



**MetaMesh**  
**Three-dimensional Conformal**  
**Mesh Generator**

**Field Precision**  
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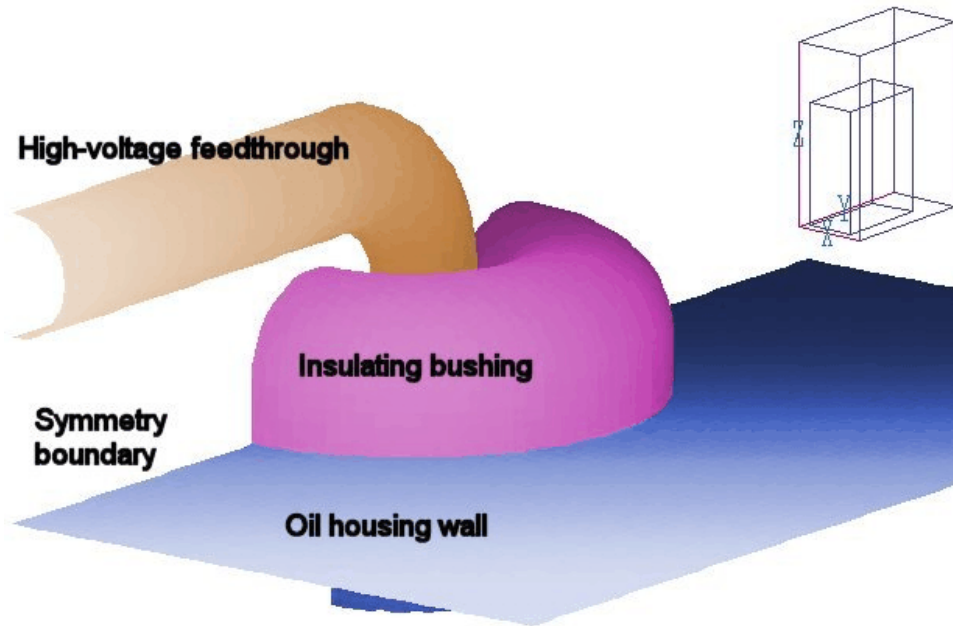
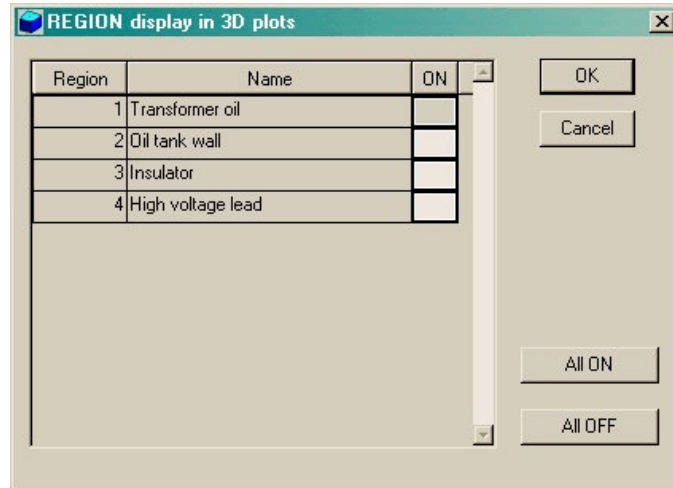


Figure 1.2. Geometry of the application example

### 1.3 Walkthrough example

The simulation shown in Fig. 1.2 illustrates the creation of a mesh and the steps involved in a three-dimensional solution. A high-voltage bus bar enters an oil housing through a shaped insulator. We want to find values of the electric field magnitude in the oil region near the penetration point. Because the rear plane is a symmetry boundary, we can model only half the system.

