Surface Quality and Analysis

Consumer products and aerodynamically important parts are characterized by smooth flowing surfaces. The quality or smoothness of a surface greatly influences the look and in some cases functionality of a product.

When a surface of a consumer product is visible to a customer, it should be without any physical imperfection. These highly aesthetic surfaces are closely associated with the like or dislike of a product. For example if you look at a new car, all of the large panels you see will need to be of high quality. The polished surface will show up the slightest defect. Even the slightest unintended deformation of the reflection is unacceptable.

Continuity

The smoothness of a curve or surface is defined by its level of geometric continuity. Continuity can be described as a measure of how well the curves or surfaces blend with each other.

There are three levels of continuity. These levels of continuity specify the smoothness of a surface or curve. These levels are as follows:

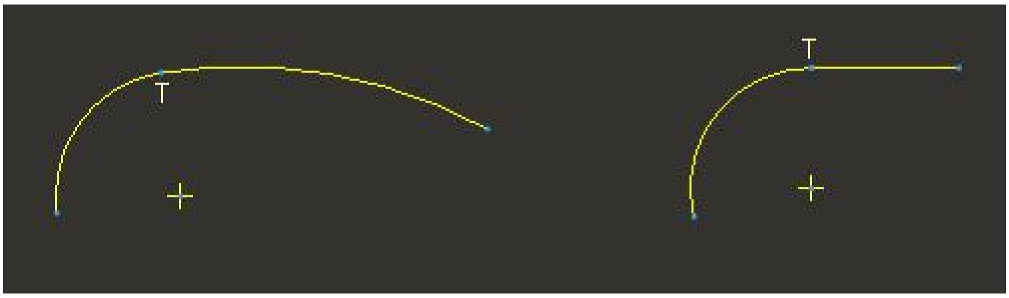
1. Positional continuity
2. Tangential continuity
3. Curvature continuity

Positional continuity (G0)

Positional continuity exists when the ends of two curves or surfaces coincide. This is the lowest level of continuity. Surfaces having this level of continuity show sharp corners so this level of continuity is seldom desired. This level of continuity is also called the G0 continuity. Examples are shown in the figure below.

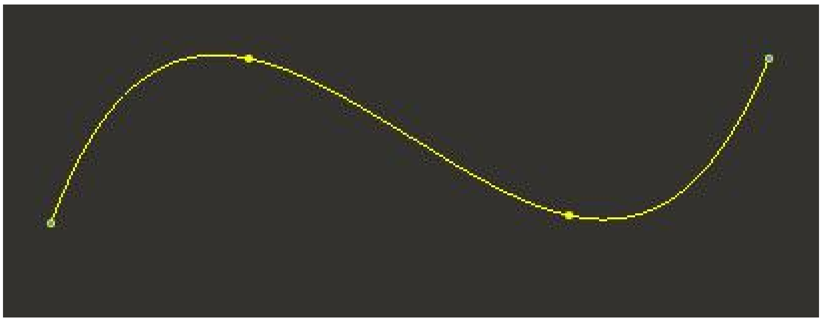
Tangential continuity (G1)

Tangential continuity exists when the ends of two curves or surfaces are coincident and tangent to each other. This level of continuity can often be sufficient for the surfaces that are not very prominent. This level of continuity is also called the G1 continuity. Examples are shown in the figure below (In figure “T” stands for tangent).



Curvature continuity (G2)

Curvature continuity exists when the ends of two curves or surfaces are tangent and their curvature matches at their ends. This can be visually recognized as “perfectly smooth”. This level of continuity is also called the G2 continuity. Usually splines are used to build the curvature continuous datum curves. A curvature continuous spline is shown in the figure below.

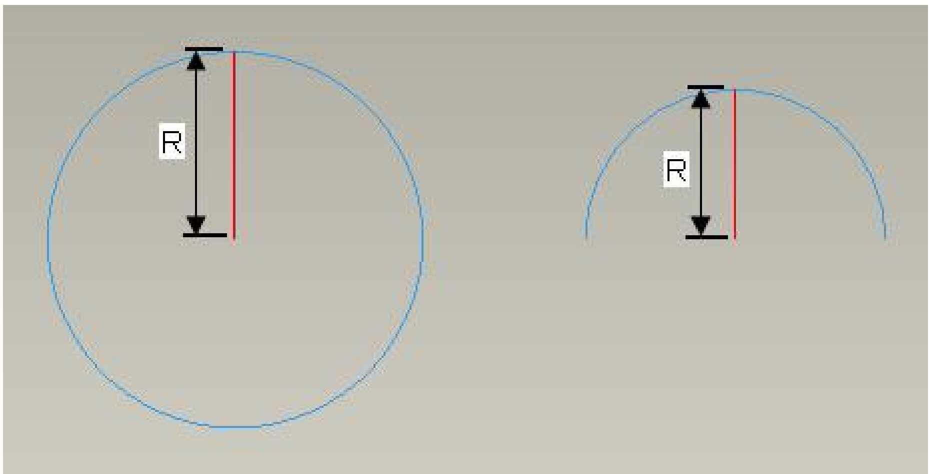


Terminology related to the concept of continuity requires some elaboration. So now we will give an explanation for the following commonly used terms.

1. Radius
2. Radius of Curvature
3. Curvature

Radius

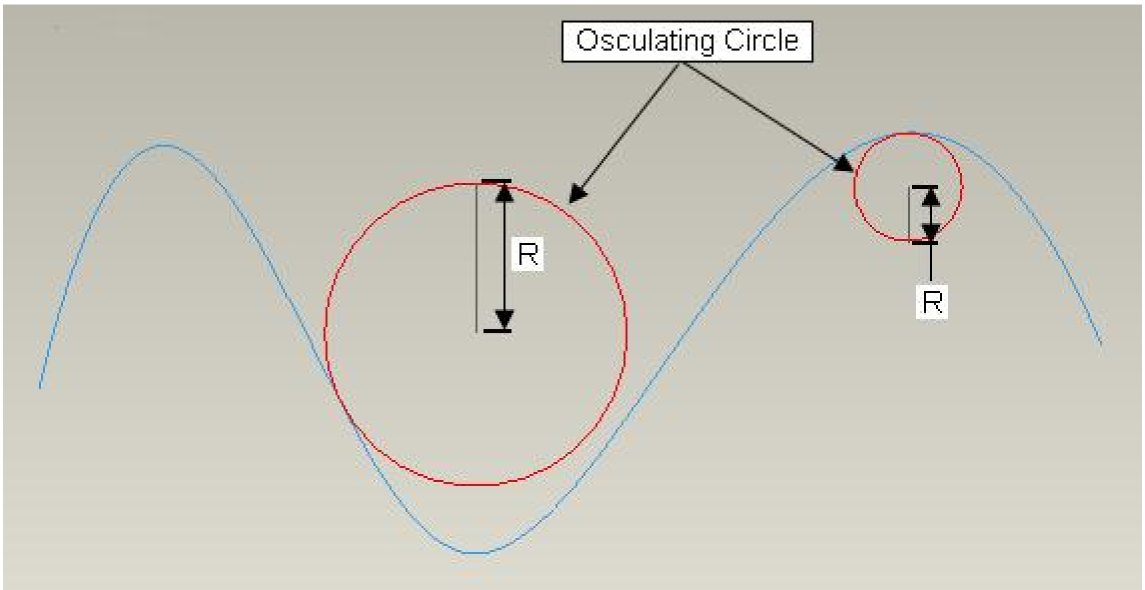
For a simple circle or a circular arc, radius is defined as the length of a straight line extending from the center of a circle to its edge. In the following figure, radius is denoted by R.



A straight line is considered to have a very large radius approaching infinity.

Radius of curvature

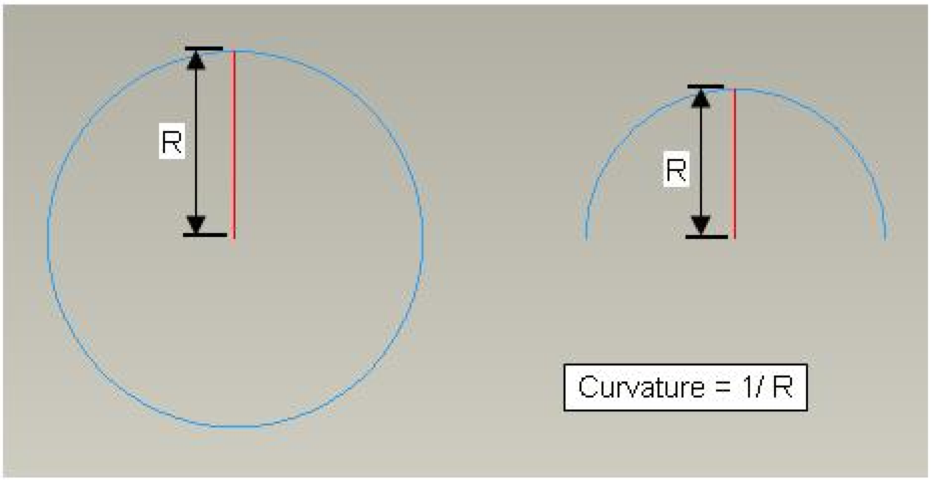
The radius of curvature of a curve at a point is the radius of the osculating circle at that point. Osculating circle is defined as a circle that "fit" the curve at a point. If the curve is turning sharply, the radius of curvature is small and if the curve is turning slowly, the radius of curvature is large.



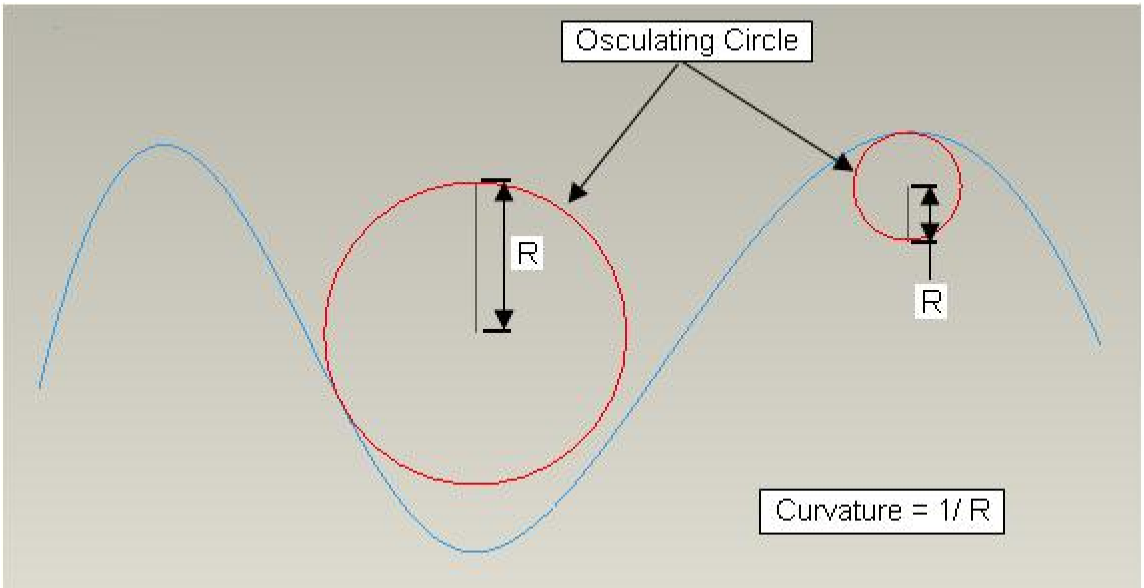
Please note that radius of curvature for a spline is not constant and varies along the length of curve.

Curvature

The curvature of a circle or circular arc is the inverse of its radius.



The curvature of a curve is the inverse of radius of curvature at any given point.



So the curvature of a circle or circular arc is constant and for a freeform curve changes at any given point.

The curvature for a straight line is 0 (as 1/Infinity = 0)

Note: In this section, splines are frequently used. So you must have gone through the exercises in “Sketched Datum Curves” sub-section that is located inside the “Datum Features” section.

Curve Quality

As the quality of a surface depends upon the underlying curves, so it is important to create smooth flowing or curvature continuous curves to achieve the high quality surfaces.

Creo provides the following tools to analyze the quality of a surface.

Radius analysis

Display the radius of the curve at the selected point

Curvature analysis

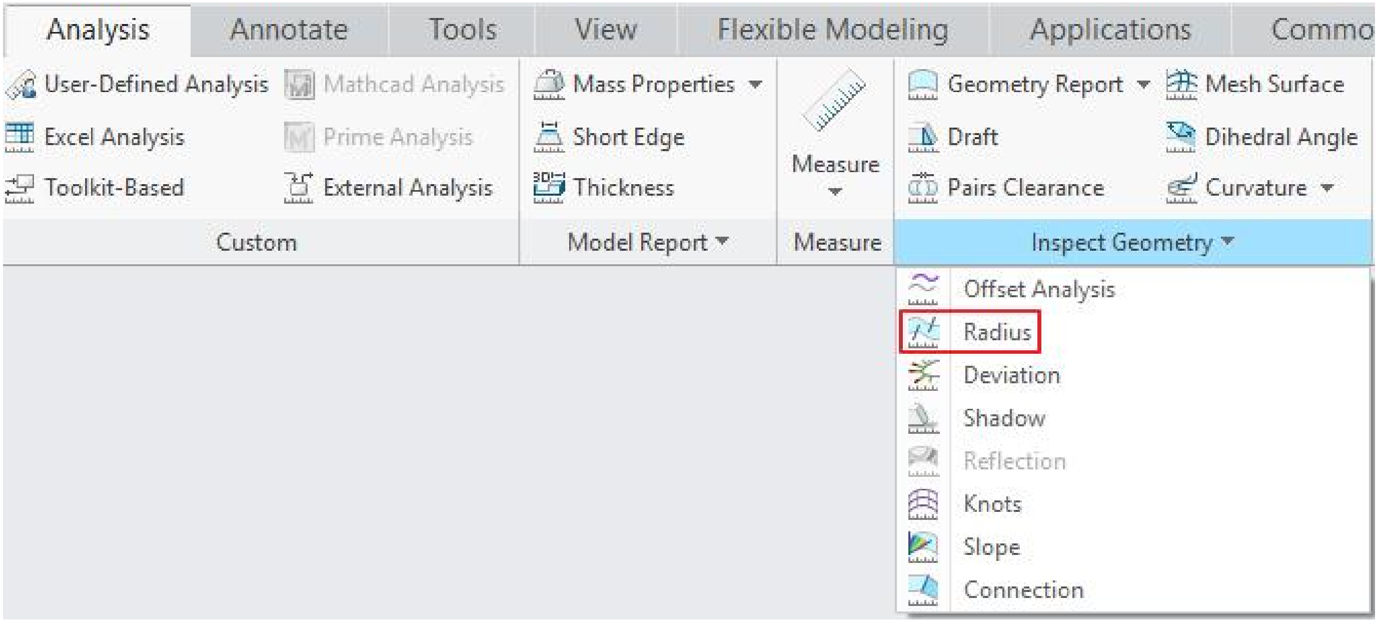
Curvature analysis plots the curvature of a selected curve, in order to analyze its smoothness. Ideally, a curvature plot should be smooth. Dips and bumps in the curvature plot are signs that the curve has a rapid change in shape

Exercise 1

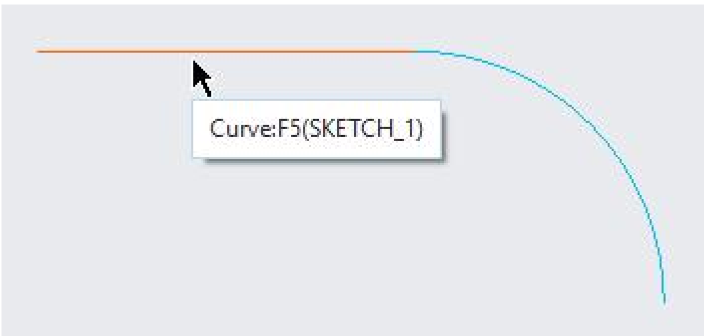
In this exercise we will learn how to analyze a curve using Radius and Curvature analysis tools.

Set the working directory to the ANALYSIS folder and open the model CURVE1.PRT

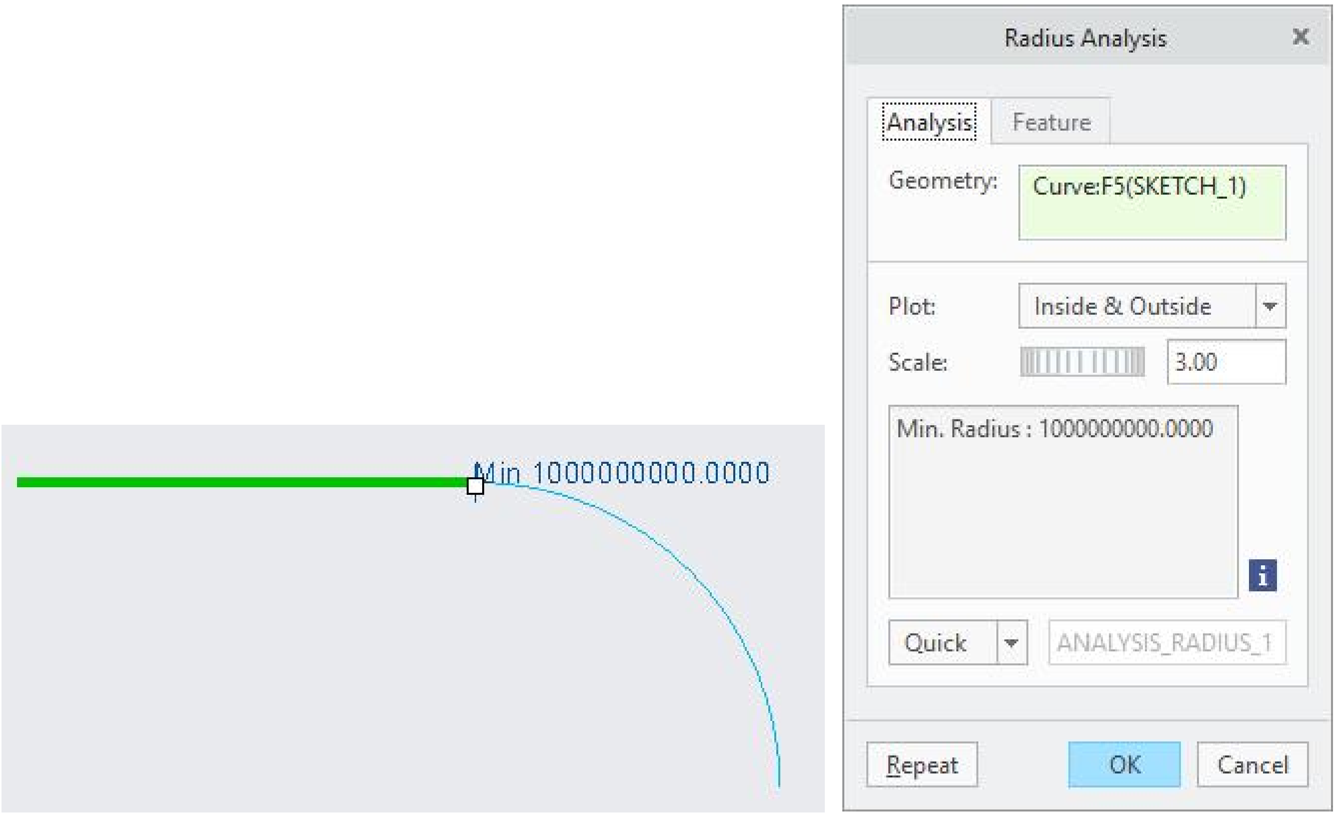
First we will analyze the curve with Radius Analysis tool. So pick  on the Analysis tab.



Now system will ask you to pick a curve to be analyzed. So pick the line segment of the sketched curve as shown in the figure below. (Note: do not select the complete sketched curve)

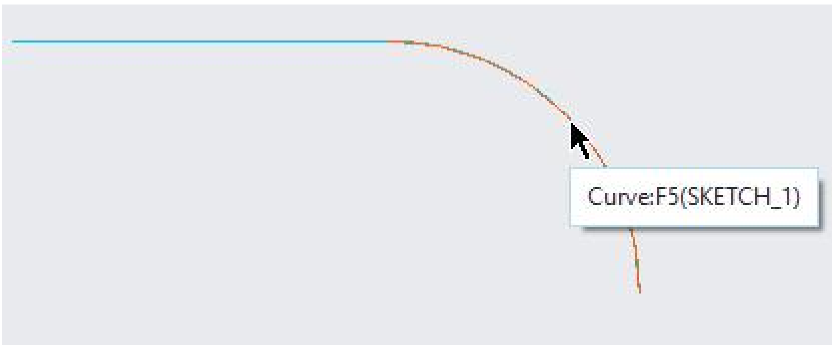


System will show the radius as shown below

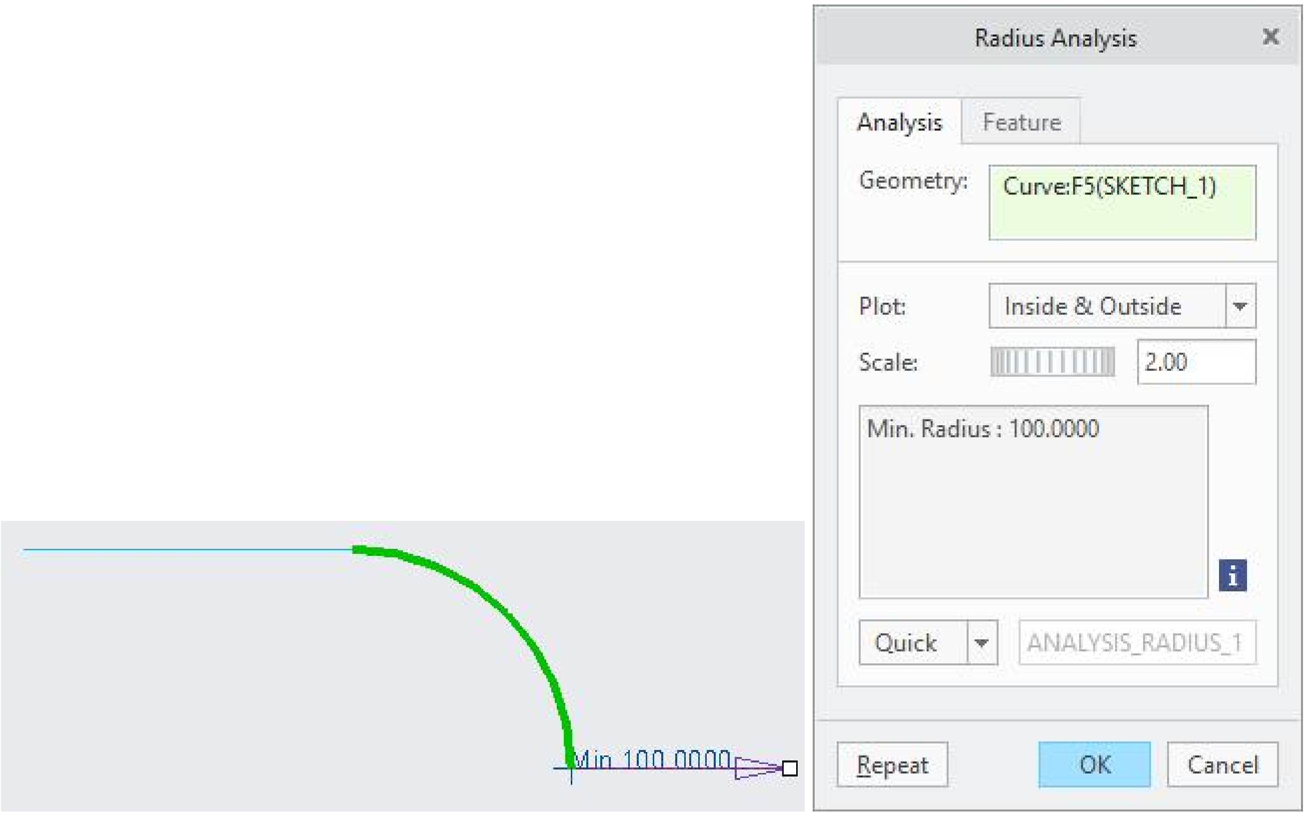


As we know that a straight line is considered to have a very large radius approaching infinity. Therefore system is showing a very large value.

