Nest Tutorial: Using Automatic Nested Refinement

Nested Refinement is a unique adaptive refinement technique used to refine specific regions in the grid with cells of 1-1 connectivity. Nesting of topologies becomes useful when you handle geometries with features of different scale. This feature can be applied to topologies either manually or automatically. For automated nesting a feature called Nest was added to v4.2. It has been upgraded from then on and the new Nest feature has new flavors.

Application:

The application of Nest will be discussed here with a few cases:

1. An oil pipeline in large field.
2. A submarine with a sail.
3. Array of pipes.

The cases discussed here are representative, the feature can be used in all cases where there are geometries of different scales involved.

What does Nesting Do?

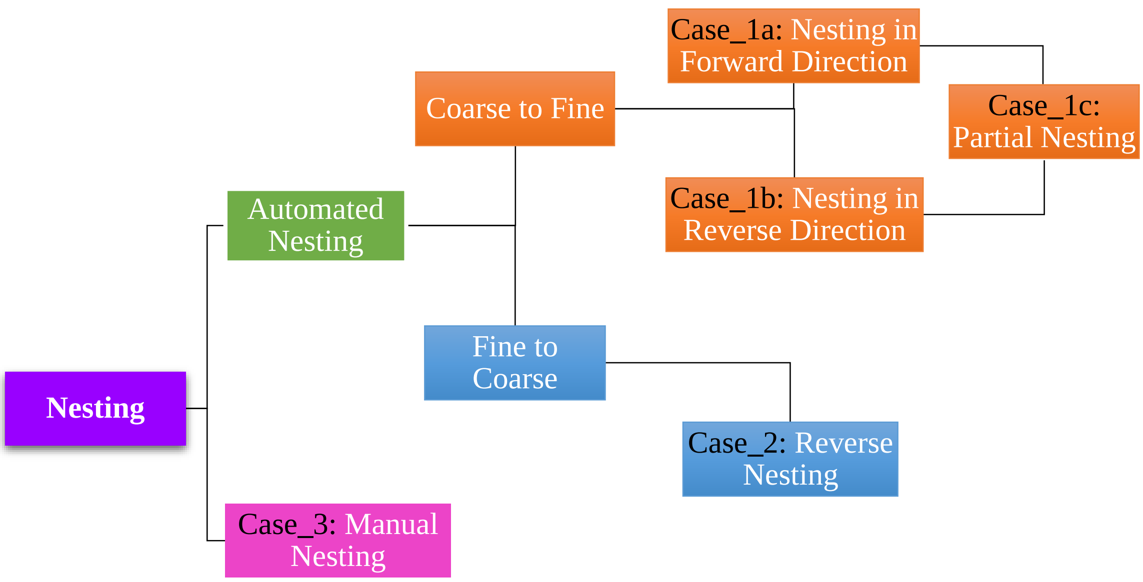
Conventional meshing techniques on geometries with scale differences create grids with large aspect ratio esp. near the smaller features. Improvement on the aspect ratio can be done by increasing the density throughout the geometry to capture the geometry of a smaller scale.

The refinement near the geometry is necessary, but limiting because refinement propagates to the farfield. This limitation can be overcome by using nesting.

Thus the powerful feature of nesting helps to increase number of grid points near the geometry of concentration locally, with one to one connectivity, without increasing the points elsewhere.

The nested structure loops back blocks near the geometry and in the defined region.

CLASSIFICATION OF NESTING



The classification in the above figure is based on automation in the first level and in the second and third levels it is done based on refinement and direction of refinement.

Case 1a: FORWARD NESTING

A pipe with a small radius is considered in a large field.

Loading an Initial Topology File

- The case files can be found in the 'GridPro' Installation directory. The path is mentioned below GridPro/doc/Tutorials/Utility_Tutorials/Nest/Case_1a.
- The Nest folder can be copied to either the Documents or any other convenient location to avoid directory permission errors.
- Load file 'step1_for_nest.fra' into AZ.

Step1_for_nest.fra is a topologically complete with all the surfaces assigned to the respective surfaces. The case file consists of a pipe with a radius of 5 units while the dimensions of the outer domain 24000 x 24000 x 200.

Zoom in the geometry to have a better view.

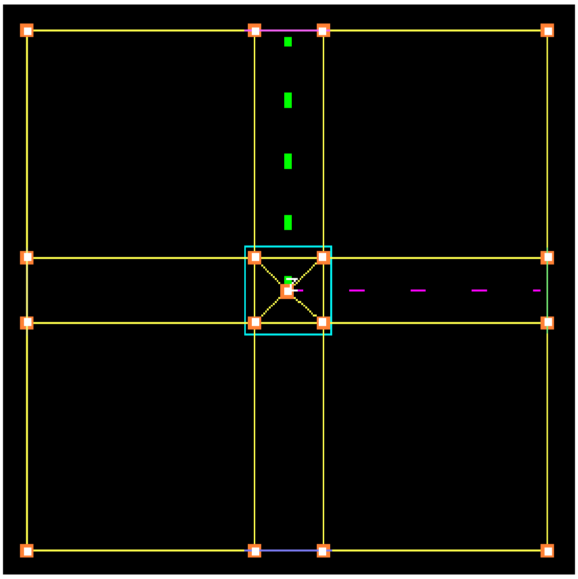


Figure 1

Start the Gridding Process

The topology provided is meshed by running Ggrid to analyse. The topology shown in fig 1, describes the conventional approach used.

- Select `Ggrid: start` from the `topo` pull down menu bar to start the gridding process.
- Click on 'OK' to start the gridding process.
- Switch to Grid Viewer Panel.
- Load the blk.tmp file and click on shell to view the grid.

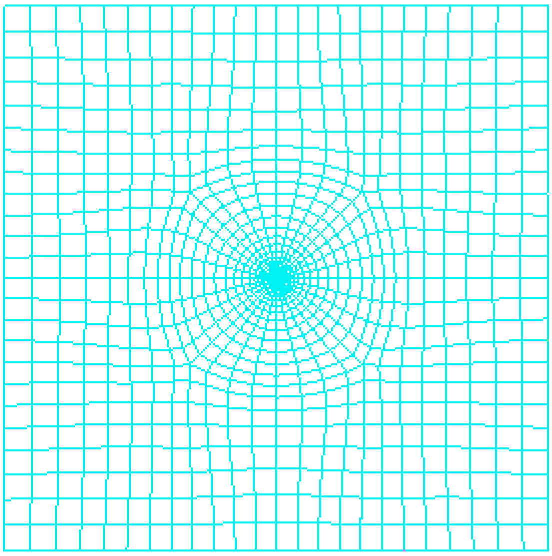


Figure 2

Select two perpendicular sheets, one along the axis of the pipe and the other along the cross section of the pipe using edge option.

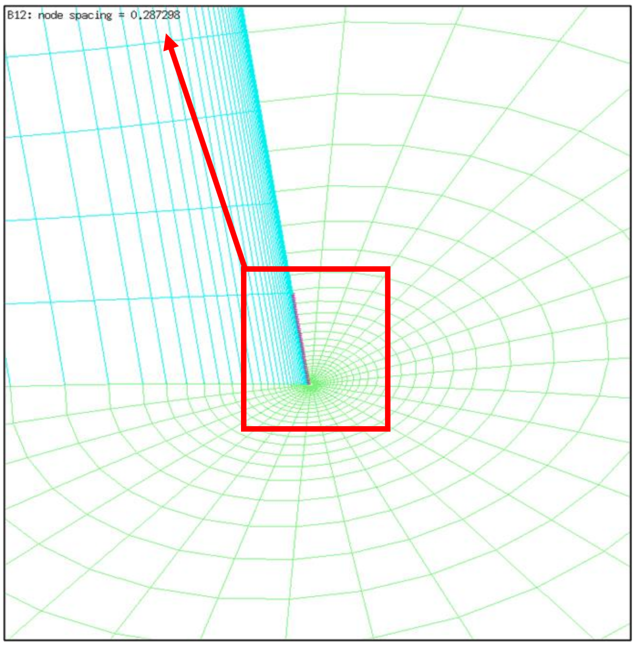


Figure 3.1

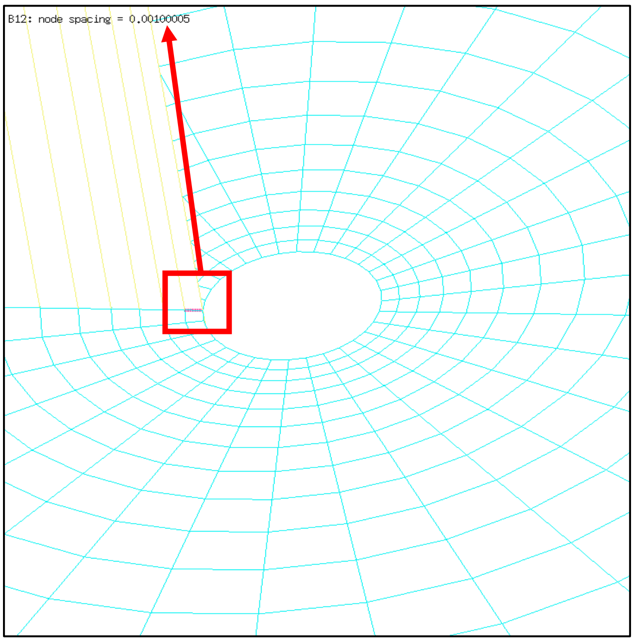


Figure 3.2

The figure 2, figure 3.1 and 3.2 show the grid, the cell lengths on the pipe and perpendicular to the pipe. The lengths are measured using the “space” option in the Grid Viewer panel. The cell spacing is along the pipe length is 0.287 as shown in figure 3.1 and the first cell height normal to the pipe is 0.001 as shown in figure 3.2. The aspect ratio of the cell on the pipe is calculated to be 287 based on the values measured above.

Nesting – in forward direction.

The nesting of topology from an outer layer to an inner layer is termed as Nesting-in the forward direction. The user needs to identify three sets of corners (sheets of corners) and store them in three different groups as mentioned below.

1. **The High Density Group -** Group of edges where the density needs to be high
2. **The Low Density group -** Group of edges where the density needs to be maintained as original.
3. **The Direction Group,** which helps in identifying the direction of application of nested refinement. Mostly direction group is along the wrap direction.
4. The **number of levels of refinement** is the number of levels the nesting has to be done should also be specified by the user.

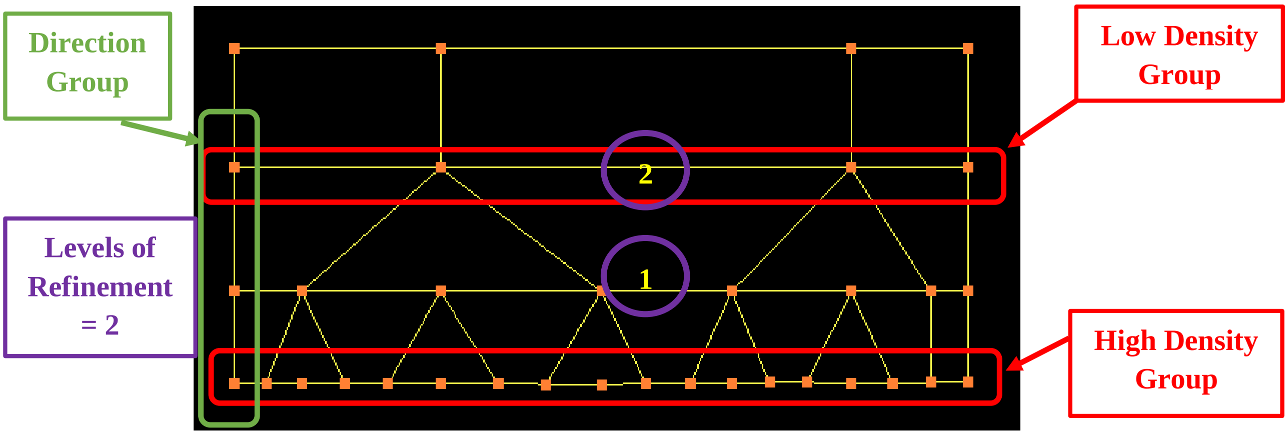


Figure 4

Nesting Requirements:

- A five point singularity corner cannot be used in either high or low density group.
- There should be one-to-one connectivity between Low Density Group and High Density Group.
- Nesting cannot be applied for 3-D as it may encounter a singular point. As shown in figure 5, it cannot be applied along 3D sheet.
- Nesting can be performed along 2-D sheet only as seen in figures 6a & 6b.

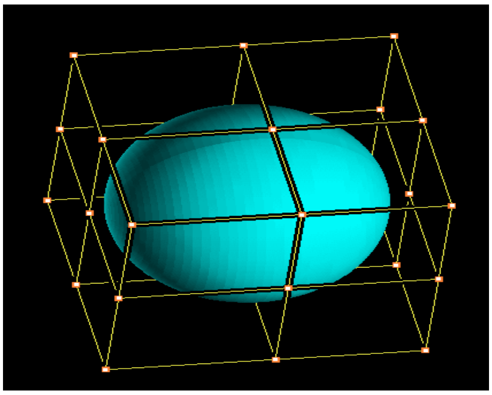


Figure 5

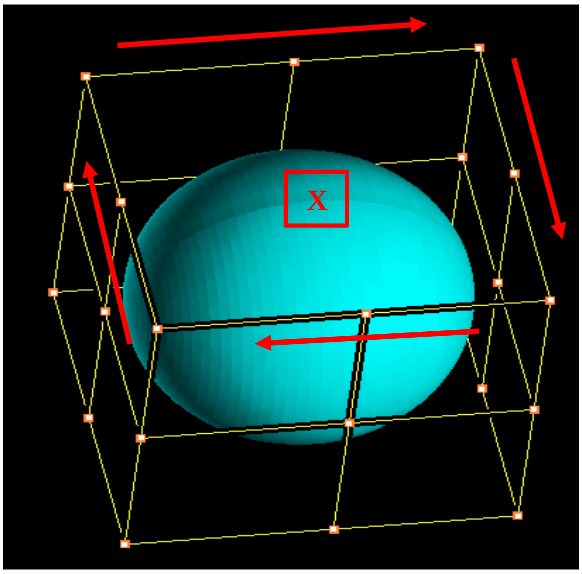


Figure 6a

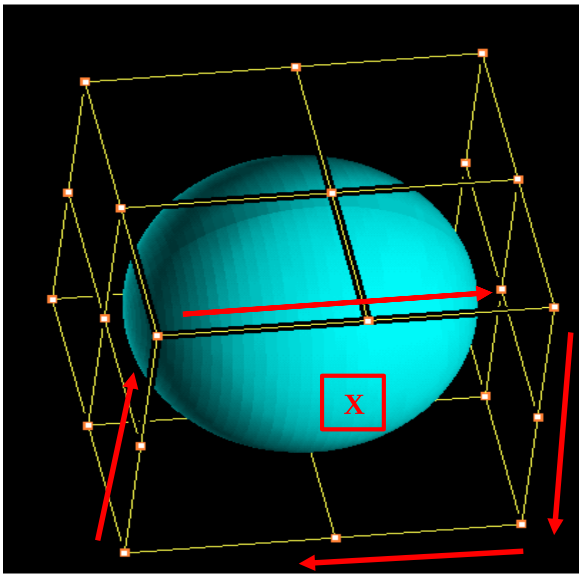


Figure 6b

Group Selection

In the current case, the 8 corners assigned to the pipe are added to a group to be defined as the high density group.