First we will briefly review the example and then return to consider some of the details. Copy the file `WALKTHROUGH.MIN` from `\AMAZE\EXAMPLES` to a temporary data storage location such as `\AMAZE\BUFFER`. Run `METAMESH.EXE` and click on *Load MIN file* in the *File* menu. Go to the data directory, pick `WALKTHROUGH.MIN`, and click *OK*. The status bar at the bottom of the window (Fig. 1.1) shows that a file has been loaded but not processed. Click on the command *Process mesh*. **MetaMesh** starts work, reporting the progress of the analysis in a text box. The program analyzes the file content and performs the following operations: 1) create a foundation mesh, 2) assign elements of the foundation mesh to approximate the specified geometry, 3) shift nodes so that element faces fit on material boundaries, and 4) check the integrity of the resulting elements. The main purpose of the rapidly-scrolling screen display is to give you the sense that the program is busy. The information is also recorded in a listing file, `WALKTHROUGH.MLS`, so you can view it

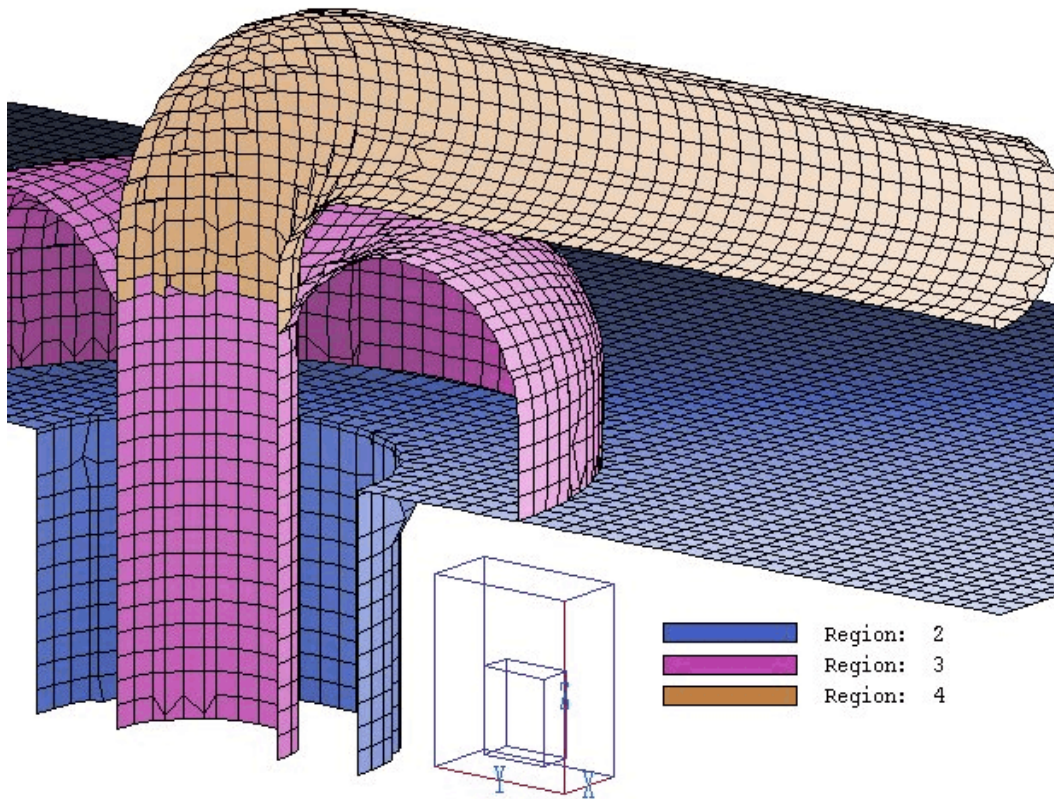


**Figure 1.3.** Region display dialog.

at leisure with a text editor. Mesh generation should take a few seconds. At the end of the analysis click a mouse button or press any key to proceed