Now pick the arc segment of the sketched datum curve as shown in the figure below.



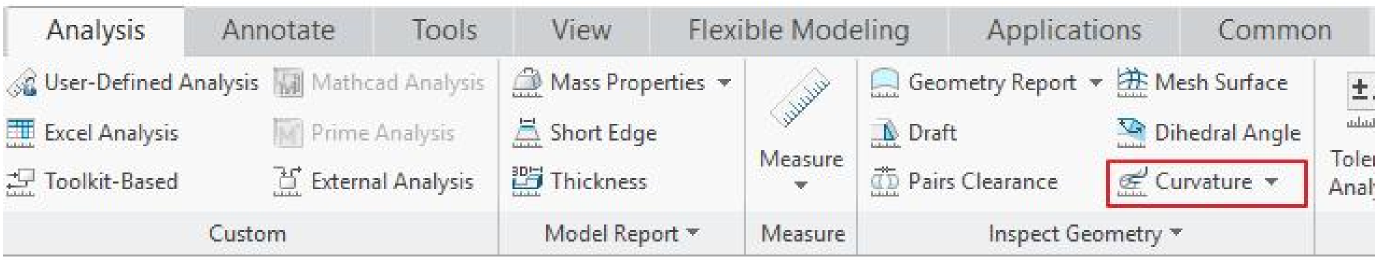
System will shown the radius as shown below



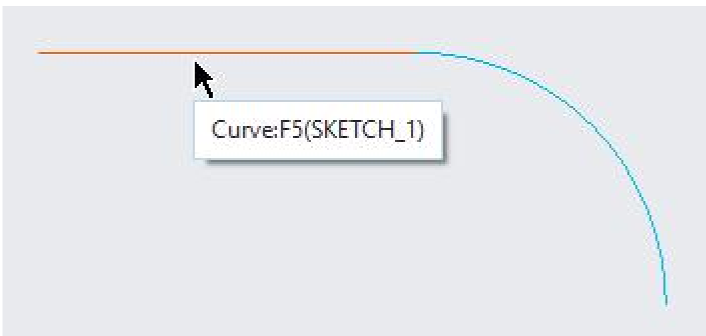
The Results box shows that minimum radius is 100 (you can confirm the radius by redefining the sketch).

Pick  to exit the dialog box.

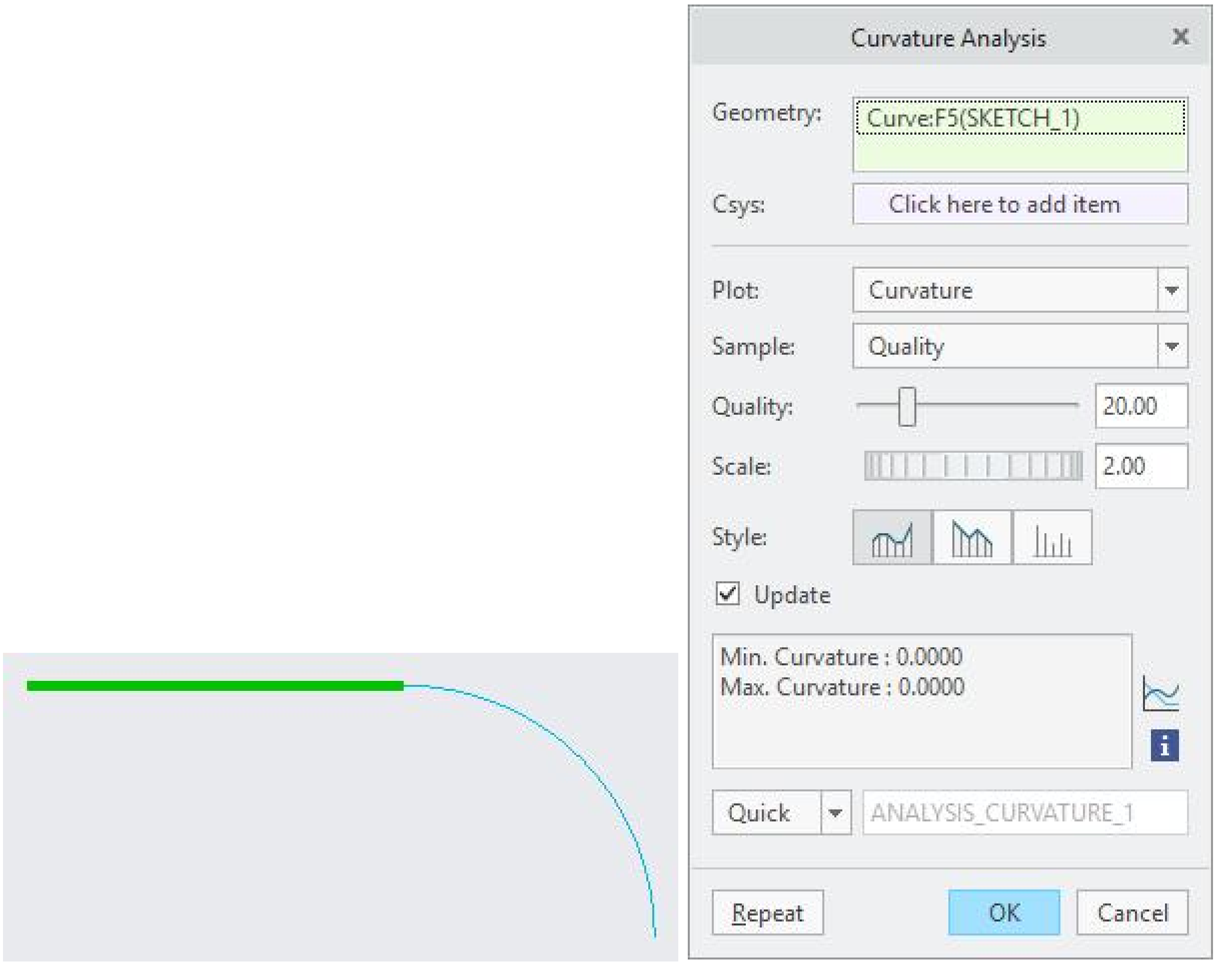
Now we will analyze the curve with Curvature Analysis tool. So pick  on the Analysis tab.



System will ask you to pick a curve to be analyzed. So pick the line segment of the sketched curve as shown in the figure below.

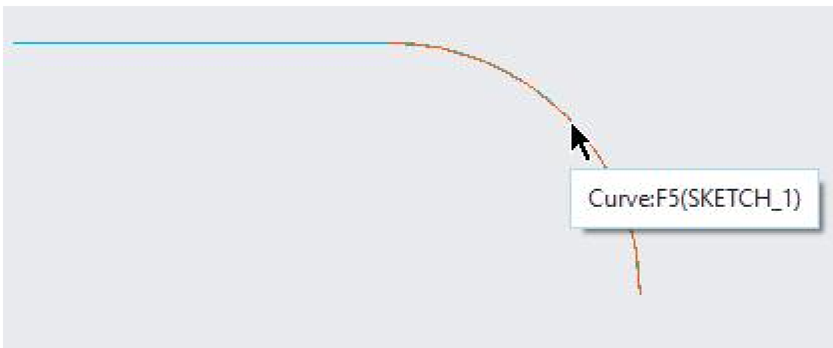


System will shown the curvature as shown below

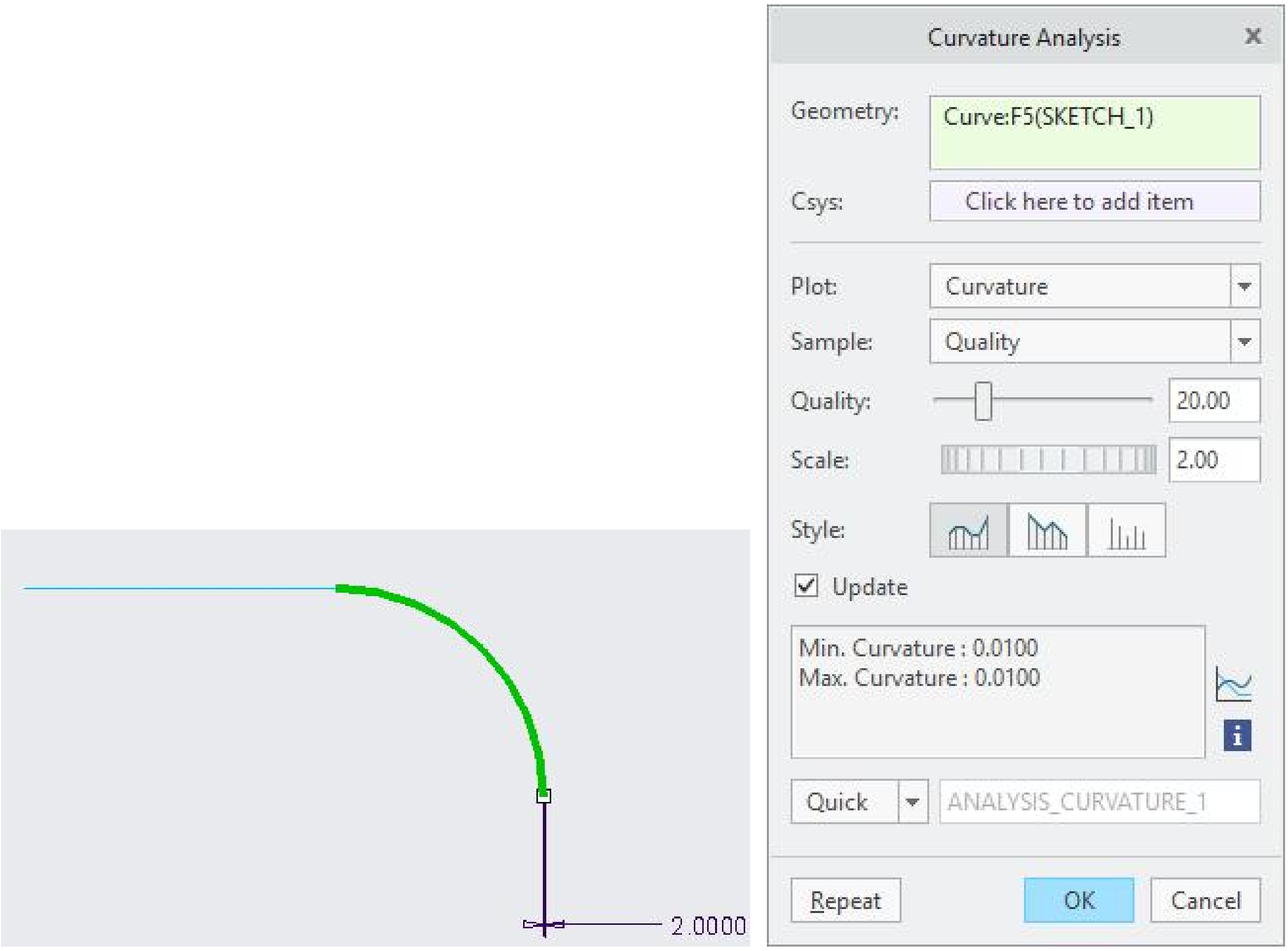


As the selected curve is a straight line so system is showing its curvature as 0.

Now pick the arc segment of the sketched datum curve as shown in the figure below.



System will shown the curvature as shown below



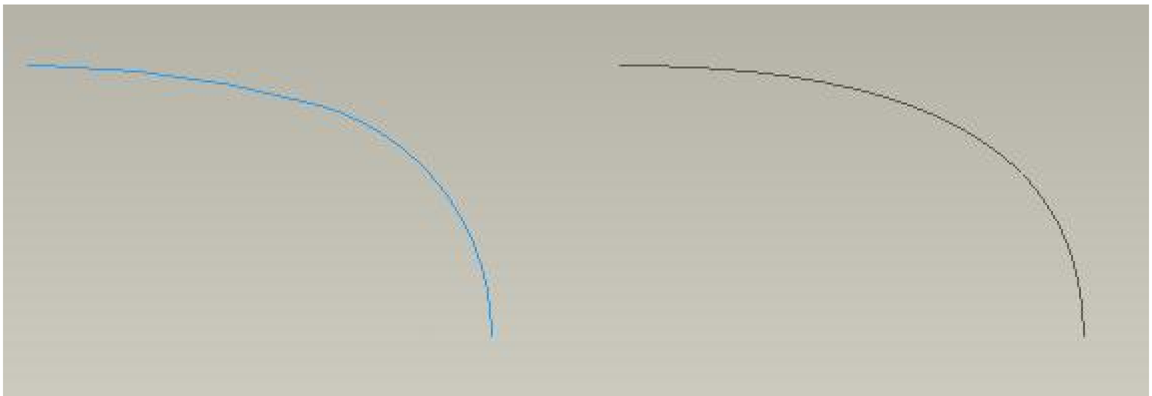
Notice that the curvature is 0.01 that is the inverse of radius of arc (i.e. 1/100)

Exercise 2

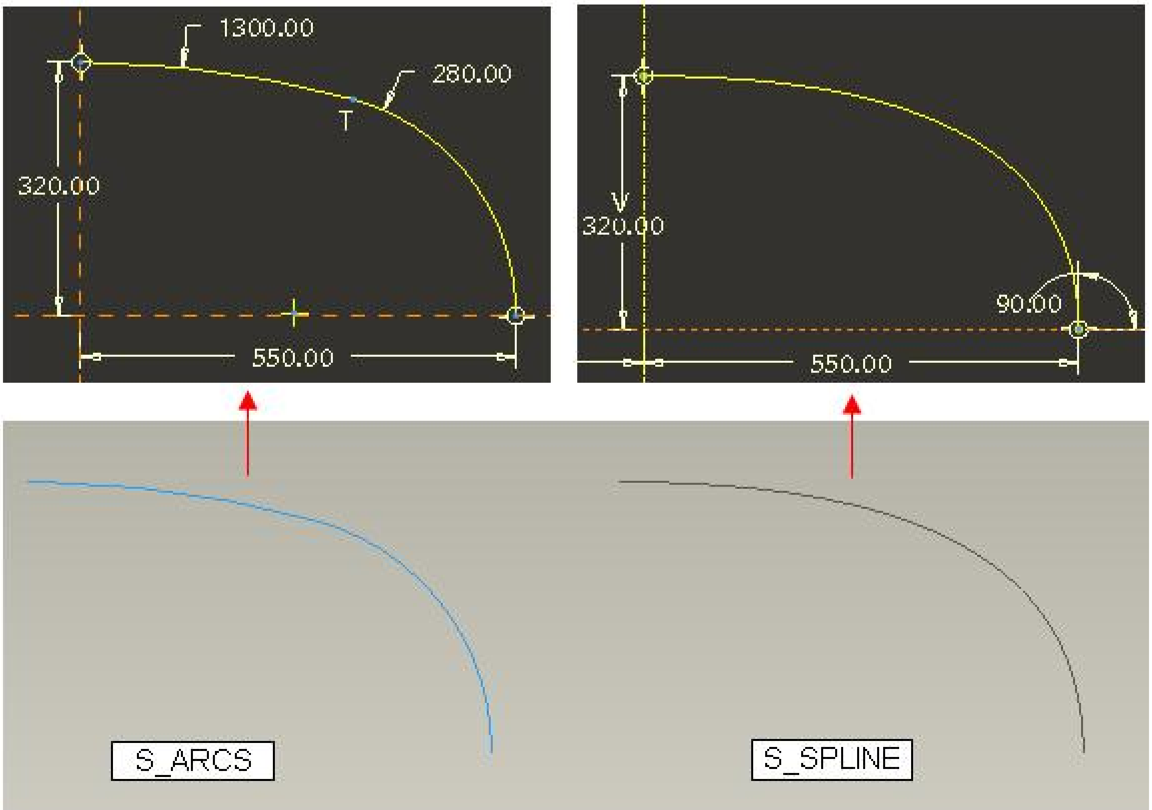
In this exercise we will analyze a curve using Curvature analysis tool and understand the difference between curvature continuous and discontinuous curves.

Set the working directory to the ANALYSIS folder and open the model CURVE2.PRT

The part consists of two datum curves. The curves appear as shown below.



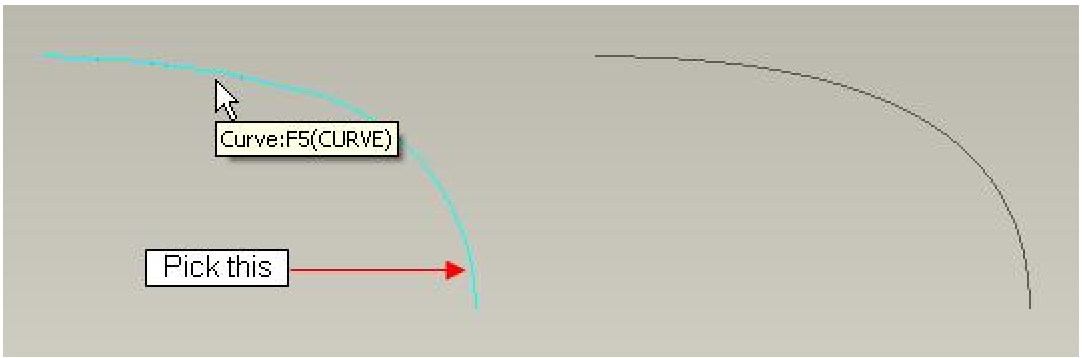
The first curve S_ARCS consists of circular arcs and the second S_SPLINE consists of a single spline as shown below.



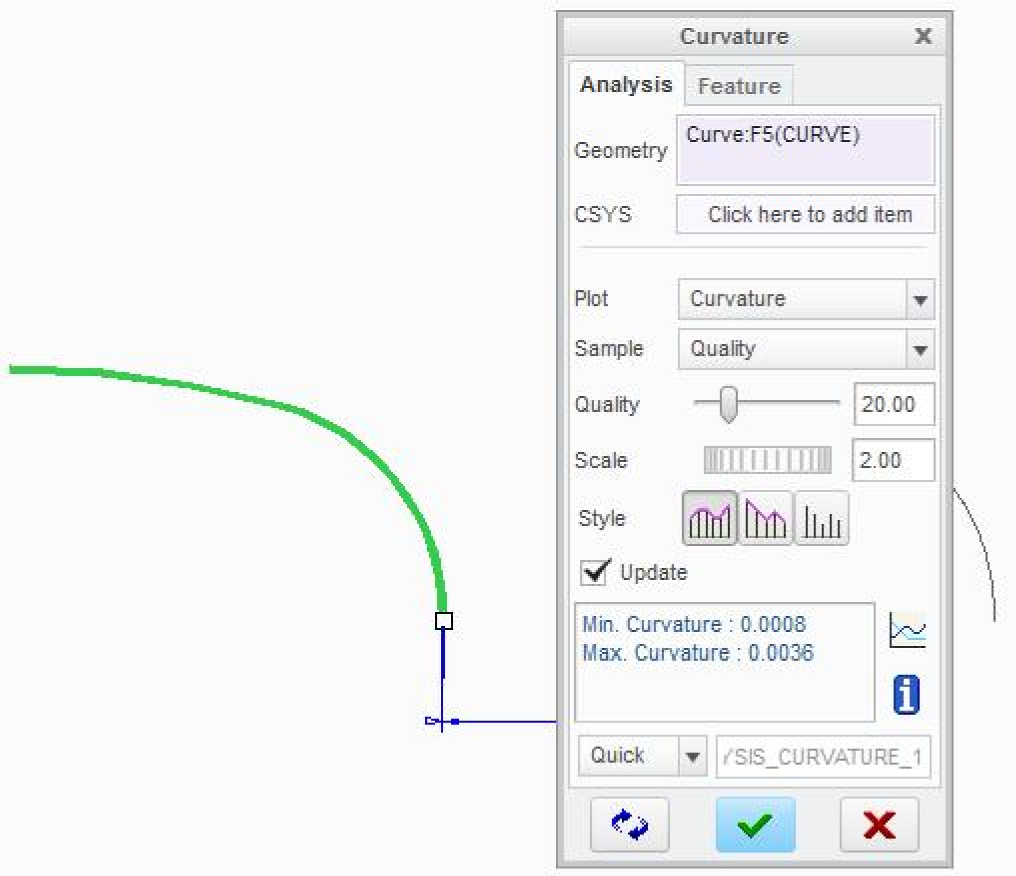
Now we will analyze the curve with Curvature Analysis tool. So pick 

on the Analysis tab.

Now system will ask you to pick a curve to be analyzed. So pick the following curve feature. (Note: Right-click over the curve unless complete curve is highlighted and then select with left mouse pick.)

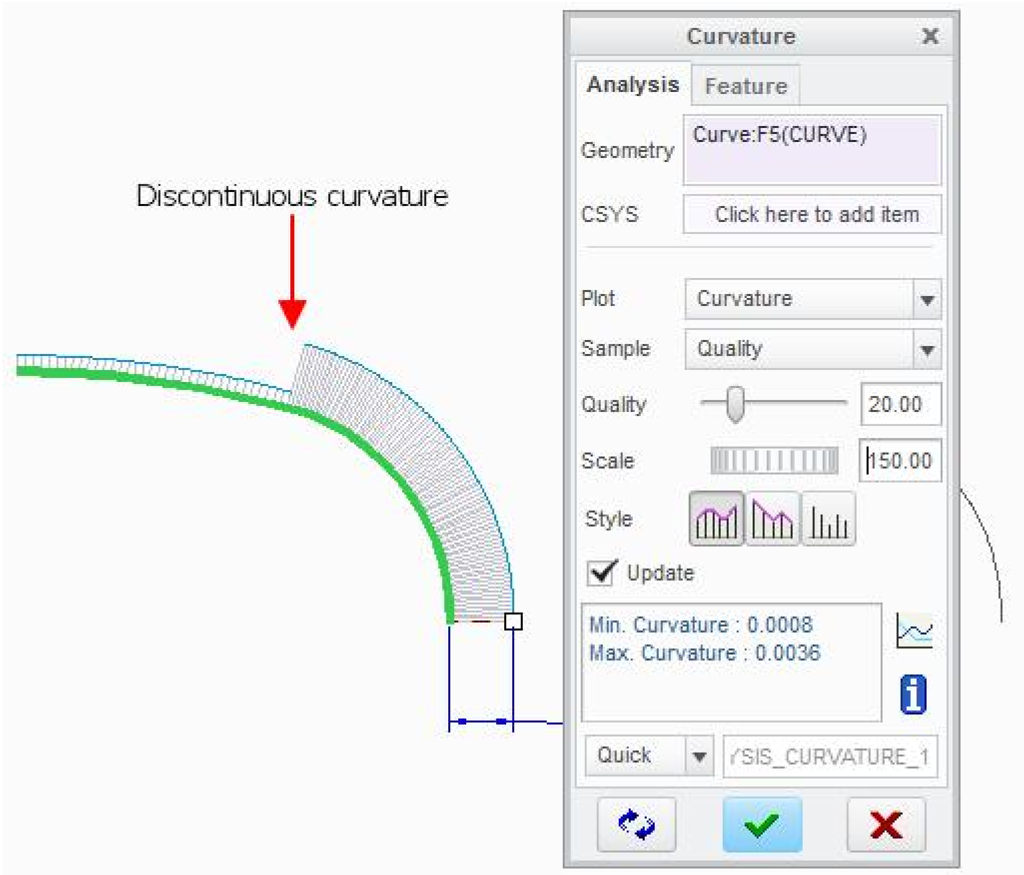


System will shown the curvature as shown below



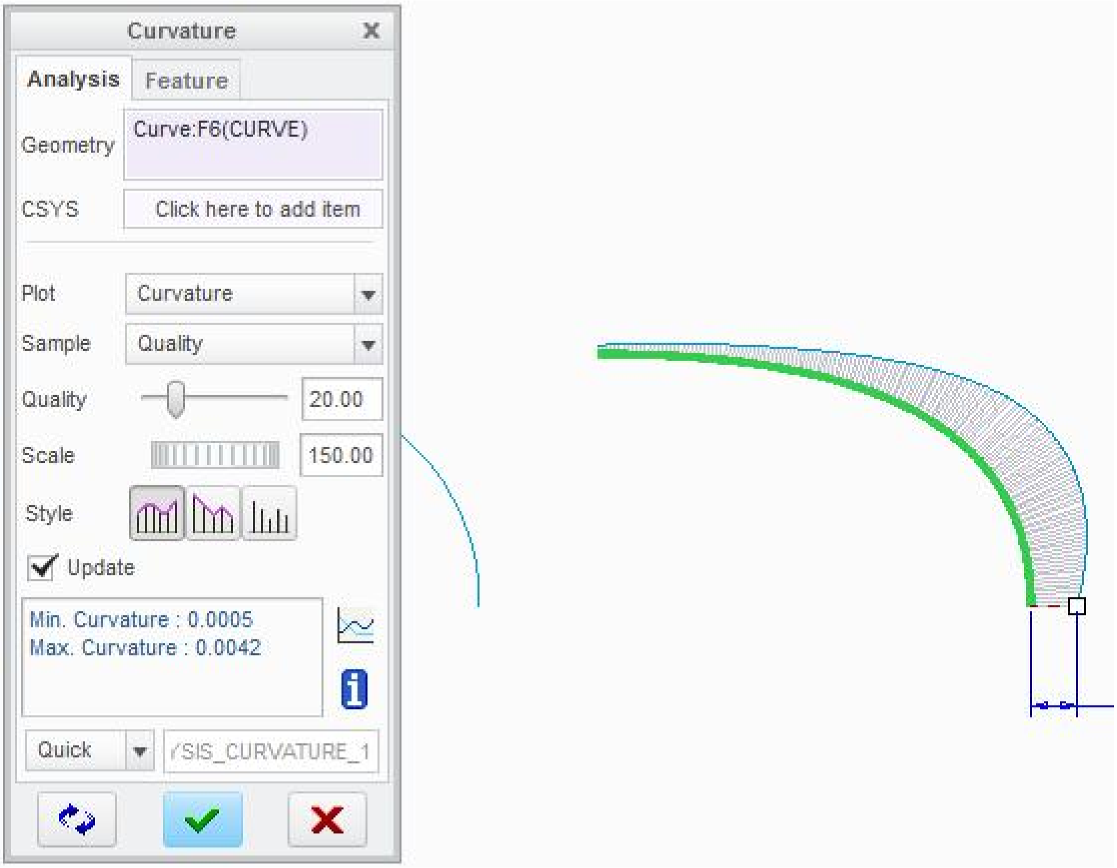
The visual display is not very clear so we need to increase the scale of curvature display.