- Switch on group 1 and add 8 inside corners assigned to cylinder as shown in figure 7.

Having defined the high density group we now have to define the low density group.

So sheet next to low density group can be selected, but corners in that sheet are shared by five blocks. Hence that sheet cannot be used as it is having a five point singularity, which can be seen in figure 7. So create an insert between these two sheets and that sheet will be selected as low density group.

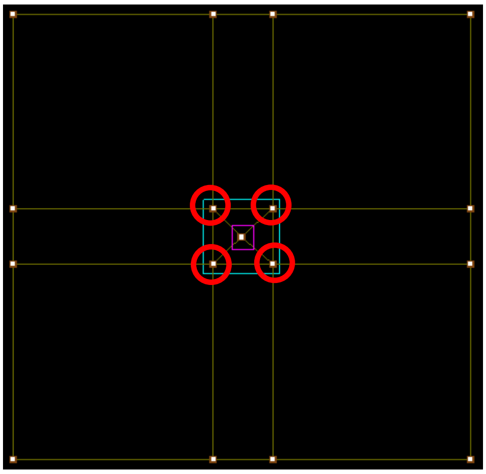


Figure 7

- Switch off group 1.
- Create an insert in between the two sheets as shown in figure 8.1.
- Add the newly created corners in group 2 as shown in figure 8.2.

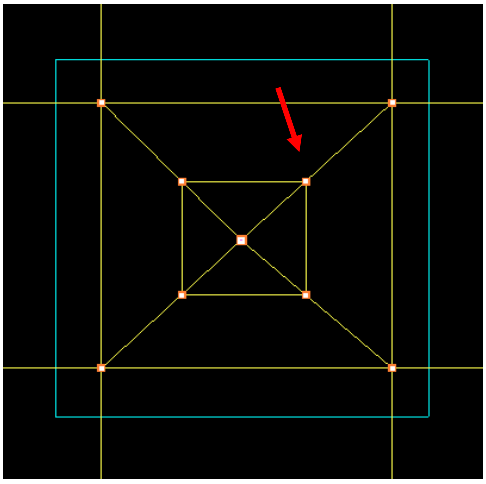


Figure 8.1

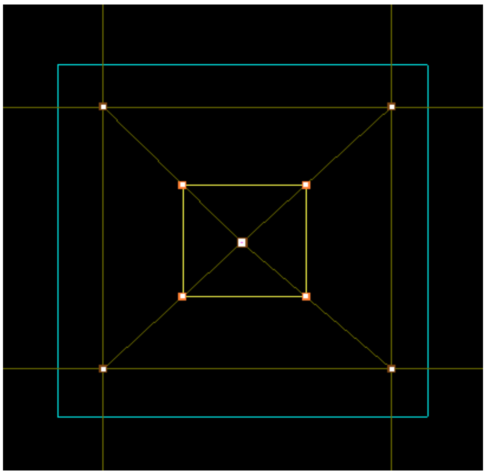


Figure 8.2

Wrap edges would be defined as direction group.

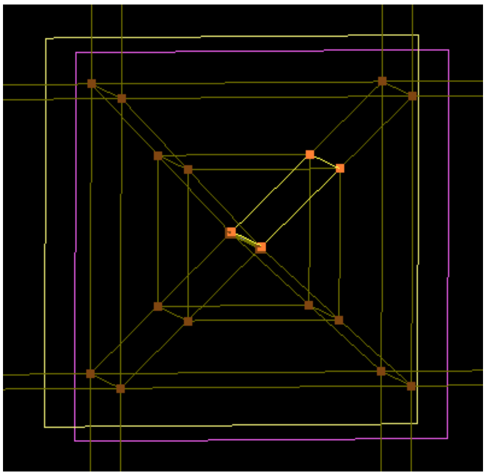


Figure 8.3

- Switch on group 3 and add corners shown in figure 8.3.

Save file as step2.fra

Insert Edges

To proceed with nesting, two more inserts are required for the following reasons.

1. An insert along the length of cylinder is needed because the corners assigned to the two plane surfaces (surf id 5 & 6) cannot be used for nesting since they are bounding planes. So at least one insert is needed along the length of cylinder.
    - Create an insert along the length of cylinder as shown in figure 8.4.

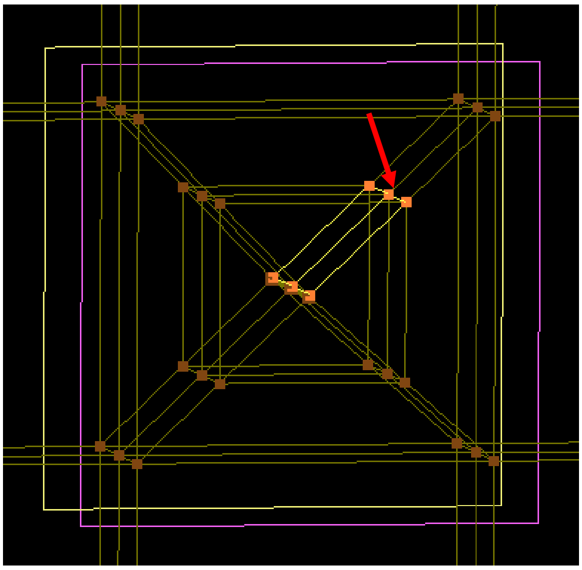


Figure 8.4

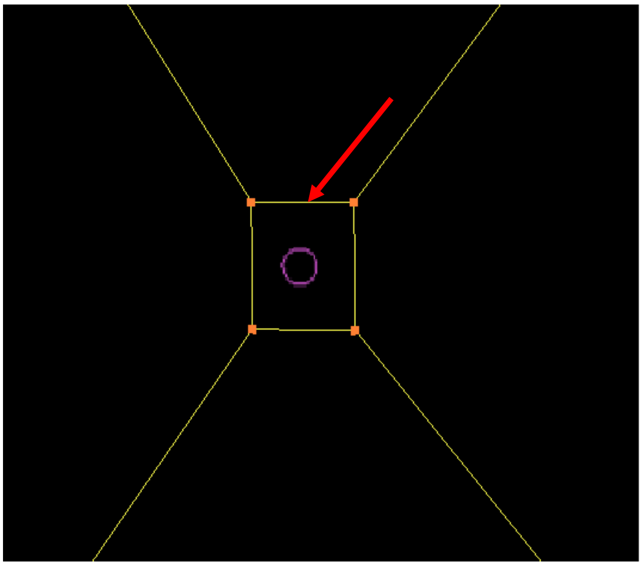


Figure 8.5

2. In order to exclude the inside block which was formed by the low density group as shown in figure 8.5, one insert is required and edges crossing through that block should be deleted. It is needed to resolve an ambiguity, which is a common requirement for many of the utilities. The assigned corners of surf id 5&6, at either ends of the cylinder form faces. So the high density group (containing corners assigned to cylinder surface) forms two cubes with 8 corners each as

shown in figure 8.6. This leads to an ambiguity in determining the nesting orientation and propagation of surface assignments. The nesting direction group can be used to resolve the orientation but there would still be a confusion in propagation of surface assignments.

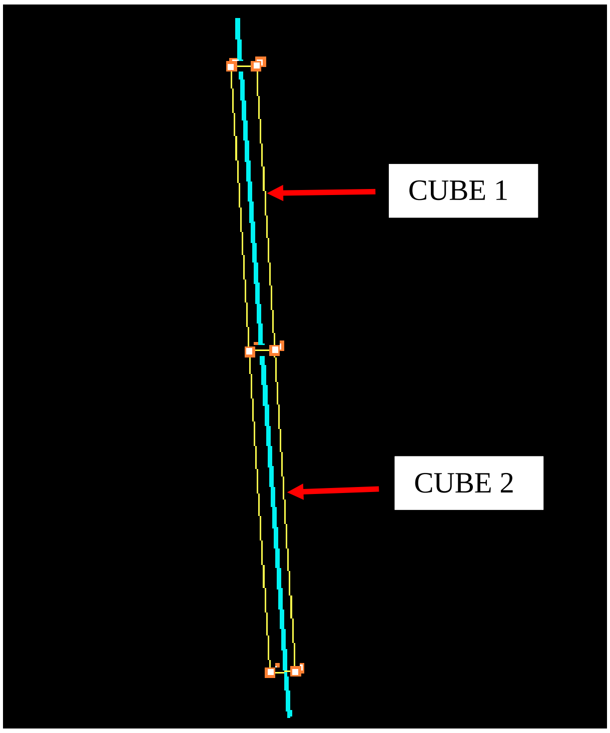


Figure 8.6

By adding one extra insert and deleting edges passing through the inside corners, the assigned corners do not form a closed box anymore and the ambiguity is resolved.

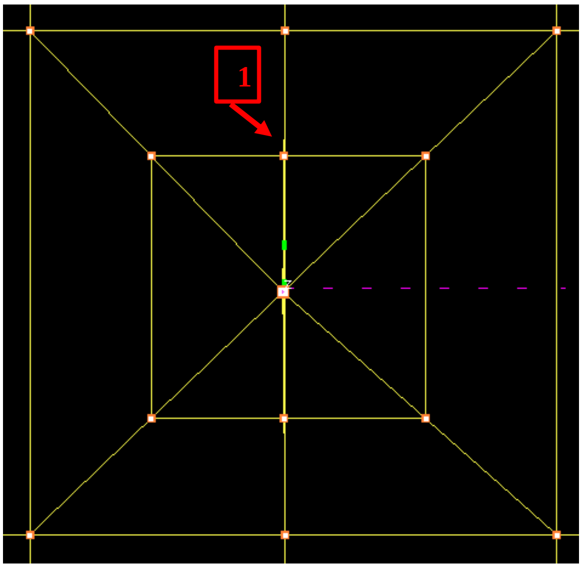


Figure 8.7

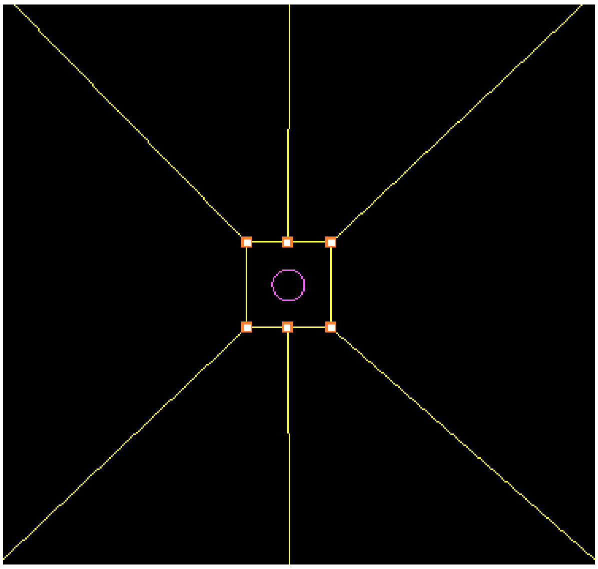


Figure 8.8

- Create an insert as shown in figure 8.7.
- Zoom in near the cylinder.
- Delete all the edges passing through the cylinder so the final topology can be as seen in figure 8.8.

Save file as step3.fra

Calculate the Aspect Ratio

- Run the Ggrid, and calculate the cell aspect ratio near the cylinder as performed earlier to define number of levels of nested refinement parameter.

The new aspect ratio is 85.

Apply Nest

- Select the nest option in TOPO sub-command panel shown in figure 9.1

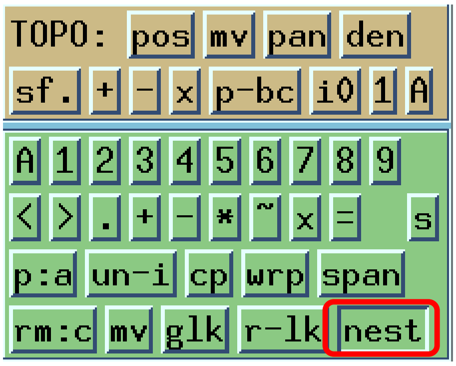


Figure 9.1

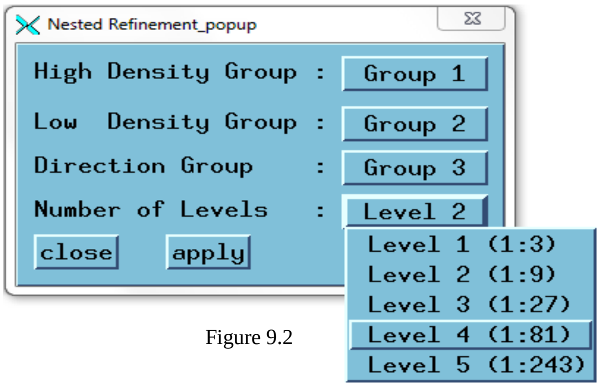


Figure 9.2

- Select group 1 as High density group which is having corners assigned to cylinder.
- Select group 2 as Low density group which is having corners created after making insert on wrap edge.
- Select group 3 as direction group.
- Number of Levels of refinement by default is 2, it is need to be defined based upon aspect ratio.

The ratios alongside the number of levels guides in selecting the number of levels. In this case, aspect ratio near the cylinder is 85, so choose level 4(1:81). *(If the grid had an aspect ratio of 30, the optimal choice would have been level 3 (1:27).*

- Select Level 4 as Number of Levels.
- Click on 'Apply' and wait for message '*Nest is Successful*' on top-left side of GUI.
- Close the Nested Refinement_popup.

When given apply in Nested Refinement_popup, the input topology in the current directory would be saved as *nest.input.fra* file and the nest utility creates a topology file called *nested.fra*.

A sheet with nesting is shown in figure 10. Four levels of refinement can be easily seen.