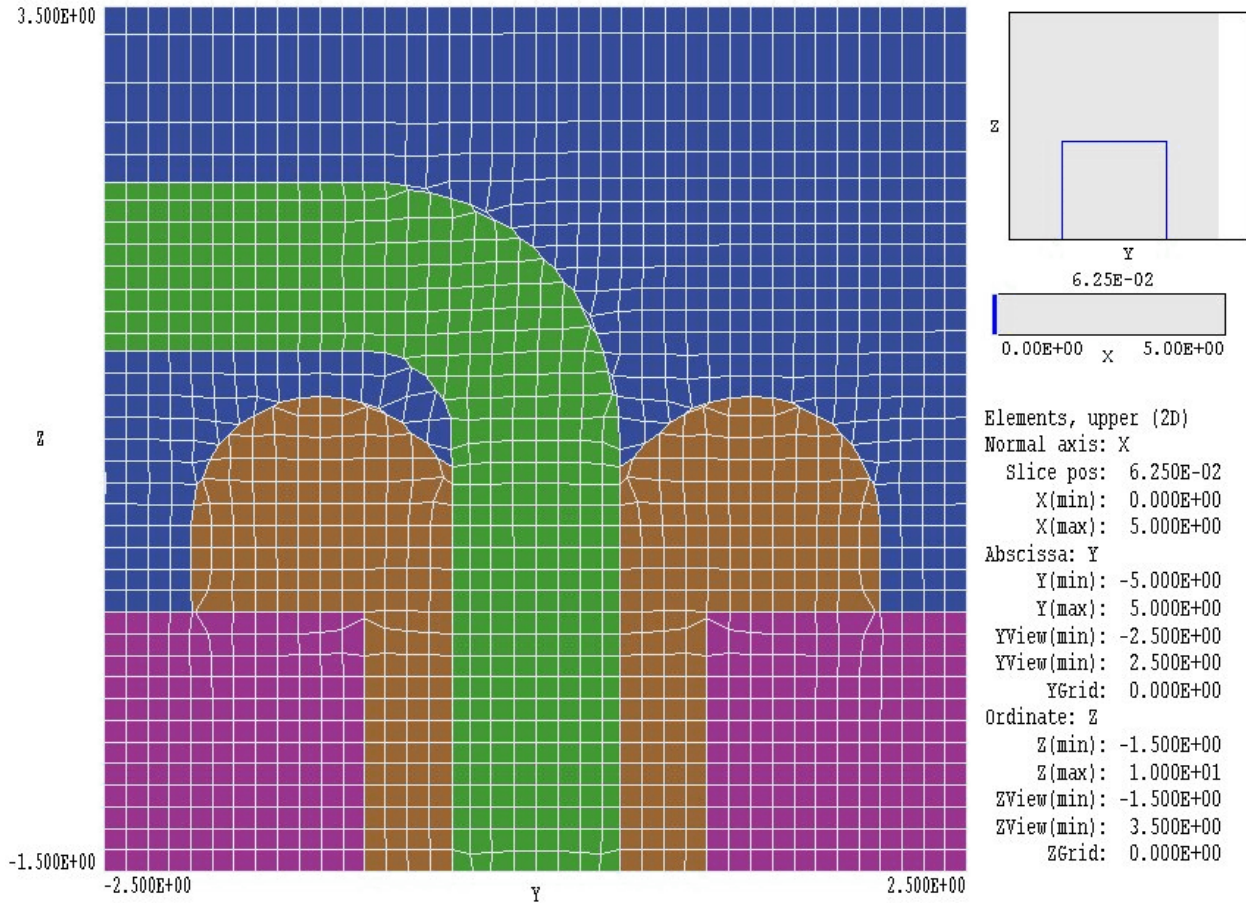
The plot menus become active when the mesh has been successfully processed. Click on *Plot3D*. **MetaMesh** makes a default surface plot of Region 2 (in this case, the metal wall of the oil tank). The plot shows facets of elements on surfaces of selected regions. Pick the command *Region/part display* in the *Plot control* menu to call up the dialog of Fig. 1.3. Activate Regions 3 and 4 to display the insulator and high-voltage rod. You should see a plot similar to that of Fig. 1.4. It will be necessary to rotate and to shift the plot to achieve the same view. The orientation tools with red arrows on the right-hand side of the screen are used to rotate about the Cartesian axes or to translate the viewpoint. You can also zoom in and out. Move the mouse over an arrow and click the left mouse button to move the thumbnail display in the upper-right corner of the screen. Click the right mouse button to update the main plot.

