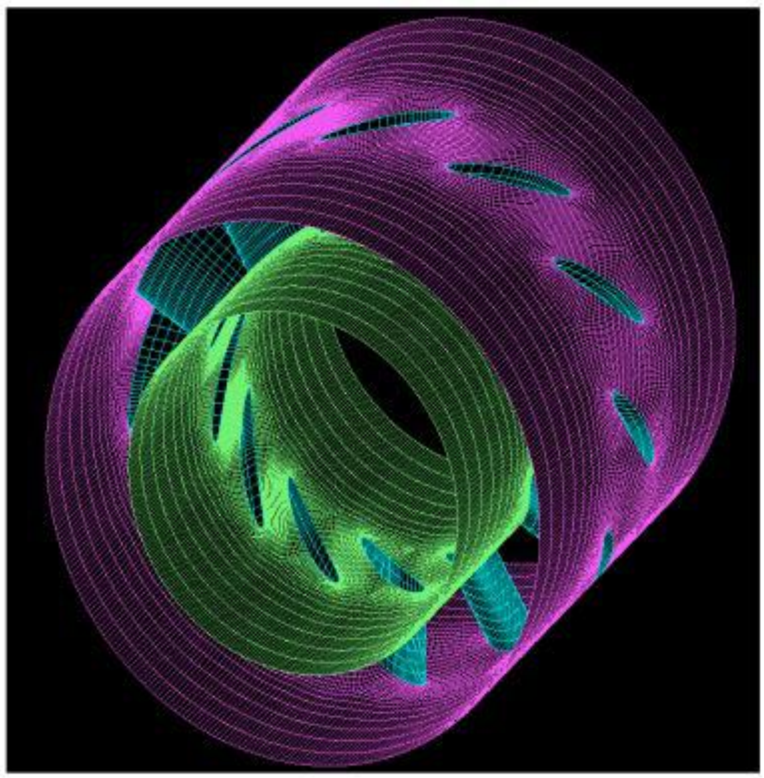
Tutorial 9.2: A Rotationally Periodic Turbine

What You Will Create



What You Will Learn

- Using the *x-polar* pseudo surface to representthe periodic boundaries of a rotationally symmetric object
- Creating cylinders in GridPro
- Duplicating and rotating the grid section to generate the complete grid

Step 1 Creating the Geometry

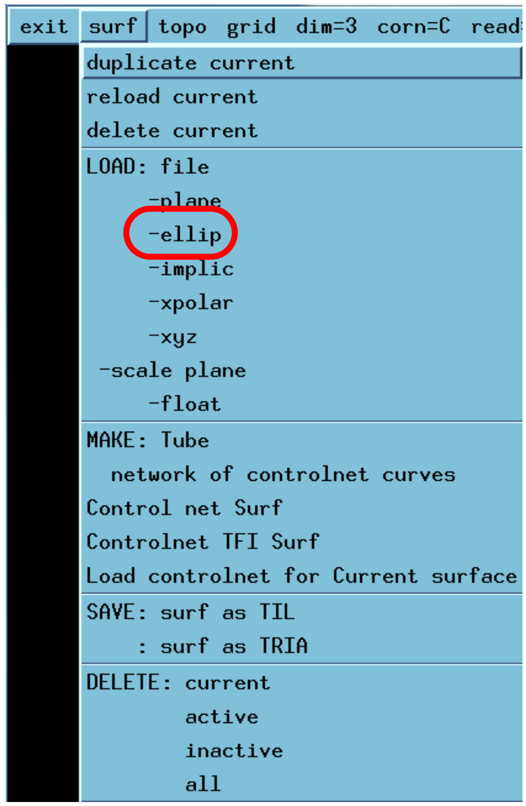
The geometry we are going to create consists of a hub, a shroud, a skewed cylinder which will be the turbine blade and 2 planes which will represent the axial ends of the turbine. Other than these physical surfaces, we will also be constructing a pseudo ***x-polar*** surface to represent the periodic boundary.

There are built-in surfaces in **GridPro**® to generate all these surfaces. Go to the **surf** menu and you can look at some of the surfaces you can import. Remember we had used the **load -file** operation to load the blade surface in Tutorial**_9.1**. Similarly you can use the **load -ellip** to load the cylinders.

Cylinders in GridPro

The Cylinder is a commonly used surface. **GridPro** interprets cylinders as ellipsoids with one infinitely long axis. To create a cylinder, simply access the **load-ellip** operation in the **surf** menu, and give one axis a very long length**.**

Run **az** to load the graphic manager. We will create the hub of the turbine first. Go to the **surf** menu and select **load -ellip**.

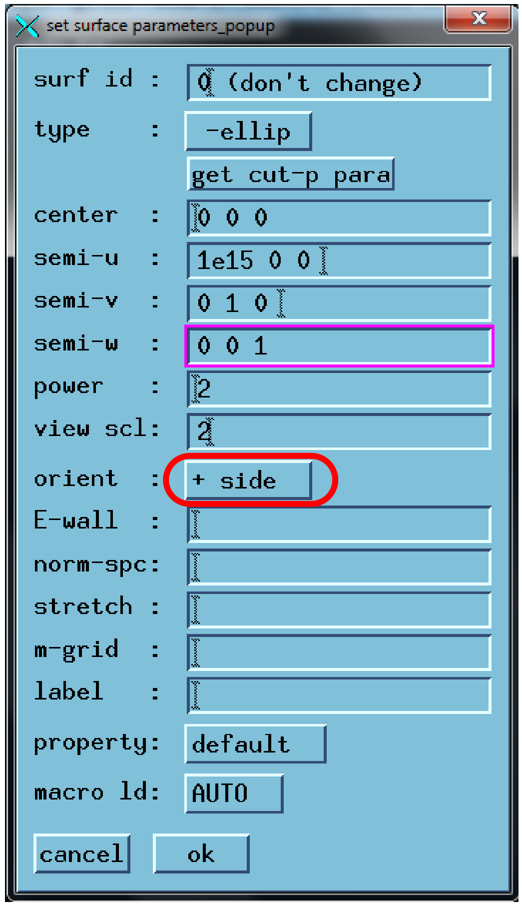


Enter the parameters as shown below and then press **OK** to make the cylinder. Remember to make the **orient** as **side with + ort**. This function ensures that the surface has the proper orientation.

Surface Orientation

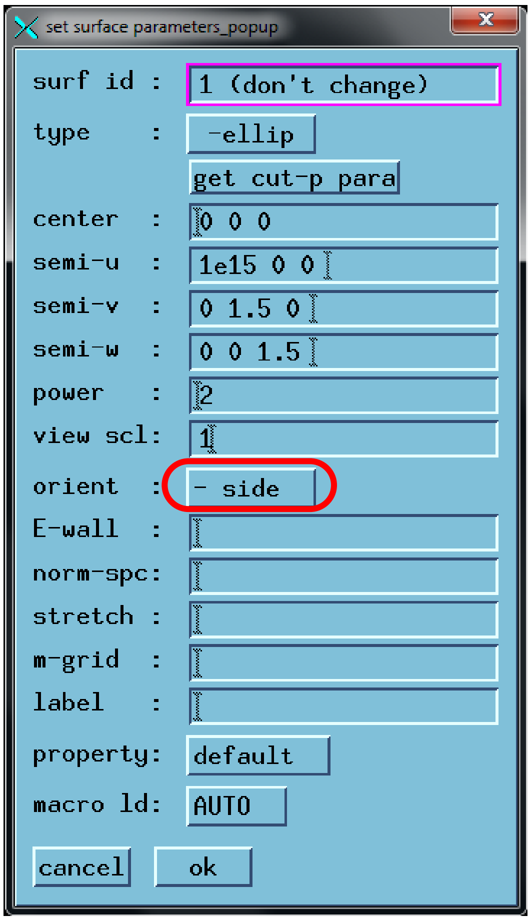
If you click on the button alongside the **orient**, you will see a pull down menu which gives you the choices you have for the different orientations you can assign to a surface. You had already used this feature in **Tutorial 4** when you assigned a two-sided orientation for the internal surface. The general need for orientation is to make sure that surface normal vectors point into the regions to be gridded. For internal surfaces it is on both sides and thus we have normals pointing to each of the two sides. For -ellip, the natural (our native selection) is for "+" to mean that normal points away from the super-elliptical center. However, when the topology is in place, it can be used in an automatic selection that will relieve the user from the need to choose between + and -.

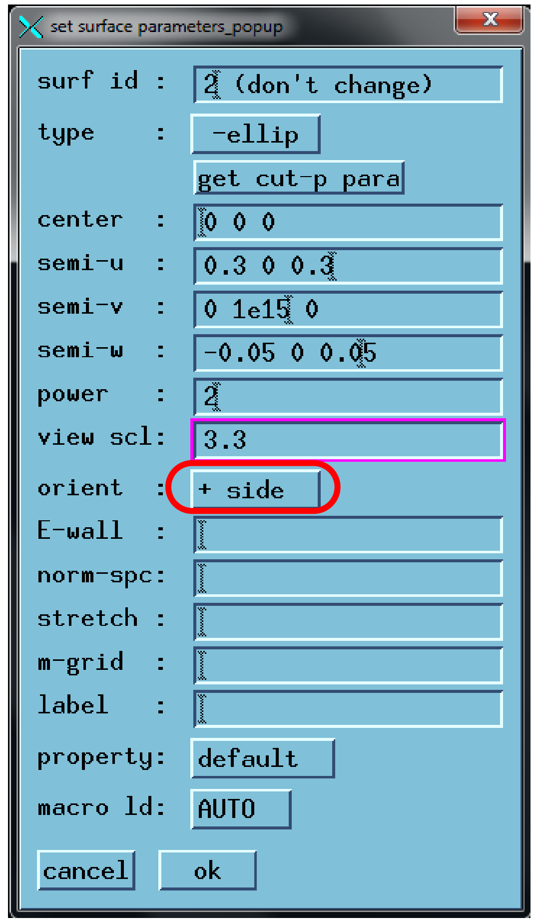
The Hub



Similarly, use the **load -ellip** option in the **surf** menu to create the shroud and the blade with the parameters given below.

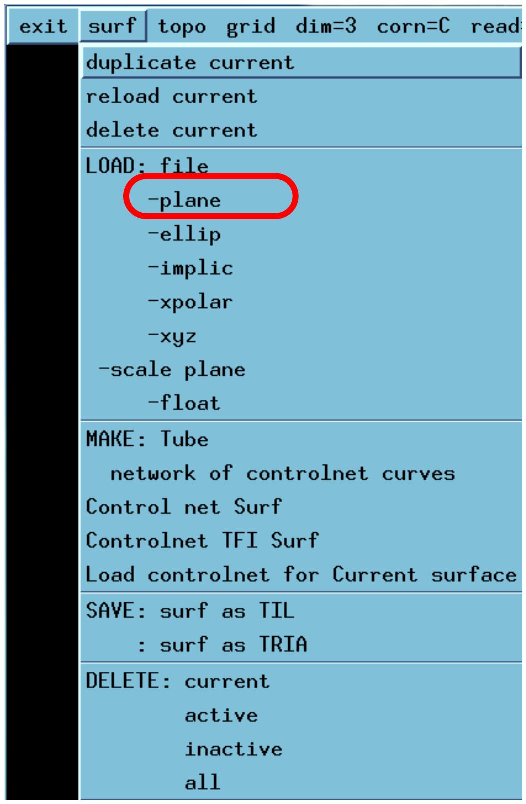
The Shroud **The Blade**





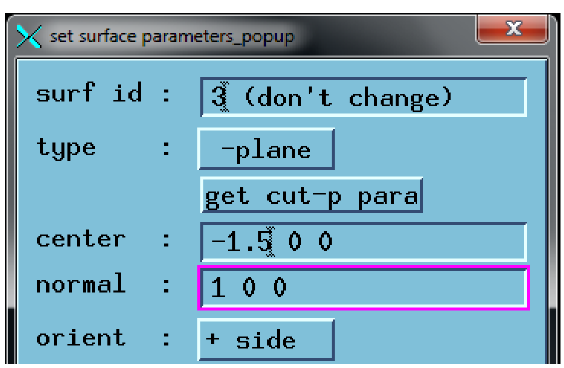
Remember to assign the surface orientations accordingly. Because we are gridding the region outside the hub and inside the shroud, we define the orientation of the hub to be positive and that of the shroud to be negative. The orientation of the blade surface is positive because we are gridding around the blade.

Similarly, use the **load -plane** operation in the **surf** menu to create the two planes.