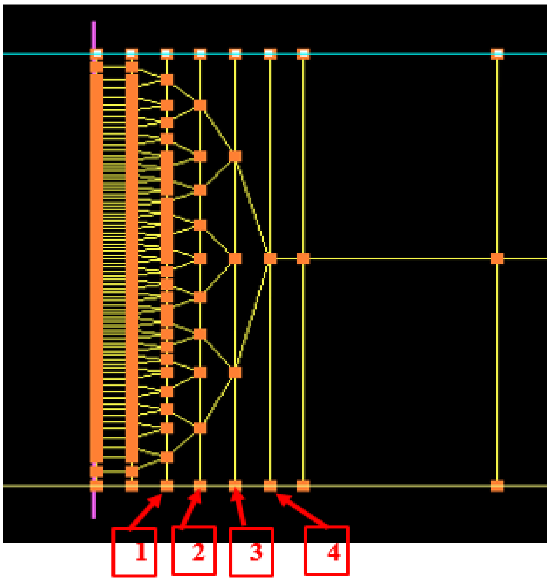


Figure 10

Save file as step4.fra

Start the Gridding Process

- Go to `topo` pull down menu bar and select `Ggrid: start` to start the gridding process.
- Click on 'OK' to start the gridding process.
- Switch to Grid Viewer Panel.
- Load the blk.tmp file to view the grid.

Grid can be seen in figure 11.

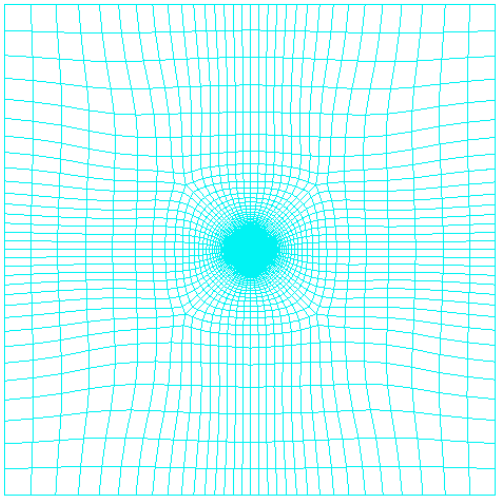


Figure 11

Grid sheets having nesting can be seen in figure 12. After nesting aspect ratio is reduced to 2.67

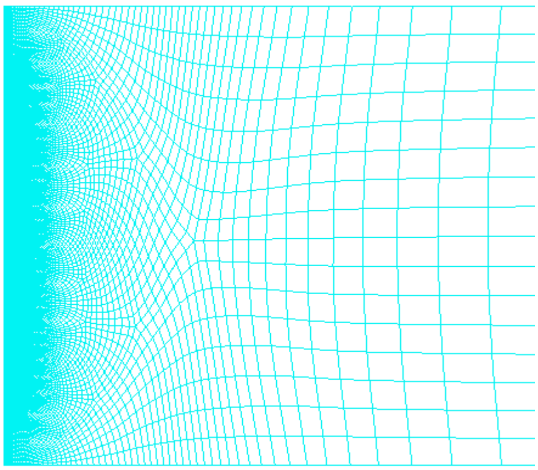


Figure 12.1

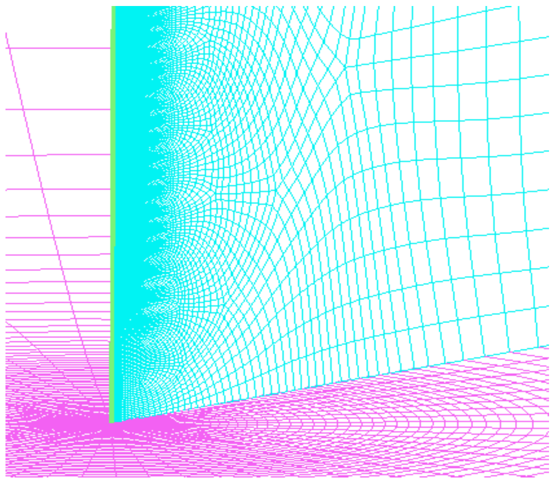


Figure 12.2

Grid without nesting and with nesting can be seen in figure 13. Near the boundary, grid density is same in both the cases.

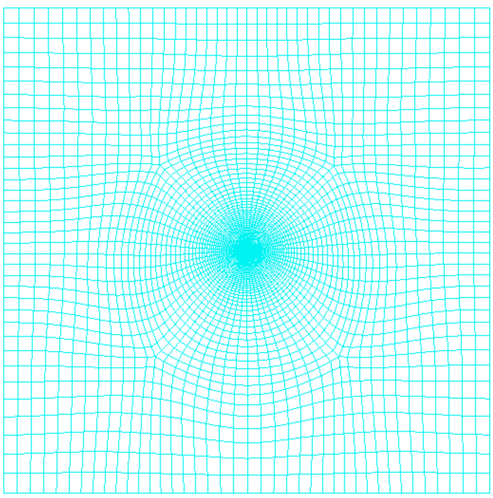


Figure 13.1 Grid without Nesting

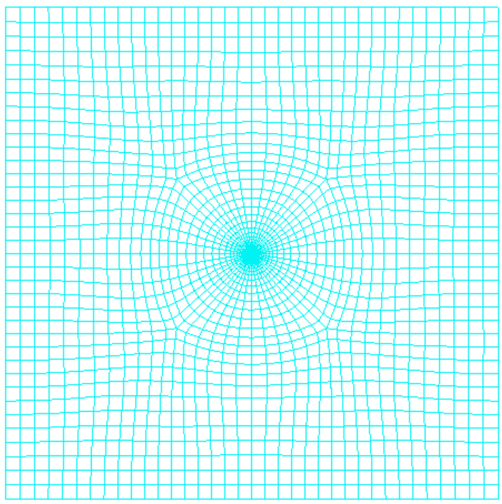


Figure 13.2 Grid with Nesting

Case 1b: FORWARD NESTING IN A REVERSE DIRECTION

Nesting can also be done in reverse direction, by interchanging the high density group to low density group and vice versa. Cases where high density is required in farfield and low density near the geometry.

Just interchanging the group number of low density and high density will give the forwards nesting in reverse direction.

- Exit the current GridPro.
- Load the step3.fra in the GridPro Gui.

Grouping the Corners

Here groups for high density and low density will be interchanged. Group 1 is having corners for Low Density Group as shown in figure 14.1. Group 2 is having corners for High Density Group as shown in figure 14.2.

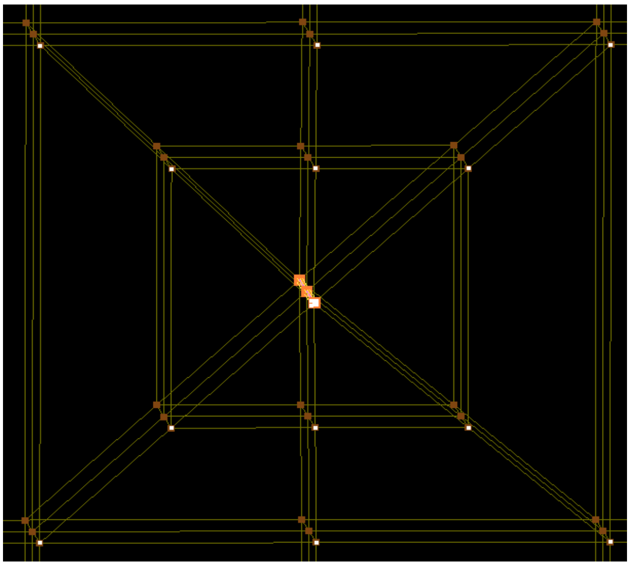


Figure 14.1

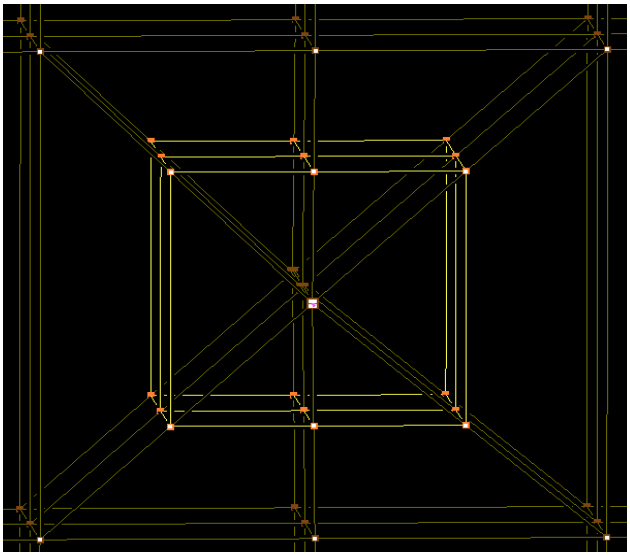


Figure 14.2

Group 3 is having corners for Direction Group as shown in figure 14.3.

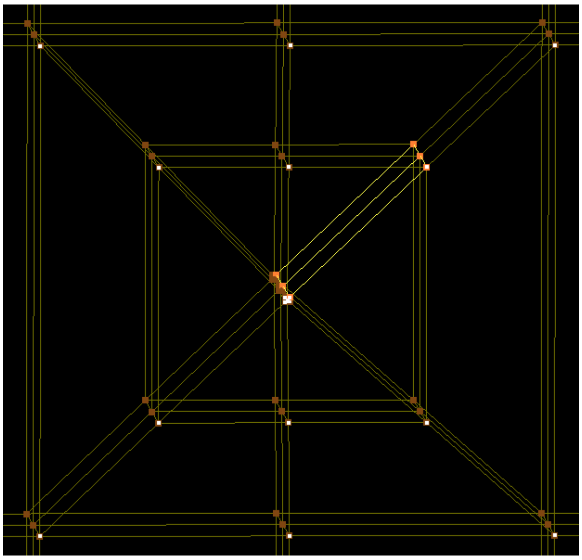


Figure 14.3

- Select the nest option in TOPO sub-command panel
- Select group 1 as Low density group which is having corners assigned to cylinder.
- Select group 2 as High density group as shown in figure 14.4.
- Select group 3 as Direction group.
- Select Level 4 as Number of Levels of Refinement.
- Click on 'Apply' and wait for message '*Nest is Successful*' on top-left side of GUI.
- Close the Nested Refinement_popup.

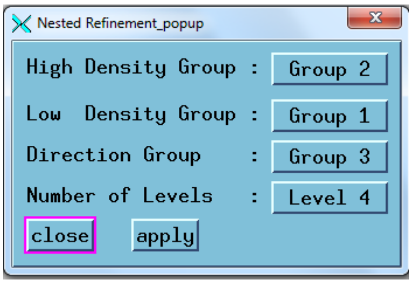


Figure 14.4

Figure 15.1 shows the sheet with forward nesting done using group 1 as High density group and figure 15.2 shows sheet with forward nesting done in reverse direction using group 2 as High density group.

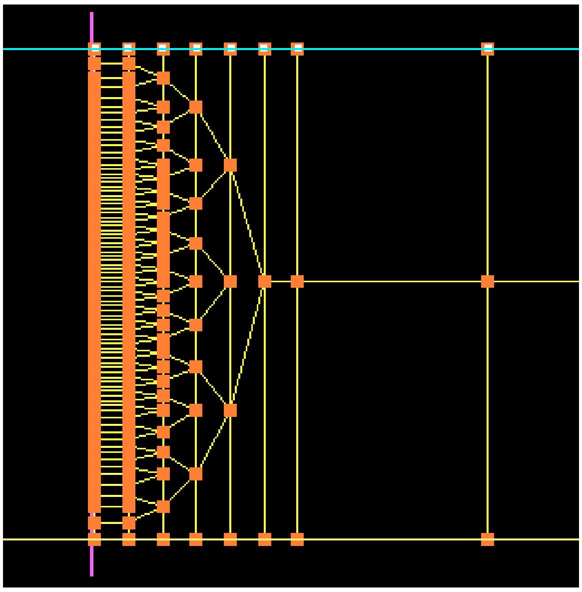


Figure 15.1

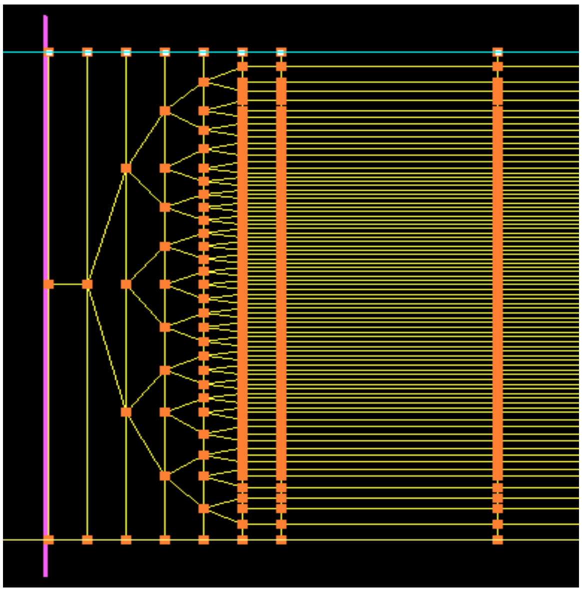


Figure 15.2

Forward nesting in reverse direction is not required for this case. Just for knowledge sake, it was performed.

Case 1c: PARTIAL FORWARD NESTING

There might be some cases when user wants to perform nesting for a particular portion of topology. This even can be done using Nest operation. Consider a sub-marine similar to DARPA sub-off having a sail

Loading an Initial Topology File

- Load step1_submarine.fra from the 'Case_3' folder inside the 'Nest' directory

A complete topology has been provided over here. Zoom in the geometry to have a better view. A submarine with a sail can be seen in figure 16.2.

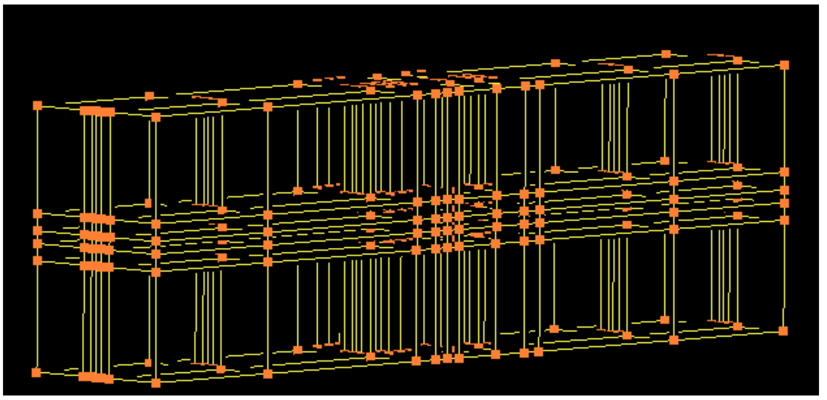


Figure 16.1

Figure 16.2

It's a complete topology with all the surfaces assigned and with density balance and ready to run.