At this point you can experiment with the three-dimensional plot capabilities. Pick the *Plot type* command in the *Plot control* menu and try the wireframe display. Although the display may be more difficult to comprehend for complex meshes, the plot regenerates quickly. You can use the wireframe view to orient the plot and then switch back to the hidden surface view. You can also try plotting by parts rather than regions. In this case, the program does color coding on the basis of the part number rather than the region number. The high voltage rod will have three colored zones because it was constructed from three different parts.



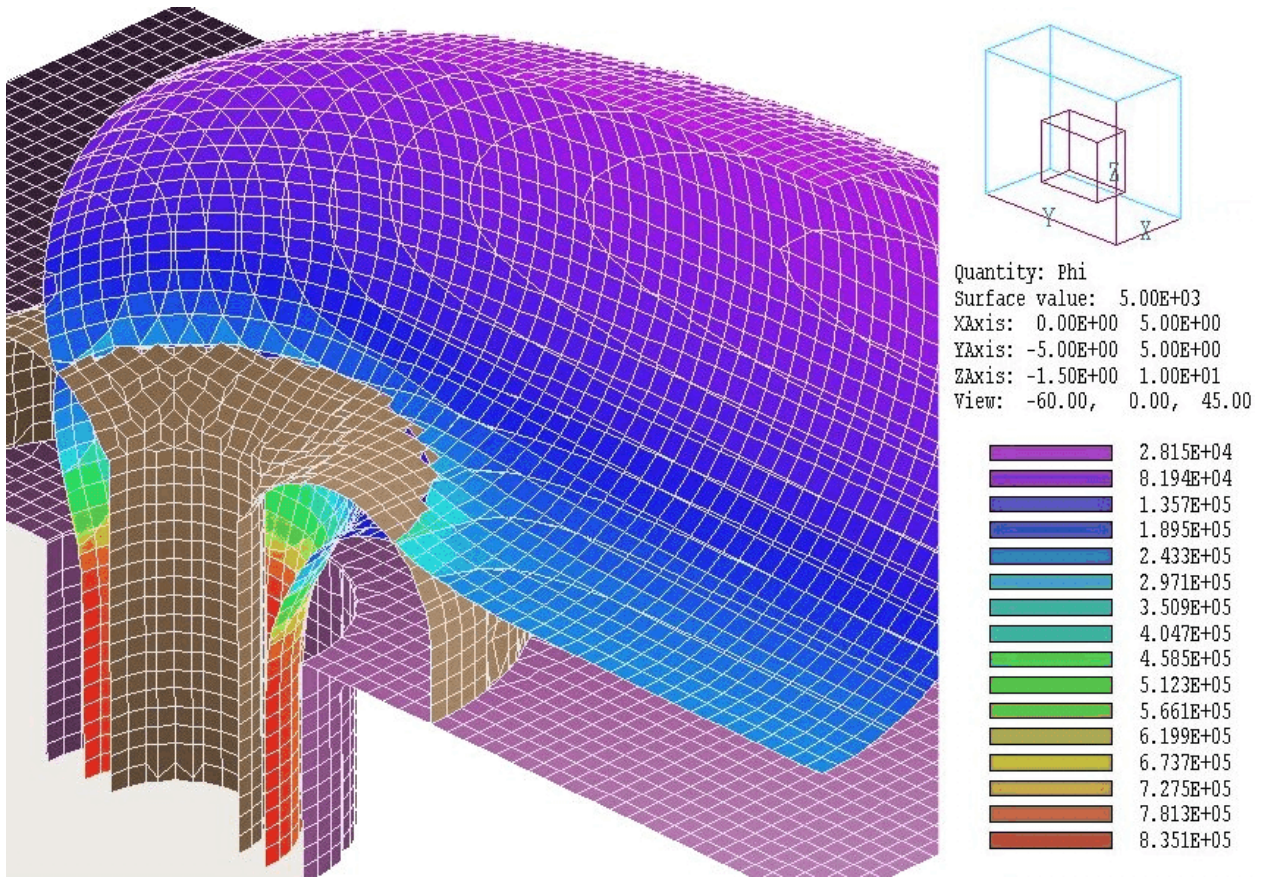
**Figure 1.4.** 3D view of region surfaces in the completed mesh