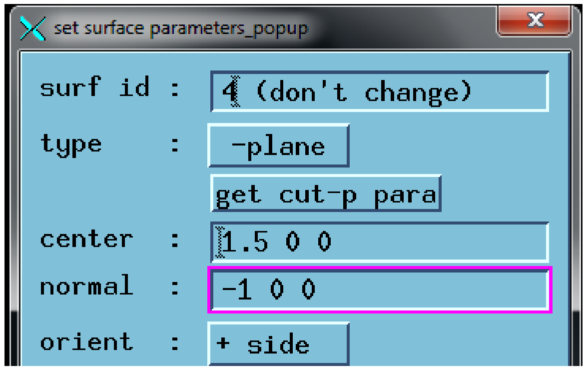


The planes are created as shown below. Use the default values for the other parameters.

The Left Plane



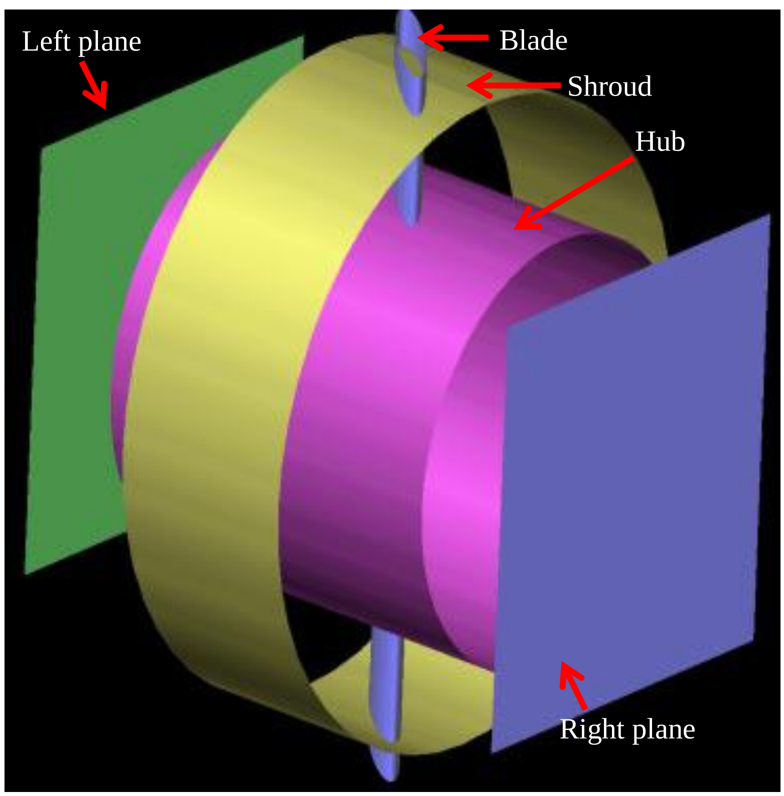
The Right Plane



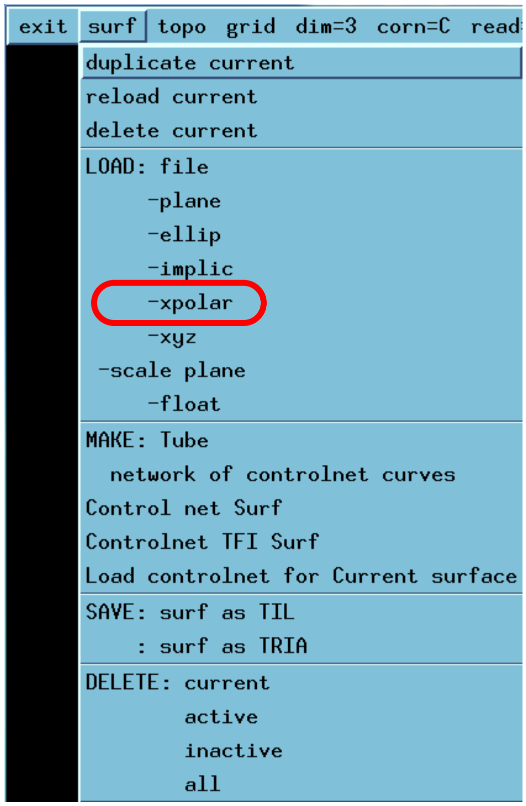
This creates two planes, each at a distance 1.5 from the origin. The normals are defined to account for the grid in between.

After this, you can look at the geometry to see what you have created. You should be able to see this in the window.

THE GEOMETRY



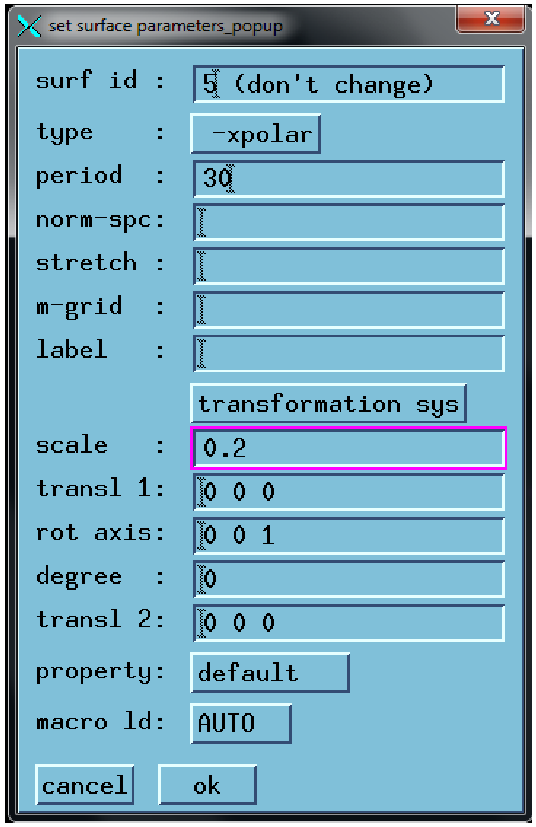
Now the periodic surface is going to have a period of 30 degrees. To make the periodic surface, go to the **surf** menu, and choose **load-xpolar**.



Assign a period of 30 and a scale of 0.2 to the xpolar surface as shown in the next figure.

Viewing the Xpolar Surface

The **xpolar surface**, unlike the XYZ periodic surface which is completely invisible, can be seen as a torus (or a doughnut if you wish). **GridPro** automatically displays a representation of the periodic axis, and this representation is a torus. The axis extending through the torus's center hole is the periodic axis. By default, this is the x-axis. This can be changed with the help of the trans-rotation properties in the **Set surface parameters_popup** window. We should keep in mind that the torus serves solely as a visual aid, and does not represent the physical properties of the surface. The torus can be scaled to any size.



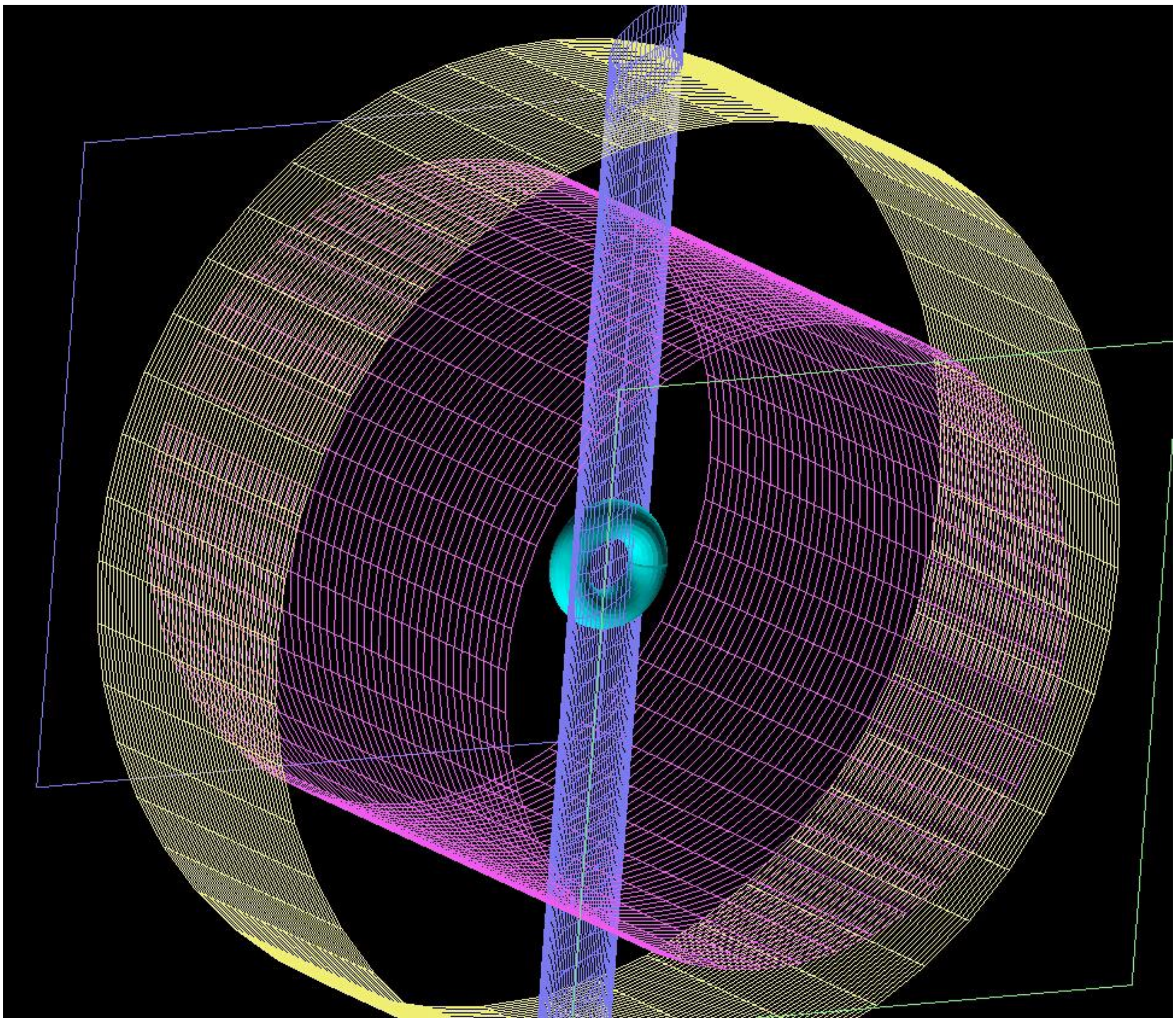
The Xpolar Surface

When to Create the Xpolar Surface

Generally, the **xpolar** surface is created first. The torus then serves as a guideline to the creation of the other surfaces, reminding us of the periodic axis. We have created the **xpolar** surface last in this particular example which allows you to understand the geometry first and then create the **xpolar** surface.

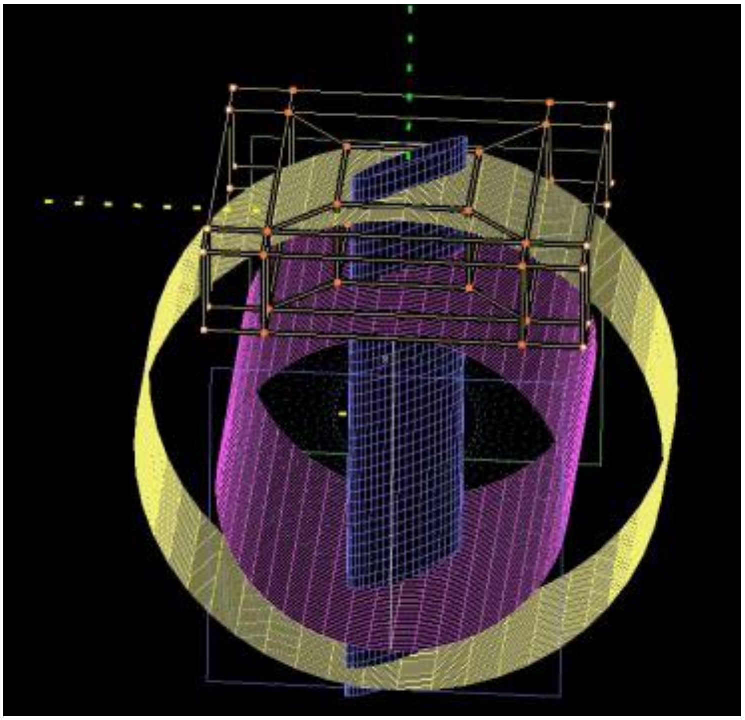
You have now created all the required surfaces. Look at the geometry to get a feel for the problem you are solving. Also, note the position of the torus. A view of the geometry is given below.