Start the Gridding Process

- Go to `topo` pull down menu bar and select to `Ggrid: start` start the gridding process.
- Click on 'OK' to start the gridding process.
- Switch to Grid Viewer Panel.
- Load the blk.tmp file to view the grid.

Loaded grid can be seen in figure 17.

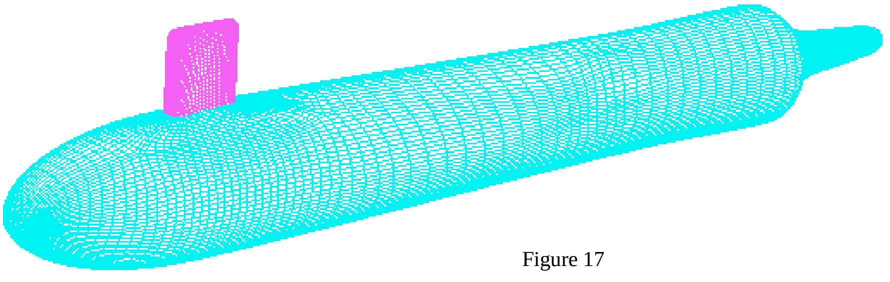


Figure 17

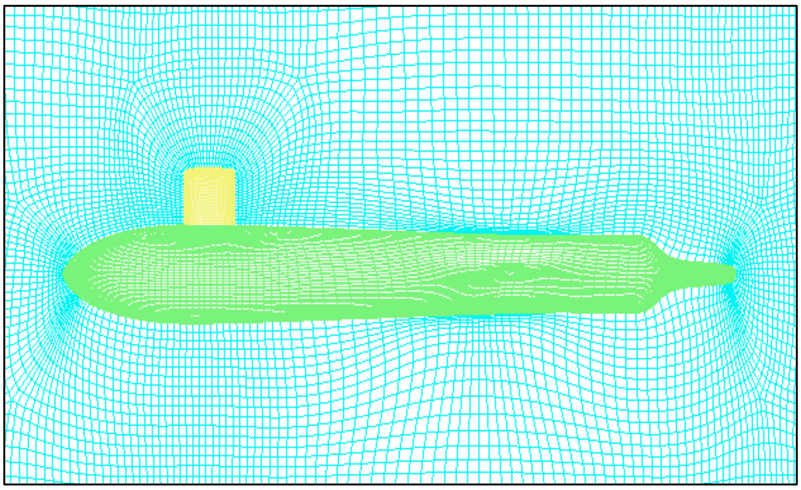


Figure 18.1

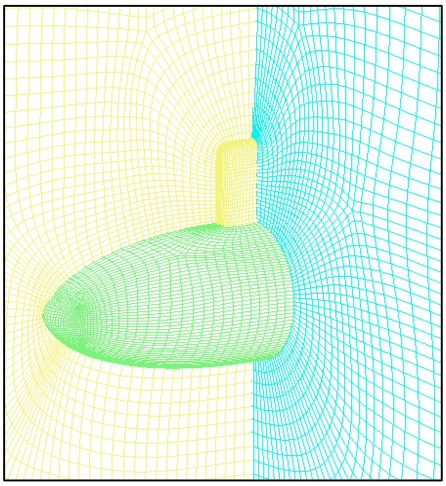


Figure 18.2

As seen in figure 18, refinement near the sail is required which will be done using nesting.

Grouping the Corners

- Switch back to Topology panel.
- Empty the group 1 and add corners assigned to sail i.e. surf 0 to it as shown in figure 19. This will be defined as high density group.

As already mentioned above, automated nesting cannot be applied in 3-directions, hence above layer corners won't be used.

But necessary criterion for nesting is, there should be at least three inserts to proceed with nesting.

Make an insert as shown in figure 20.1.

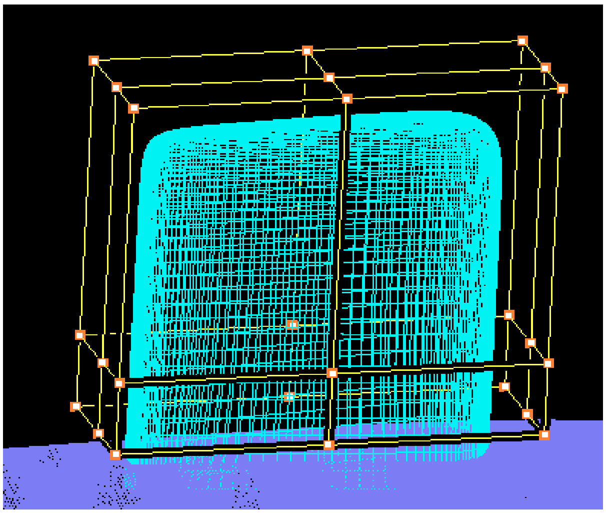


Figure 19

Save file as step1.fra

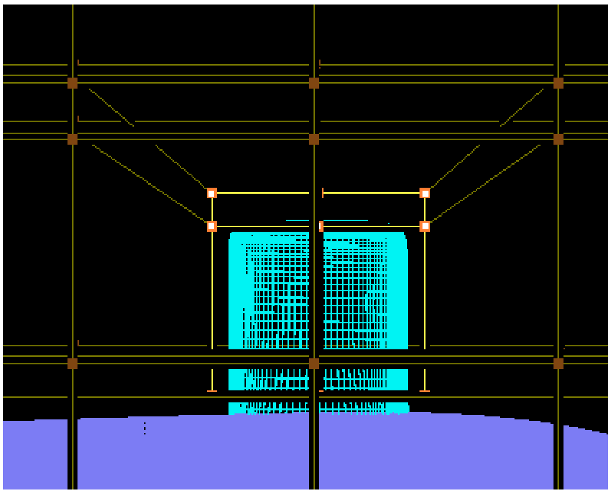


Figure 20.1

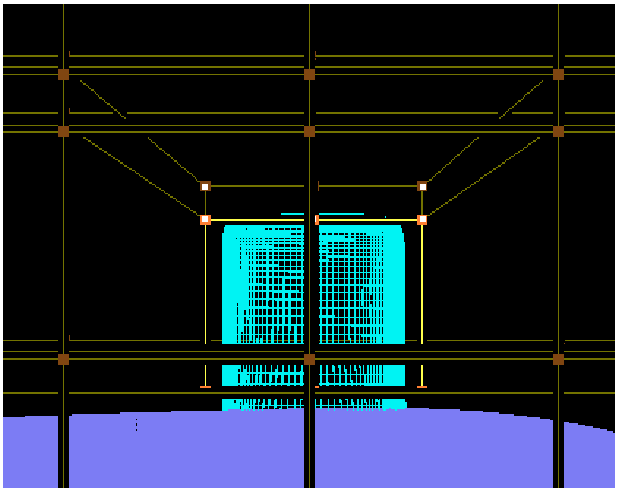


Figure 20.2

- Remove the above corners layer from group 1 as shown in figure 20.2.

- Now switch on group 2, kill everything in it. Add group 1 corners to it and span out 1 layer as seen in figure 21.1.

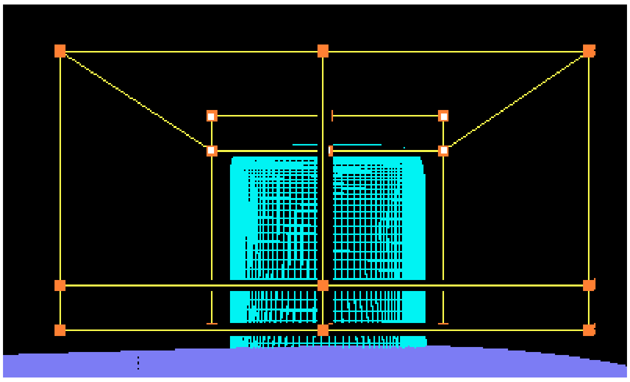


Figure 21.1

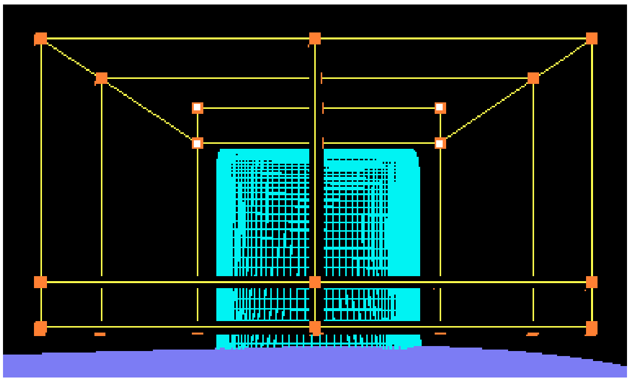


Figure 21.2

- Make an insert on wrap layer as shown in figure 21.2.
- Switch on group 3, kill everything in it and select the newly inserted corners as shown in figure 22. Don't add the top layer corners. This group will be defined as Low Density Group.

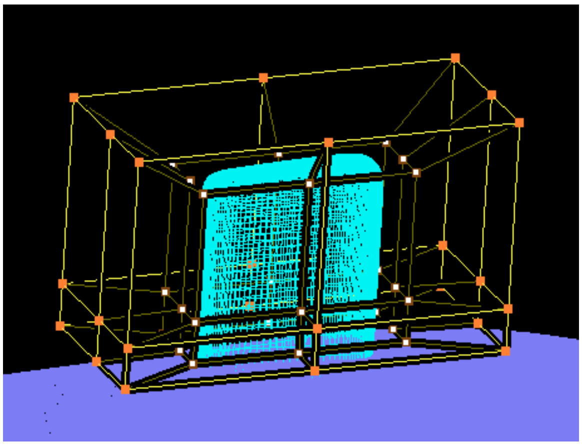


Figure 22

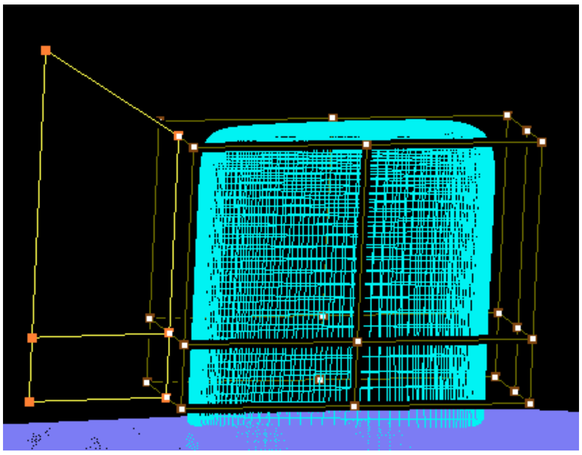


Figure 23

- Switch on group 4 and kill everything in it. Add corner shown in figure 23 to it. This group will be defined as Direction group.

- Save file as step2.fra

Apply Nest

- Select the nest option from Topo sub-command panel.
- Select group 1 as High Density Group, group 3 as Low Density Group and group 4 as Direction Group as seen in figure 24.
- Define Level 3 as Number of Levels of Refinement.
- Select Level 4 as Number of Levels.
- Click on 'Apply' and wait for message '*Nest is Successful*' on top-left side of GUI.
- Close the Nested Refinement_popup.

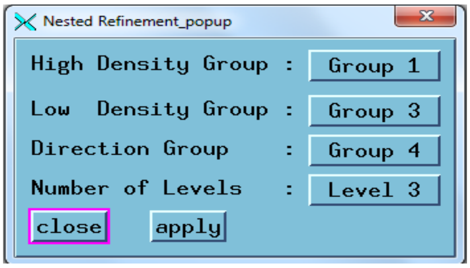


Figure 24

Two sheets having nesting is shown in figure 25.

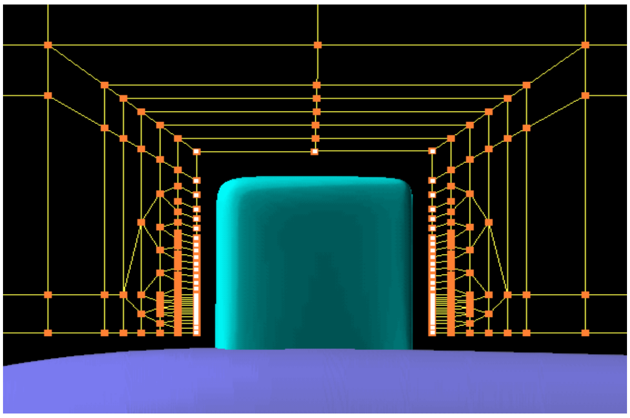


Figure 25.1

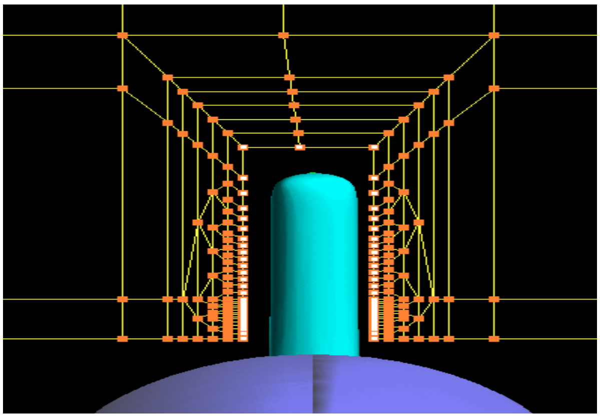


Figure 25.2

Save file as step3.fra

Start the Gridding Process

- Go to `topo` pull down menu bar and select to `Ggrid: start` start the gridding process.
- Click on ‘OK’ to start the gridding process.
- Switch to Grid Viewer Panel.
- Load the blk.tmp file to view the grid.

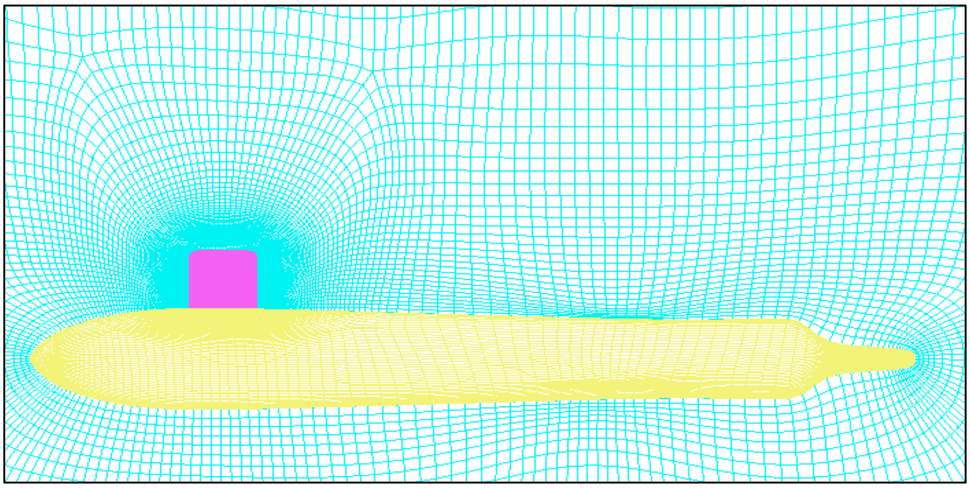


Figure 26.1

As seen in figure 26, there is a fine mesh near the sail. Increasing in points near the sail is not affecting whole grid which was done by using nesting.

