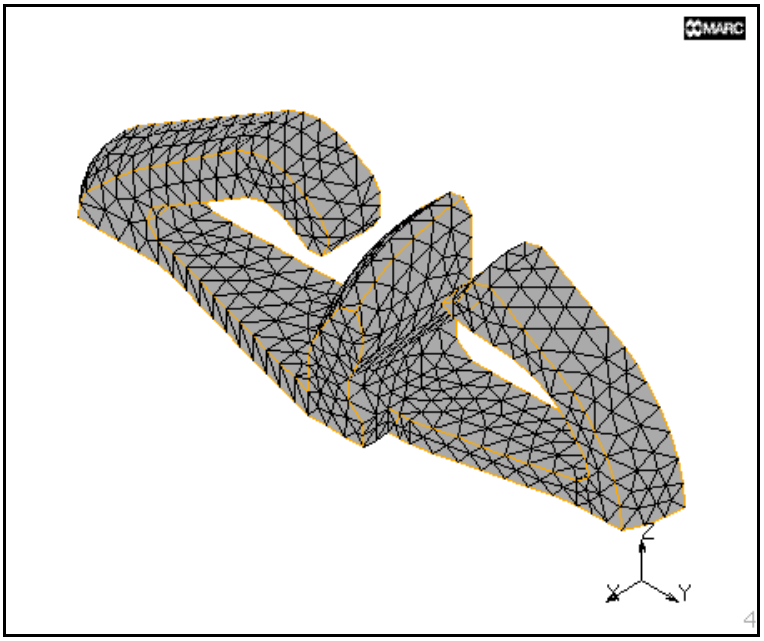
1. Sweep any extra nodes by specifying:
   - a sweep tolerance (.05)
   - a list of nodes to sweep (all existing)
2. Click **PLOT** and change the following plot settings to view the mesh more clearly:
   - Set the drawing of curves and surfaces to OFF.
   - In the Elements areas, click **SOLID** to display the element faces in solid color.

Preparing the Input List for MARC/HexMesh

3. Click **REDRAW** to redraw the model with the new settings.
4. Choose Main>Mesh Generation>Automesh>Solid Meshing.
5. In the Hexmesh area, **CLICK EDGE SENSITIVITY** and specify a value (.5).
6. Click **DETECT EDGES** to identify the geometric edges in the triangular elements and specify a list of edges (all existing).
7. Choose Main>Visualization>Colors>Select Edges
8. Change the selected edge color by specifying a colormap number (23 1 0.6 0).
9. Choose Main>Mesh Generation>Automesh>Solid Meshing.
10. Click **EDGE SENSITIVITY** and specify a higher edge sensitivity (.6).
11. Click **DETECT EDGES** again and specify a list of edges (all existing).
12. Click **EDGE SENSITIVITY** and set the edge sensitivity even higher (.7) to detect more edges.
13. Specify a list of edges (all existing).
14. Zoom in on the model and pick a few more edges (for specific edges, *See "Procedure File" on page 37*).
15. Click **FILL VIEW** to make the entire model visible.
16. Rotate the model, zoom in, and pick a few more edges (for specific edges, *See "Procedure File" on page 37*).

Preparing the Input List for MARC/ HexMesh (Contd.)

17. Rotate the model again to ensure that you picked all the edges.
18. Click **RESET VIEW** to reset the view to its original state.
19. Click **FILL VIEW** to make the entire model visible again.

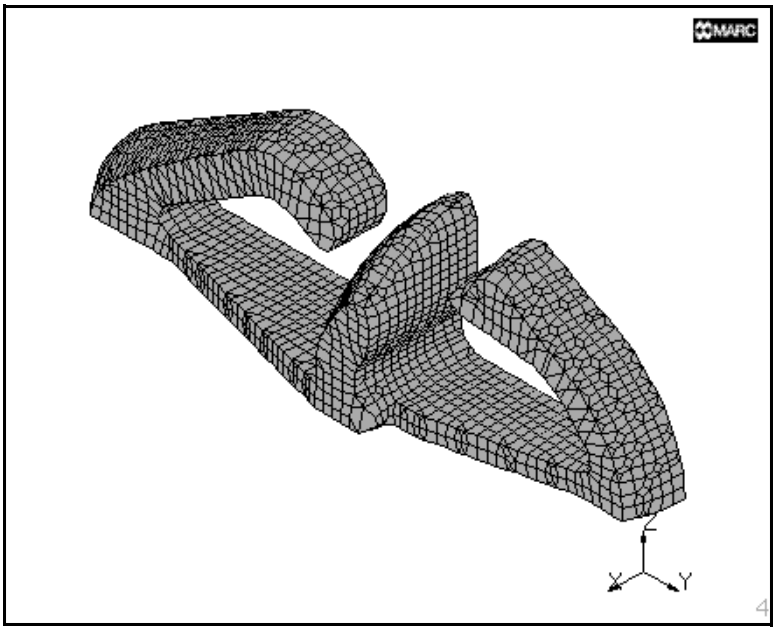


edges picked

Applying MARC/ HexMesh

To apply MARC/HexMesh:

1. Choose Main>Automesh>Solid Meshing.
2. In the Hexmesh area, click **ELEMENT SIZE** and specify the element sizes in x, y, and z directions (.4, .4,.4).
3. Click **HEXMESH!** and specify a list of edges (all existing).



MARC/HexMesh applied

Procedure File

About the Procedure File

The following pages describe the contents of the procedure file, **hexmesh.proc.**:

```
| Procedure file hexmesh.proc to demonstrate HexMesh in Mentat
open_model hexmesh.mfd
*fill_view
*set_points off
*set_nodes off
*show_view 4
*redraw
*fill_view
*rm_free_curves
*fill_view
*break_curves
| Break the curves so you are able to have a conforming mesh
.05
all_existing
*set_mesh_min_tol
.01
*set_mesh_param_tol
.01
*clean_surface_loops
| Clean the loops in case there are some tiny curves or open loops
all_existing
*check_surfaces
| All the surfaces are okay
all_existing
*set_curve_div_type_fix_avgl
*set_curve_div_avgl
1
*apply_curve_divisions
all_existing
*match_curves
| Ensure that divisions match up
.05
all_existing
*dt_surface_trimesh
| Now mesh the surfaces (Any mesher will do)
all_existing
*set_sweep_tolerance
| Don't forget to sweep up those extra nodes
```

```
.05
*sweep_nodes
all_existing
*set_curves off
| Change some plot settings so we can appreciate our mesh
*set_surfaces off
*elements_solid
*redraw
*set_hexer_edge_sensitivity
| This is the default value
.5
*hexer_detect_edges
all_existing
*color 23 1 0.6 0
| Change the selected edge color to see them better
*set_hexer_edge_sensitivity
| Set the sensitivity a little higher to pick up more edges
.6
*hexer_detect_edges
all_existing
*set_hexer_edge_sensitivity
| Set it even higher to try to pick up more edges
.7
*hexer_detect_edges
all_existing
*zoom_box
*zoom_box(4,0.086168,0.265903,0.258503,0.432570)
*select_edges
| Select a few more edges manually
 200:1
 1007:2
| Click on those edges twice to get both of them & avoid confusion
# | End of List
*fill_view
*zoom_box
*zoom_box(4,0.411565,0.576336,0.575964,0.730280)
 497:2
 922:2
 497:0
| Get these edges over here, too...
 900:0
 520:2
 903:2
# | End of List
```

```
*fill_view
*rot_model_cspace_z_for
| Now rotate to get a good look at the selected edges
*rot_model_cspace_z_for
*rot_model_cspace_z_for
*rot_model_cspace_z_for
*rot_model_cspace_x_for
*rot_model_cspace_x_rev
*rot_model_cspace_x_rev
*rot_model_cspace_x_rev
*rot_model_cspace_z_for
*rot_model_cspace_z_rev
*rot_model_cspace_z_rev
*rot_model_cspace_y_rev
*rot_model_cspace_y_for
*rot_model_cspace_y_for
*rot_model_cspace_y_for
*rot_model_cspace_y_for
*fill_view
*zoom_box
| Here's another edge to pick...
*zoom_box(4,0.804989,0.444020,0.917234,0.548346)
 627:0
 845:2
# | End of List
*fill_view
*rot_model_cspace_x_rev
| Rotate it around some more to be sure you are not missing any edges
*rot_model_cspace_x_for
*rot_model_cspace_x_for
*rot_model_cspace_x_for
*rot_model_cspace_x_for
*rot_model_cspace_x_for
*rot_model_cspace_x_for
*rot_model_cspace_x_for
*rot_model_cspace_x_for
*rot_model_cspace_x_for
*rot_model_cspace_x_for
*rot_model_cspace_x_for
*reset_view
*fill_view
*set_hexer_element_size
| Now you are ready to apply the HexMesh
```

```
.4 .4 .4
*hexer_hexmesh
all_existing
| Rotate it around and make some of those elements invisible
| if you want to get a good look at the hex mesh.
```

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Document Title: **MARC/HexMesh™: User Guide**
Part Number: UG-31013-1
Revision Date: May, 1998

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