A View of the Geometry



Step 2 Creating the Topology

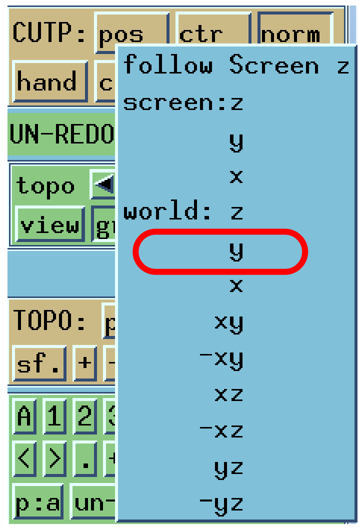
You have to create a wireframe topology around the blade to grid the section. Just to give you an idea of the type of topology you have to create, here is a picture of what the final topology looks like.



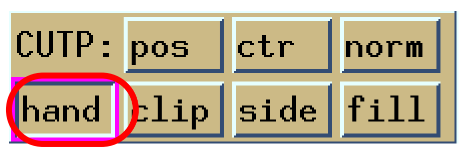
You will be using the cut-plane to generate the topology. The cutplane as we had seen in **Tutorial 3.2** is a very useful tool for creating topologies in three-dimensions.

To begin, start by turning on the cut-plane if you had turned it off. You can turn on the cut-plane by pushing the **cutp** button in the **SHOW** panel.

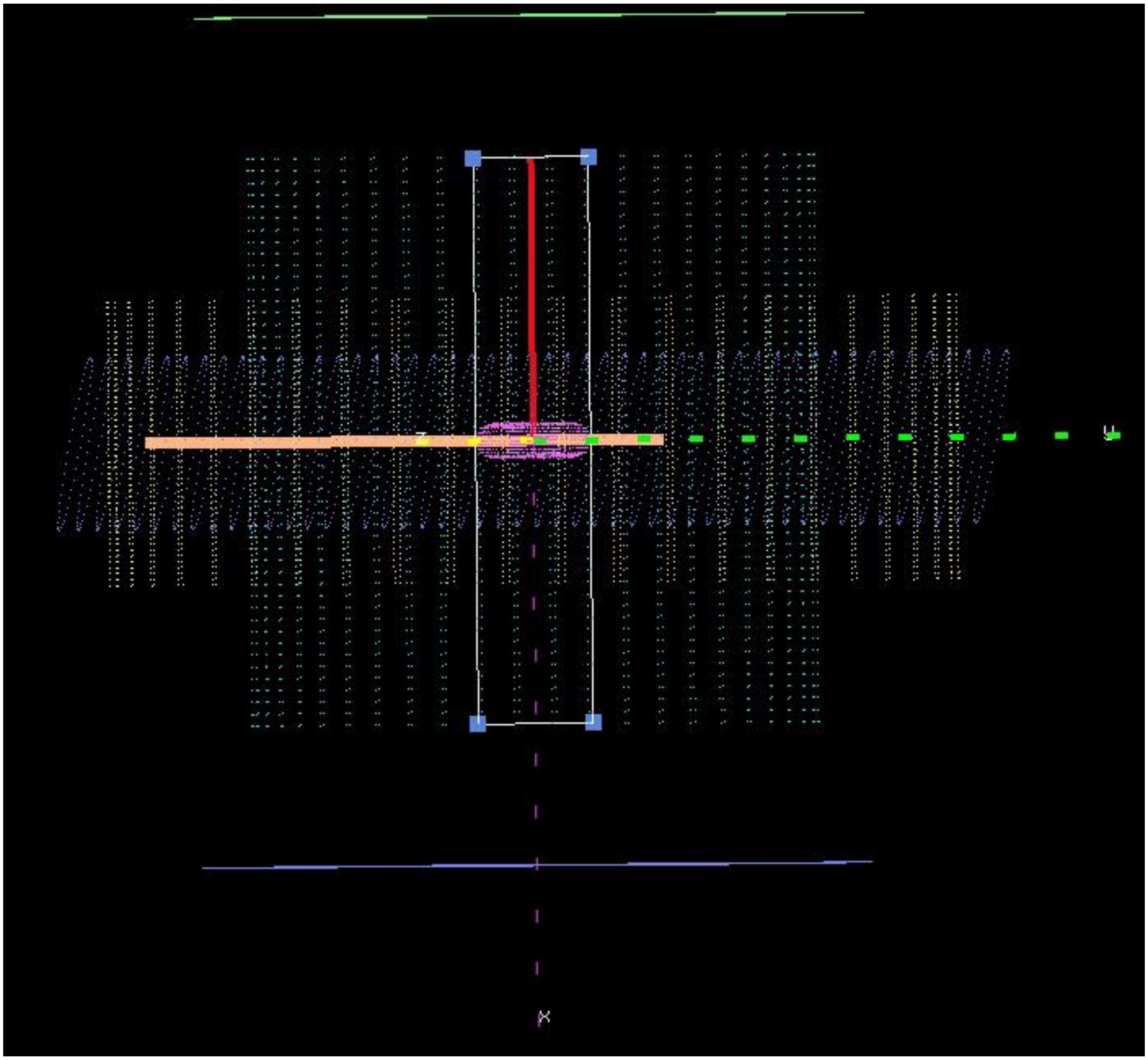
First, orient the cut-plane such that the normal of the cut-plane is parallel to the world: y. For this, use the pull down button **norm** in the **CUTP** panel and select **world: y** as shown below.



Also, turn on the cut-plane axis by pushing the **hand** button in the CUTP panel axis.

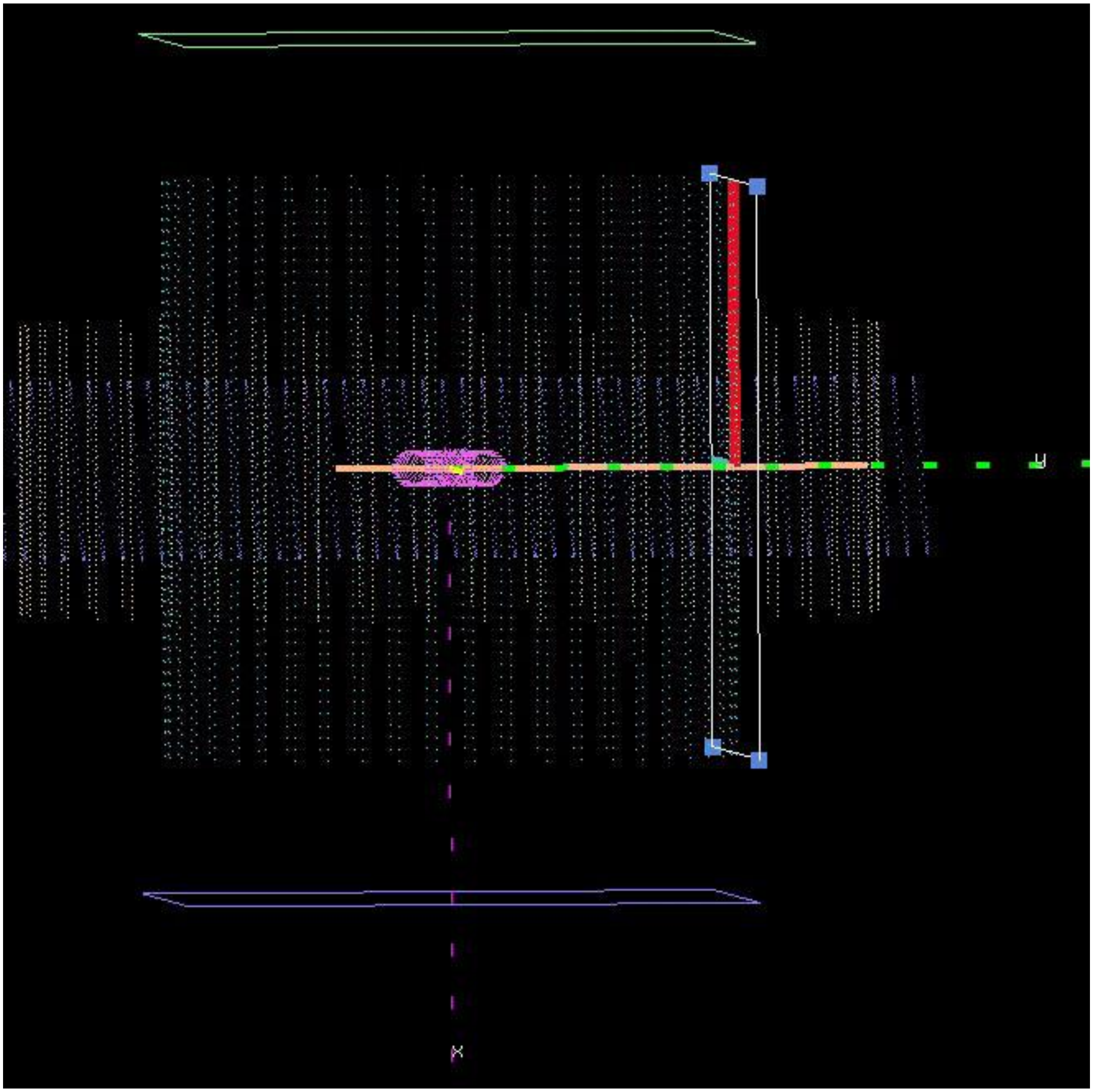


Now, you should be able to see the cut-plane axis. Snap the whole geometry to the XY plane. In this view, the cut-plane is just a line. Rotate the geometry slightly to have better look at the cut-plane. A view of what it might look like is shown below.



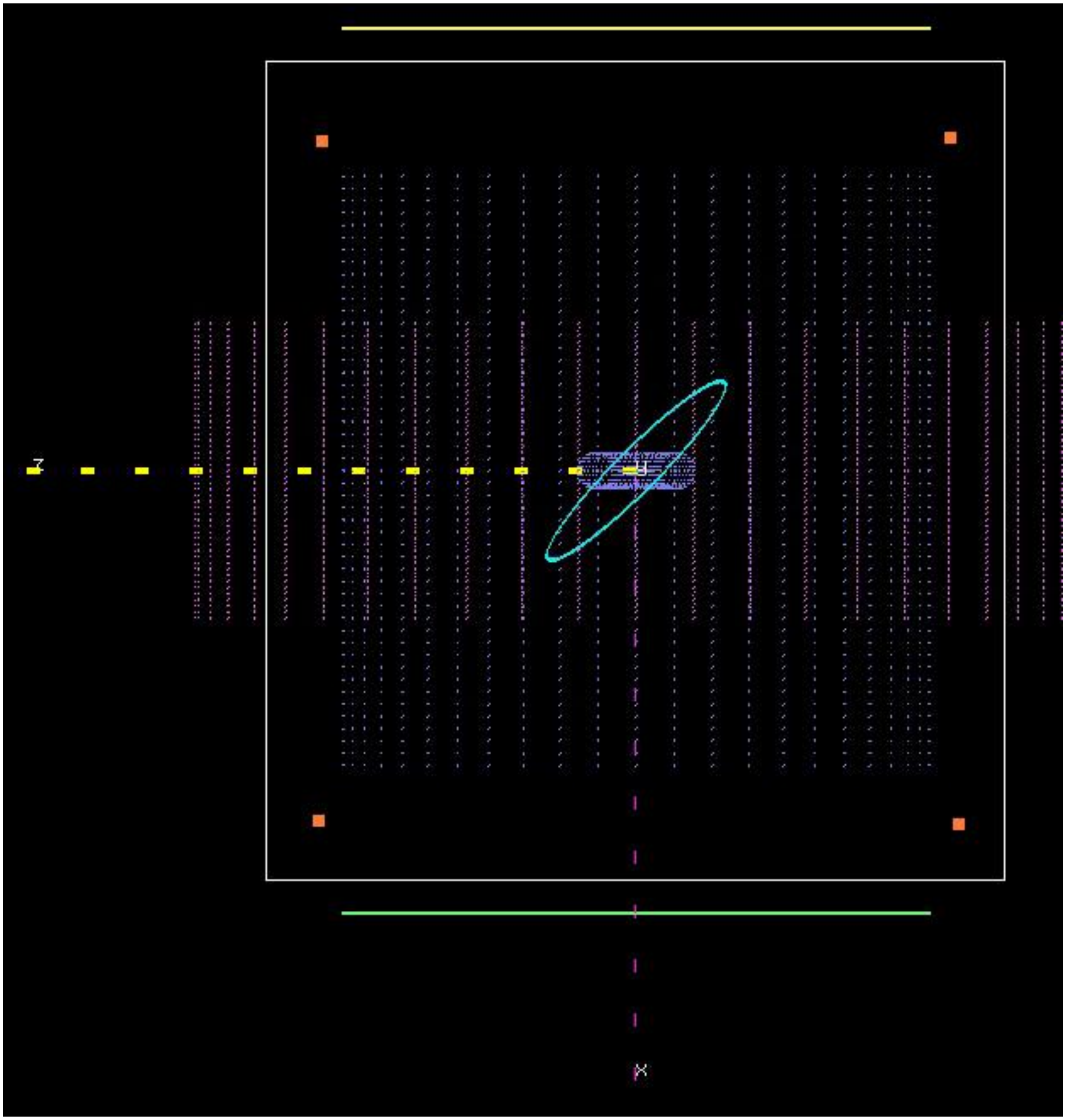
The style of all the surfaces has been set to **points** for a better view of the cut-plane.