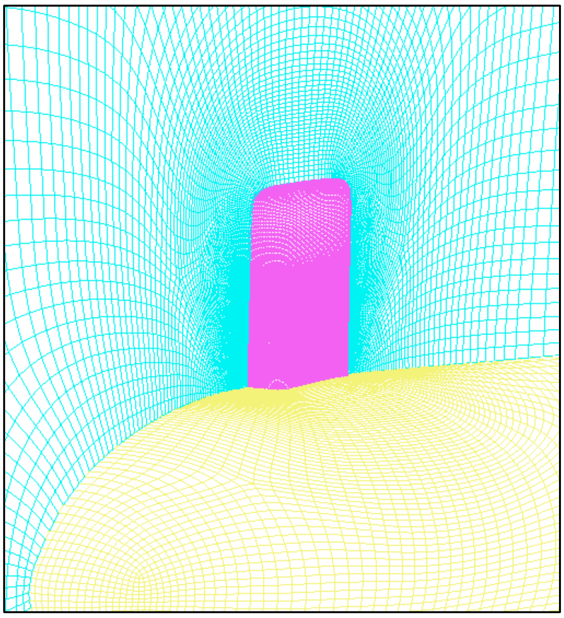


Figure 26.2

Case 2: REVERSE NESTING

Refer ‘Reverse Nest Tutorial’.

Case 3: MANUAL NESTING

Manual nesting is a user-build nesting structure as shown in figure 27.1. The difference between the automated and manual nesting is the nesting structure and the automation. Both can be used in internal and external flow geometries whereas manual nesting is more preferable in internal geometries because of the space constrain and the automated nesting is recommend where there is a constrain on number of blocks. The automated nesting requires larger space to converge compare to the manual nesting. Figure 27 is showing both the automated and manual nesting structure in 2D for comparison.

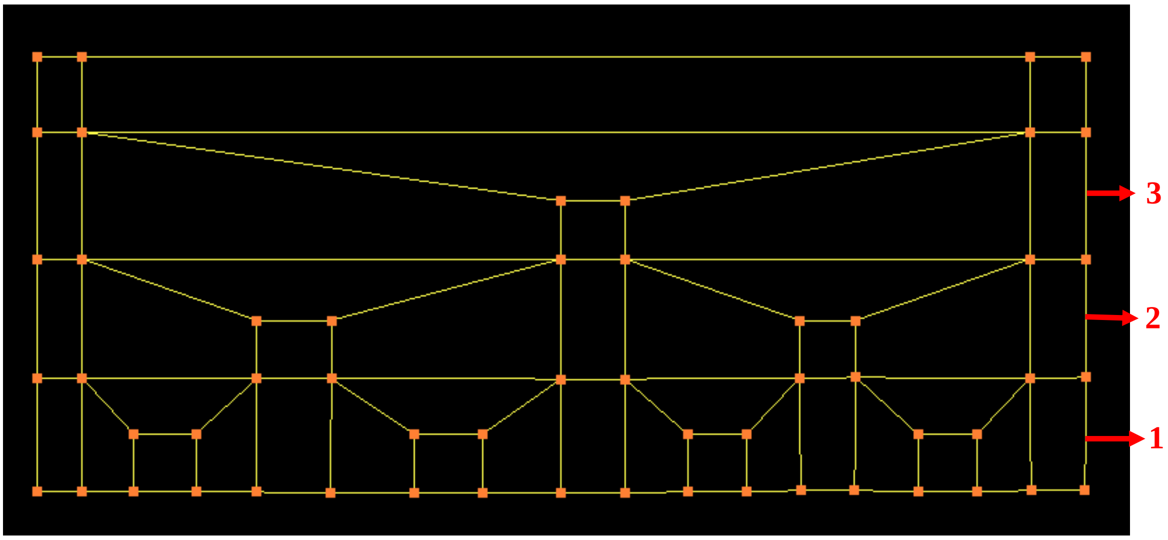


Figure 27.1

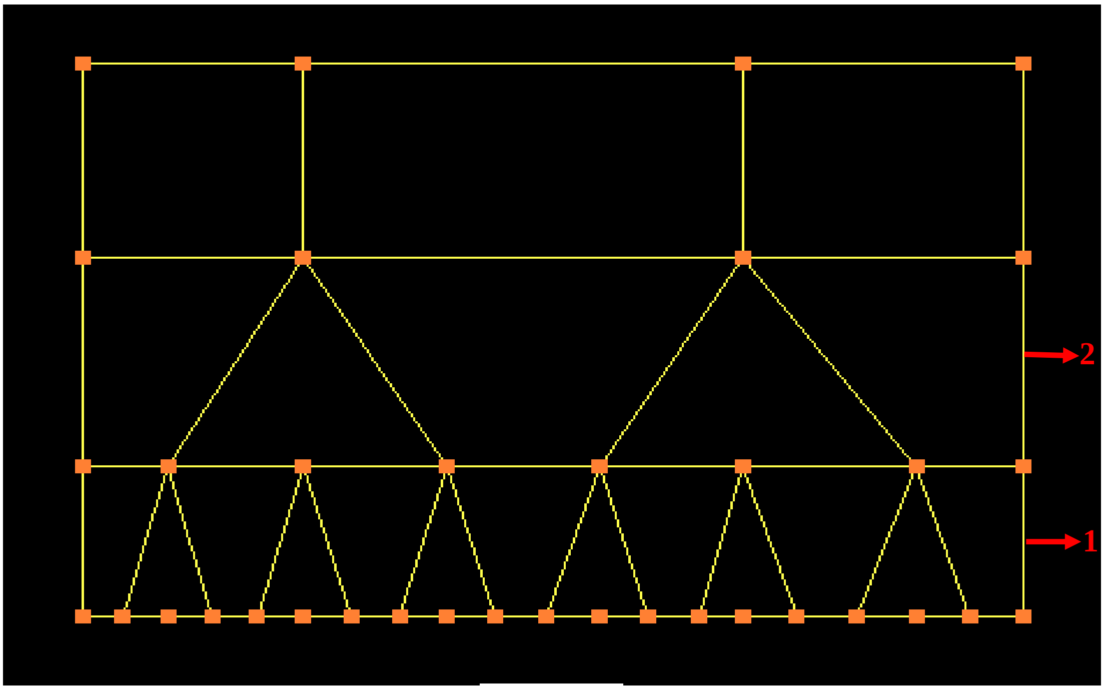


Figure 27.2

The figure 27.1, manual nesting would have given the user some idea on how to build such a structure, the following will explain how to build it in an easier way.

- Load step2.fra file from the 'Case_3' folder inside the 'Nest' directory.

This case has 4x4 array of pipes as seen in figure 28.1 on which the topology is built in top-down approach which can be seen by loading the 'step1.fra'. For this case, only the topology which is enclosed the pipes are taken as seen in figure 28.3 (which is saved in 'step2.fra') and the manual nesting would be applied.

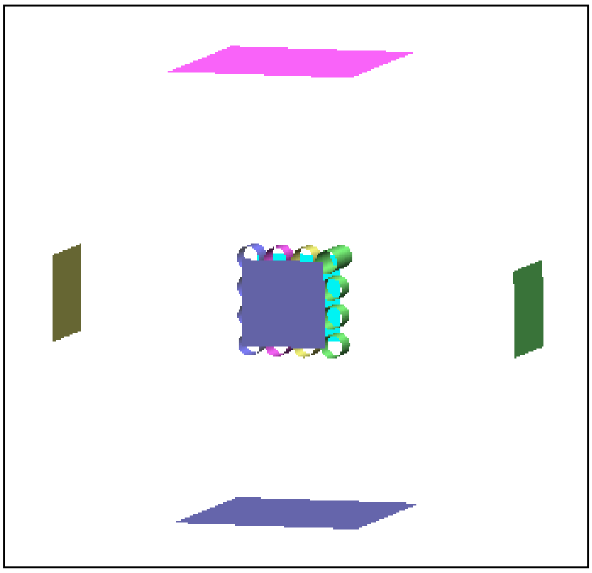


Figure 28.1

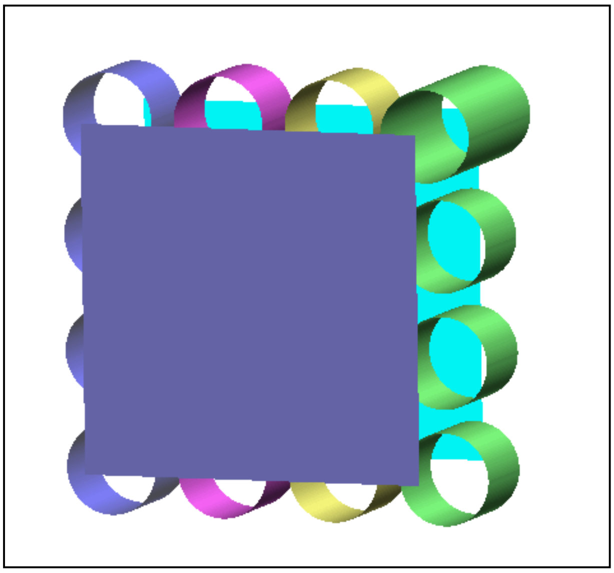


Figure 28.2

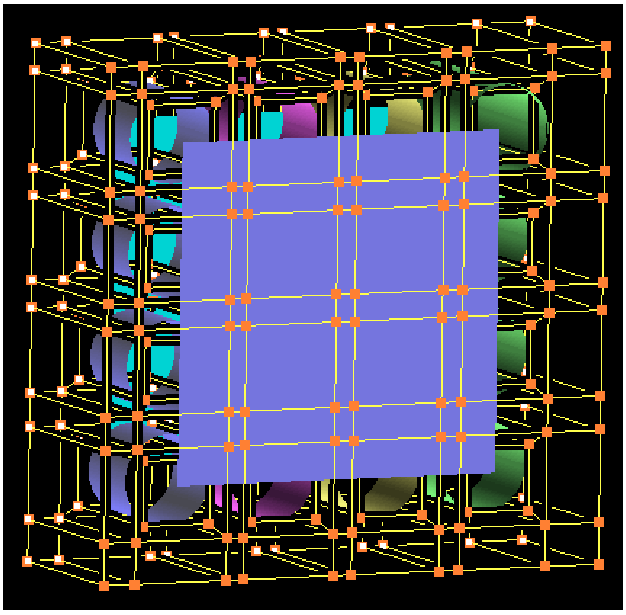


Figure 28.3

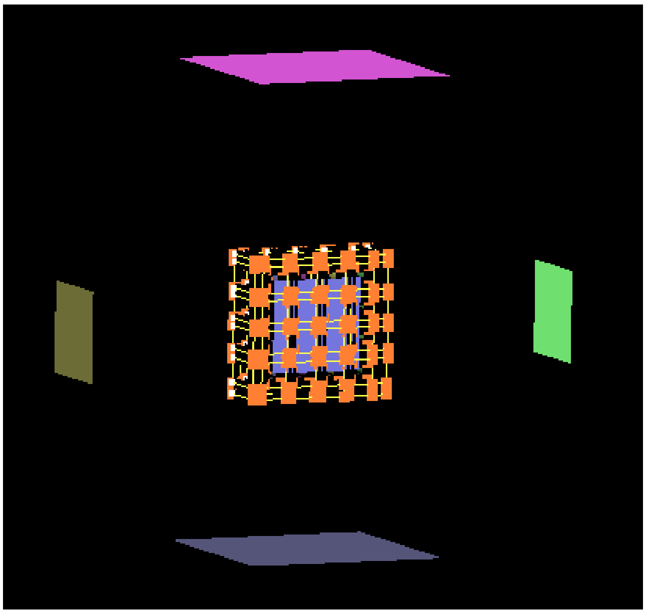


Figure 28.4

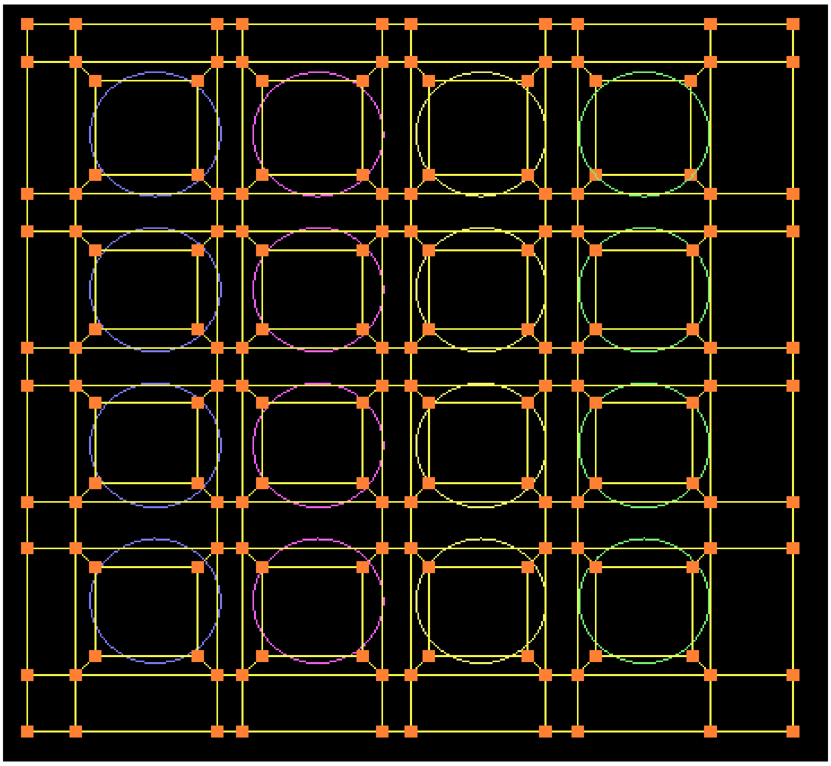


Figure 28.5

- Group the outermost layer corners on top as shown in figure 29.1 in a group, say group 2.
- Centre the cut-plane by selecting `grp fit 1` from `ctr` the button in the cutp sub-command panel.
- Switch on the handles of the cut-plane by clicking on `hand` the button.
- Move the cut-plane to a distance as shown in figure 29.3 and copy the grouped corners of group 2 by clicking `+drop back edges` on the option `cp` from the drop down list as seen in figure 29.4