Next we shall check the slice plot capability. Click the *Return* command to return to the main menu and then click *Plot2D*. The default plot is normal to the  $z$  axis at a slice position near the middle of the solution volume. In the *Adjust view* menu click on *Plot slice* to display a dialog. Use the radio button to pick the  $x$  axis and move the slider to  $x = 0.0$ . You can use the *Zoom window* command in the *Adjust view* menu to get a closeup view like that of Fig. 1.5. The red arrow tools take you up and down in the  $x$  plane. At this point, you can experiment with different view and plot options. In some cases regions may appear to have ragged edges. Chapter 12 gives a complete description of the slice plot algorithms and their limitations. The *Hardcopy* command sends plot information to the Windows default printer. Be sure the default is set correctly before clicking on the command.



**Figure 1.5.** View of the mesh in a slice normal to the x-axis.

The plot of Fig. 1.5 illustrates the remolding of the foundation mesh boxes by the fitting process. The region where the high-voltage rod enters the insulator (center of plot) is noteworthy. The insulator profile does not exactly follow the theoretical shape because the element size was not small enough to resolve the sharp corner. The example illustrates useful properties of **MetaMesh**: tolerance and flexibility. If you don't give the code enough elements to work with, it will do the best job possible. In this case, the sharp corner has a negligible effect on the fields of interest so finer zoning is unnecessary. Finally, note the change of element resolution in the  $z$  direction. The volume  $z \geq 4.0$  was included to approximate a free-space boundary condition. Figure 1.6 shows an electrostatic solution by the **HiPhi** program using the mesh. The oil inside the tank has a dielectric constant  $\epsilon_r = 1.5$  and the insulator has  $\epsilon_r = 5.3$ . The tank is grounded and the conductor has an applied potential  $V_0 = 120$  kV. The calculated surface is an equipotential at  $\phi = 5$  kV. The color coding shows the magnitude of the electric field.



**Figure 1.6.** Electrostatic solution using the **HiPhi** program.  
 Surface of  $\phi = 5$  kV color-coded by  $|\mathbf{E}|$ .

At this point you may wonder how much work was required to specify the mesh geometry. To conclude the example we shall inspect the input script. Press *Return* to go back to the main menu and then click on *Edit MIN file* in the *File* menu. The program loads WALKTHROUGH.MIN into the internal text editor. The full text is listed at the end of this section. Here we will step through some parts.

Optional commands of the form:

```
RegName 1 TransformerOil
```

are helpful to organize the mesh construction session. Note that the names appear in the dialog of Fig. 1.3.

The following statements define the foundation mesh:

```
XMesh
  0.000  5.000  0.125
End
YMesh
 -5.000  5.000  0.125
End
ZMesh
 -1.500  3.000  0.125
  3.000 10.000  0.500
End
```

The commands give the limits of the solution volume along each axis and the element dimensions in the foundation mesh. Note there are two entries for the  $z$  axis to define regions of different element sizes.

The remaining command groups set the geometries of parts and regions. Some of the sections are simple:

```
Part 2
  Type Box
  Region 2
  Fab   10.000  10.000  1.500
  Shift 0.000  0.000  -0.750
  Surface Region 1
End
```

The section defines the oil tank wall as a box fabricated with lengths 10.0" in  $x$  and  $y$  and 1.5" in  $z$ . The box is constructed in the workshop (reference frame) and then shifted -0.75" in  $z$  to its proper position. The statement `Surface Region 1` indicates that all nodes on the boundary with Region 1 (the oil inside the tank) should be shifted to and clamped at the border of the box at  $z = 0.0$ .