Let’s create the inside face of the topology block first. Move the cut-plane by pulling on the brown axis of the cut-plane. Position the cut-plane so that it cuts through a small portion of the hub as shown in the figure below.

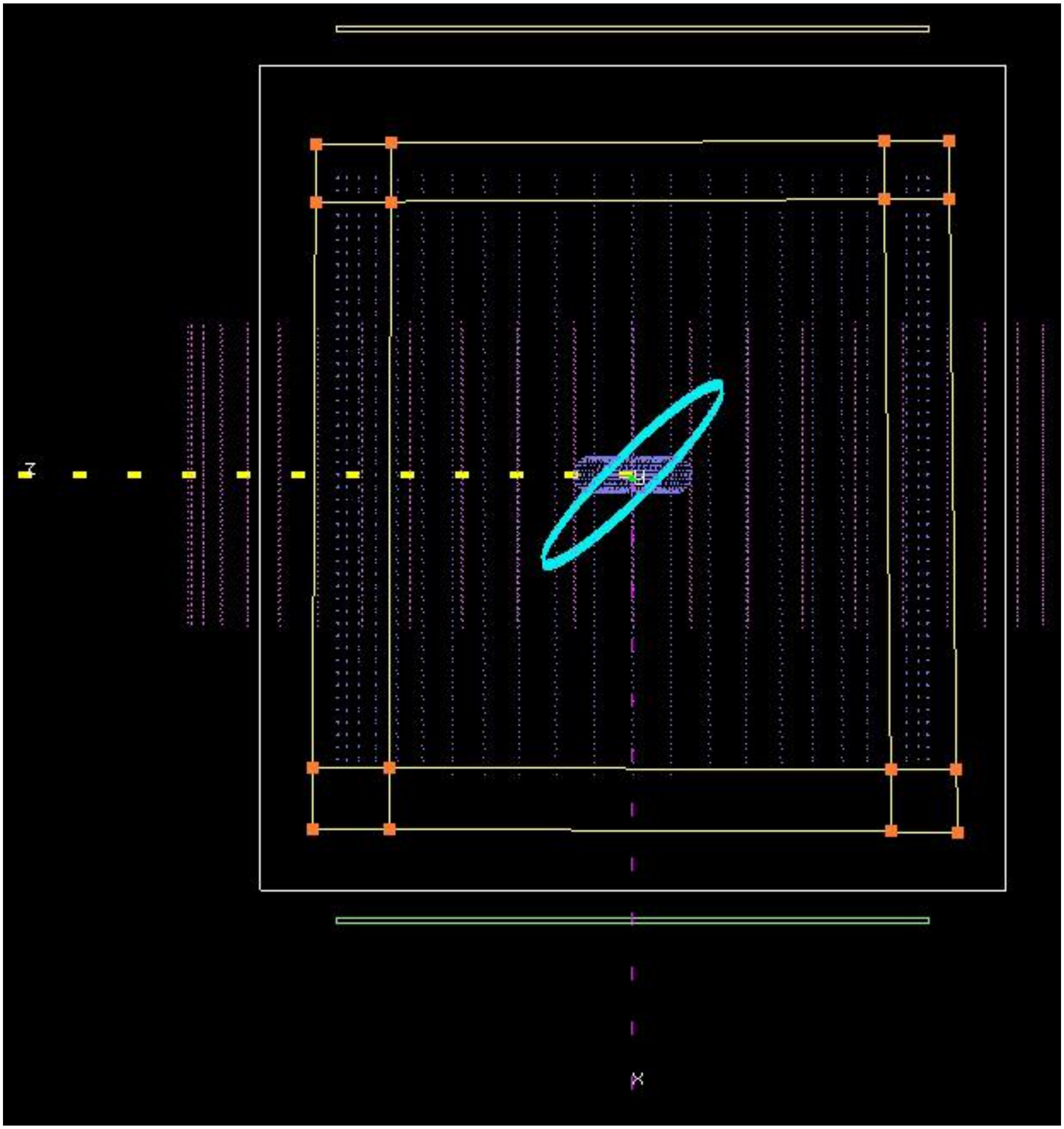


Again, I have rotated the view slightly to give a better view of the cut-plane. You have now positioned the cut-plane and you are ready to create the inside face of the topology. You can **turn off** the cutplane axis by pressing on the **hand** button in the **CUTP** panel. This is to make sure you do not move your cut-plane position again after you have set it.

Snap the view to the **XZ** position. Now, add four points around the blade by pressing **C** in the keyboard and left-clicking in the appropriate place. The four points should form a sufficiently big box around the blade.

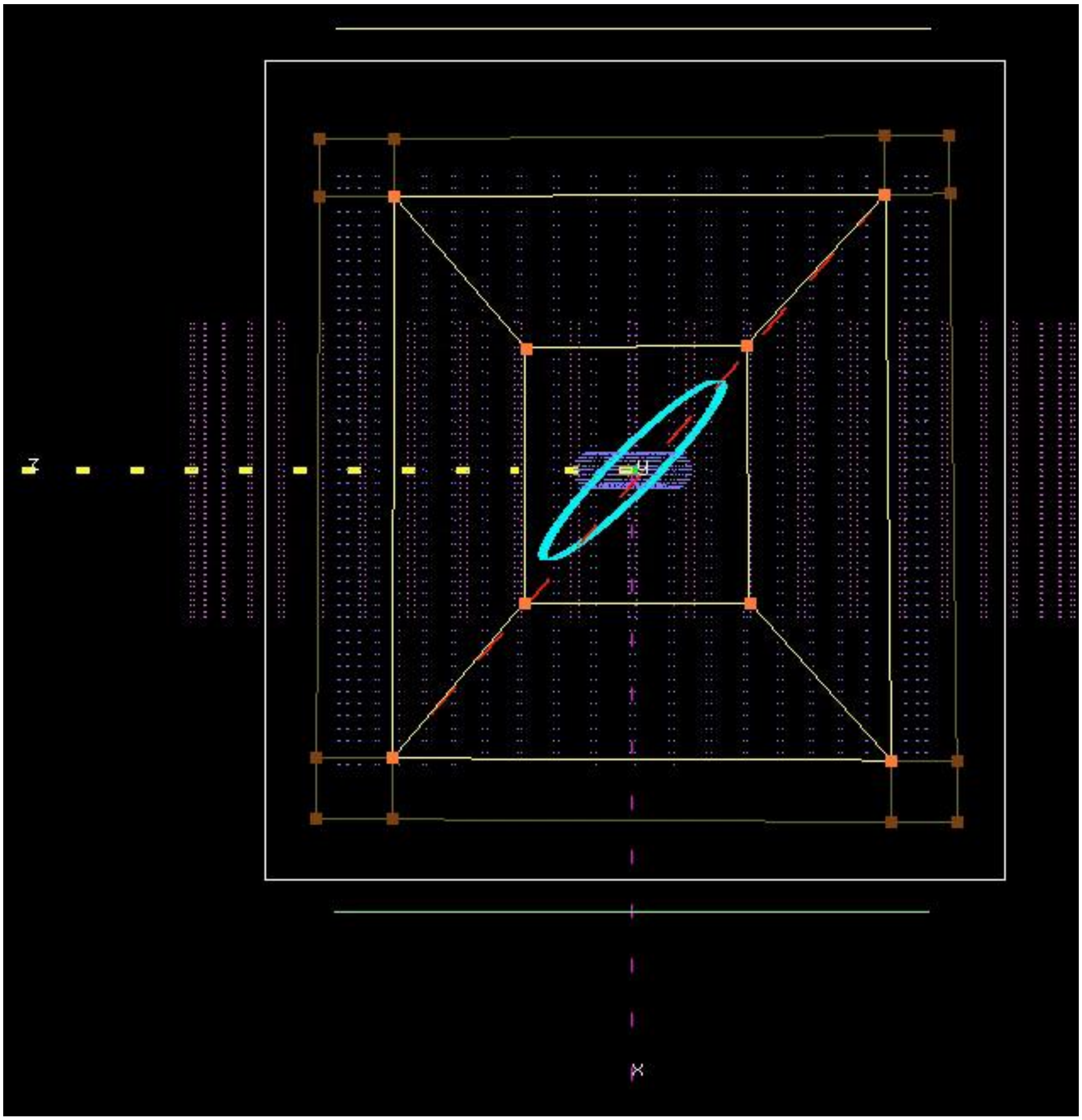


Now, link up the four points to form a box. This is done by pressing **E** in the keyboard and clicking on any two points you want to link. After you have formed a box, you are ready to create an inner topology around the blade and then wrap it. Create the inner topology by pressing **I** in the keyboard, and then inserting new corners in the edges such that a box is created around the blade as shown below.



After you have created this, add the inner topology to a group (group 2). Before you wrap the topology, you will have to exclude the face so that you do not create a three-dimensional counter volume over the face. This insures that the wrap stays in the face. It is done by pressing **F** in the keyboard and then clicking on any two diagonal corners in the face. After you have excluded the face you will see a red dotted line along that diagonal to show you that the face has been excluded.

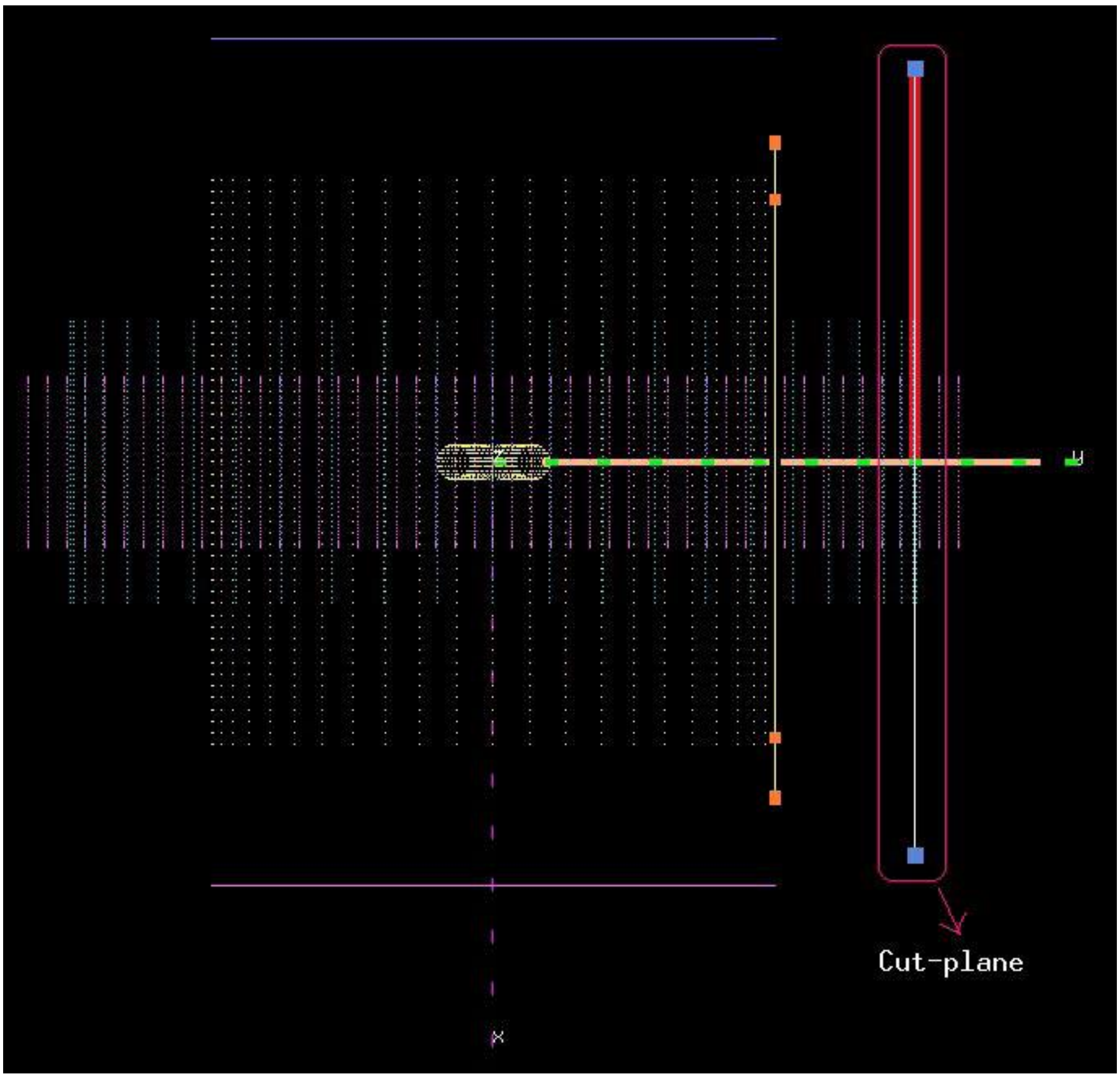
Now, wrap the group by 50% smaller. If the wrap is not a reasonable size, use the mouse to drag around the inner corners so that the inner corners just cover the blade. You should be able to make a topology that looks like this.