Change the scale to about **150** and the curvature plot will appear as shown below.



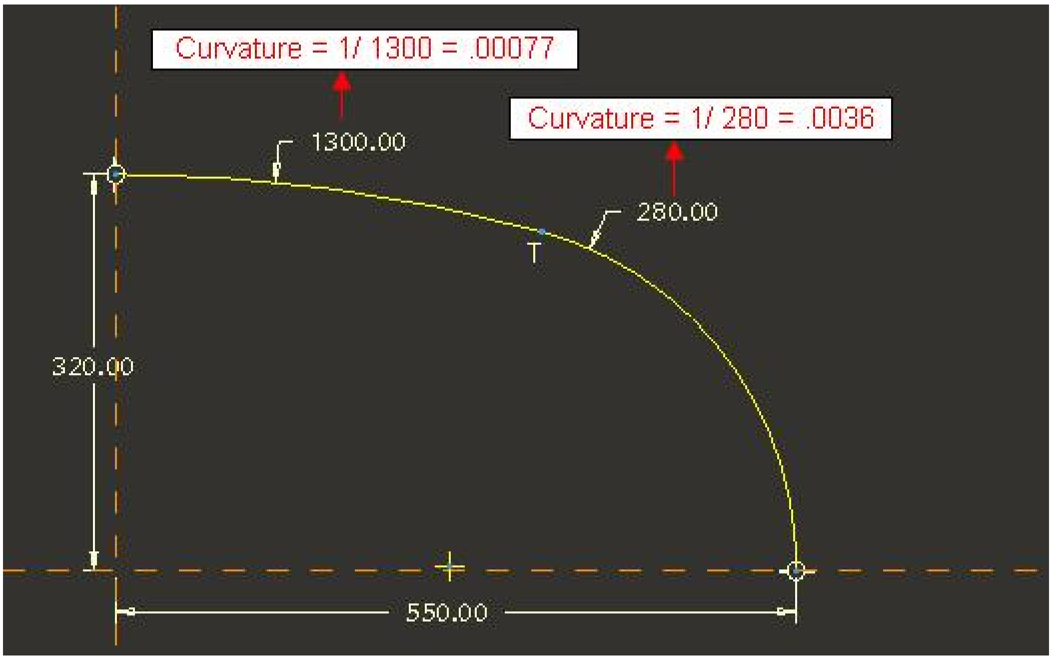
You can notice, in the above figure, the sharp break or discontinuity in the curvature of the selected curve.

Now pick on the second curve feature and system will display its curvature plot as shown below.



You can notice, in the above figure, the curvature plot is very smooth and there is no sharp break or discontinuity. So this curve will be called **curvature continuous**.

The discontinuity in the first datum curve is due to the different radiuses of the arcs. If you edit the definition of the S_ARCS sketched curve you will notice that curve consists of two arcs of different radius.



Exercise 3

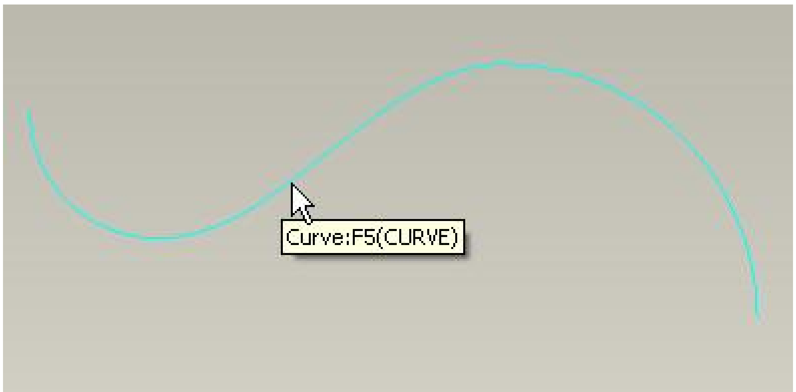
In this exercise we will analyze a curve using Curvature analysis tool and then modify it to make it curvature continuous.

Set the working directory to the ANALYSIS folder and open the model CURVE3.PRT

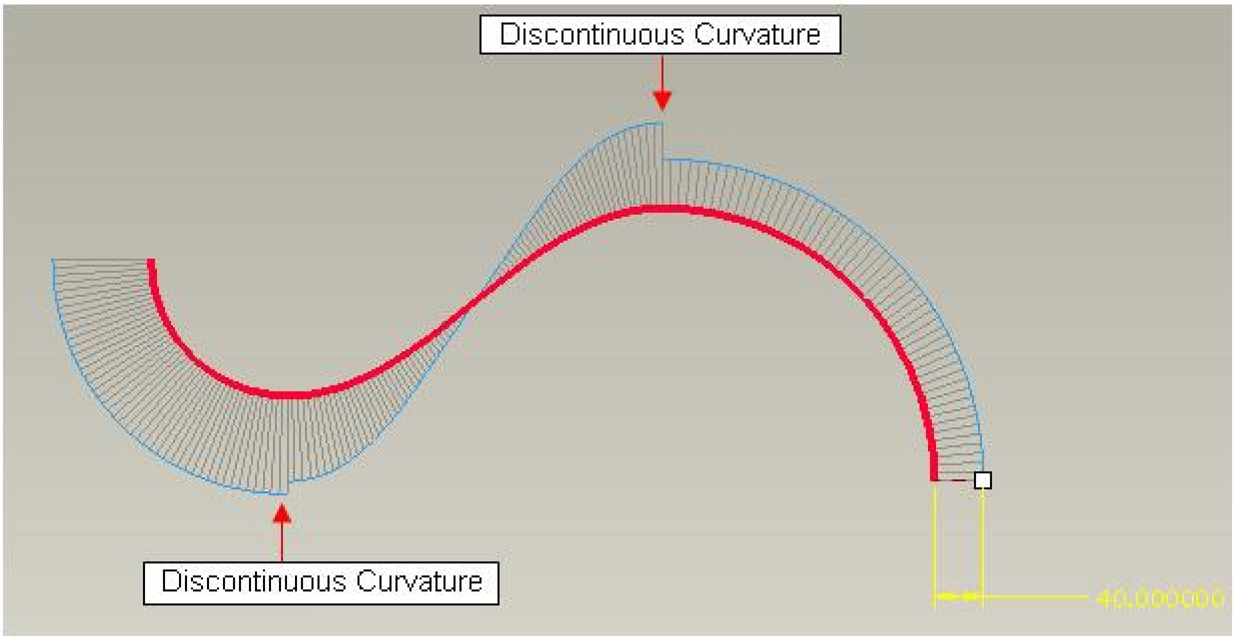
First we will analyze the curve with Curvature Analysis tool. So pick 

on the Analysis tab.

Now system will ask you to pick a curve to be analyzed. So pick the following curve feature.



Increase the scale of curvature display to about **40** for clear display and the curvature plot will appear as shown below.

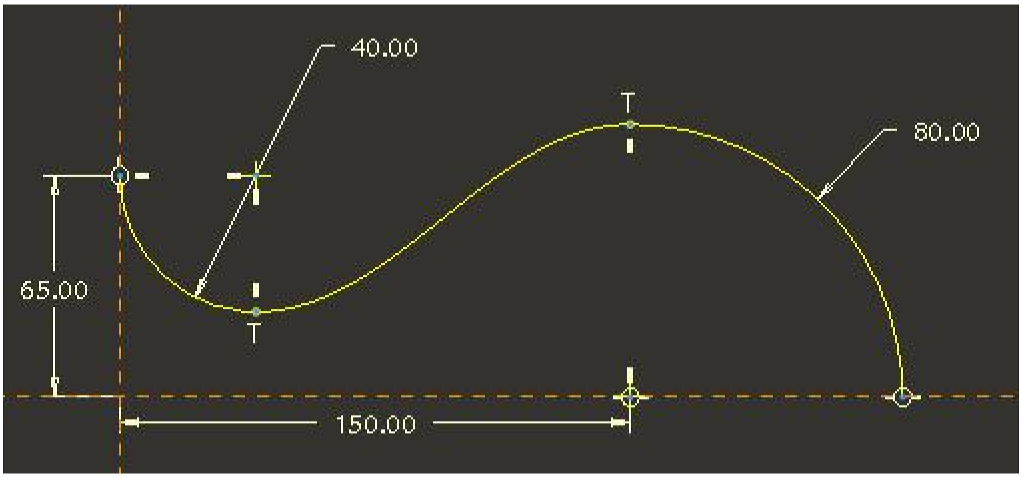


You can notice, in the above figure, the sharp break or discontinuity in the curvature.

Now we will redefine the sketched datum curve and analyze the cause of discontinuity.

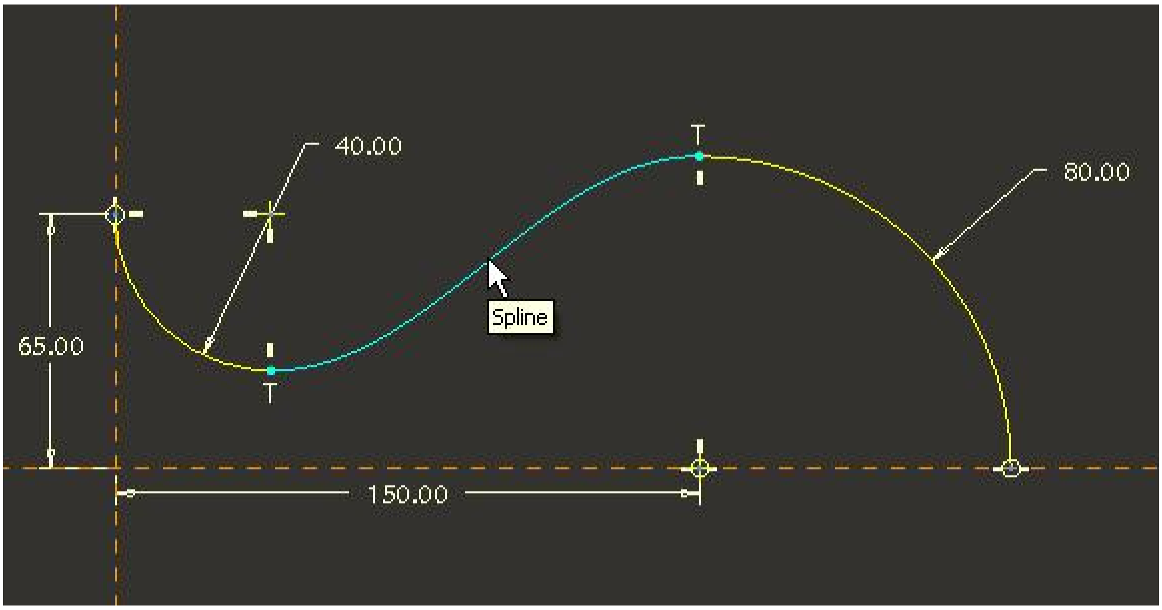
Pick  to exit the dialog box.

Select the "Sketch 1" in model tree and select and sketch will appear as shown below.



In the above figure you can notice that it consists of three segments, the first and last one are circular arcs (evident from the radius dimensions). But it is not clear what type the mid segment is of.

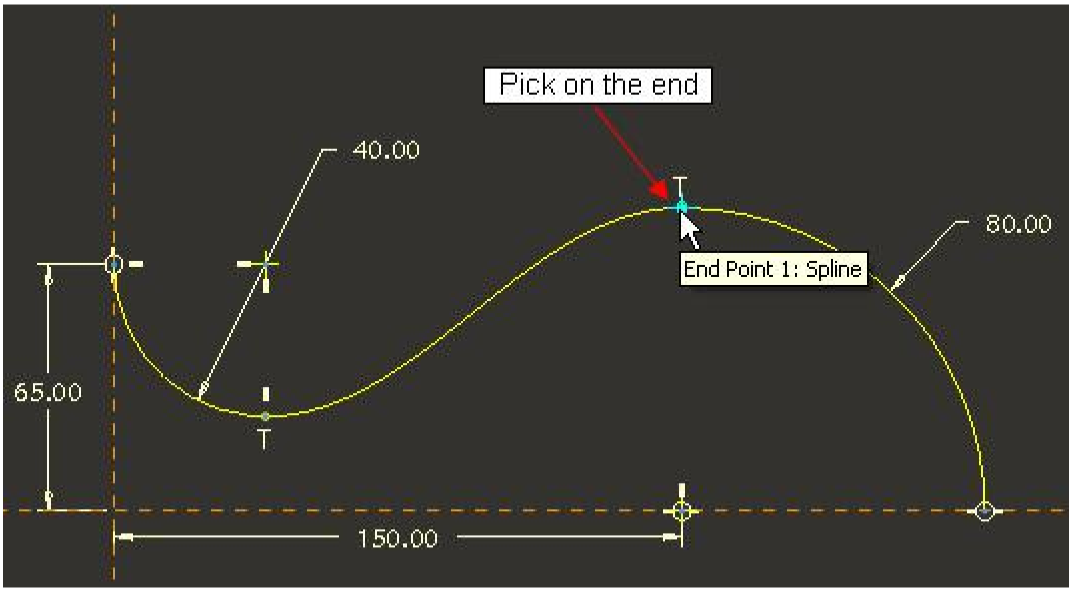
If you place your mouse pointer on the middle entity a tool tip will appear showing that it is a spline as shown below.



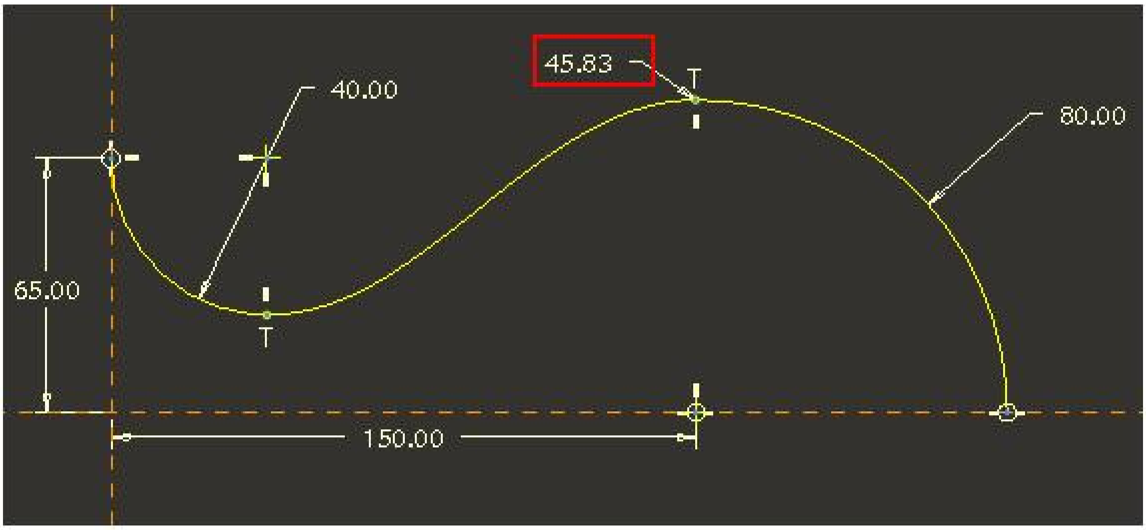
Now we will dimension the radius of curvature at the ends of the spline to be equal to the adjacent arcs so that their curvatures become equal.

So pick

Now pick on the spline endpoint as shown below

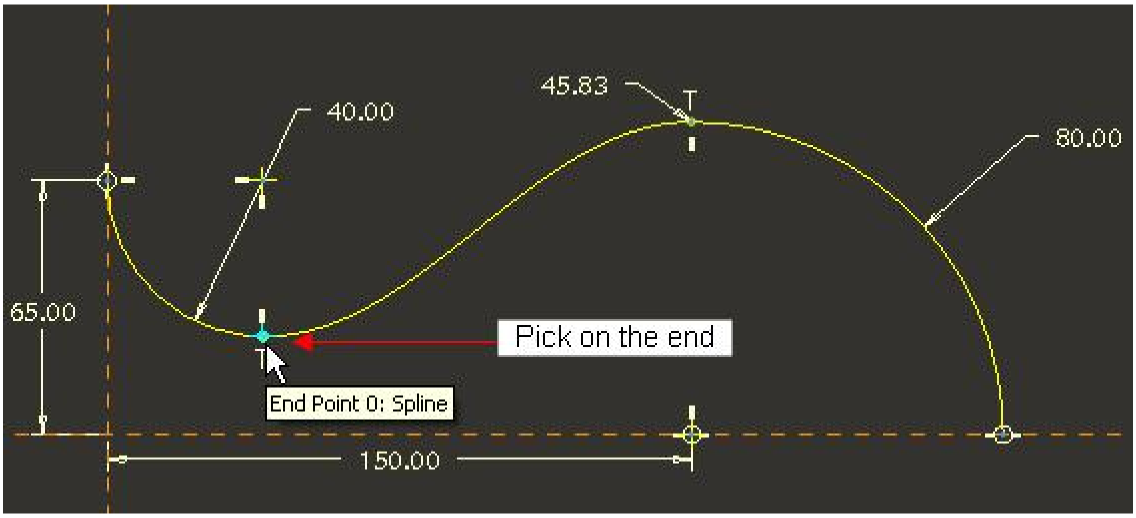


Click the middle mouse button to place the dimension. Middle click once again and the dimension will appear as shown below. (The dimension value may vary for your case)

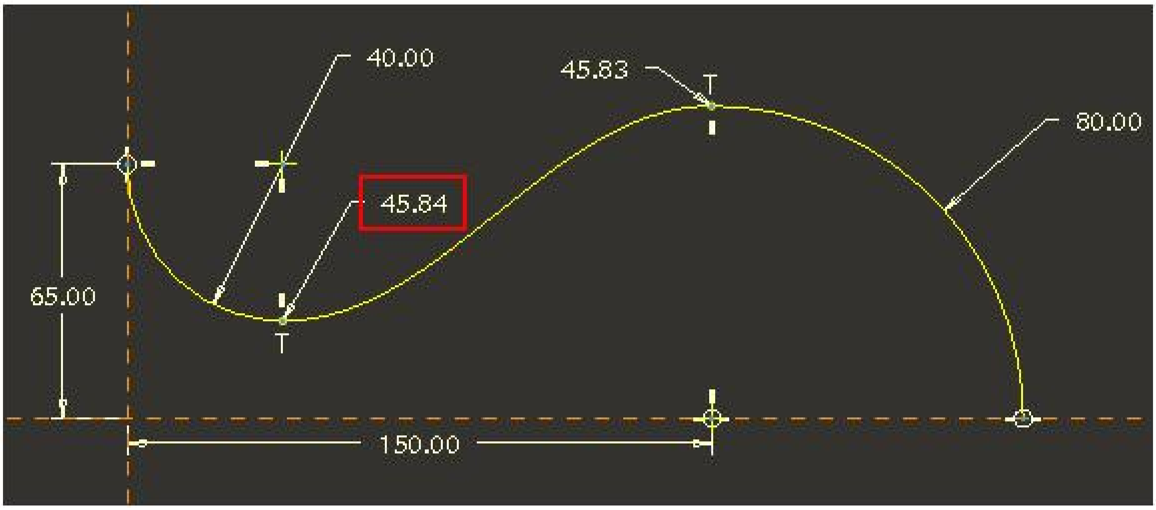


To dimension the second end again pick  if it is not active.

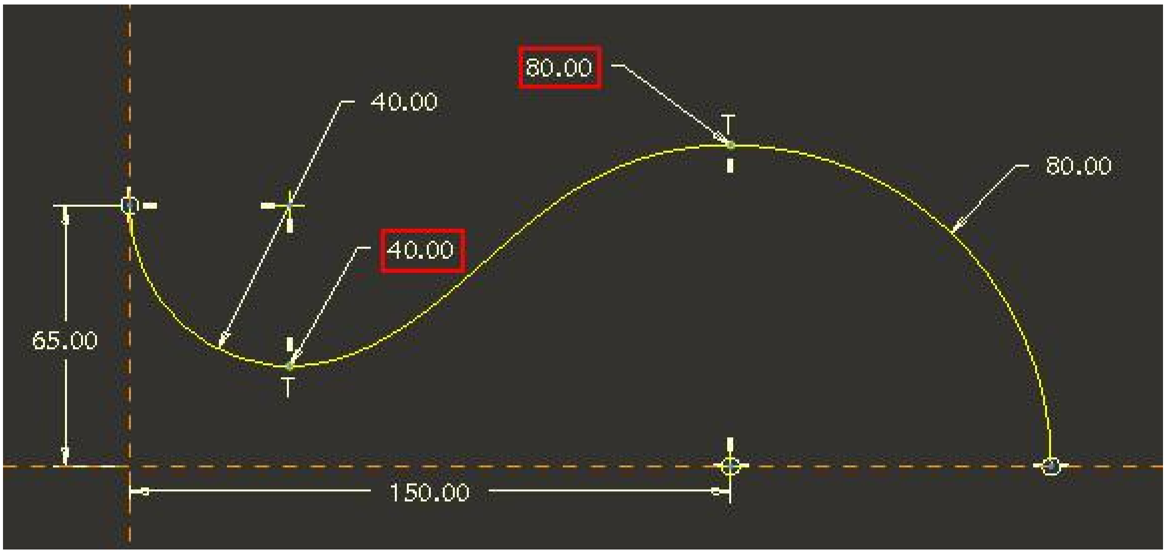
Now pick on the spline endpoint as shown below



Click the middle mouse button to place the dimension. Middle click once again and the dimension will appear as shown below. (The dimension value may vary for you case)



Now modify the dimension values to **40** and **80** for the left and right end respectively as shown below.