You can also specify complex custom shapes. The following section describes the insulator. The part penetrates the tank wall and has a shaped protrusion in the oil region:

```
Part 3
  Type Turning
  L   -1.50  0.50  0.50  0.50
  A   0.50  0.50  1.25  1.25  0.50  1.25 S
  A   1.25  1.25  0.50  2.00  0.50  1.25 S
  L   0.50  2.00  0.00  2.00 SE
  L   0.00  2.00  0.00  1.00 SE
```

```

        L    0.00  1.00 -1.50  1.00
        L   -1.50  1.00 -1.50  0.50
End
Region 3
Fab    0.0  360.0
Surface Region 1 Edge
Surface Region 2 Edge
Coat 2 2
End

```

The lines beginning with *A* and *L* are a set of line and arc vectors that outline the insulator shape in *r-z* space (Fig. 1.5). The outline is rotated about the *z* axis of the reference frame from 0.0° to 360.0° to form a solid. The portion of the part outside the solution volume ( $x < 0.0$ ) is ignored – **MetaMesh** performs automatic clipping. After identifying elements of the foundation mesh that comprise the volume, **MetaMesh** works to shift nodes bordering on the tank (Region 2) and the oil (Region 1) to the specified surfaces.

The part that requires the most effort is the elbow on the high voltage lead. It is a turning with a circular cross-section that extends from 0.0° to 90.0°:

```

Part 6
Type Turning SideFit
  A    0.00  0.50  0.50  1.00  0.00  1.00
  A    0.50  1.00  0.00  1.50  0.00  1.00
  A    0.00  1.50 -0.50  1.00  0.00  1.00
  A   -0.50  1.00  0.00  0.50  0.00  1.00
End
Region 4
Fab    0.0  90.0
Shift  0.000  -1.000  1.000
Rotate 90.0  0.0  90.0 XYZ
Surface Region 1
End

```

The orientation (as fabricated in the reference frame) must be adjusted by two 90° rotations in *x* and *z*. The position must then be adjusted by shifts along *y* and *z*. In this case, we used the graphical capabilities of **MetaMesh** to situate the part correctly in a few tries.



**Table 1.1. Complete listing of the file WALKTHROUGH.MIN**

```

Global
* Region names
  RegName 1 TransformerOil
  RegName 2 OilTankWall
  RegName 3 Insulator
  RegName 4 HighVoltageLead
  XMesh
    0.000  5.000  0.125
  End
  YMesh
    -5.000  5.000  0.125
  End
  ZMesh
    -1.500  3.000  0.125
    3.000 10.000  0.500
  End
  AxisSmooth Z 5
End
* -----
Part 1
  Type Box
  Region 1
  Fab 10.000 10.000 20.000
End
* -----
Part 2
  Type Box
  Region 2
  Fab 10.000 10.000 1.500
  Shift 0.000 0.000 -0.750
  Surface Region 1
End
* -----
Part 3
  Type Turning
  L -1.500 0.500 0.500 0.500
  A 0.500 0.500 1.250 1.250 0.500 1.250 S
  A 1.250 1.250 0.500 2.000 0.500 1.250 S
  L 0.500 2.000 0.000 2.000 SE
  L 0.000 2.000 0.000 1.000 SE
  L 0.000 1.000 -1.500 1.000 S
  L -1.500 1.000 -1.500 0.500
  End
  Region 3
  Fab 0.0 360.0
  Surface Region 1 Edge
  Surface Region 2 Edge
  Coat 2 2
End

```

```

* -----
Part 4
  Type Cylinder
  Region 4
  Fab 0.500 2.50
  Shift 0.000 0.000 -0.250
  Surface Region 3 Edge
  Surface Region 1 Edge
End
* -----
Part 5
  Type Cylinder
  Region 4
  Fab 0.500 4.000
  Rotate 90.0 0.0 0.0
  Shift 0.000 -3.000 2.000
  Surface Region 1 Edge
End
* -----
Part 6
  Type Turning SideFit
  A 0.000 0.500 0.500 1.000 0.000 1.000 S
  A 0.500 1.000 0.000 1.500 0.000 1.000 S
  A 0.000 1.500 -0.500 1.000 0.000 1.000 S
  A -0.500 1.000 0.000 0.500 0.000 1.000 S
End
  Region 4
  Fab 0.0 90.0
  Shift 0.000 -1.000 1.000
  Rotate 90.0 0.0 90.0
  Surface Region 1
End
* -----
EndFile

```