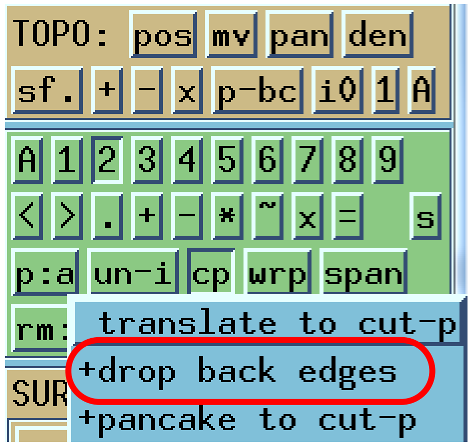
You can now un-exclude the face. If you keep the mouse pointer over the dotted red line, you will see a red X. Now, press **R** and left click the mouse. This will un-exclude the face. You should not be able to see any dotted red lines after you have unexcluded a face.Sometimes, you might have to move around the view slightly to refresh the view before you see this happen.

After this, you can rotate the view around and get a look at the topology you have created. Now, we need to create a duplicate of this near the shroud, and for this we will have to use the cut-plane again.

Rotate and snap the geometry to the **XY plane** again. You should be able to see the cut-plane near the hub, at the position where you had placed it. Turn on the **cut-plane axis** by pressing the **hand** button in the **CUTP** panel. To initail a group action, put the whole topology in group 2. To provide proper alignment, go to the **ctr** button in the **CUT-P** panel and select group. Now, move the **cut-plane** by dragging the brown colored cut-plane axis and position the **cut-plane** such that it just touches the outer edge of the shroud.



After you position the cut-plane, you will realize that you will have to create the same topology again in this face. You can use the **cp** button in the **TOPO** panel to do this. Press the **cp** button in the **TOPO** panel and select the **+ drop back edges** as shown below.



Now, you have created the entire topology needed for gridding. You might have noted that creating this topology was easier than creating the topology in some previous tutorials, even though this problem is considered to be more difficult to grid. This is because **GridPro**® automatically generates the periodic surface, doing most of the difficult work in this problem, and leaves you with the easier work of creating a rectilinear wireframe topology.

Step 3 Surface Assignments

After creating the topology, it's time for the surface assignments. We have six surfaces totally, including the periodic surface.

1) **The Blade** **:** The innermost box near the blade is assigned to the blade surface.

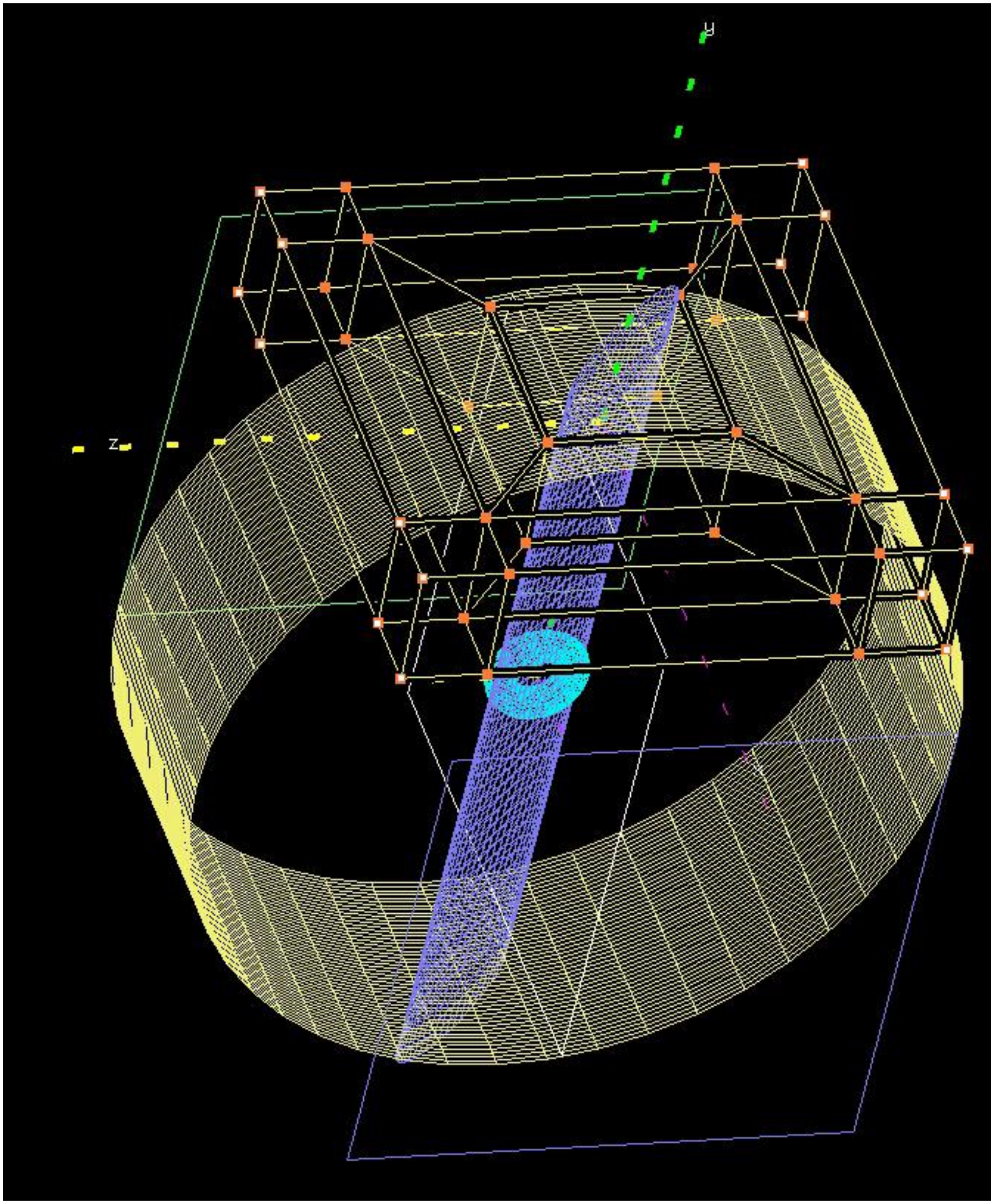
2) **The Hub** **:** All the points in the face near the hub are assigned to the hub.

3) **The Shroud** **:** All the points in the face near the shroud are assigned to the shroud surface.

4) **The Left Plane** **:** All the points in the left face of the topology are assigned to the left plane.

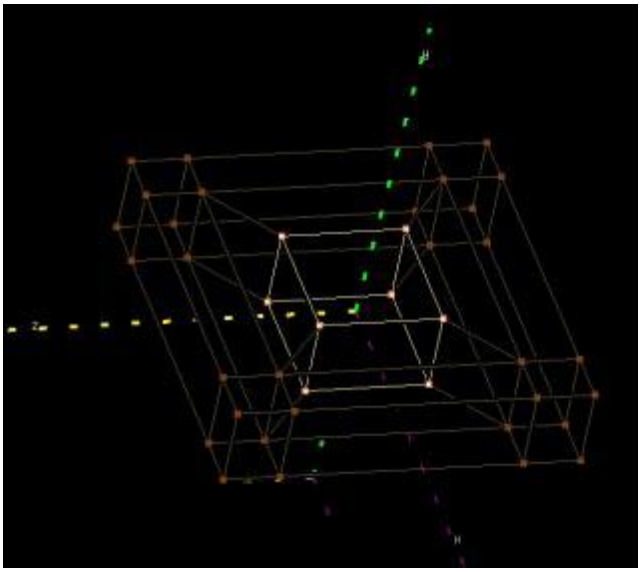
5) **The Right Plane:** All the points in the right face of the topology are assigned to the right plane.

6) **The Torus** **:** Remember that the torus is a representation of the periodic surface and that we assign the corners to periodic surfaces in pairs. Just like in **Tutorial_9.1**, we use the "**p-bc**" button in the **TOPO** menu to assign the surfaces.

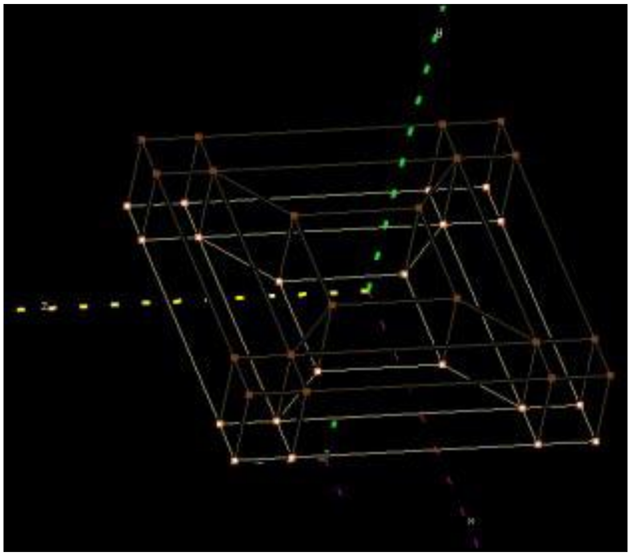


The above picture shows you the topology and surfaces which will allow you to understand where the points are. Only the topology (in the same orientation as in the previous picture) will be given in the pictures below to remove the clutter created by the surfaces.