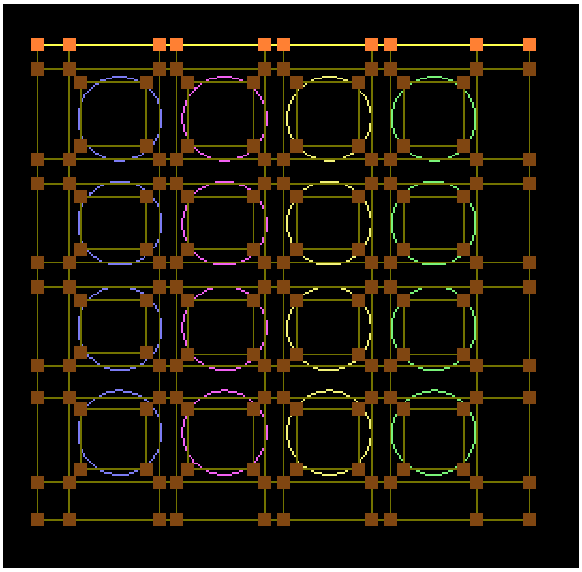


Figure 29.1

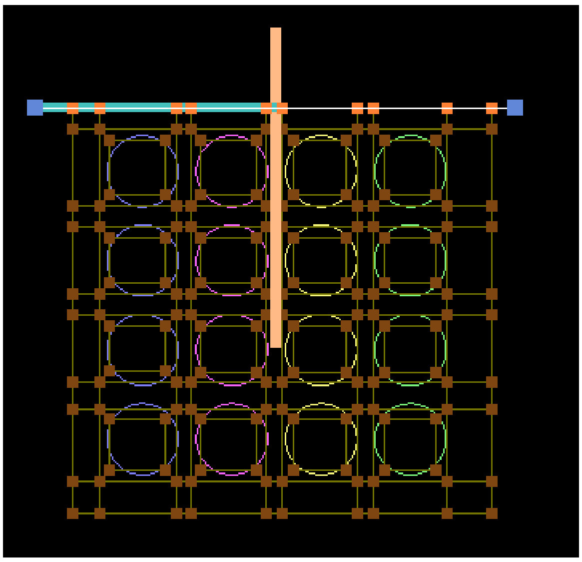


Figure 29.2

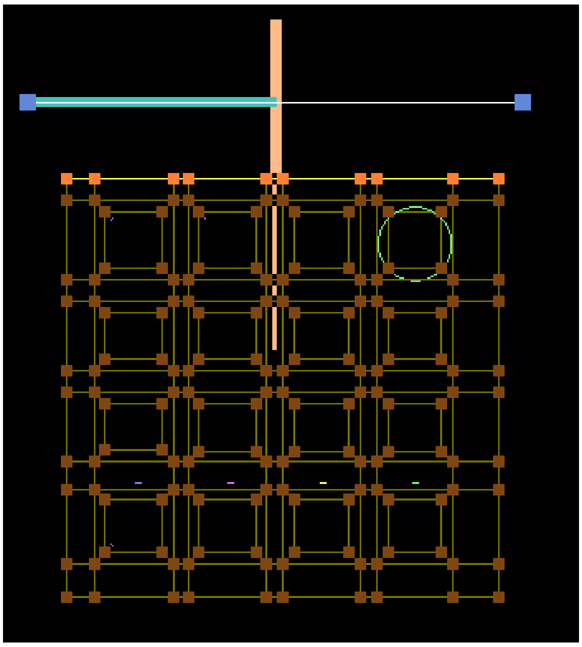


Figure 29.3

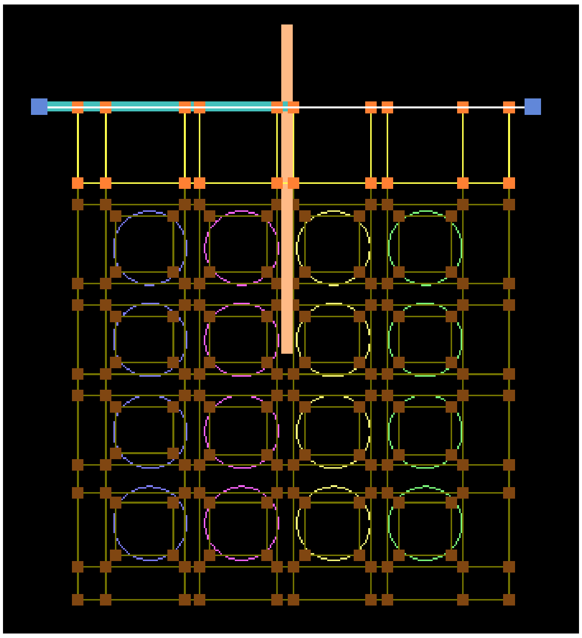


Figure 29.4

Save file as step3.fra

- Group the corners in a group as shown in figure 30.1.
- Center the cut-plane to the grouped corners using 'grp fit 1'.
- Click on mv the button in the topo sub-comamnd panel and move the cut-plane slightly lower as shown in figure 30.3.
- Switch off the 'mv' button once the operation is done.
- Switch off the group and link the corners together as shown in figure 30.6.

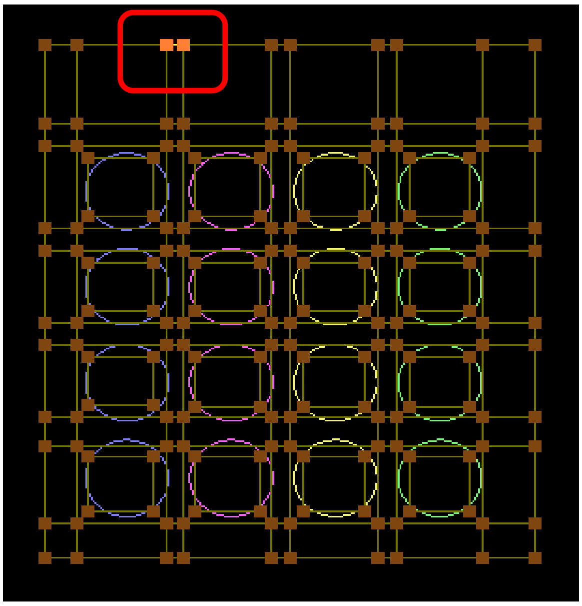


Figure 30.1

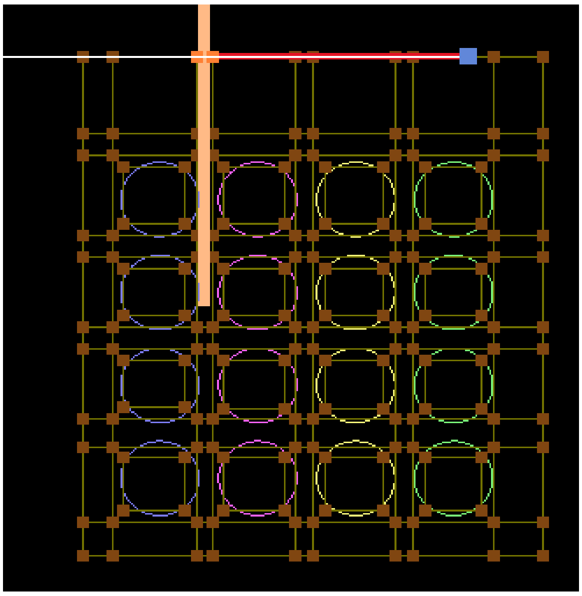


Figure 30.2

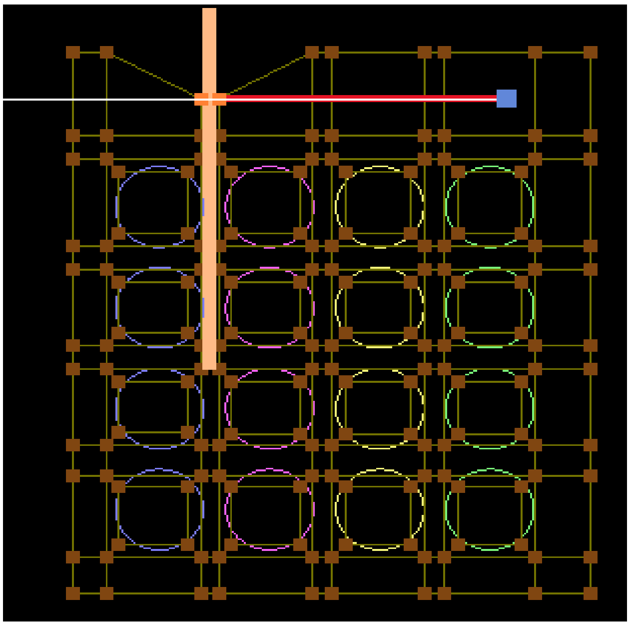


Figure 30.3

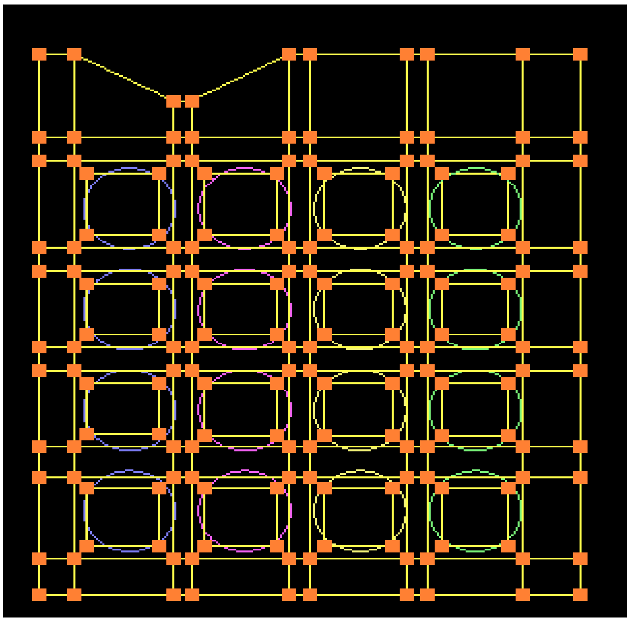


Figure 30.4

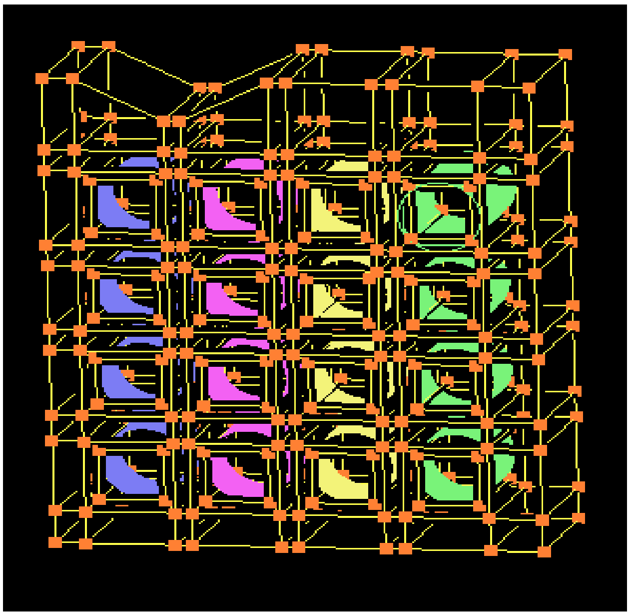


Figure 30.5

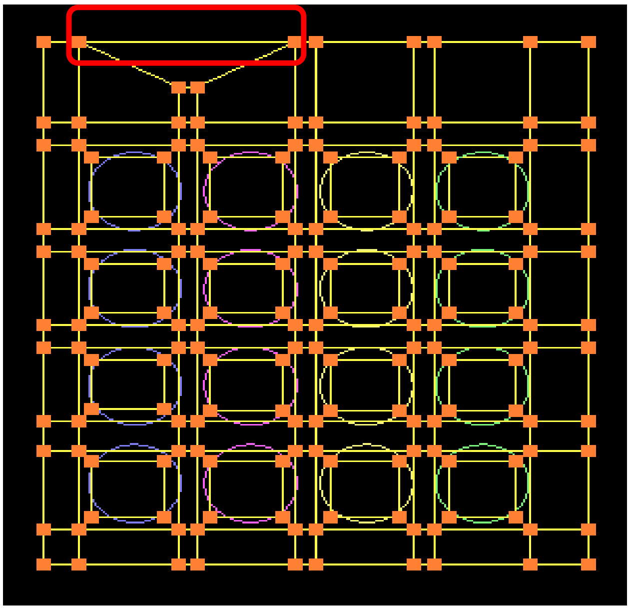


Figure 30.6

Save file as step4.fra

- Similarly group the two corners as shown in figure 31.1.
- Group fit the cut-plane and move the corners down as shown in figure 31.2.
- Link the corners together to form a new block as in figure 31.3.