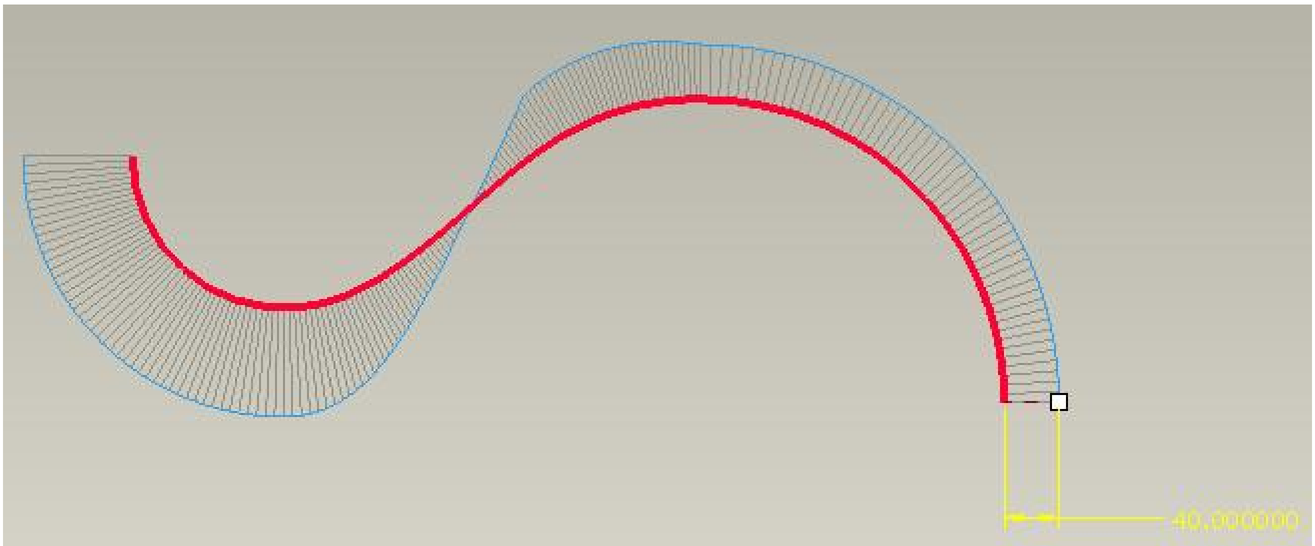
Notice that the “radius of curvature” values are now equal to the radius of adjacent arcs. So the curvatures at the ends of the spline is 1/40 and 1/80 for the left and right end respectively that is equal to that of the adjacent arcs. This makes the chain smooth and curvature continuous.

Pick  to complete the sketch.

Now we will analyze the curve with Curvature Analysis tool. So pick 

on the Analysis tab.

Select the curve and set suitable scale and it will appear as shown below.



You can notice, in the above figure, the curvature plot is very smooth and there is no sharp break or discontinuity. So this curve will be called **curvature continuous**.

Select **File > Save** to save the work done so far.

Exercise 4

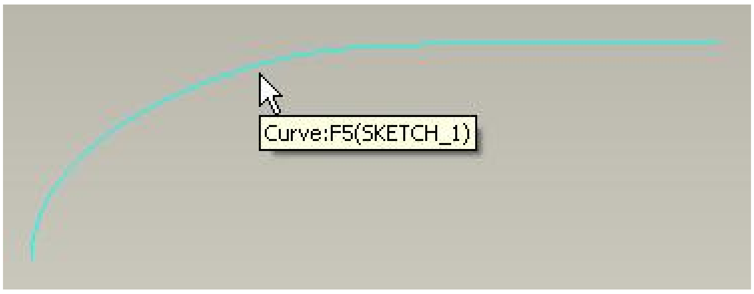
In this exercise we will analyze a curve using Curvature analysis tool and then modify it to make it curvature continuous.

Set the working directory to the ANALYSIS folder and open the model CURVE4.PRT

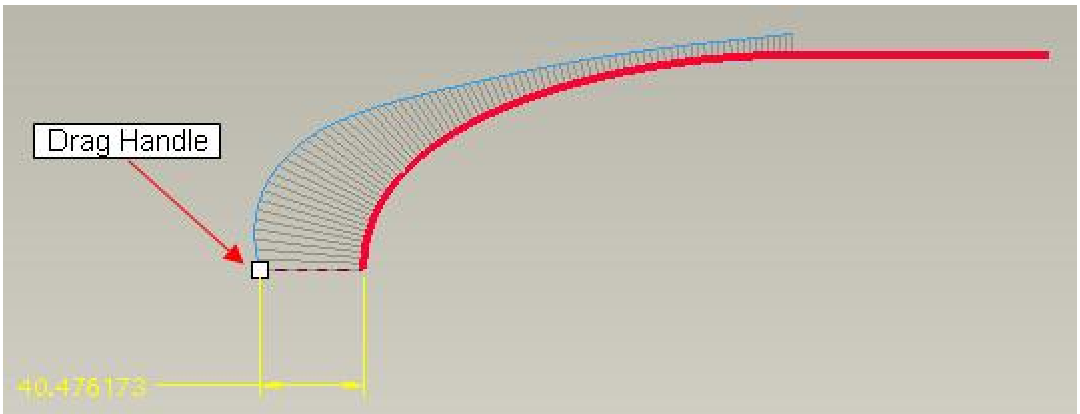
First we will analyze the curve with Curvature Analysis tool. So pick 

on the Analysis tab.

Now system will ask you to pick a curve to be analyzed. So pick the following curve feature.



Increase the scale of curvature display to about **40** either by dragging the Drag Handle or using the dialog box. Curvature will appear as shown below.

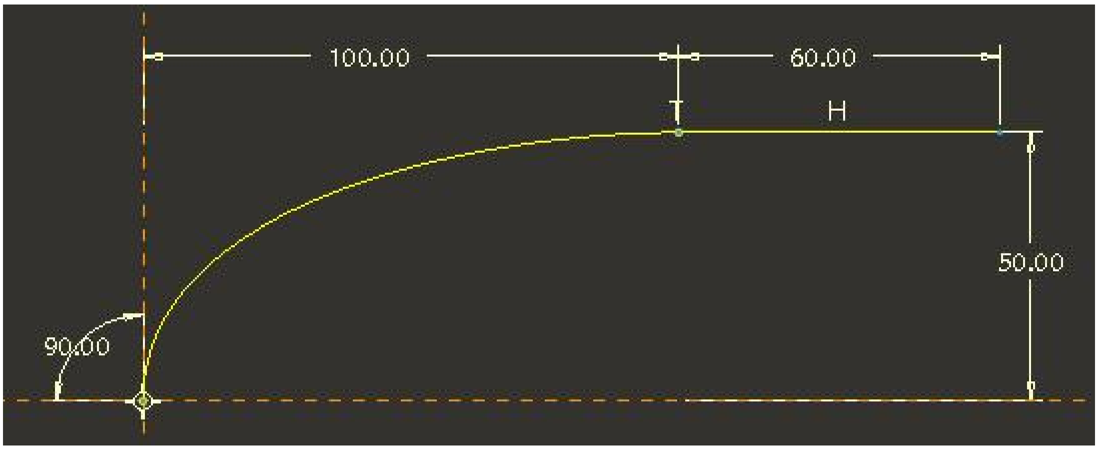


You can notice, in the above figure, the sharp break or discontinuity in the curvature.

Now we will redefine the sketched datum curve and analyze the cause of discontinuity.

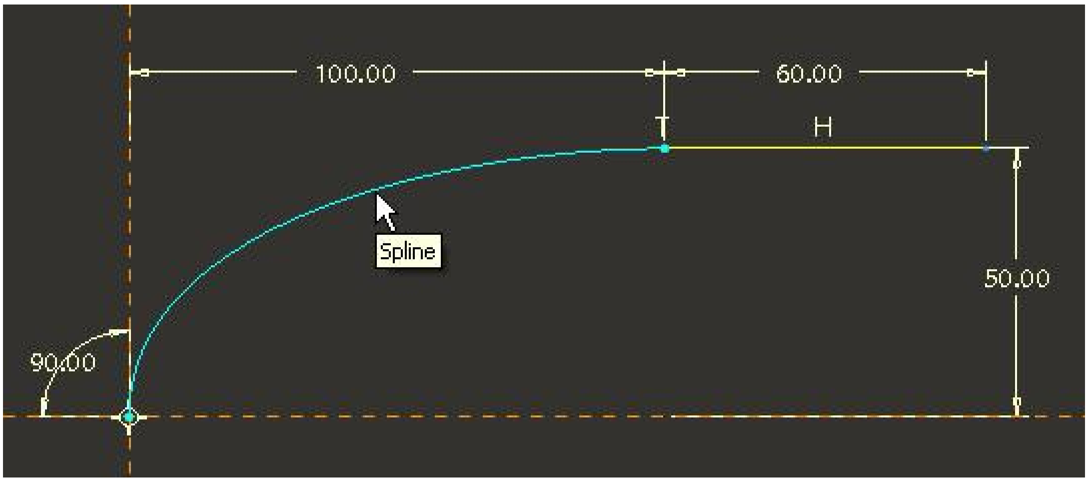
Pick  to exit the dialog box.

Select the “Sketch 1” in model tree and select  and sketch will appear as shown below.



In the above figure you can notice that it consists of two segments, the right segment is a line apparent from horizontal constraint.

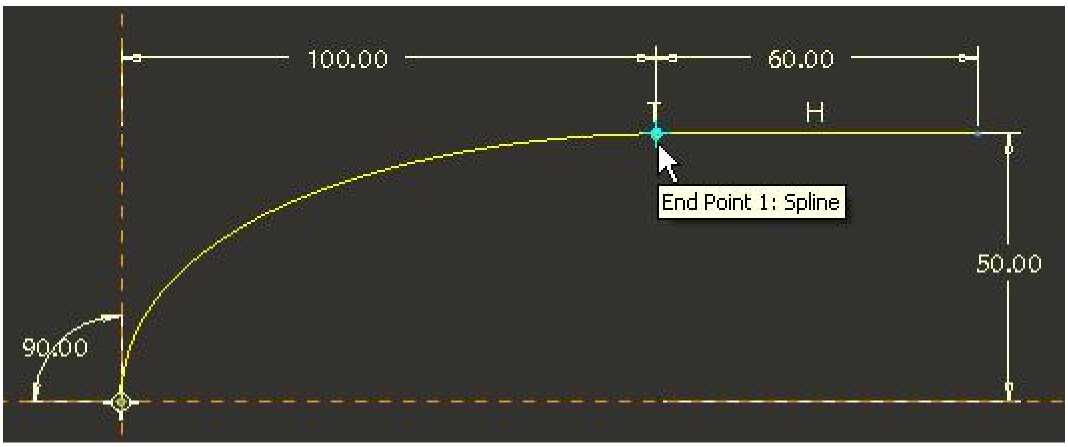
If you place your mouse pointer on the left entity a tool tip will appear showing that it is a spline as shown below.



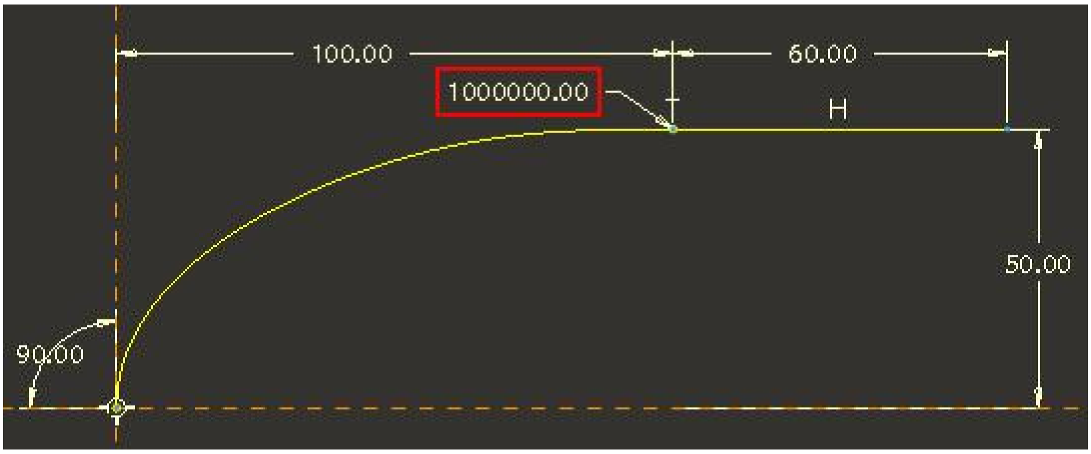
A straight line is considered to have a very large radius approaching infinity and hence zero curvature. So we need to make the “radius of curvature” of the end of spline large so that its curvature approaches zero.

Pick 

Now pick on the spline endpoint as shown below



Click the middle mouse button to place the dimension and enter **1000000** as dimension value. The dimension will appear as shown below.

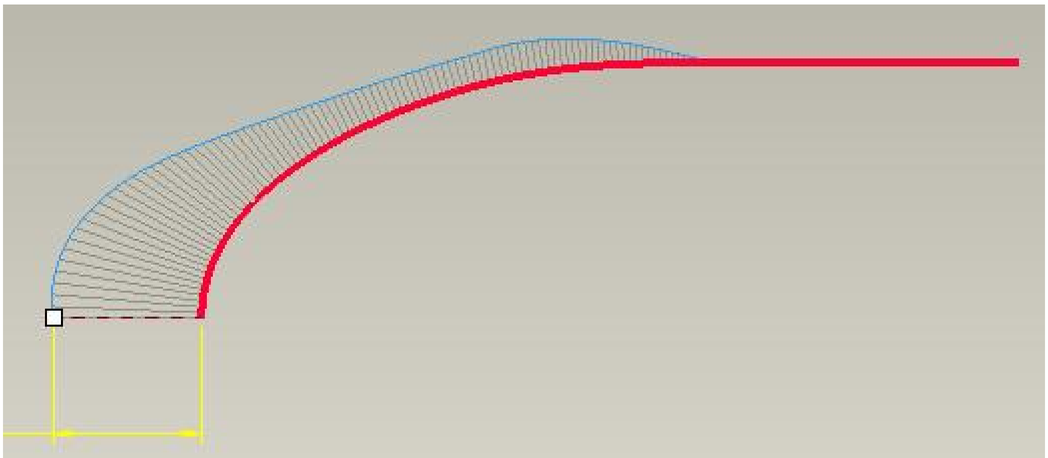


We have chosen a large value so that the curvatures at the end of the spline is 1/1000000 that is approximately equal to zero. This makes the chain smooth and curvature continuous.

Pick ✓ to complete the sketch.

Now we will analyze the curve with Curvature Analysis tool. So pick Curvature on the Analysis tab.

Select the curve and set suitable scale and it will appear as shown below.



You can notice, in the above figure, the curvature or the curve gradually reduces to zero instead of making a break or step in curvature plot. So this curve will be called **curvature continuous**.

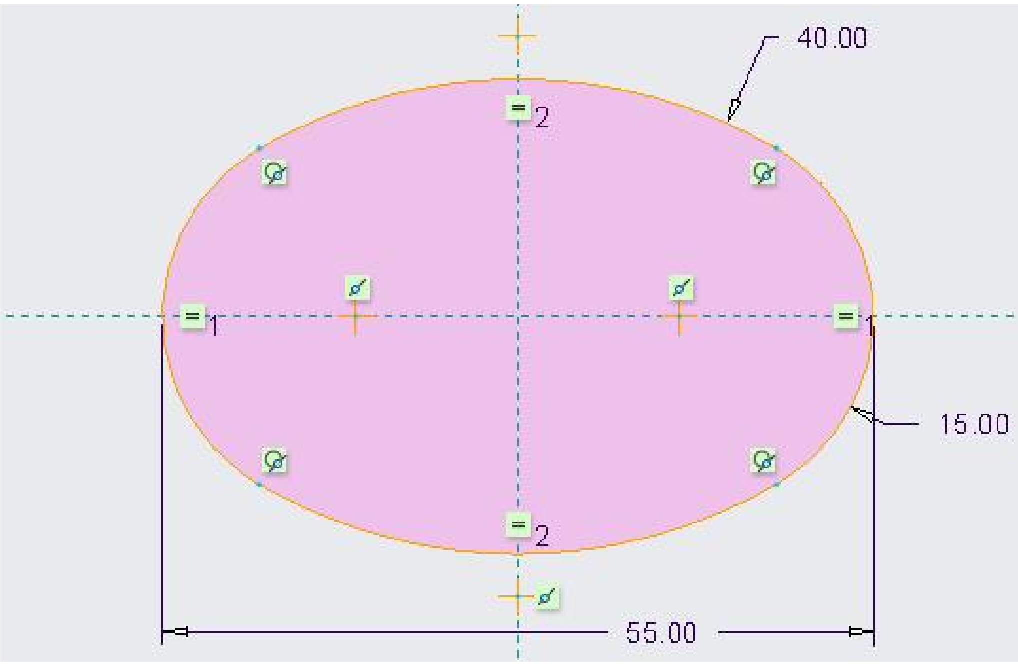
Select **File > Save** to save the work done so far.

Exercise 5

In this exercise we will make a copy of a curvature discontinuous sketched datum curve. We will learn how to transform the copied feature to a curvature continuous curve.

Set the working directory to the DATUMS folder and open the model CURVE5.PRT

The model consists of a sketched datum curve. The following figure shows the sketched datum curve in sketcher mode. You can see that the datum curve consists of four Arc segments that are tangent to each other.

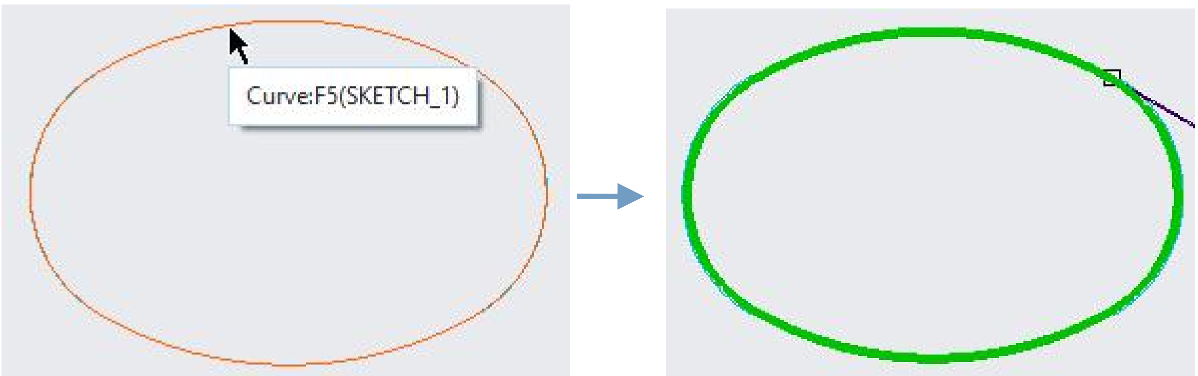


Now we will analyze the curve with Curvature Analysis tool. So pick 

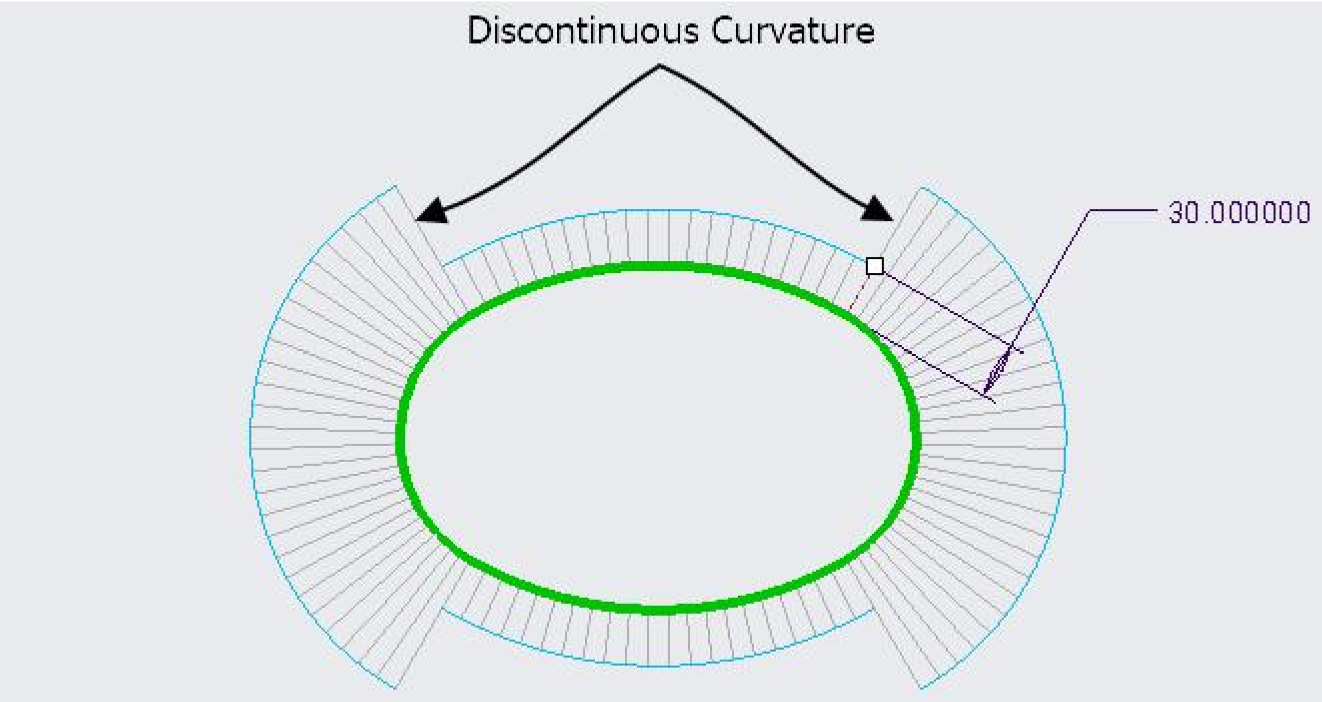
on the Analysis tab.

Now system will ask you to pick a curve to be analyzed.

Right-click over the curve until complete curve is highighted and then pick with left mouse pick.



Increase the scale of curvature display to about **30** for clear display. Now the curvature plot will appear as shown below.

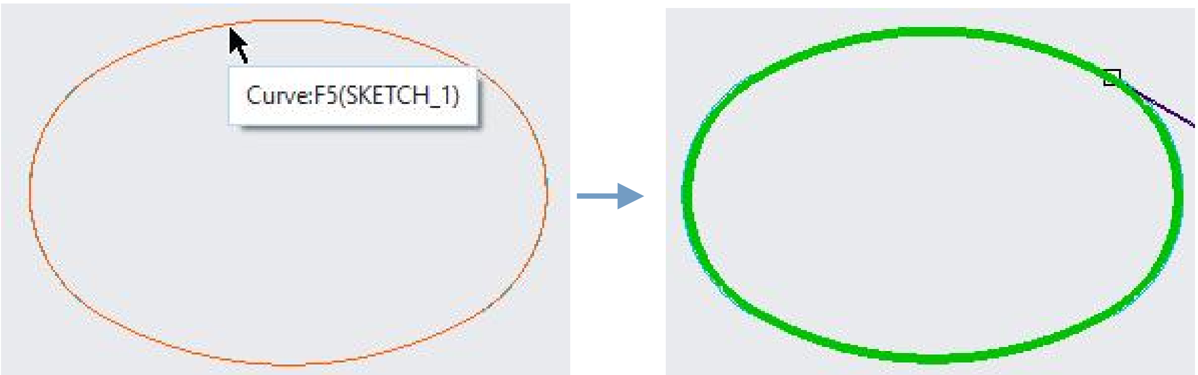


You can notice, in the above figure, the sharp break or discontinuity in the curvature of the selected curve.

Pick OK to exit the dialog box.

Now we will create a copy of sketched datum curve.

So pick the sketched datum curve with left mouse pick as shown below.



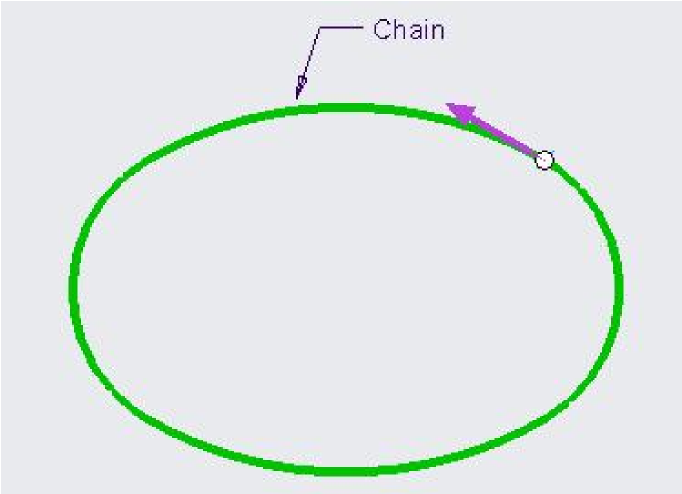
While this curve is selected, pick copy icon ( ) on the Model tab or press Ctrl+C on the keyboard.