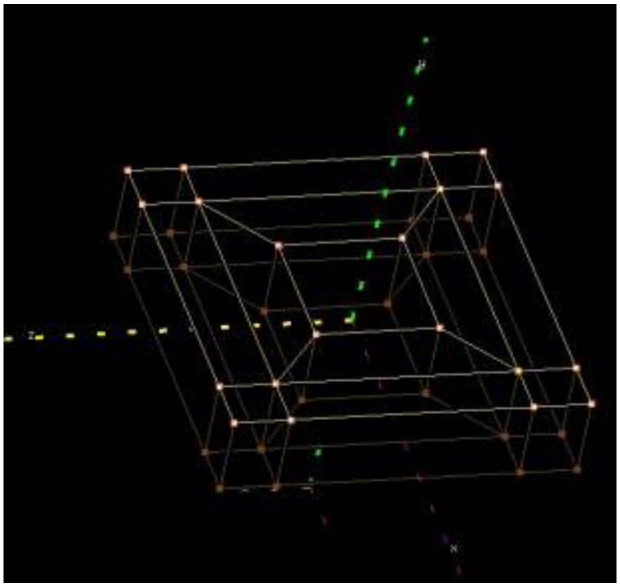
Surface Assignments for the Blade



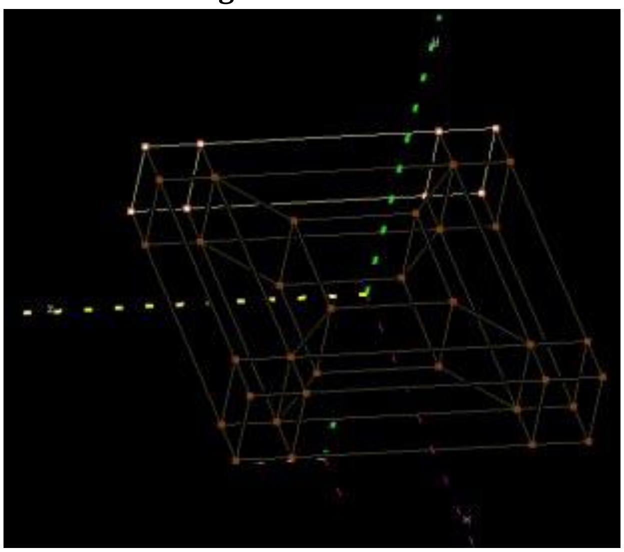
Surface Assignments for the Hub



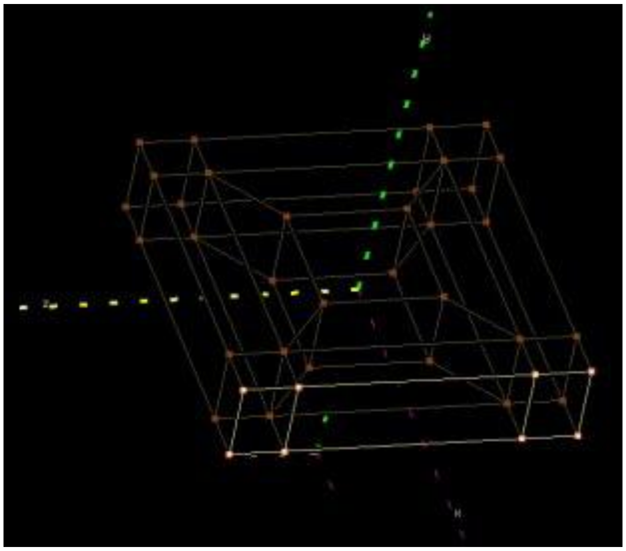
Surface Assignments for the Shroud



Surface Assignments for the Left Plane

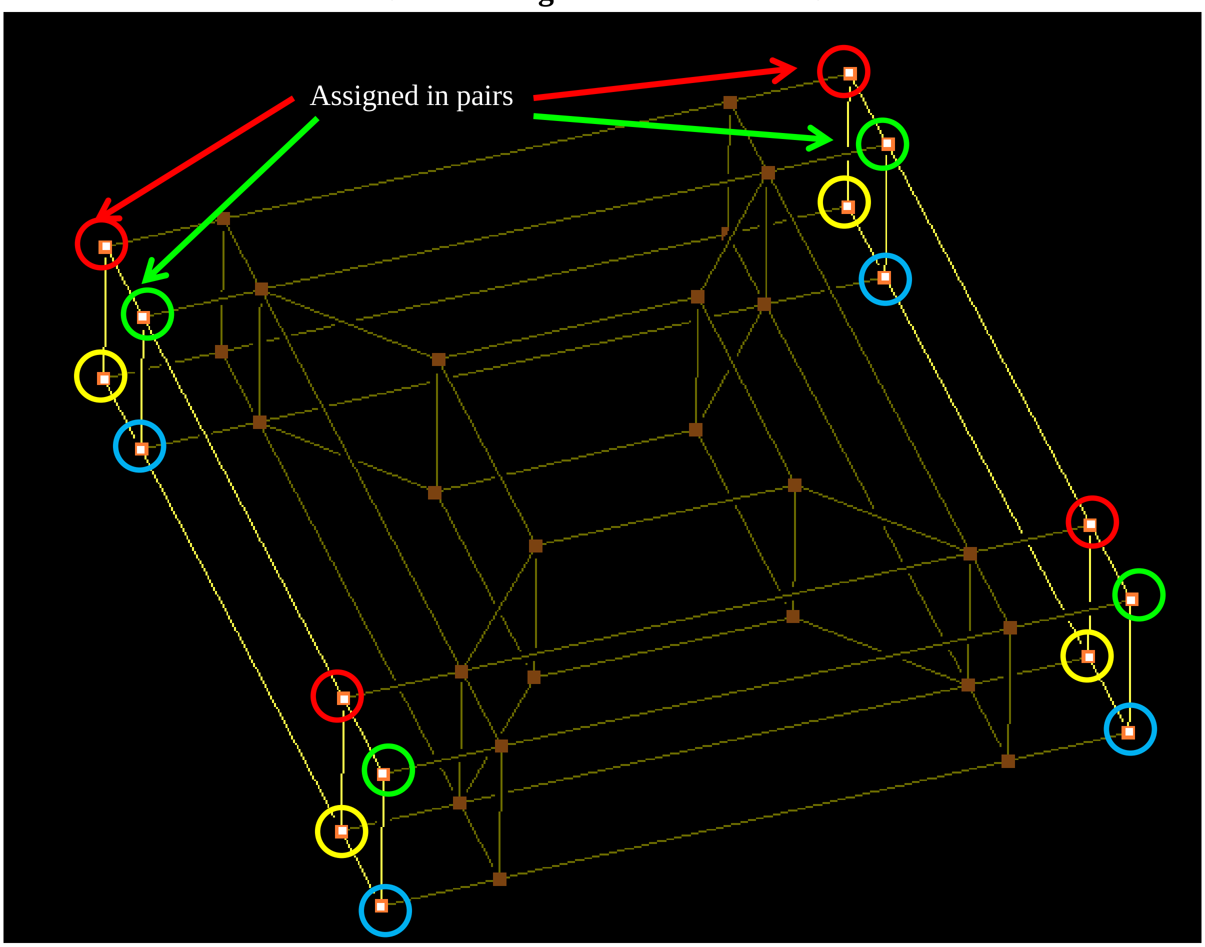


Surface Assignments for the Right Plane



Remember that we have to assign surfaces in pairs for the torus. In the picture given below, such pairs are circled using the same color so that you can easily identify and color the pairs.

Surface Assignments for the Torus



Remember to use the **p-bc** button in the **TOPO** panel to assign these corners to the torus. If you have any doubts about how to use this feature, refer to Tutorial**_9.1**, where we had assigned corners to an XYZ surface using the **p-bc**.

Now, you can start the gridding process. Well, almost. You still have one small thing to take care of-the Grid Density. By default, this is set to 8 for all the surfaces, and it turns out that this is not enough to generate a smooth grid for this case. You should change the grid densities in all edges to at least 16 before proceeding to generate the grid. This ensures you have a smooth and high quality grid. Also, you can set a norm-spacing parameter of 0.01 and a stretch of 1.2 by reloading the blade surface to get a clustered grid around the blade. Remember, you have used this technique in **Tutorial 2** to cluster the grid around a wing-body configuration. But this can also be done interactively, as you have seen in **Tutorial 2**.

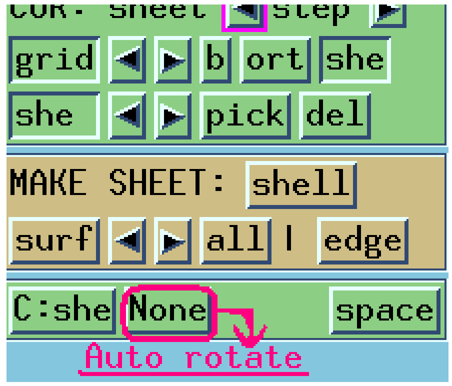
Step 4 Generating the Grid

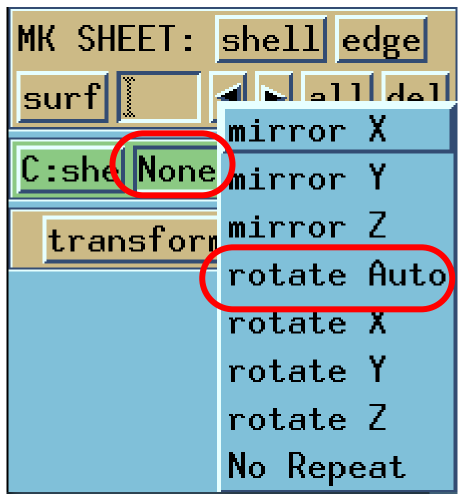
After you have done the things mentioned above, you are ready to generate the grid. Select **Ggrid: Start** from the **topo** pull down menu to generate the grid. Wait for a few minutes and then load the grid. Switch to the grid viewer to see the grid. You should be able to see the block structure. Play around with the grid viewer to get a good view of the grid.

Note that **GridPro** has automatically generated the periodic surface as shown below. Note that the periodic surface is curved. The grid is now ready to be rotated into a full turbine.

Unlike the previous case, where you had to use the **trf** command line utility to view the entire grid, you can view the entire grid in this case by using the **auto-rotate** feature in GridPro.

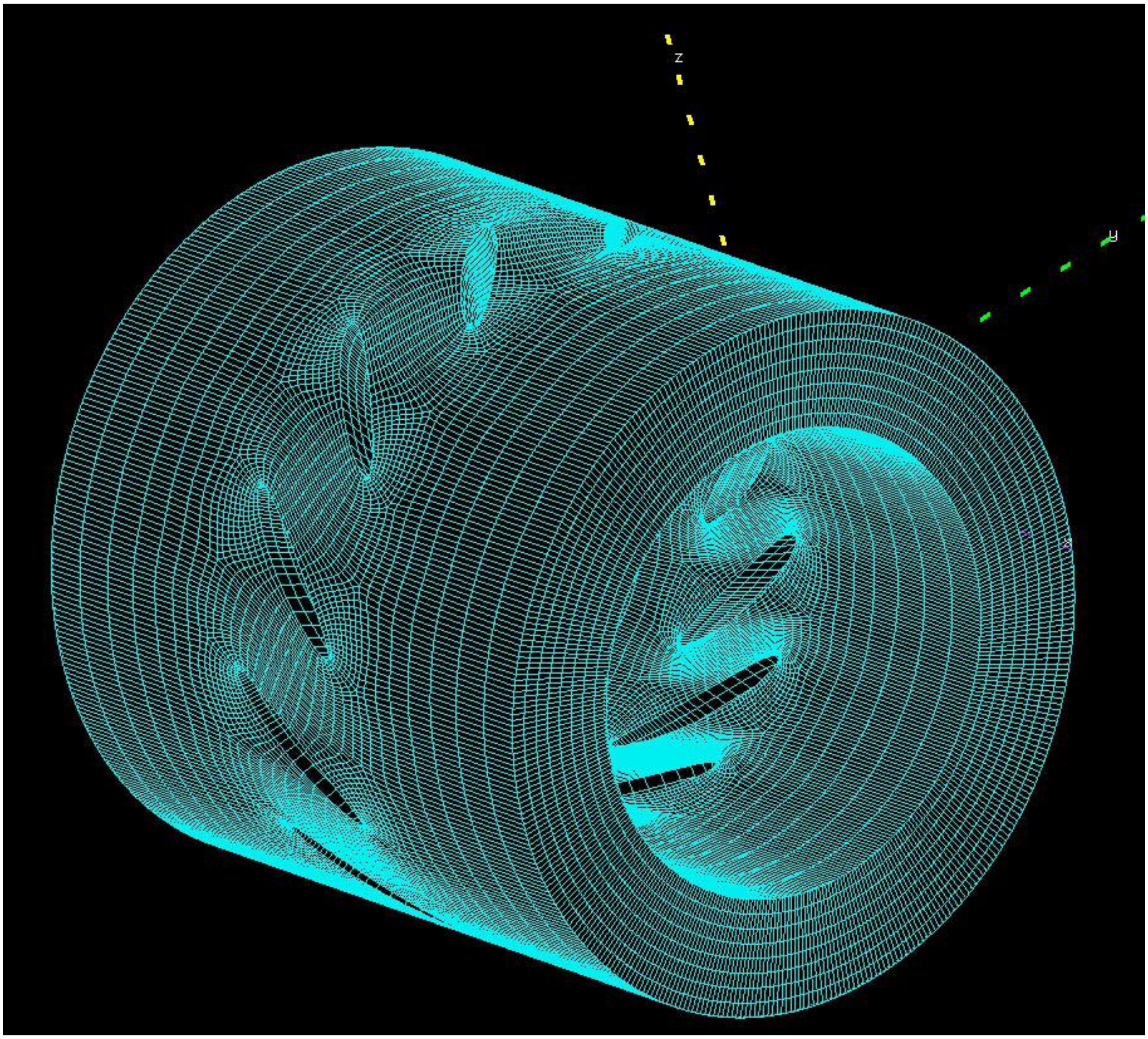
Notice the button that says **None** in the bottom-most panel for the Grid Viewer. It turns out that this is not nothing as you may have thought. It is a pull down menu, and it contains the **rotate –auto** option. Make sure that the shell is turned on if you want to see the entire grid. If you just have the blocks, you will not be able see the duplicated parts.