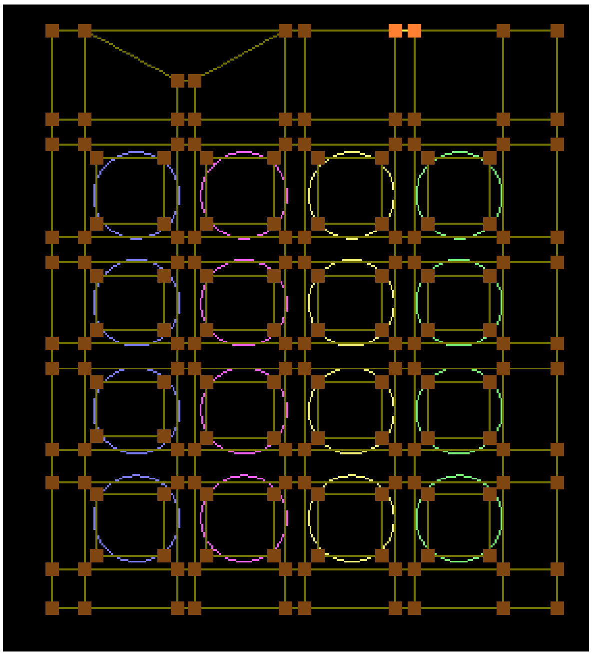


Figure 31.1

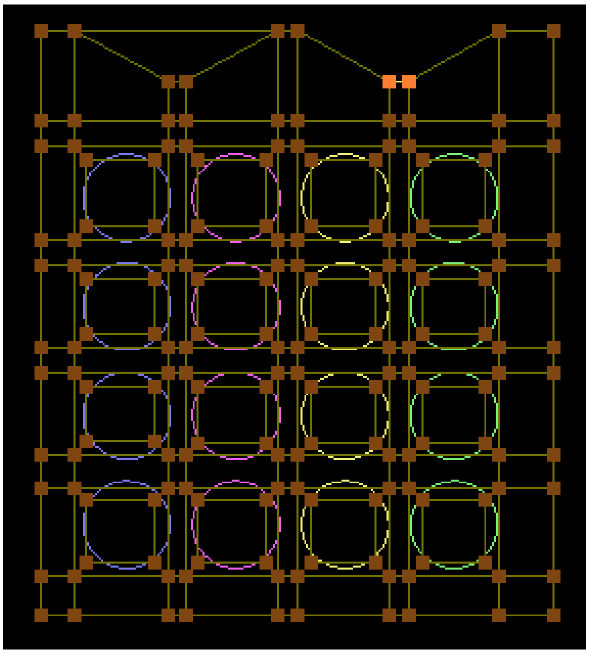


Figure 31.2

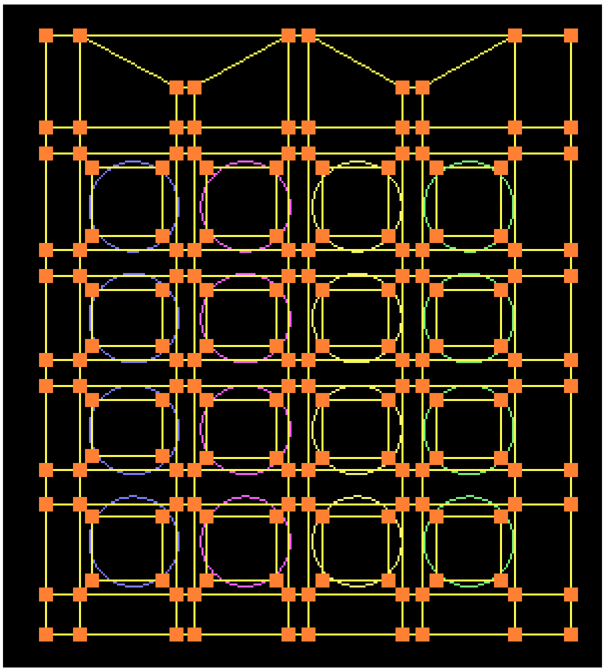


Figure 31.3

Save file as step5.fra

Thus the manual nesting structure can be built easily. Similarly let's proceed the nesting on the right side as follows.

- Repeating the above steps for the outermost layer on the right side, copy the outermost layer corners to the right side as shown in figure 32.1.
- Move the corners to form the loop as shown in figure 32.2.
- Link the corners together as shown in figure 32.3.

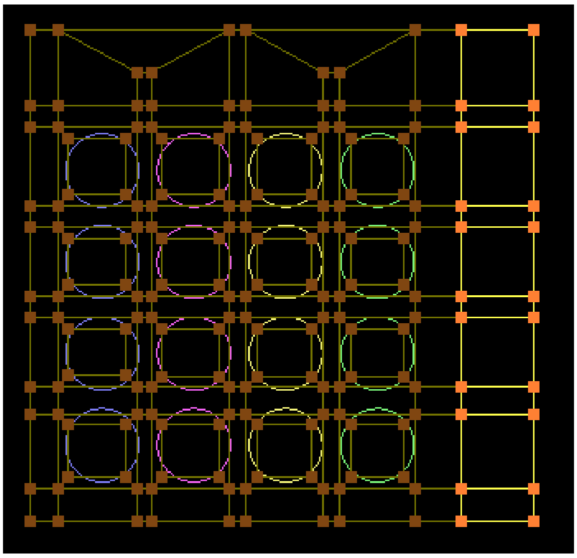


Figure 32.1

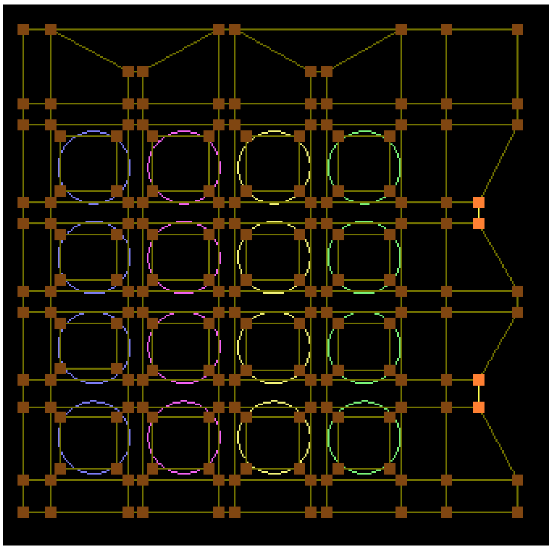


Figure 32.2

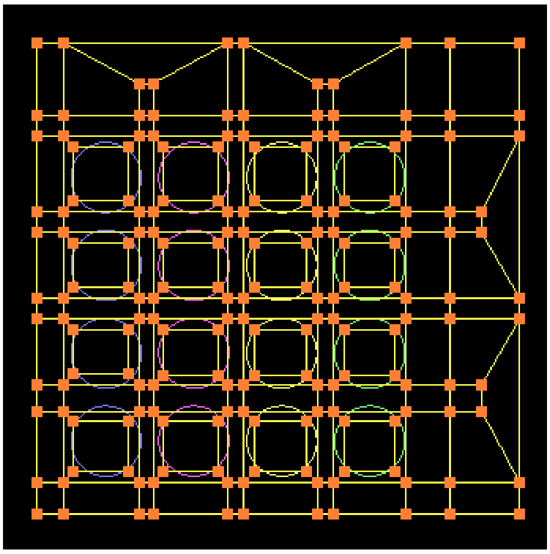


Figure 32.3

Save file as step6.fra

Similarly proceed with the bottom layer as shown in figure 33.

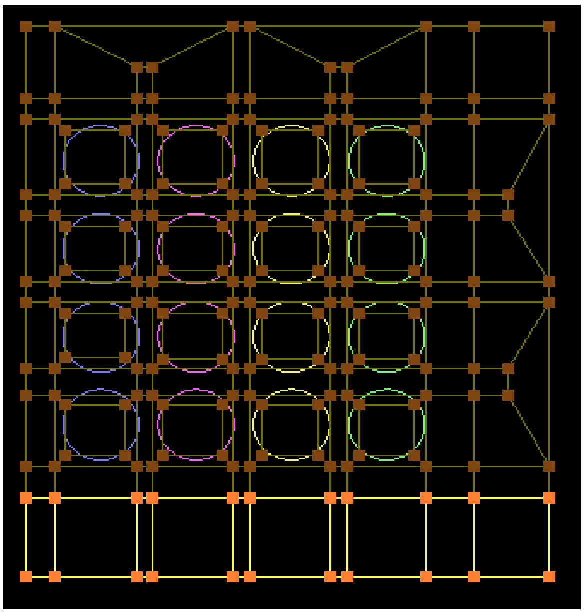


Figure 33.1

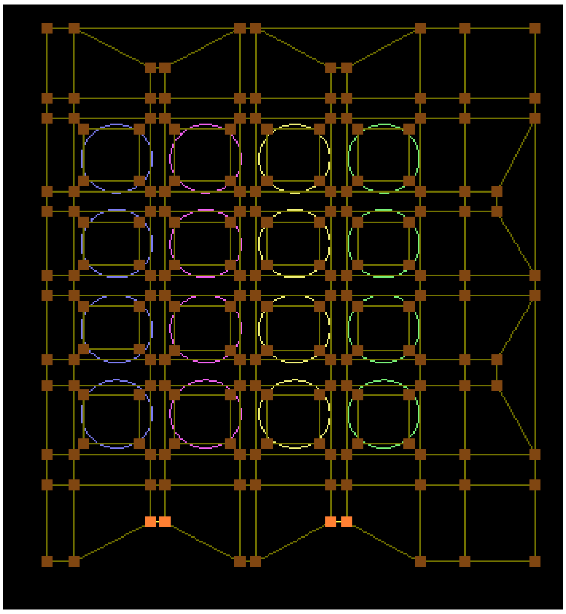


Figure 33.2

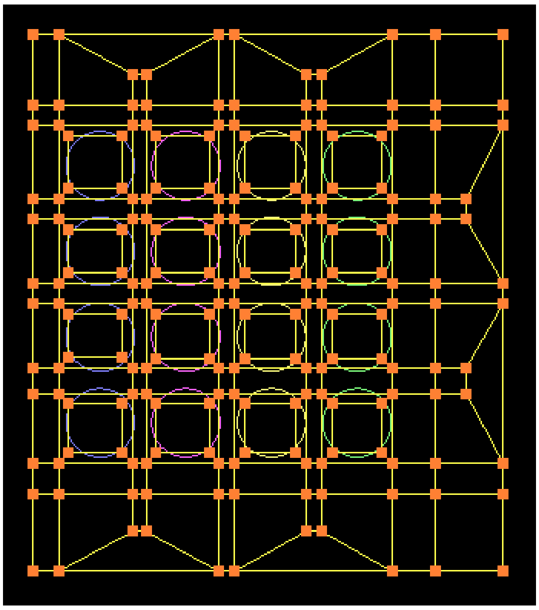


Figure 33.3

Save file as step7.fra

Similarly, do the manual nesting for left side as shown in figure 34.