Pick paste icon ( ) on the Model tab or press Ctrl+V on the keyboard.

In the dashboard change the Curve type to **Approximate**.

Only a chain of tangent curves and/or edges can be created as Approximate chain.

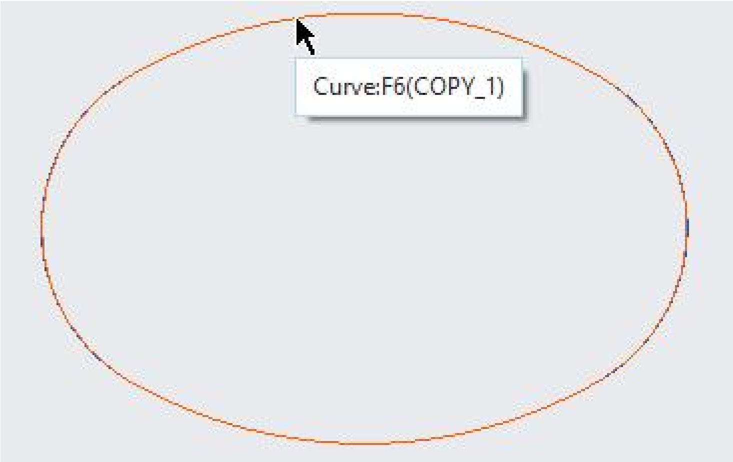
The curve should appear as shown below.



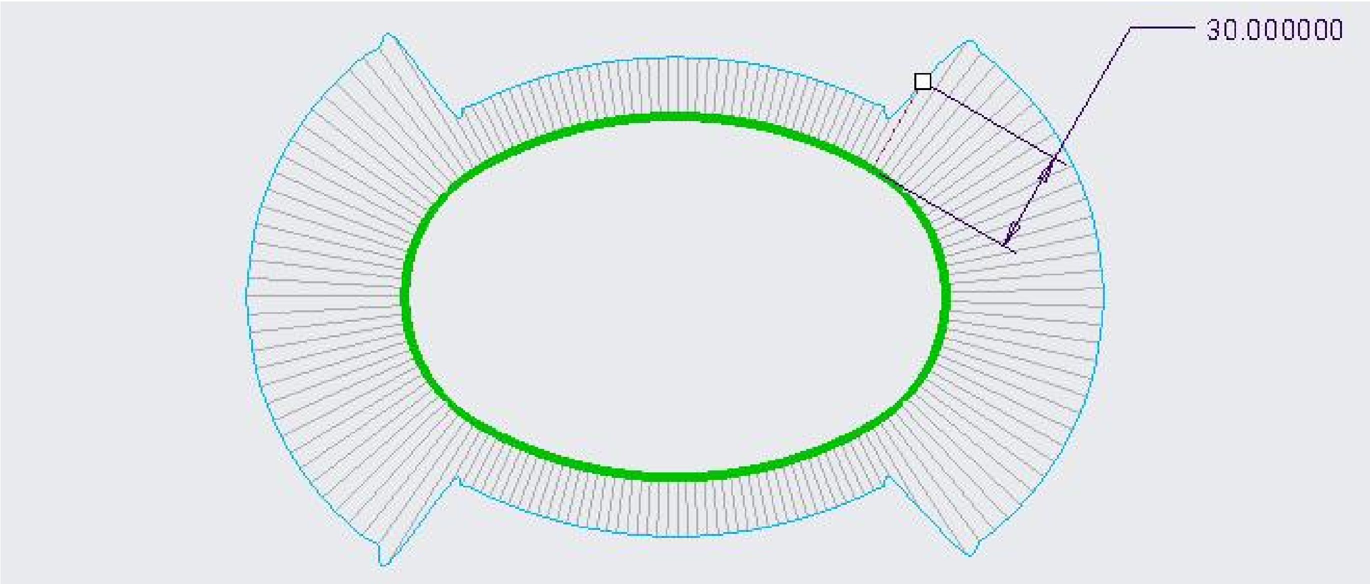
Pick  icon to complete the feature.

Now we will analyze the copied curve with Curvature Analysis tool. So pick  on the Analysis tab.

Now system will ask you to pick a curve to be analyzed. So pick the copied curve as shown below.



Increase the scale of curvature display to about 30 for clear display. Now the curvature plot will appear as shown below.



You can notice that there is no sharp step in the curvature of the copied datum curve.

An Approximate Curve is a spline which closely approximates a chain of tangent curves and/or edges. An approximate curve is coincident at the segment end points, but may vary from the rest of the curve to attain curvature continuity.

If we create the copied curve as “Exact” copy then it will not be curvature continuous as the sketched datum curve is a curvature discontinuous feature.

Select **File > Save** to save the work done so far.

Surface Quality

A surface usually consists of multiple patches. The quality of a surface is determined by the quality of individual surface patches and their connection with each other.

The patches should be joined together in such a way that the boundaries of finished product are not visible. This requires the surfaces to be curvature continuous or at least tangent, depending upon the smoothness required.

A surface analysis is usually performed after curve analysis to check the quality of the surface. Creo provides following tools to analyze the quality of a surface.

Radius
Displays the minimum radius for a surface.

Curvature
Evaluates and displays the curvature of surface.

Dihedral Angle
Displays the angle between the normals of two surfaces that share an edge. This is a useful check for continuity during the evaluation of neighboring surfaces. This tool quantifies the level of tangency across two merged surface patches. Zero value of dihedral angle means tangency.

Offset
Displays an offset for a selected set of surfaces. This analysis also checks if the surface can be offset by the specified thickness value.

Shaded Curvature
This tool is used to analyze the Gaussian Curvature. Gauss curvature is the product of the smallest and largest normal curvatures for every point on a surface

1. A value of **zero** indicates of a surface that is flat in at least one direction e.g. Cylinder, Cone and planes
2. If the Gaussian curvature is a **positive** value then the surface is locally either a peak or a valley. Examples Sphere, Torus.
3. A **negative** value indicates that the surface is of saddle shape,

Gaussian curvature analysis is especially useful in the design of Sheet Metal parts. Shapes with nonzero Gaussian curvature require that some material is stretched or deformed in the pressing process. But the surfaces that have zero curvature can be shaped without stretching or deformation.

For example, a sheet of paper can be rolled up to form a cylinder (which has zero curvature). However, we cannot roll the paper smoothly into a sphere (which is of positive curvature).

Gaussian analysis assigns values to the color range to show curvature variations

Draft
Analyzes a part design to determine if a draft is necessary for the part to be used in a tool or mold. Displays a color plot of the draft.

Slope

Displays, in color, the slope of a surface relative to a reference plane, coordinate system, curve, edge, or datum axis on a part.

Reflection
Reflection analysis displays stripes that represent the reflection due to linear sources of light on a surface. To view changes in the reflection, spin the model and observe the dynamic changes in the display.

Note: The Reflection analysis is only available if the OpenGL graphics mode is active i.e. 'graphics' option is set to 'opengl' in configuration file. If you cannot access Reflection tool even this option is set then try setting the config.pro option 'use_software_opengl' to 'yes'.

Shadow
Displays a color plot of the shadow area cast by a surface or model on another surface with reference to a datum plane, coordinate system, curve, edge, or axis.

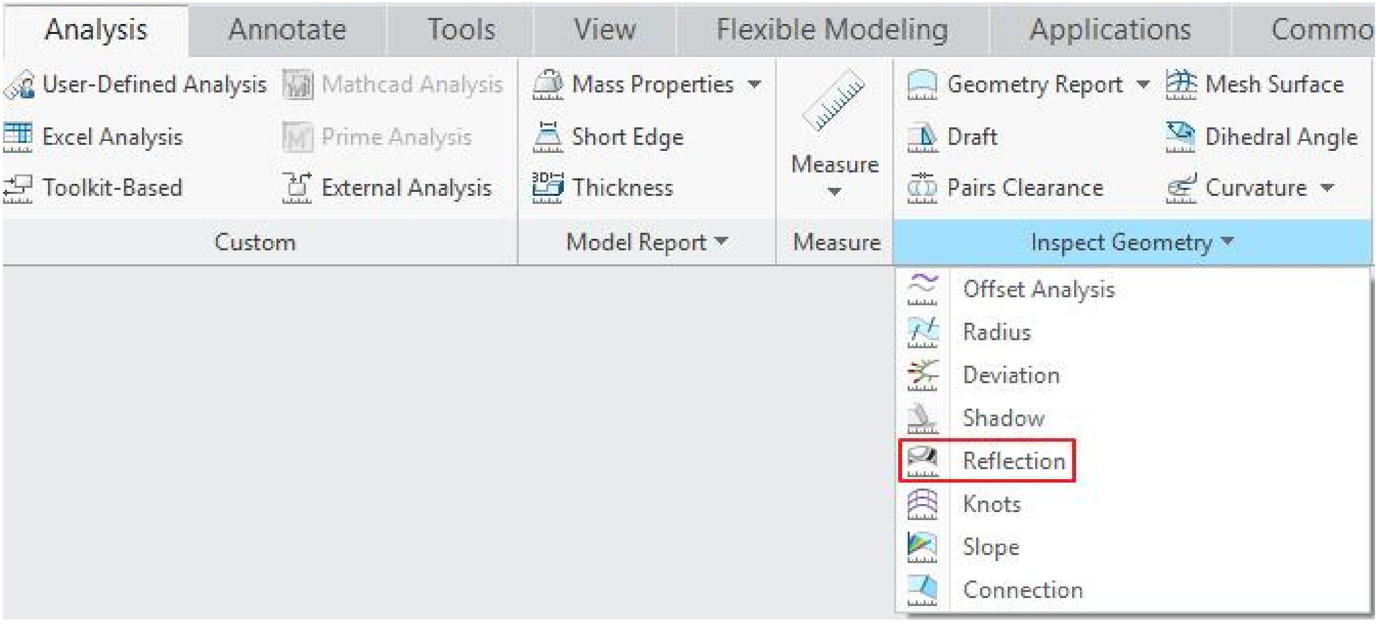
Exercise 1

In this exercise we will analyze a surface for continuity using Reflection analysis tool.

Set the working directory to the ANALYSIS folder and open the model SURFACE1.PRT

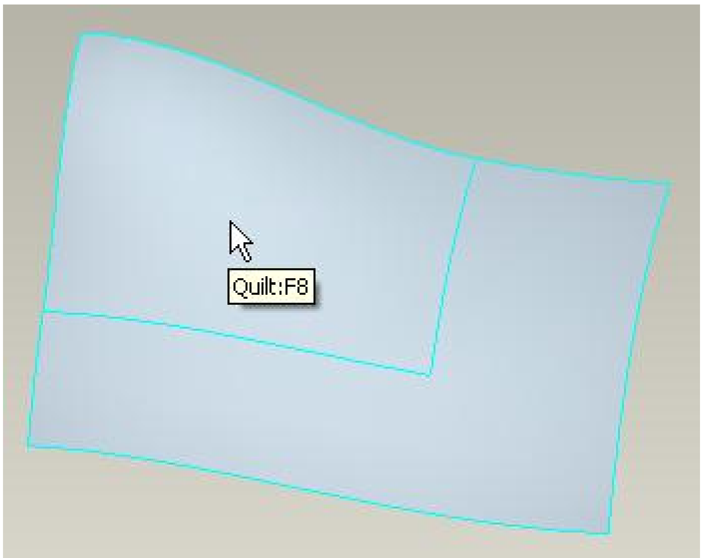
So pick 

on the Analysis tab as shown below.

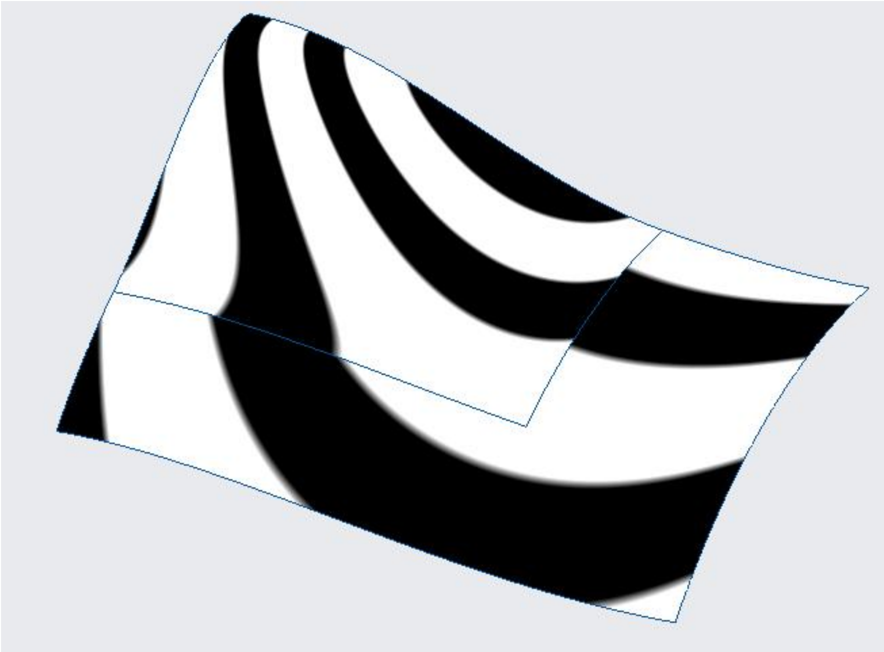


Note: The Reflection analysis is only available if the graphics card supports OpenGL. If you cannot access Reflection tool then you can try setting the config.pro option 'use_software_opengl' to 'yes'.

Now system will ask you to select a surface or quilt to be analyzed. So pick the following quilt.



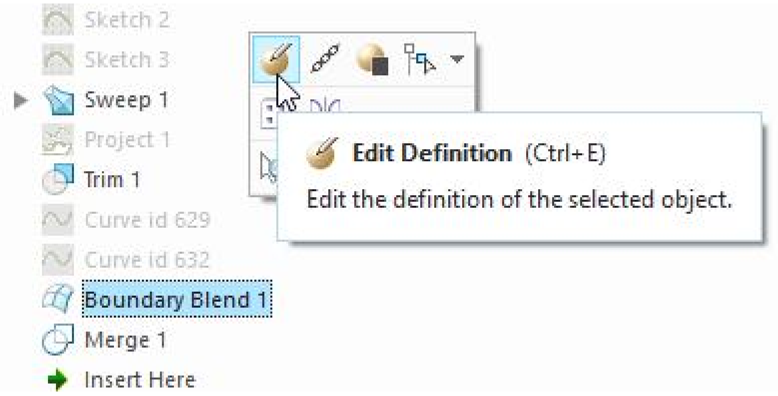
Spin the model and see how the stripes update dynamically. The stripes may appear as shown below.



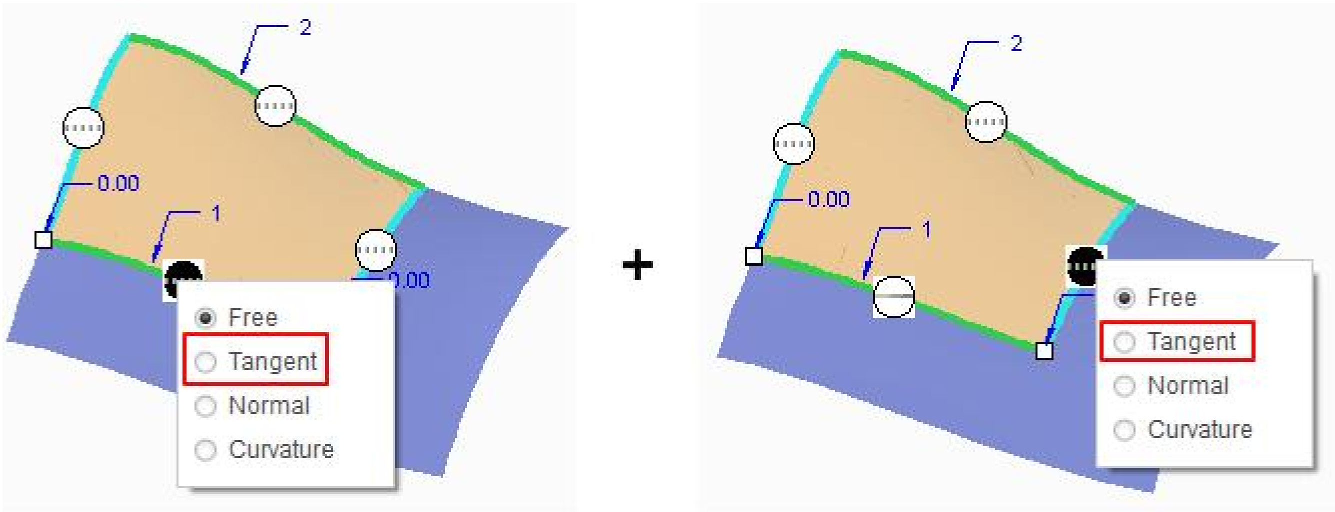
You can notice, in the above figure, the width of stripes at the joint is different. This means that the surfaces are not tangent at the joint.

So we will redefine the boundary bled surface and change the constraint at boundaries.

Select the “Boundary Blend 1” in model tree and pick  .



Change the constraint type from Free to **Tangent** for chains that are adjacent to other surface patch as shown below. (Note: Right-click over the constraint symbol to access the shown menu)

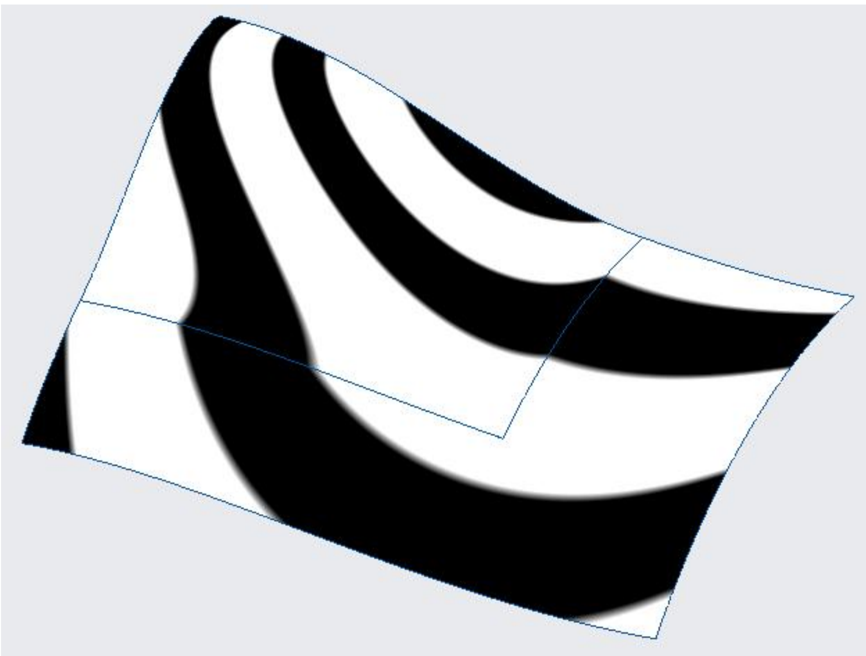


Pick  to exit the dialog box.

Again pick  on the Analysis tab to Reflection analysis tool.

Pick the same quilt.

Now the stripes will appear as shown below.



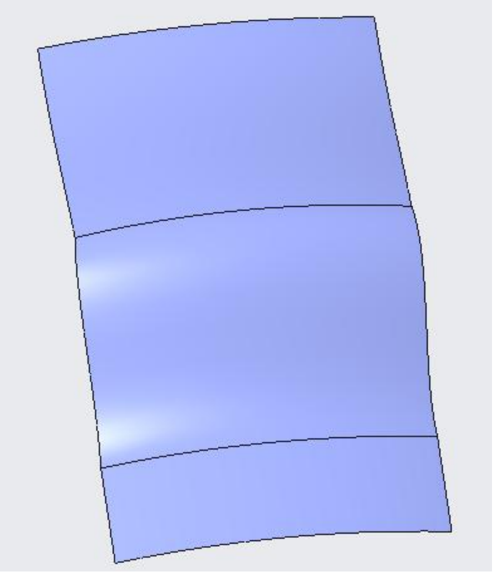
You can notice, in the above figure, the width of stripes at the joint is same and there is no mismatch. This means that the surface patches are tangent at the joint.

Select **File > Save** to save the work done so far.

Exercise 2

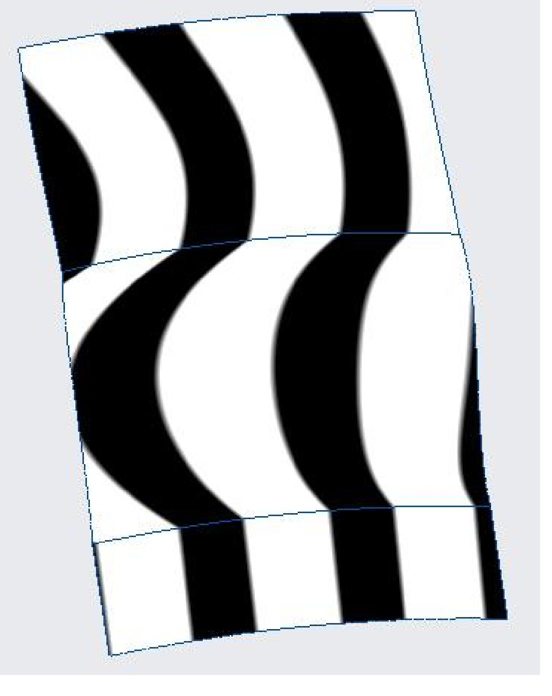
In this exercise we will analyze a surface for continuity using Reflection analysis tool.

Set the working directory to the ANALYSIS folder and open the model SURFACE2.PRT. It will appear as shown below.

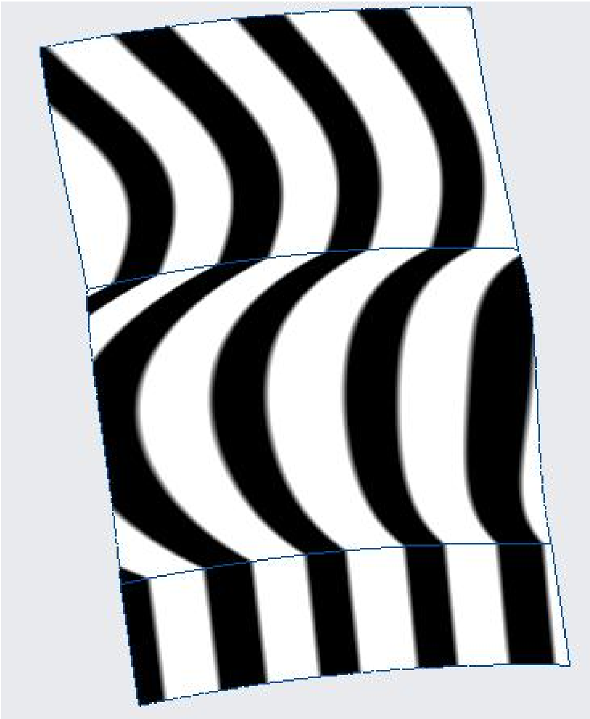
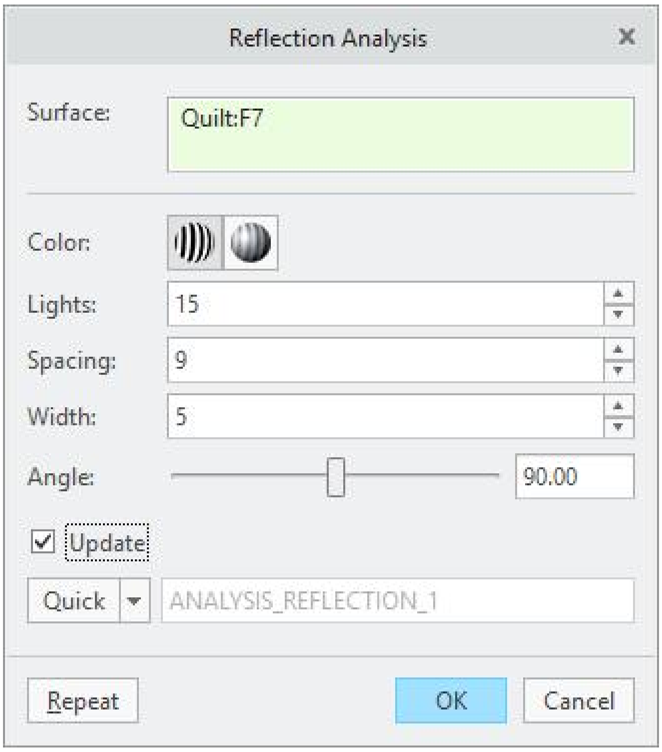


Pick  on the Analysis tab to access the Reflection analysis tool.