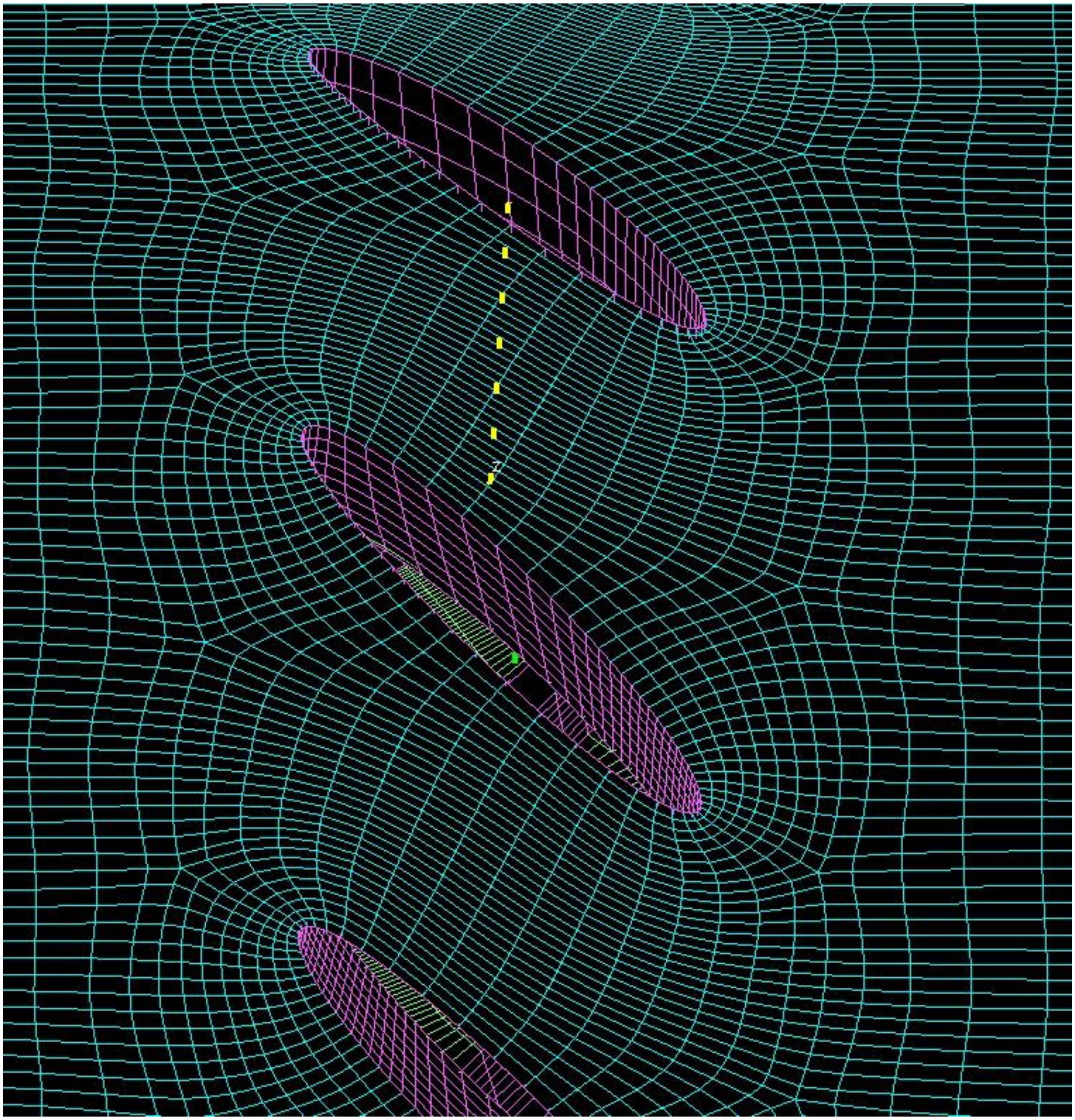


The section of the grid is rotated, duplicated and displayed. It should be mentioned here that this does not create a blk.tmp file with the entire grid. To do that, you will have to use the **trf** command line utility and rotate the grids.

You should be able to get a picture similar to the one in the next page. Now, play around with the grid. Try to use the **edge** feature to get the picture which is shown in the beginning of this tutorial.



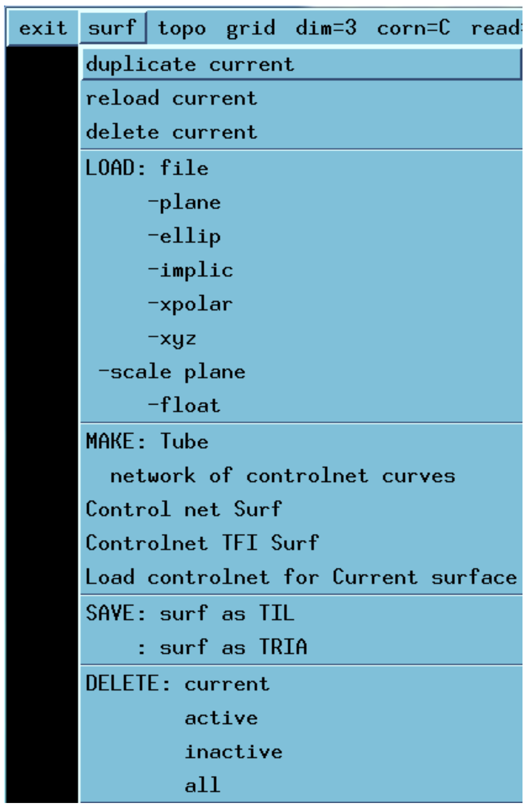
The Outer Shell



A Closer Look Near the Blades

Step 5 A Parametric Variation on the Blade Surface

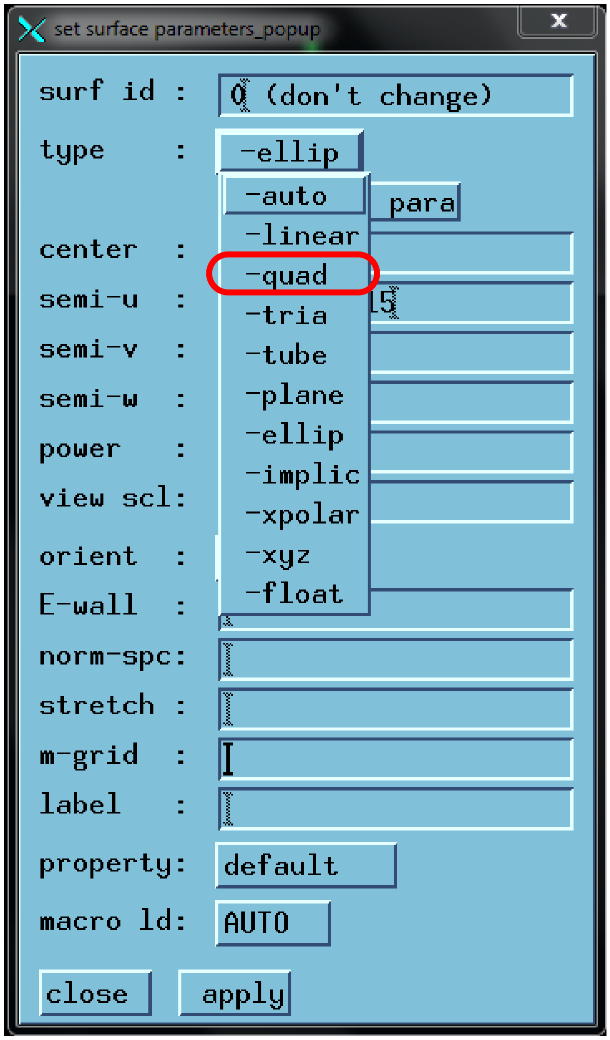
Now that you have the topology for this configuration, you can load it in different blade surfaces and grid them with the same topology. To start with, you can try loading the **blade.quad** file. To do this, make the blade surface the current one. Then, go to the **surf** pull down menu and select **reload current**.



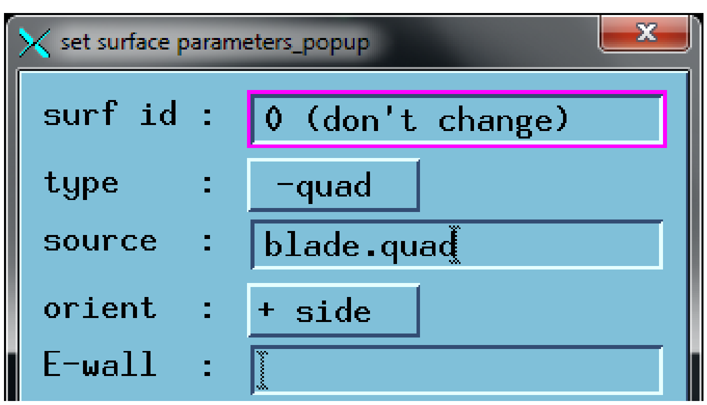
A window will pop up with the parameters of the present surface - the skewed cylinder. To replace the cylinder with the **blade.quad** surface, select the **-quad** button in the pull down menu as shown in the figure below. Type **blade.quad** as the source and Press **apply**. The blade surface will be reloaded

This surface resembles a turbine blade. You can use the same topology to grid this geometry too. Just start generating the grid and look at the results.