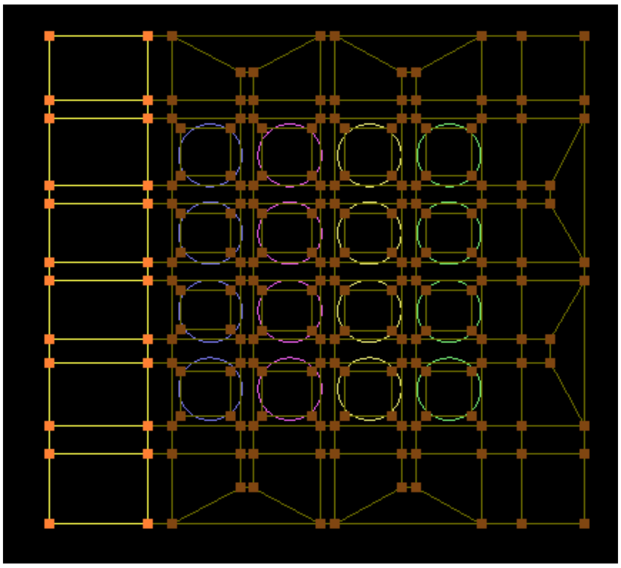


Figure 34.1

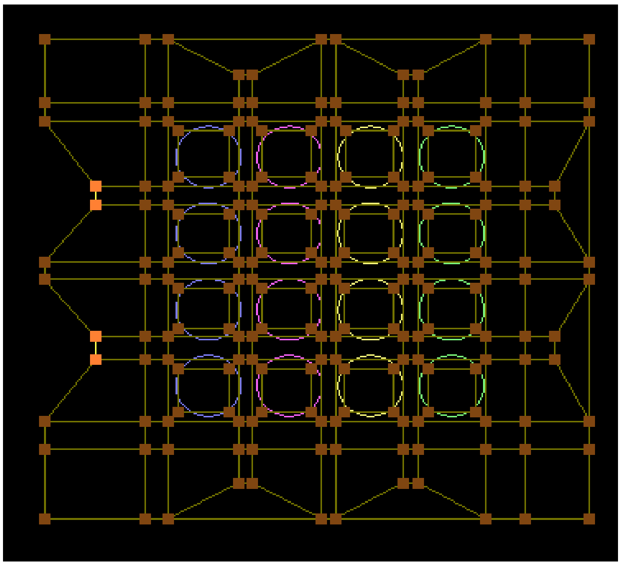


Figure 34.2

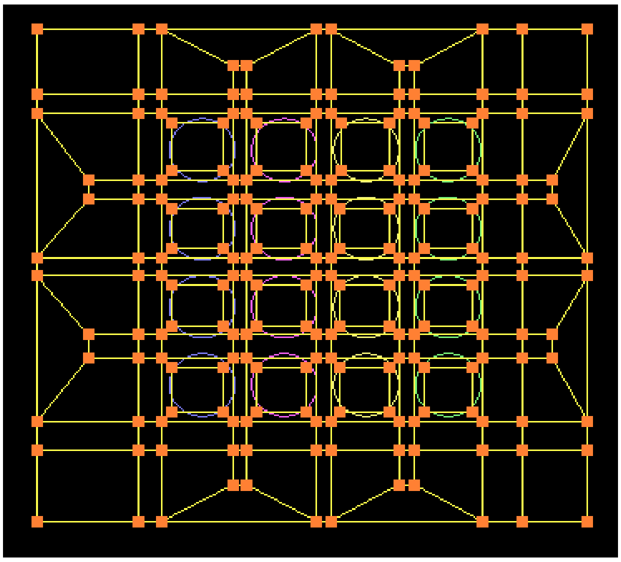


Figure 34.3

Save file as step8.fra

Perform one more layer of nesting on all sides as shown in figures 35

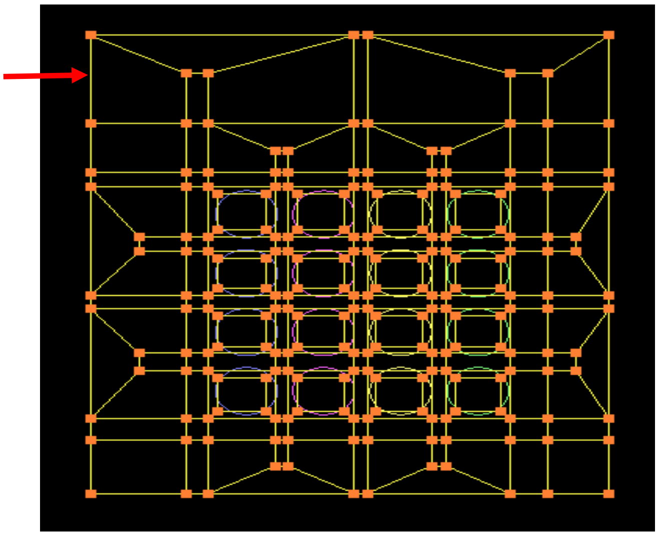


Figure 35.1

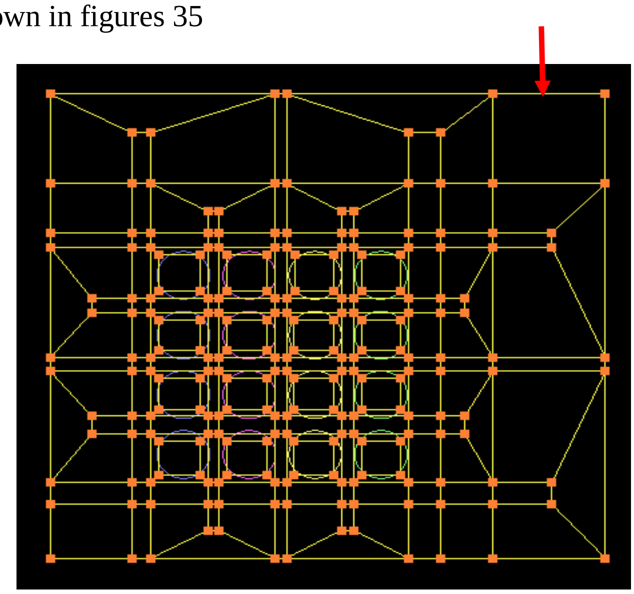


Figure 35.2

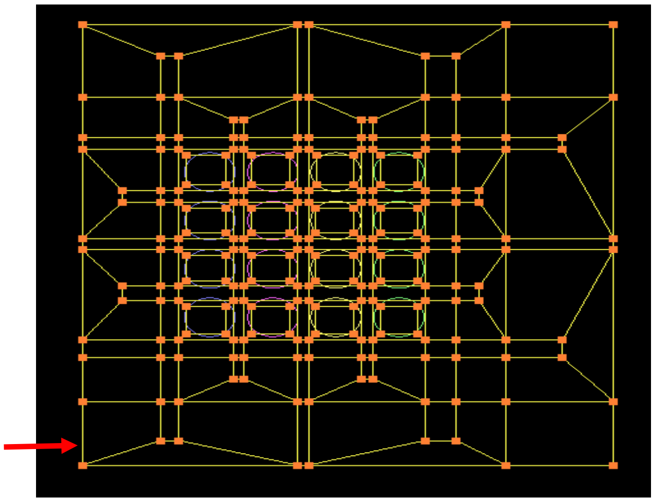


Figure 35.3

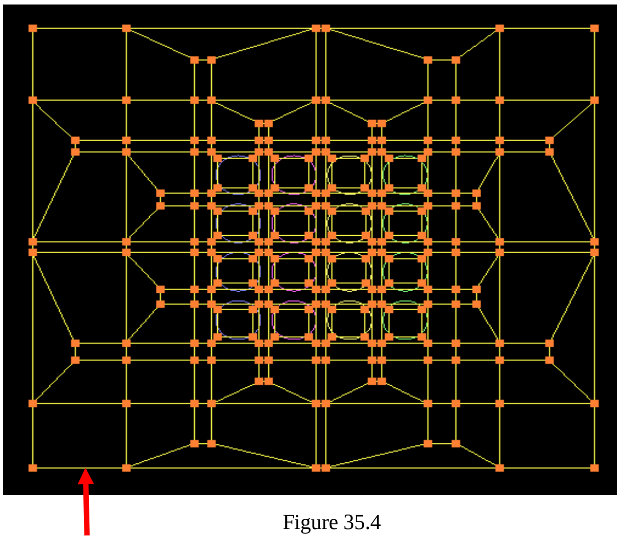


Figure 35.4

Save file as step9.fra

Nesting will be stopped at this point. But all outer layers cannot be assigned to the surfaces as it will have mediumly severe singularity on the corners as shown in figure 36. Hence, each outer layer will be copied near to their respective planes side as shown in figure 37.

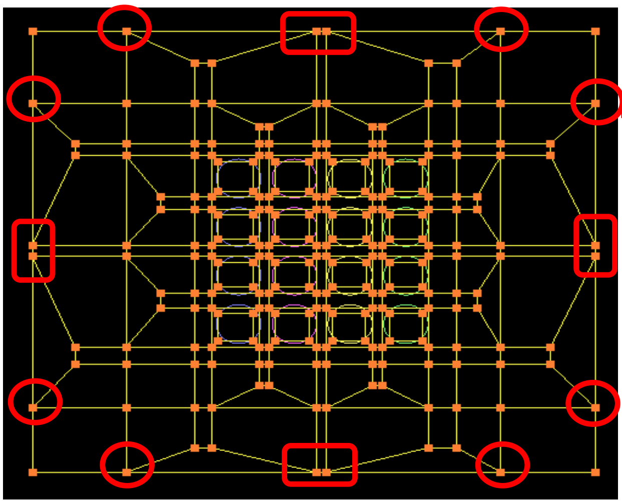


Figure 36a

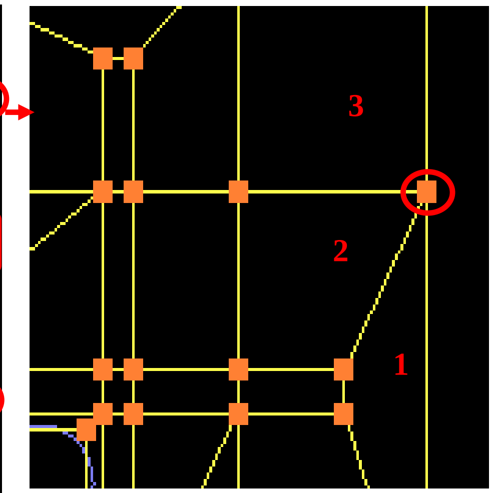


Figure 36b

As per rule 1, these corners cannot be assigned to the surfaces as there are 3 blocks emerging out of it.

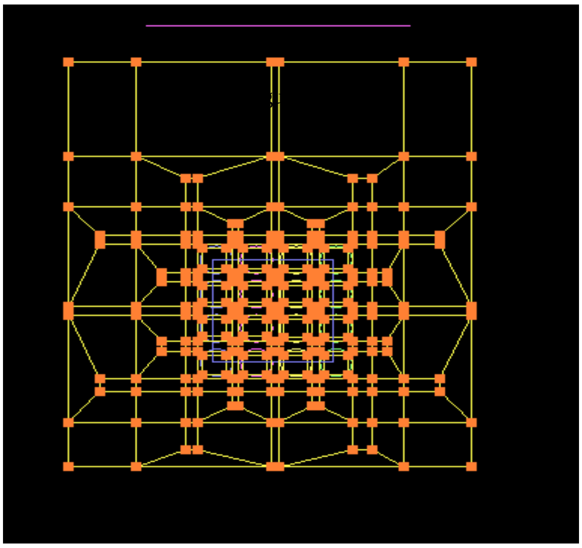


Figure 37.1

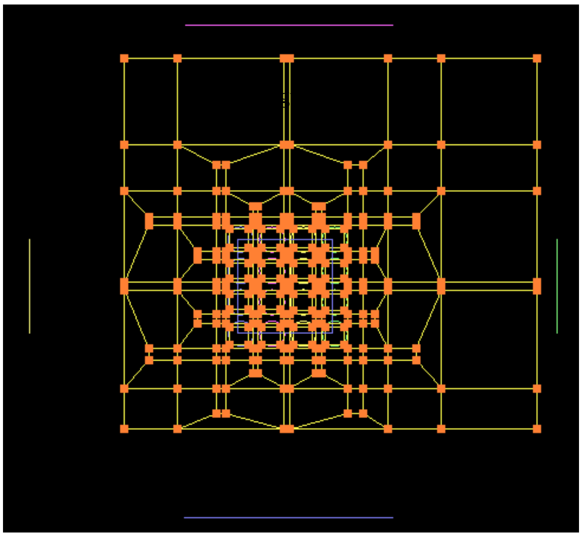


Figure 37.2

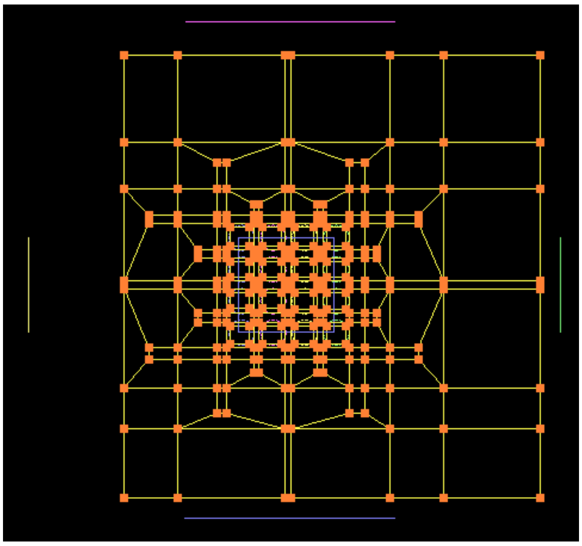


Figure 37.3

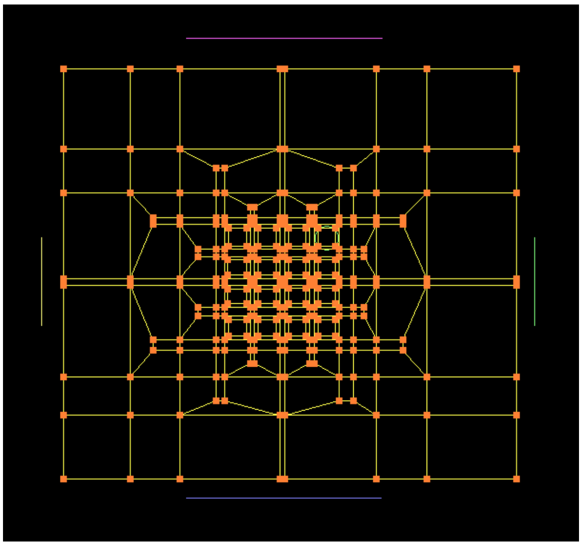


Figure 37.4

Enlarged view of final topology can be seen in figure 38.

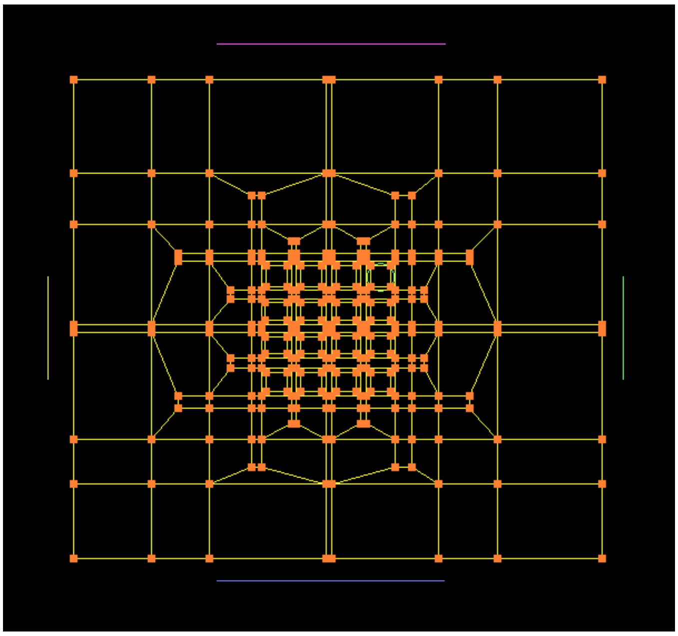


Figure 38

Assign the Corners

Assign respective outer corners to their planes. Assignment for Pipes is already done.

Save file as step10.fra

Start the Gridding Process

- Go to `topo` pull down menu bar and select `Ggrid: start` to start the gridding process.
- Click on ‘OK’ to start the gridding process.
- Switch to Grid Viewer Panel.
- Load the blk.tmp file to view the grid.

Grid can be seen in figure 39. Effect of nesting can be easily seen.

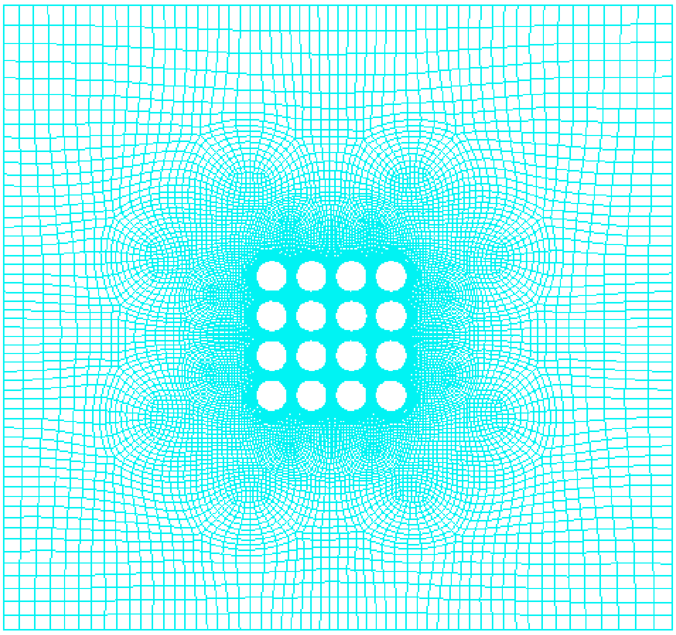


Figure 39.1

A zoomed view near top pipes and nesting can be seen in figure 39.2

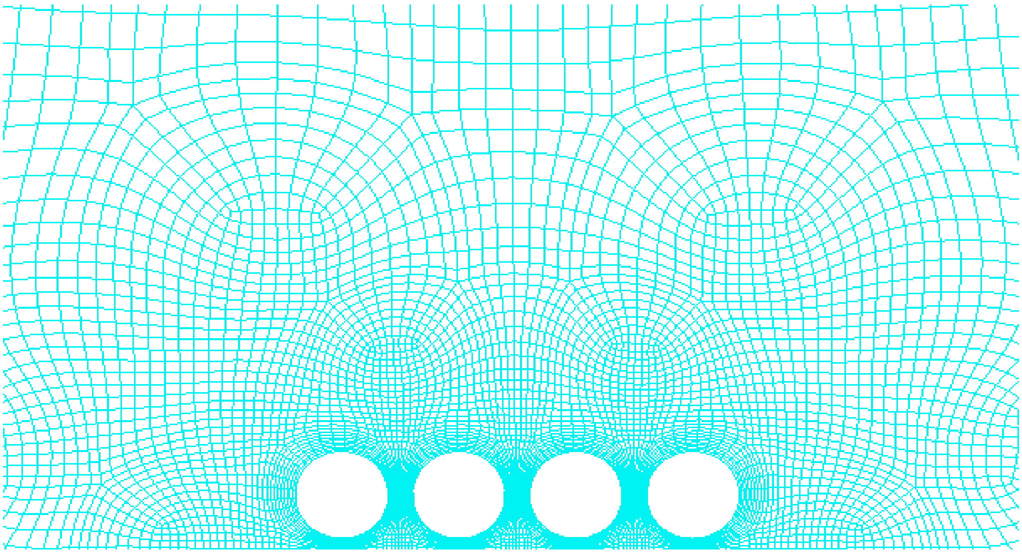


Figure 39.2