Now system will ask you to select a surface or quilt to be analyzed. So pick the quilt and stripes may appear as shown below.



As you can see there are only two stripes therefore first we will increase their number to make it more informative. So increase the Light to **15** and spin the model and see how the stripes update dynamically. The stripes may appear as shown below.

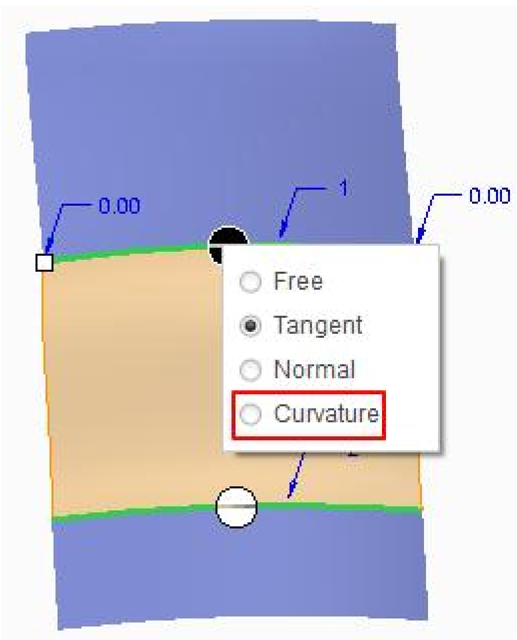
 

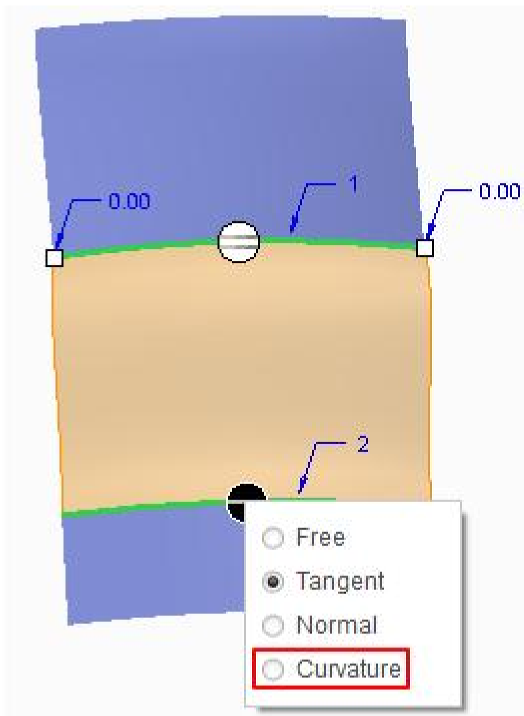
You can notice in the above figure that the width of stripes at the joint is same but the stripes are not tangent to each other at the joint of surfaces. This means that the surfaces tangent at the joint but not curvature continuous.

So we will redefine the boundary blend surface and change the constraint at boundaries.

Select the "Boundary Blend 1" in model tree and pick .

Change the constraint type from Tangent to **Curvature** as shown below.





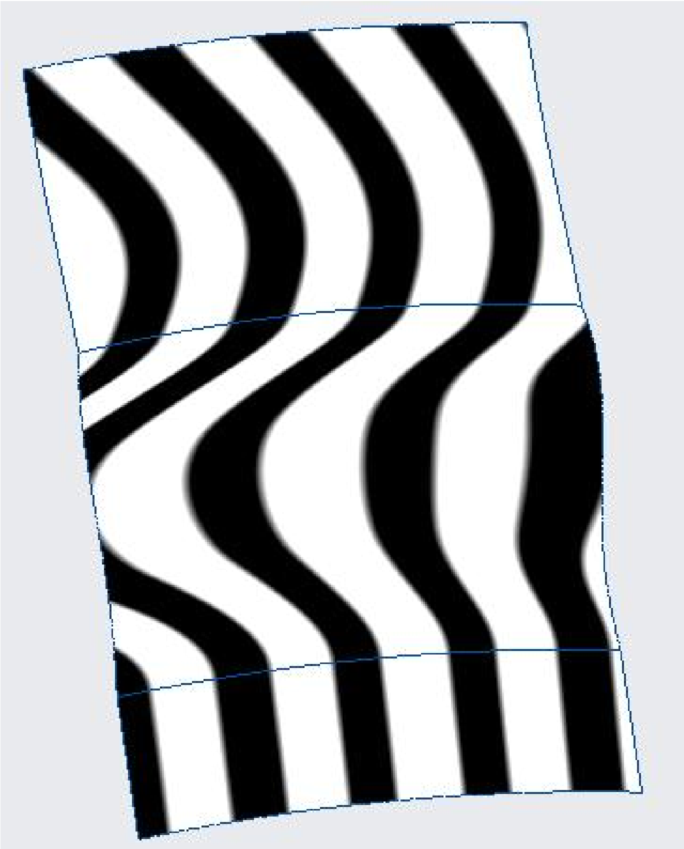
Pick 

to exit the dialog box.

Again pick 

on the Analysis tab and select the same quilt.

Now the stripes will appear as shown below.



You can notice, in the above figure, the stripes are tangent to each at the joint of surfaces. This means that the surface patches are curvature continuous at the joint.

Select **File > Save** to save the work done so far.

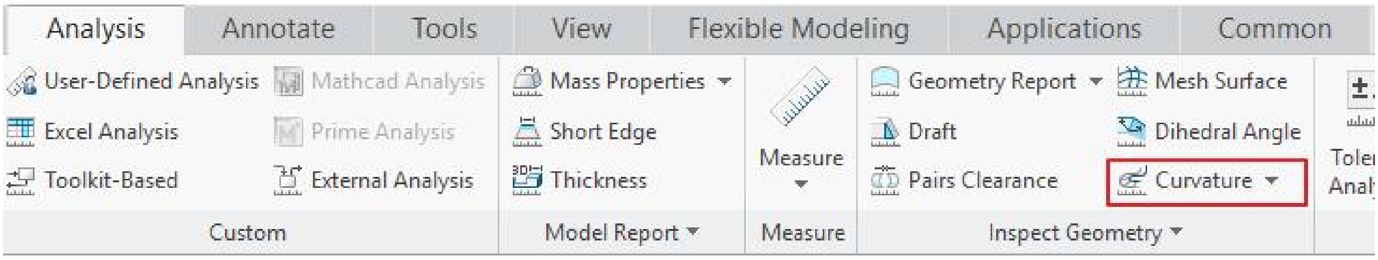
Exercise 3

In this exercise we will analyze a surface using Curvature analysis tool.

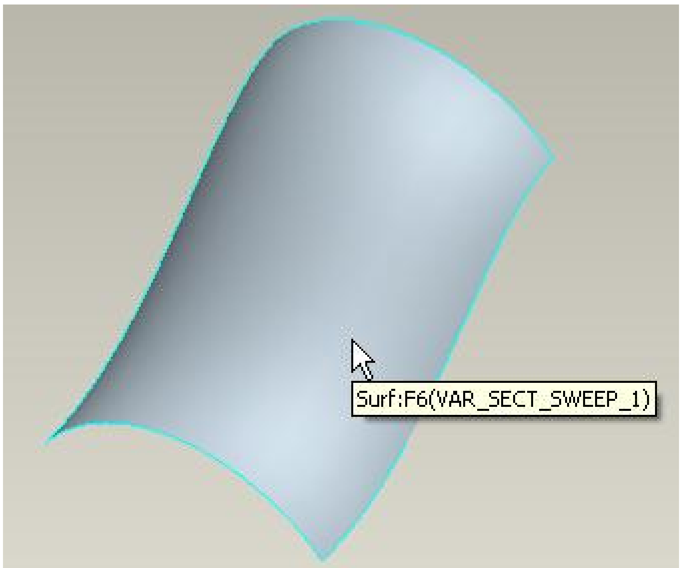
Set the working directory to the ANALYSIS folder and open the model SURFACE3.PRT

Pick 

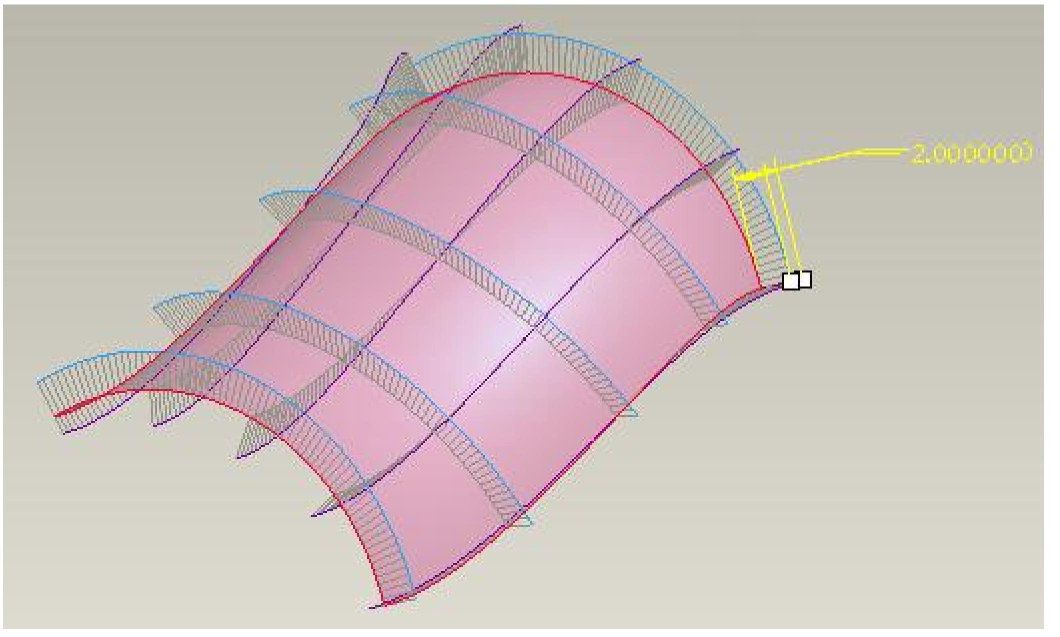
on the Analysis tab to access the Curvature analysis tool.



Now system will ask you to select a surface or quilt to be analyzed. So pick the following quilt.



Now the curvature plot will appear as shown below. (You may need to increase/decrease the scale of curvature display)



Pick  to exit the dialog box.

Select **File > Save** to save the work done so far.

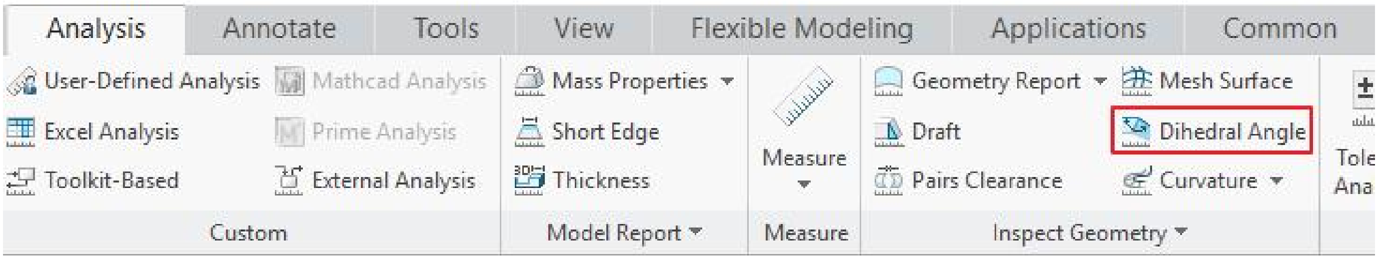
Exercise 4

In this exercise we will analyze a quilt with Dihedral Angle tool to determine the level of tangency.

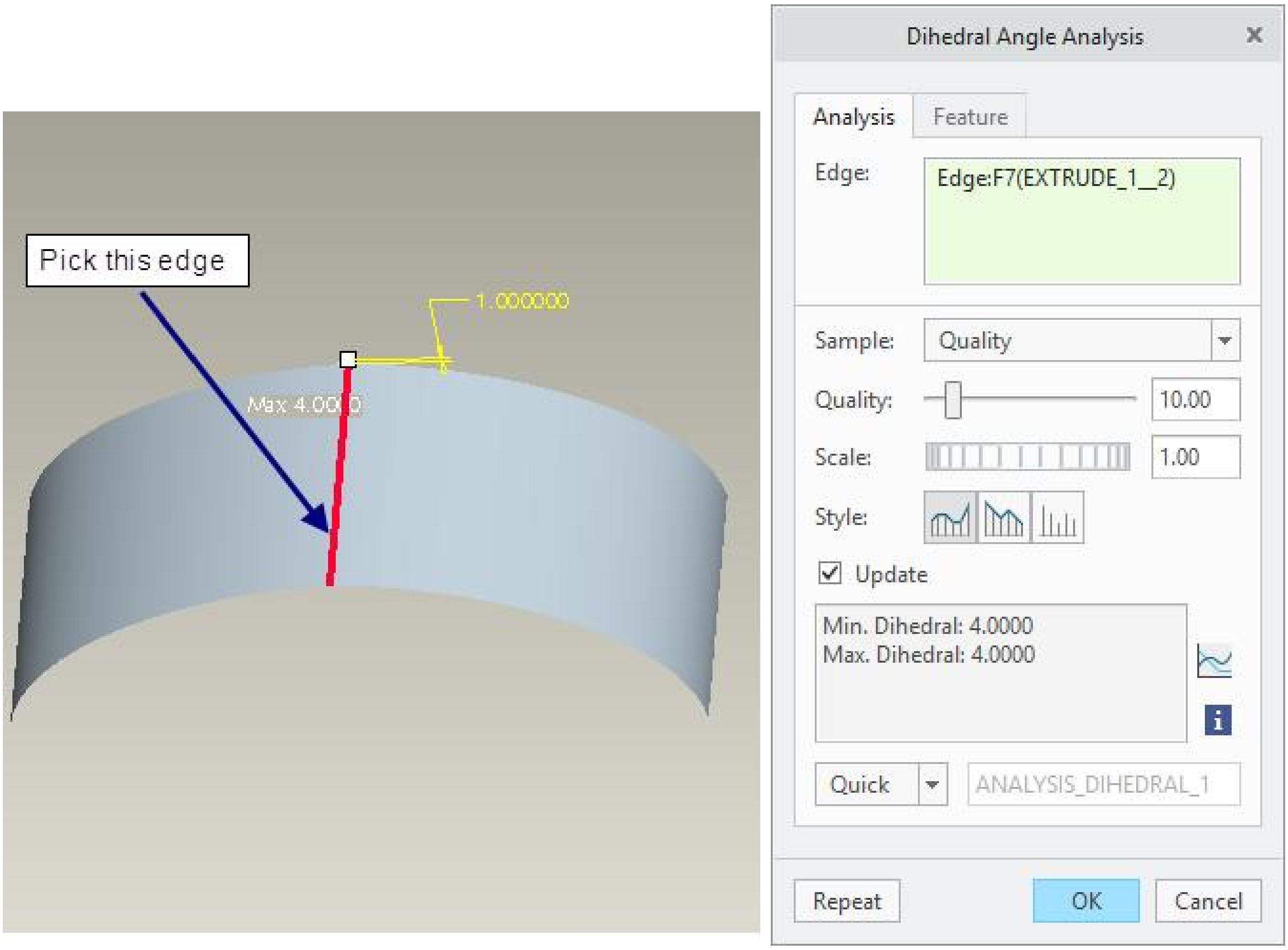
Set the working directory to the ANALYSIS folder and open the model SURFACE_MR1.PRT

So pick 

on the Analysis tab to access the Dihedral Angle tool.



Now system will ask you to select an edge to be analyzed. So pick the edge shown in the figure below.

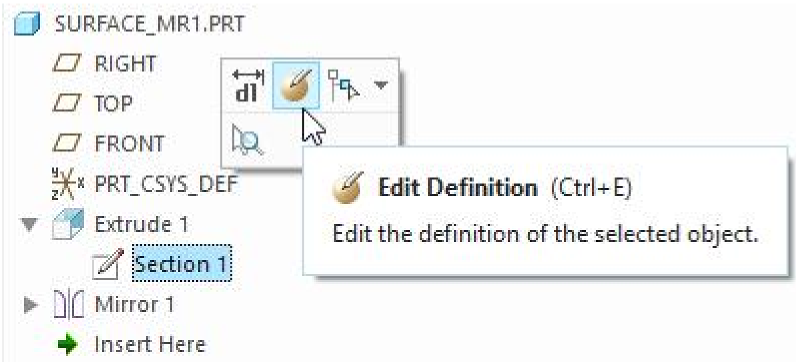


You should notice that minimum and maximum dihedral angle is not zero for this edge which means surface patches on both side of the edge are not tangent to each other. So we need to fix this surface patch.

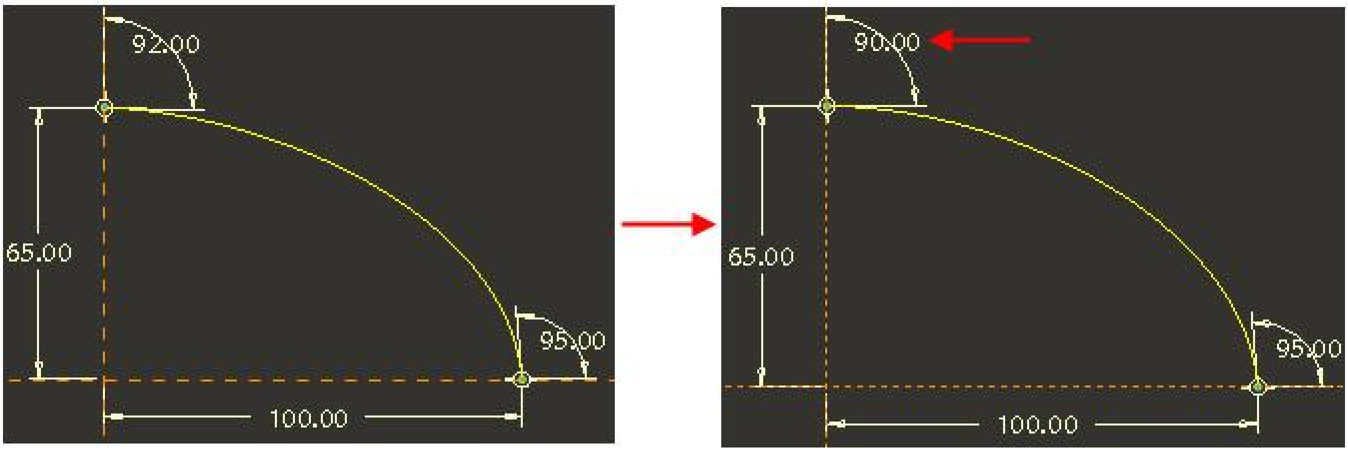
If you look in the model tree, you will notice that surface patch on left side is the mirror of extruded surface on right side. So we will make the extruded surface normal to the mirror plane to make both surfaces tangent.

To make the mirrored and parent surface tangent to each other we need to make the parent surface normal to mirror plane.

Select the sketch of the "Extrude 1" feature in model tree and select  .



Now change the tangency dimension to ***90*** as shown below.



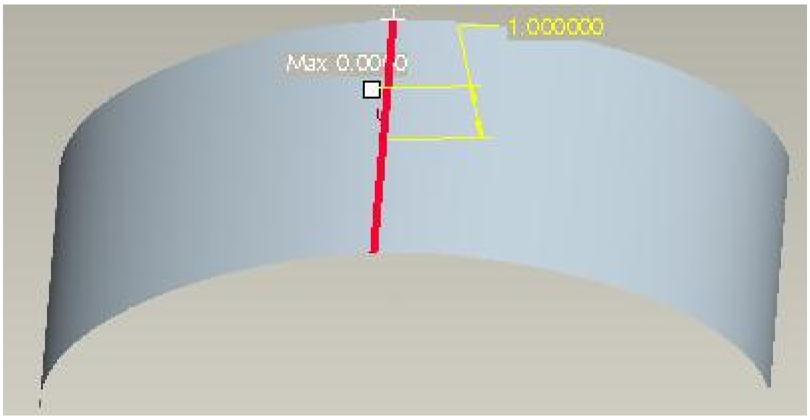
This will make the surface normal to the datum plane.

Pick  to apply the changes and exit.

Now we will again analyze the quilt with Dihedral Angle tool to determine the level of tangency.

Pick 

on the Analysis tab and select the edge shown in the figure below.



You should notice that minimum and maximum dihedral angle is “0” which means surface patches on both side of the edge are tangent to each other.

When a surface is normal to mirror plane then we refer to this situation as 'Implied Tangency' because the surface will eventually be tangent to itself when it is later mirrored.

Select **File > Save** to save the work done so far.

Exercise 5

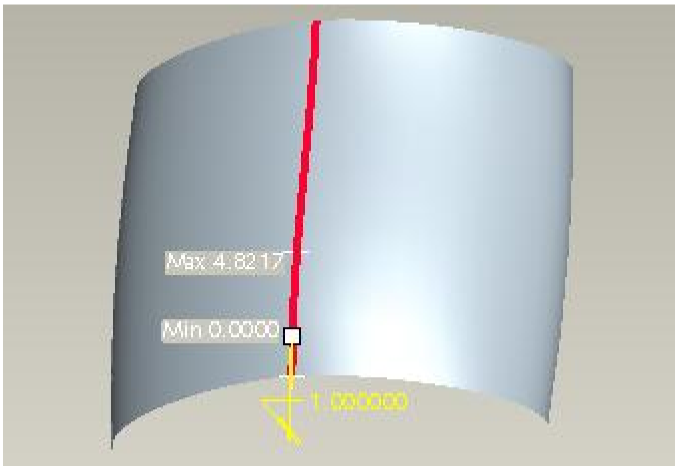
In this exercise we will analyze a quilt with Dihedral Angle tool to determine the level of tangency.

Set the working directory to the ANALYSIS folder and open the model SURFACE_MR2.PRT

So pick 

on the Analysis tab to access the Dihedral Angle tool.

Now system will ask you to select an edge to be analyzed. So pick the edge shown in the figure below.



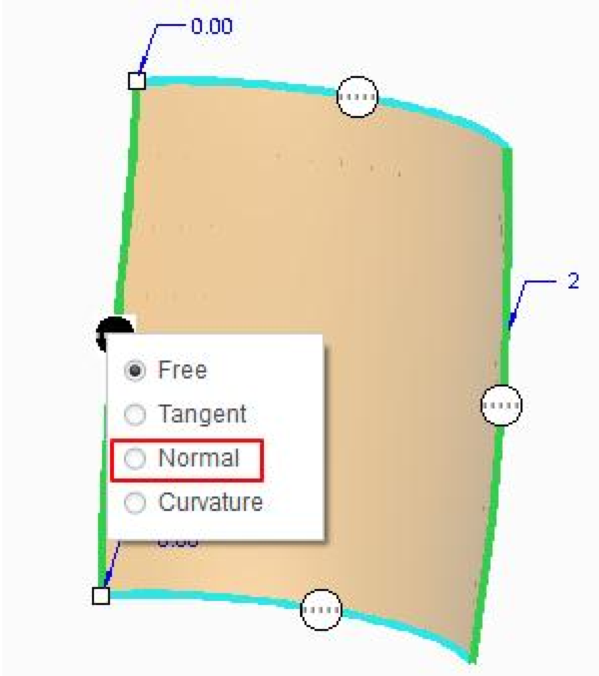
You should notice that maximum dihedral angle is not zero for this edge which means surface patches on both side of the edge are not tangent to each other. So we need to fix this surface patch.