Select type *-quad*

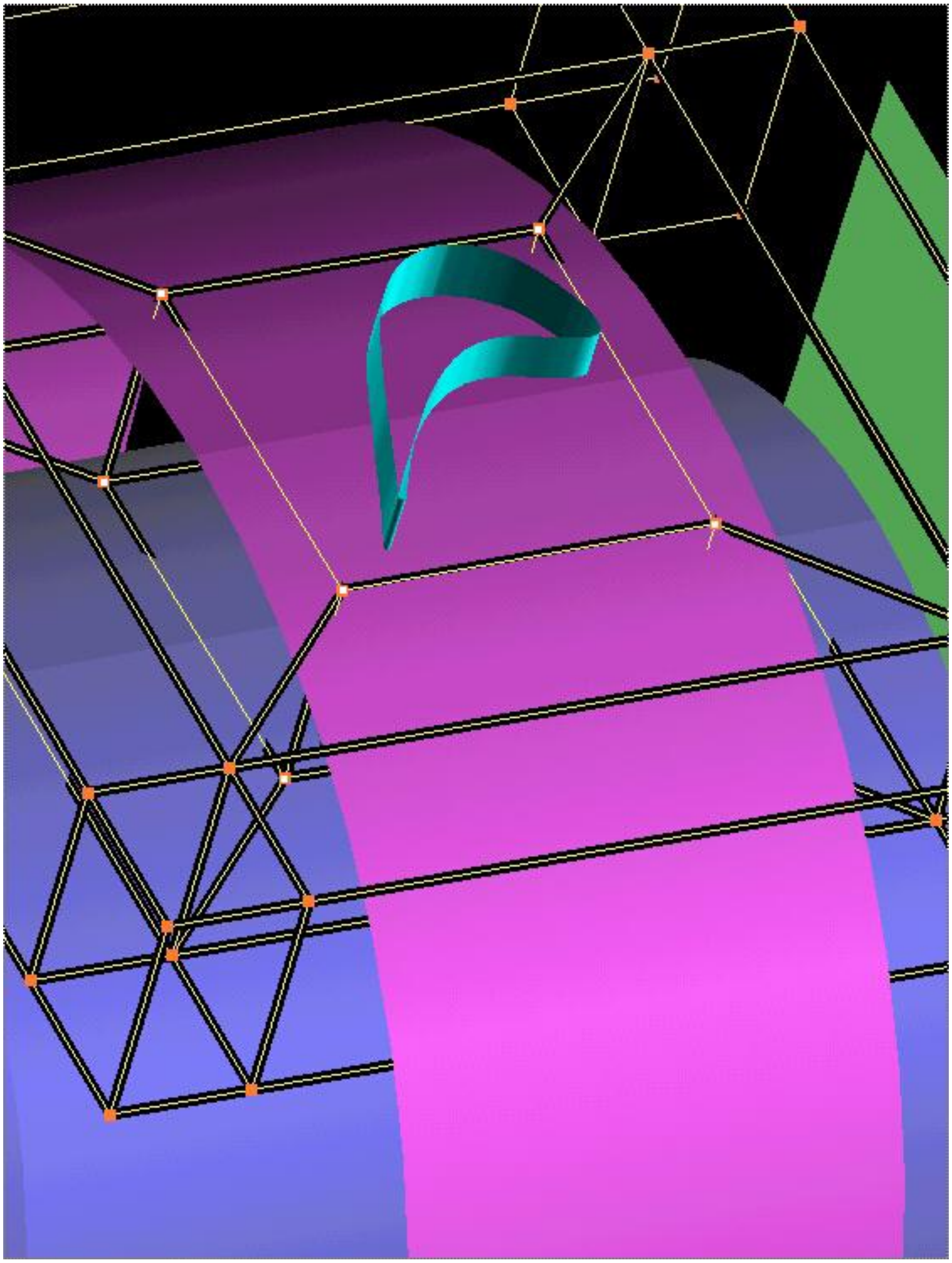


Enter filename at *source*

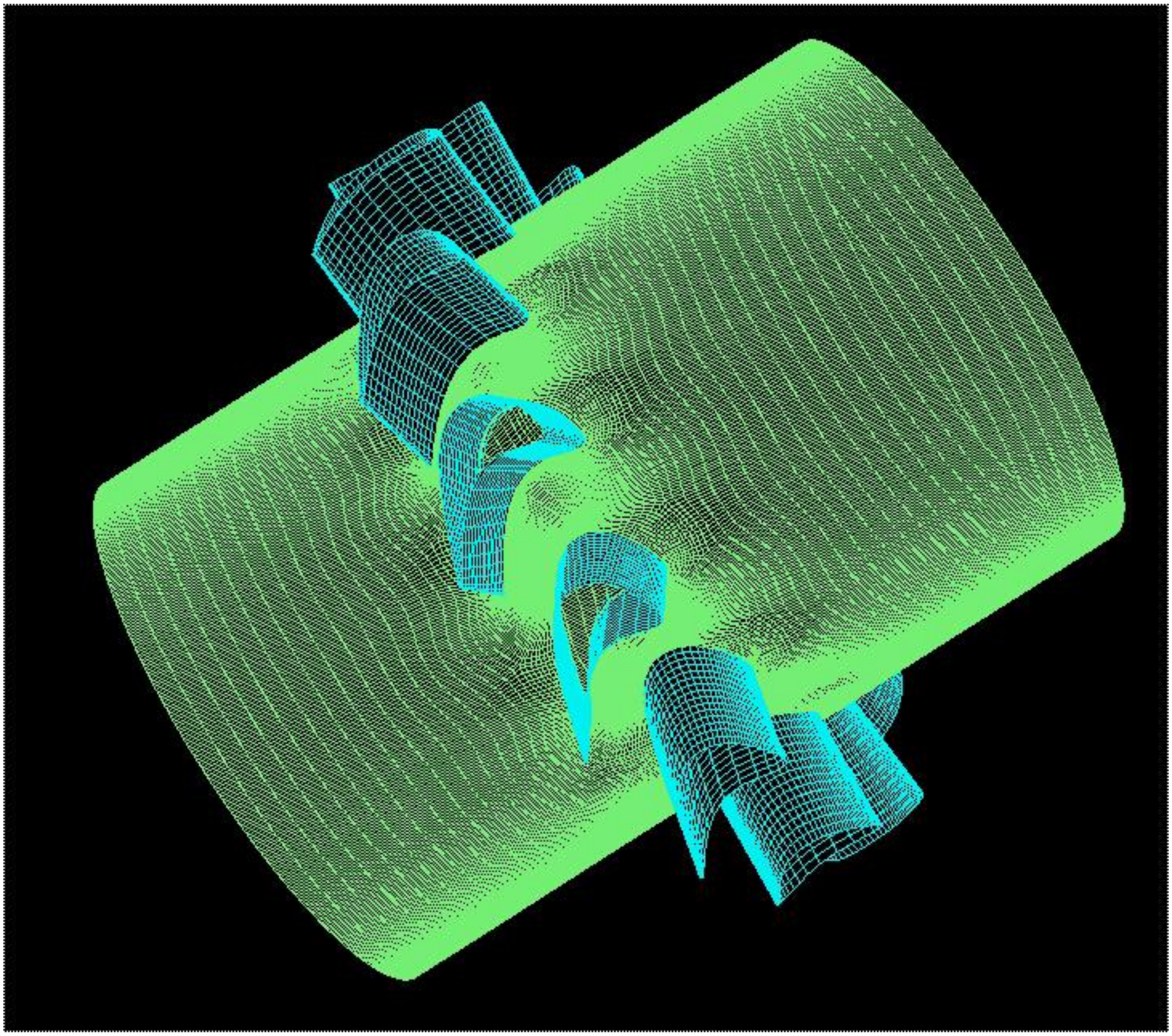


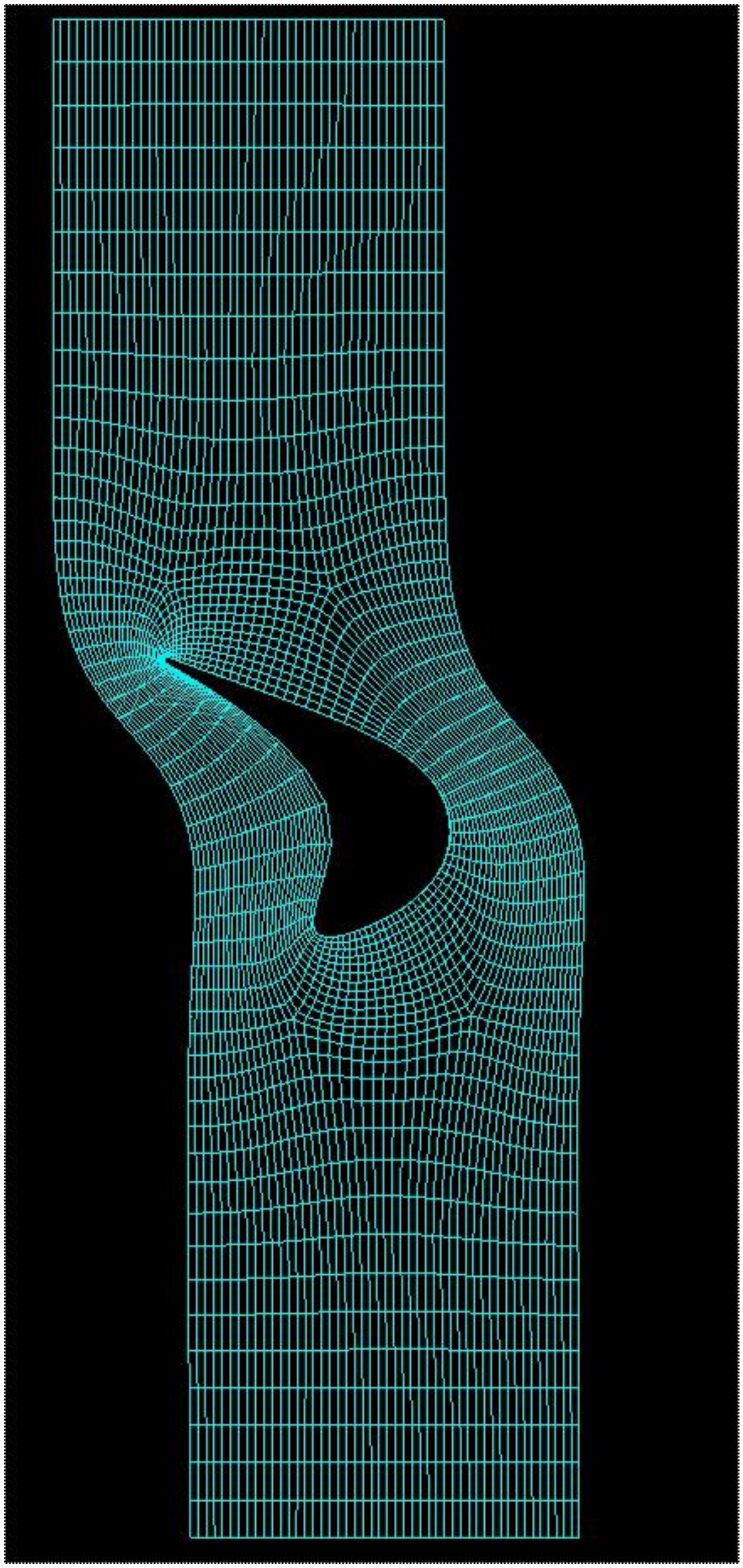
This example illustrates the power of **GridPro** for parametric variations. Once the topology has been constructed, you can make whatever changes you want to the surfaces, and just reload the surfaces to get a new grid for these surfaces.

The grid for the new blade surface is shown in the next few pages.

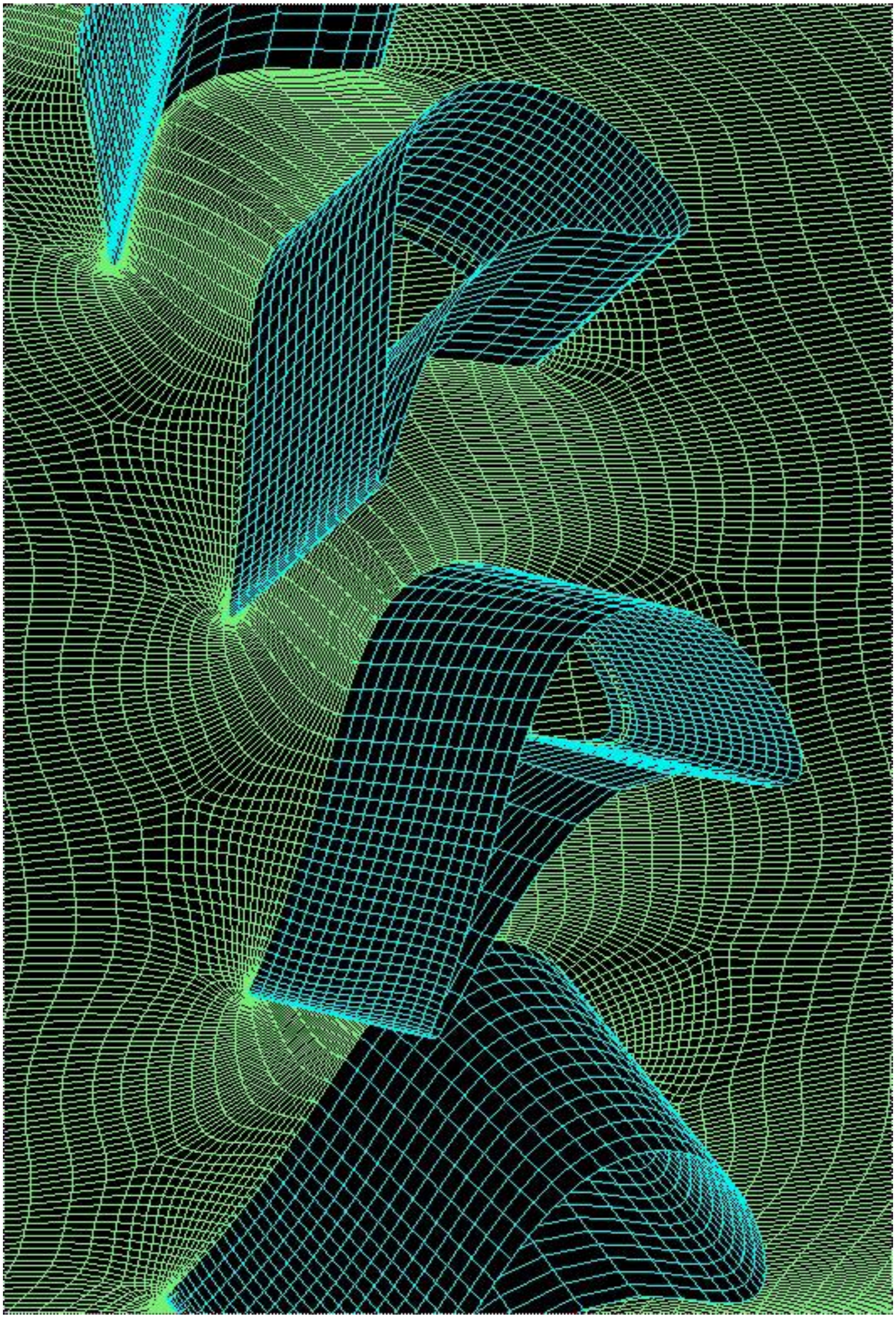


The New Blade Surface





The Periodic Boundary



A Closer Look near the Blade