If you look in the model tree, you will notice that surface patch on left side is the mirror of boundary blend surface on right side. So we will make the boundary blend surface normal to the mirror plane to make both surfaces tangent.

To make the mirrored and parent surface tangent to each other we need to make the parent surface normal to mirror plane.

Select the “Boundary Blend 1” feature in model tree and pick  .

Apply **Normal** constraint for chain that lies on the mirror plane as shown below.

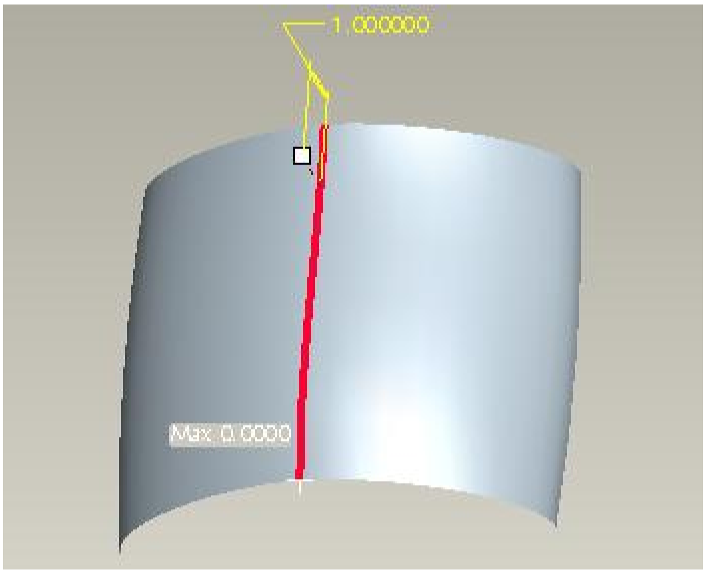


Pick  to complete the feature.

Now we will again analyze the quilt with Dihedral Angle tool to determine the level of tangency.

Pick 

on the Analysis tab.Pick the edge shown in the figure below.



You should notice that minimum and maximum dihedral angle is “0” which means surface patches on both side of the edge are tangent to each other.

Select **File > Save** to save the work done so far.

When a surface is normal to mirror plane then we refer to this situation as 'Implied Tangency' because the surface will eventually be tangent to itself when it is later mirrored.

Exercise 6

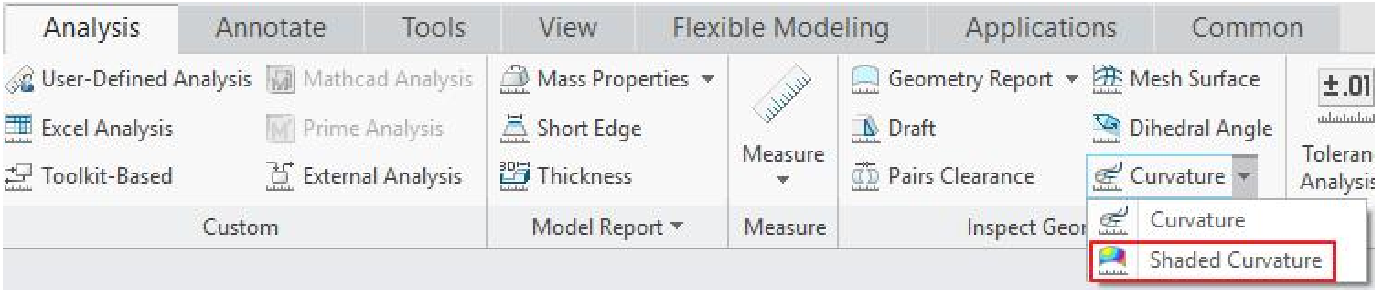
In this exercise we will analyze the Gaussian curvature of a surface.

Gaussian curvature at a point is defined as the product of of the principal curvatures.

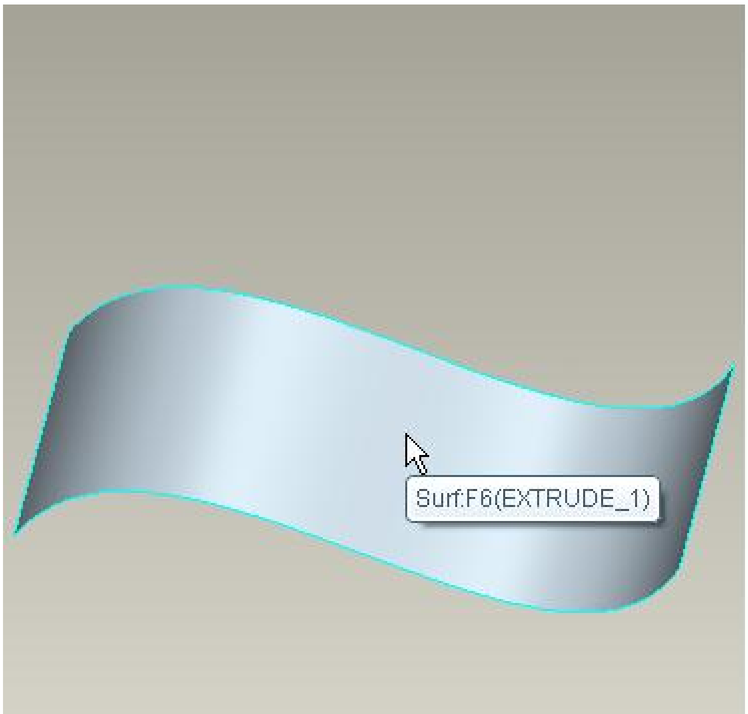
Set the working directory to the ANALYSIS folder and open the model SURFACE_GE.PRT

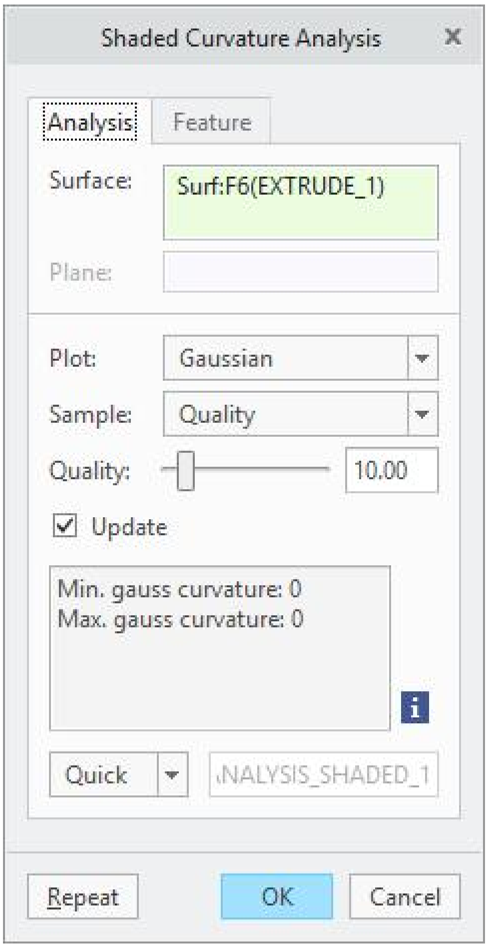
Pick 

on the Analysis tab to access the Shaded Curvature analysis tool.



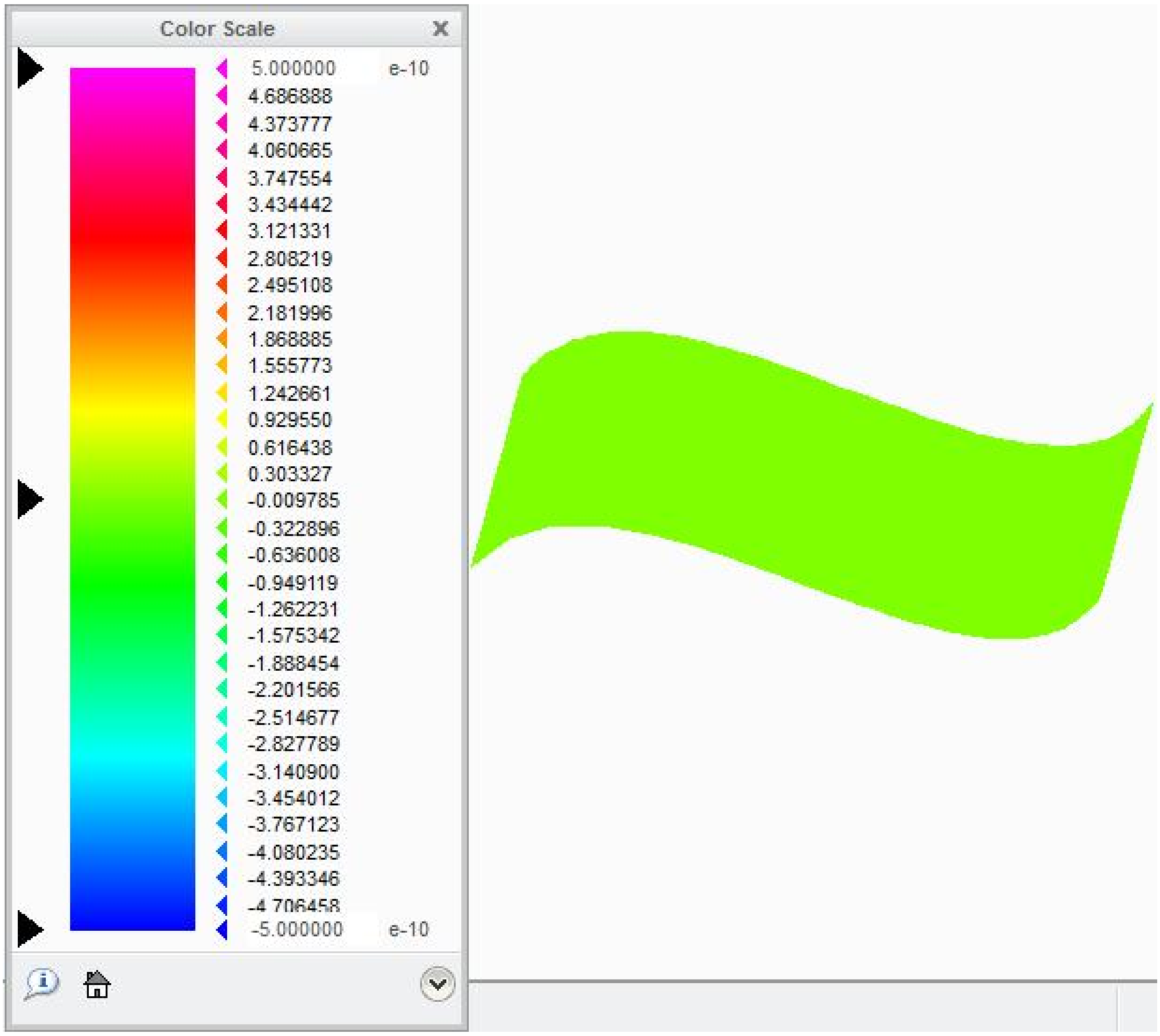
Now system will ask you to select a surface or quilt to be analyzed. So pick the following quilt.





You should make sure that Gaussian as selected as analysis type as shown below.

The Gaussian analysis of surface and legend will appear as shown below.



You can notice, in the above figure, that the Gaussian curvature of the surface is zero. This implies that shape can be produced from a flat sheet without stretching of material.

Pick OK to exit the dialog box.

Exercise 7

In this exercise we will analyze the Gaussian curvature of a surface.

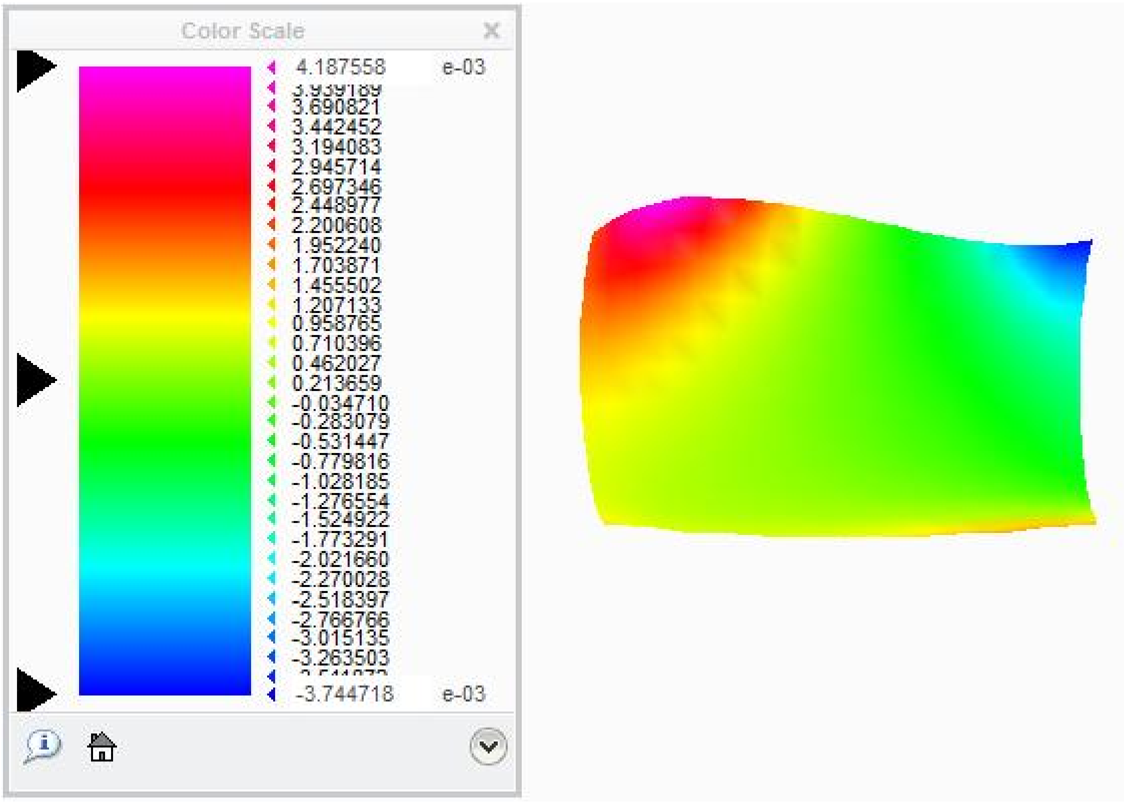
Set the working directory to the ANALYSIS folder and open the model SURFACE_GB.PRT

Pick Shaded Curvature on the Analysis tab to access the Shaded Curvature analysis tool.

Now system will ask you to select a surface or quilt to be analyzed. So pick the quilt visible on screen.

You should make sure that Gaussian is selected as analysis type.

The Gaussian analysis of surface and legend will appear as shown below.



You can notice, in the above figure, that the Gaussian curvature of the surface varies throughout the surface. So this shape cannot be produced from a flat sheet without stretching the material.

Pick OK to exit the dialog box.

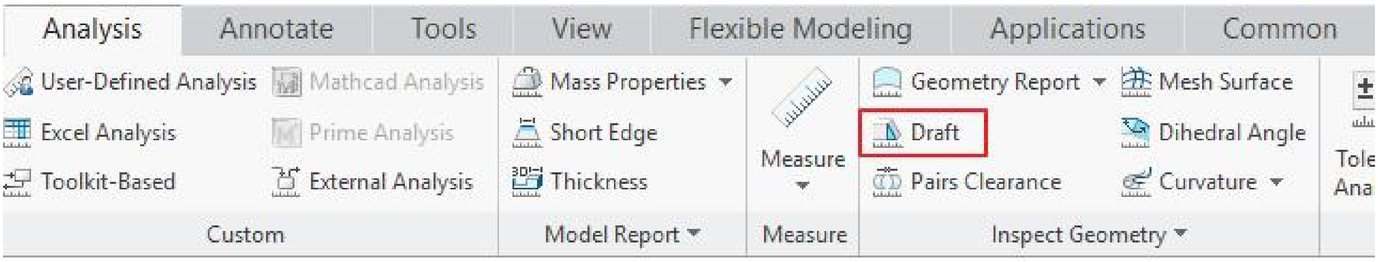
Exercise 8

In this exercise we will analyze a surface to determine if it has sufficient draft by using Draft Check tool.

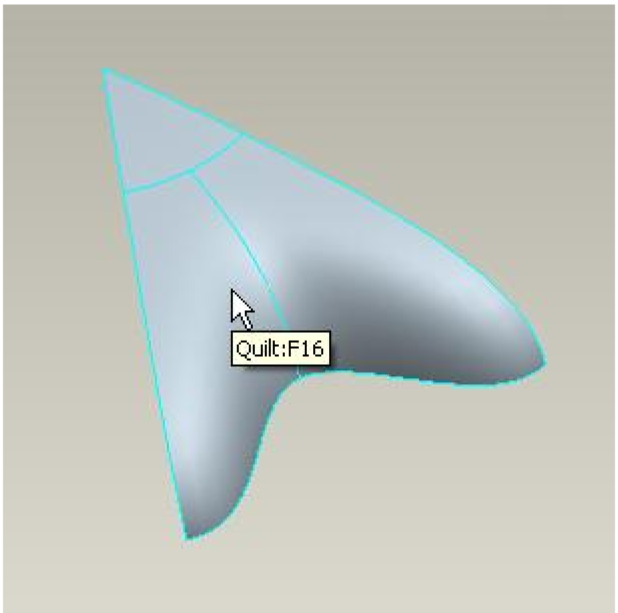
Set the working directory to the ANALYSIS folder and open the model SURFACE_DR.PRT

Pick 

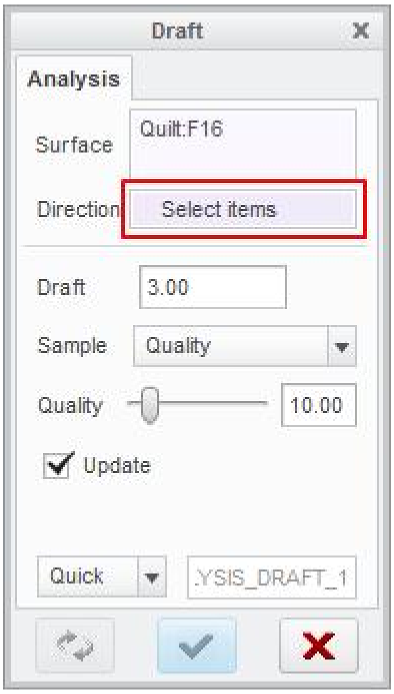
on the Analysis tab to access the Draft Check tool.



Now system will ask you to select a surface or quilt to be analyzed. So pick the following quilt.



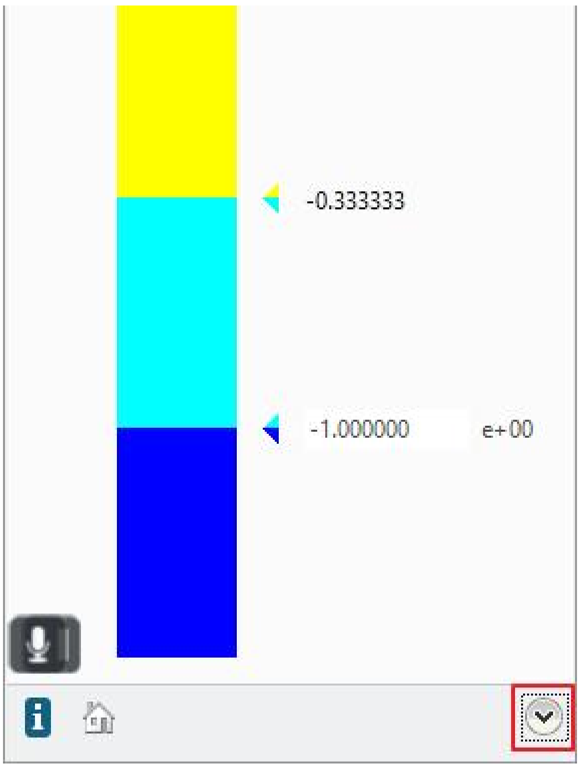
Now pick the Direction reference collector as shown below.

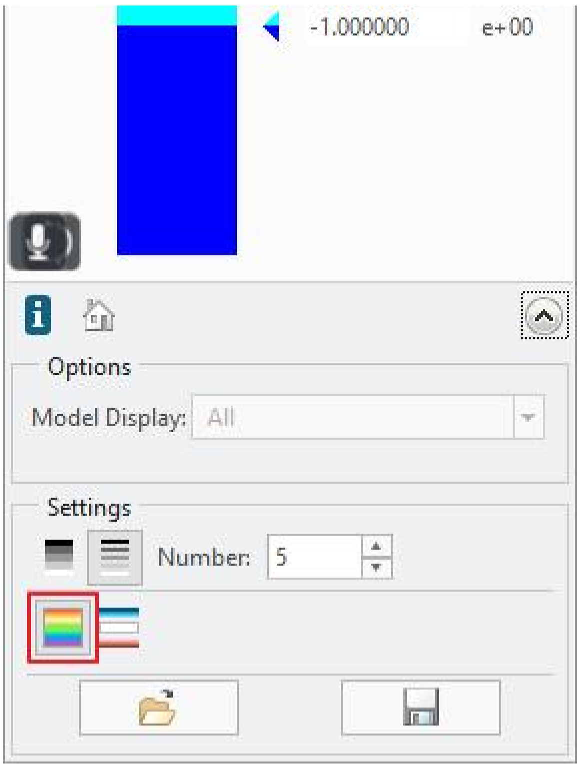


Pick **TOP** datum plane as reference.

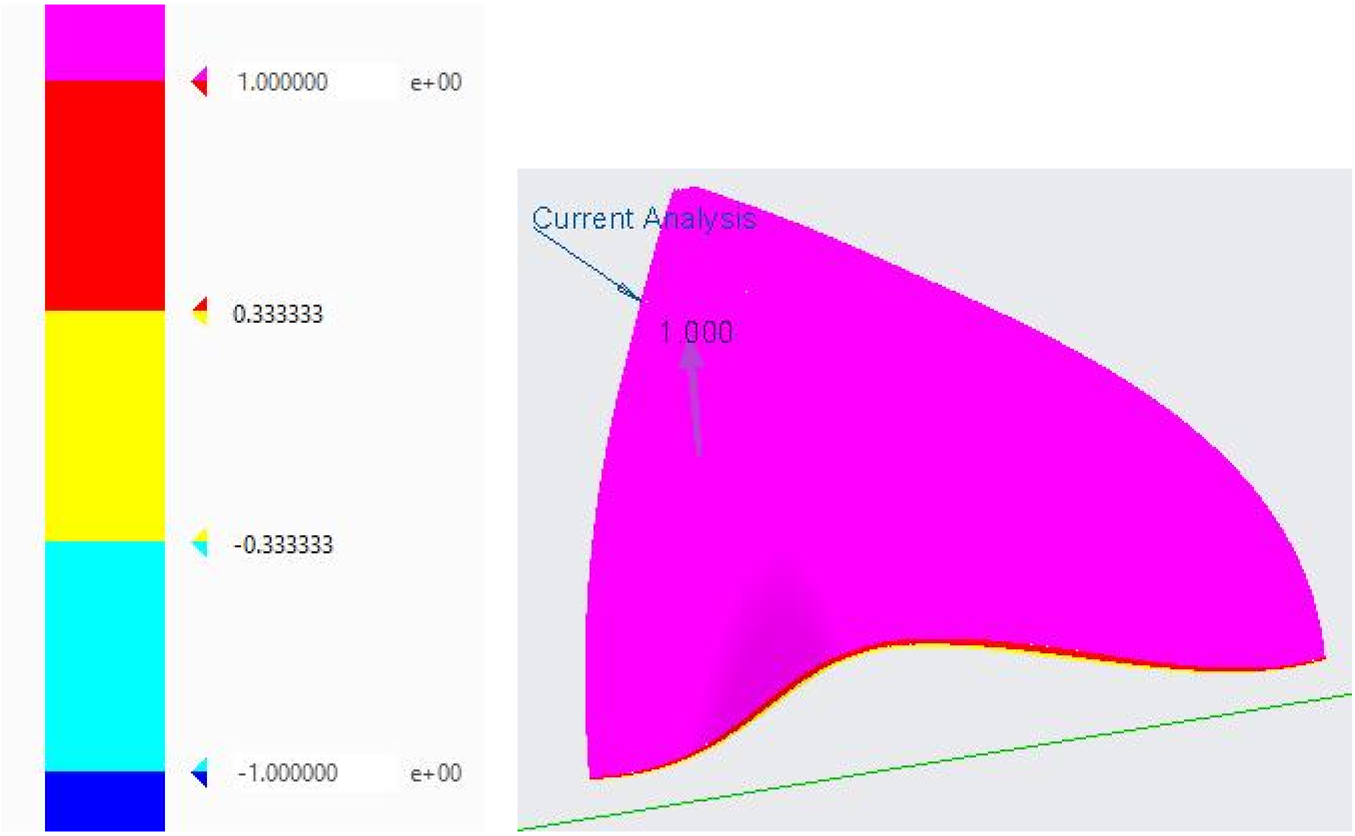
Enter ***1*** for the Draft angle to plot for and hit Enter key.

In the legend, pick  and toggle the display to rainbow ploty by picking  as shown below.





The draft analysis of surface and legend will appear as shown below.

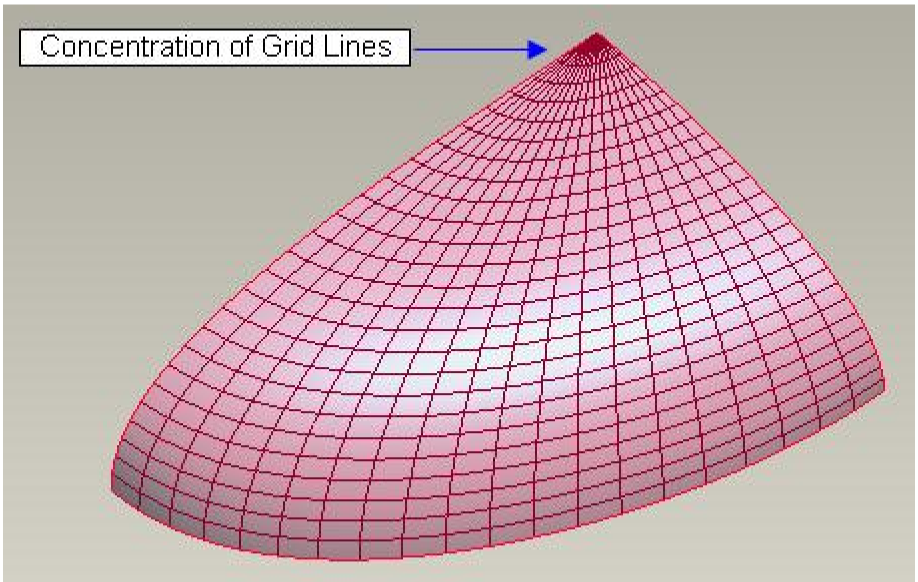


You can notice, in the above figure, that the draft angle for the most of the surface is more than 1 degree except at the lower part of surface where it is approximately zero.

Pick OK to exit the dialog box.

Singularity

A singularity is created when gridlines of a surface concentrate to a single point. In the following figure you can see the gridlines of a surface. Here the gridlines concentrate to a single point and thus cause the singularity.



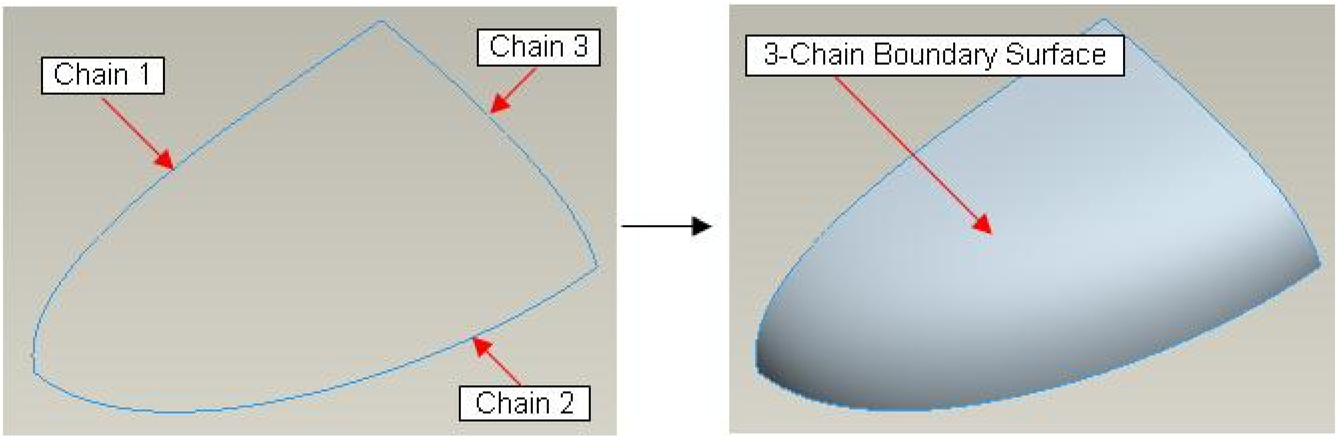
Surfaces with singularities are considered to be of poor quality and make the offset, thicken or shell operation very difficult. Furthermore surfaces with singularities are unstable during regeneration.

Singularities commonly occur while creating

a) 3-Chain Boundary Surface
b) 2-Chain Boundary Surface

3-Chain Boundary Surface

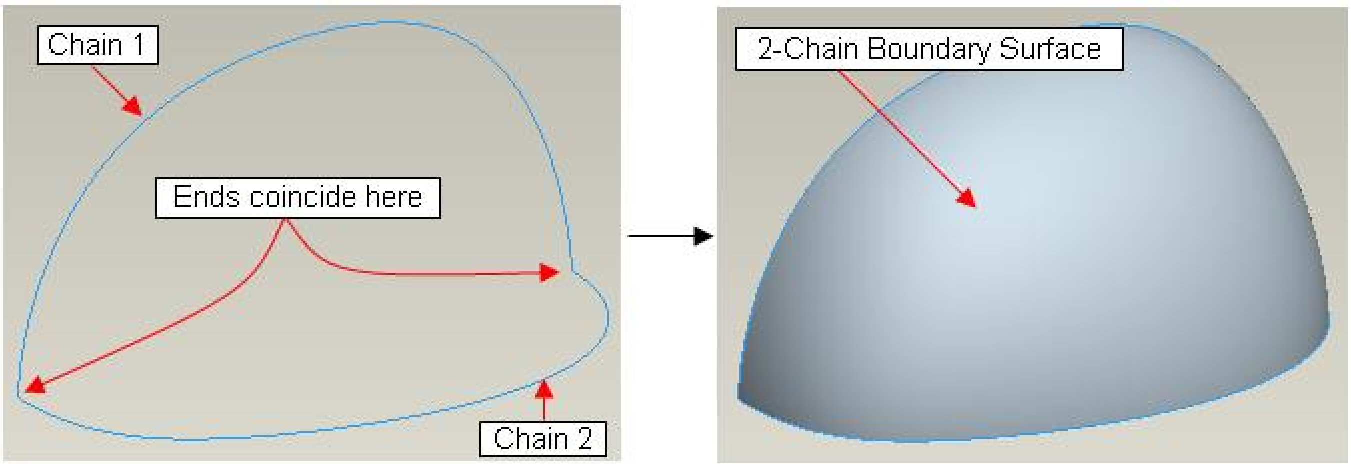
3-Chain Boundary Surface is a surface bound by only three chains.



The above surface can be created easily by using Boundary Blend Tool but this results in singularity.

2-Chain Boundary Surface

2-Chain Boundary Surface is a surface bound by only two chains. If the ends coincide, then this surface will result in singularities.



Although, the above surface can be created easily by using Boundary Blend Tool but this result in singularity.

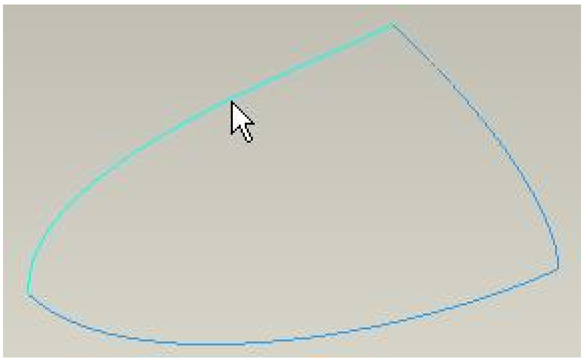
Exercise 1

In this exercise we will learn a simple technique to avoid singularity.

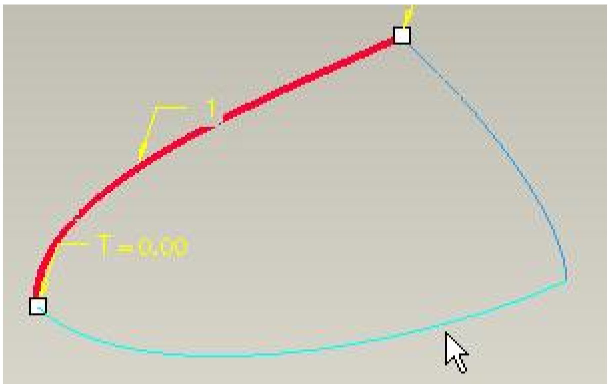
Set the working directory to the ANALYSIS folder and open the model 3SIDED.PRT
Part will appear as shown below.

First we will create a boundary blended surface that results in a singularity, just to show how intuitive is this.

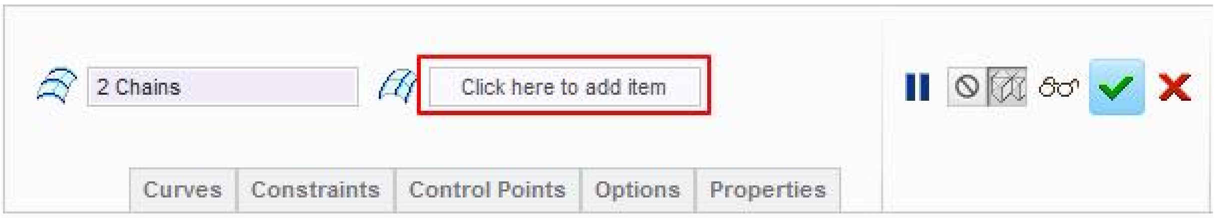
Pick  and select the curve shown in the figure below.



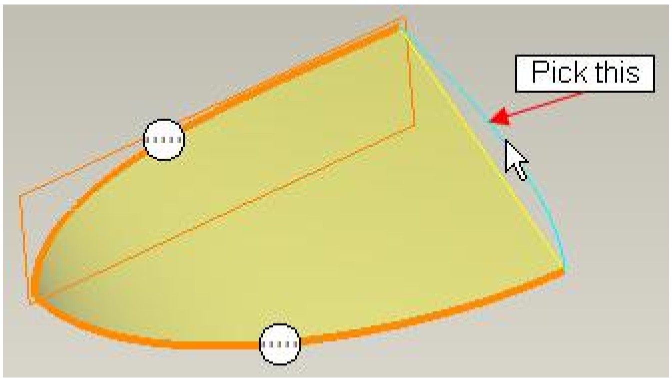
Now hold down the Ctrl key and pick the following curve as second chain.



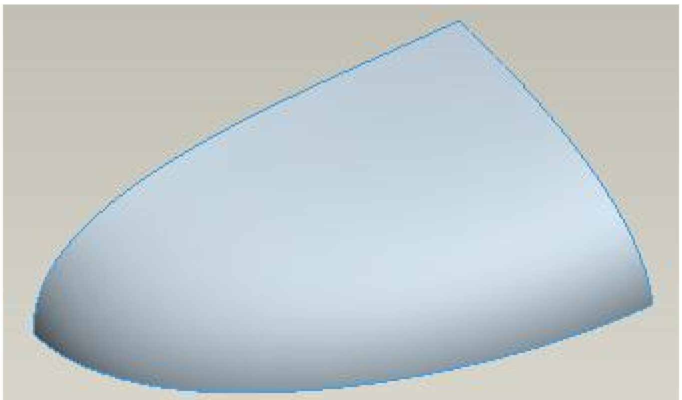
Pick in the Second Direction Collector to activate it as shown below.



Select the curve shown in the figure below as first chain in second direction.



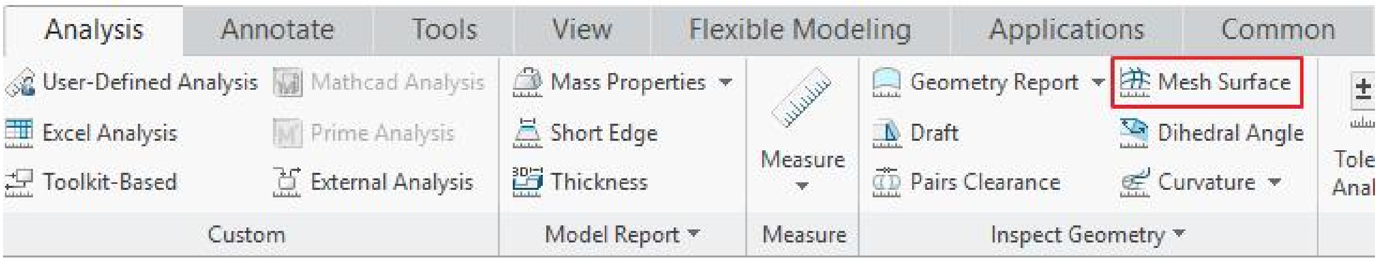
Pick  to complete the feature and it will appear as shown below.



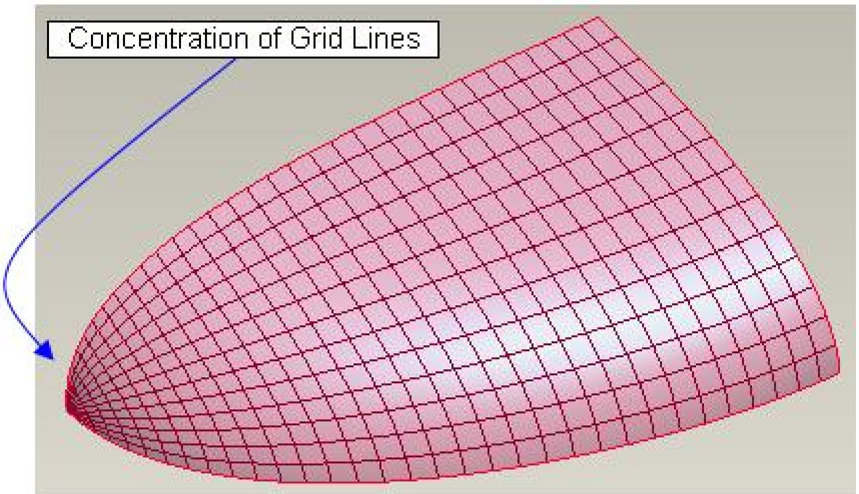
Now we will mesh the surface to create a grid line of surface.

Pick 

on the Analysis tab to access the Mesh Surface tool.



Now system will ask you to select a surface to be analyzed. So pick the newly created surface and system will mesh it as shown below.

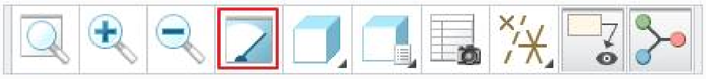


In the above figure you can see that the grid lines merge to a single point. This usually makes the offset or shell operation very difficult.

Pick 

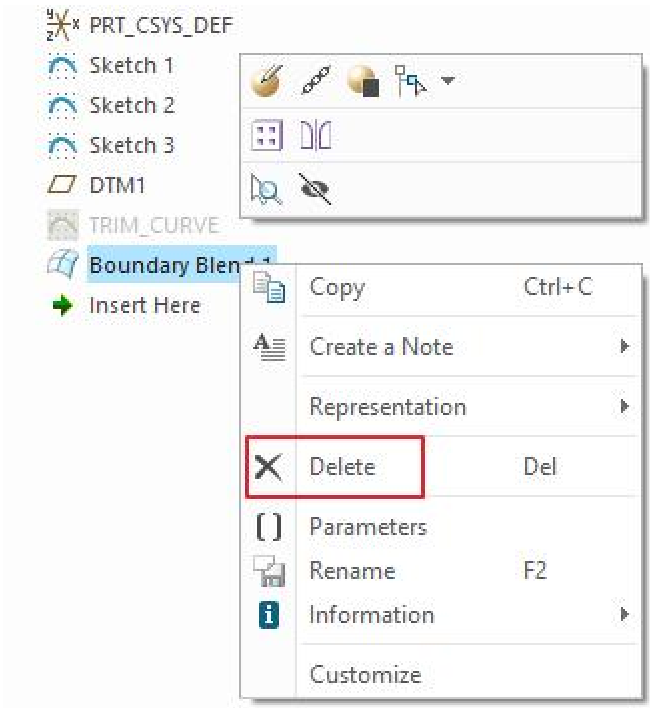
to exit the dialog box.

Pick  on the Graphics toolbar or press **Ctrl + R** on the keyboard to redraw the view to normal.



Now we will create the shape of the above surface using different technique that does not create singularity.

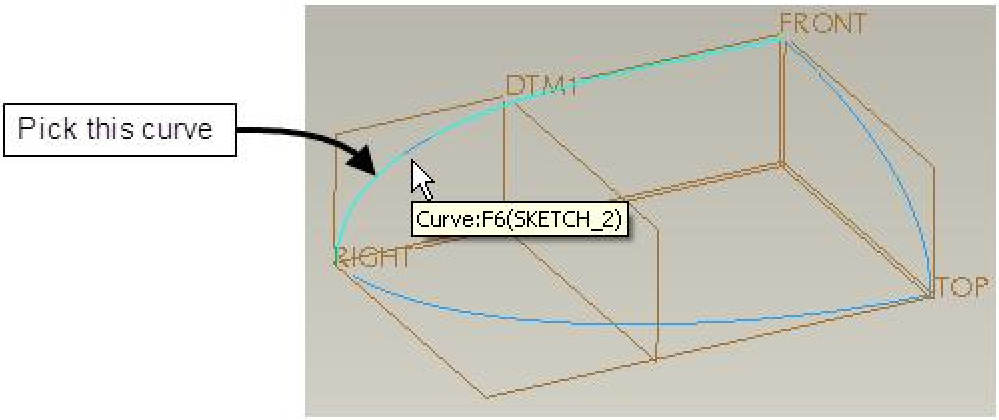
To delete the existing surface right-click the "Boundary Blend 1" feature and pick **Delete** as shown below.



We will create two surface patches instead of one to build the desired quilt. First we will create a sketched datum curve which will be used to build a surface. We have already defined datum plane “DTM1” to be used as Sketching Plane. We also need two datum points which will be used as reference during curve definition. So first we will create datum points.

Pick  on the Model tab to invoke Datum Point Tool.

Pick the following curve as reference.

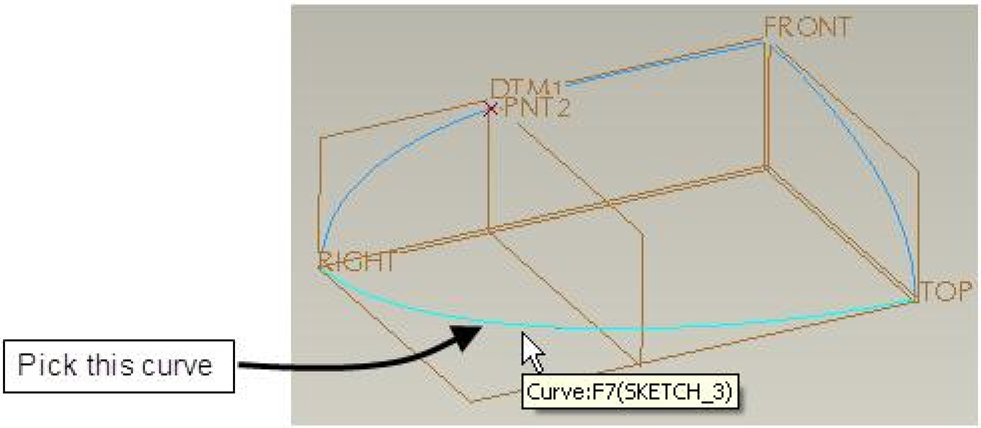


Hold down the Ctrl key and pick the **DTM1** datum plane.

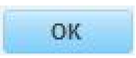
Pick  to complete the definition of datum point.

Again pick  on the Model tab to invoke Datum Point Tool.

Now pick the following datum curve as reference.

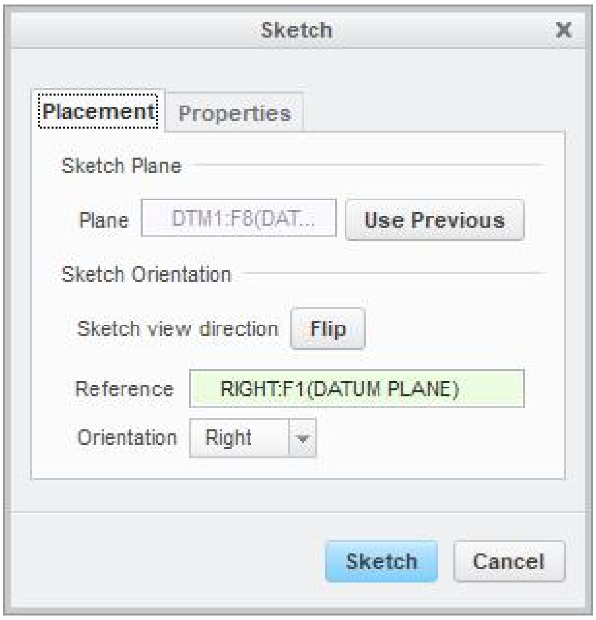


Hold down the Ctrl key and pick the **DTM1** datum plane.

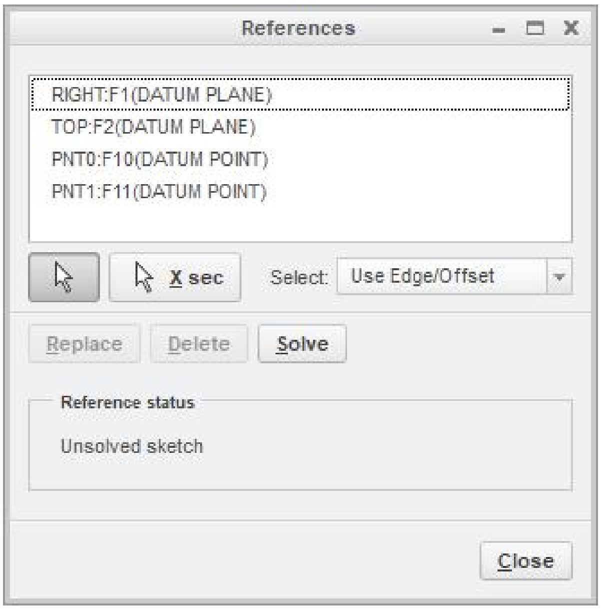
Pick  to complete the definition of datum point.

To create the sketched curve, pick  on the Model tab.

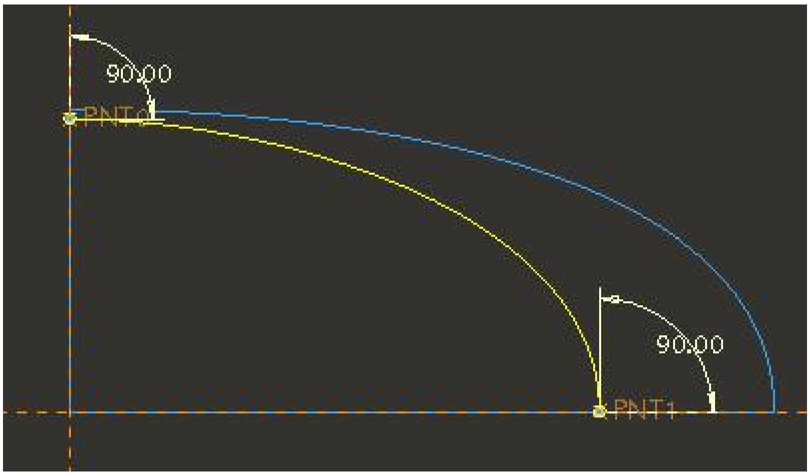
Pick DTM1 as sketching plane.



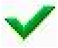
Select the datum points that we just created as reference.



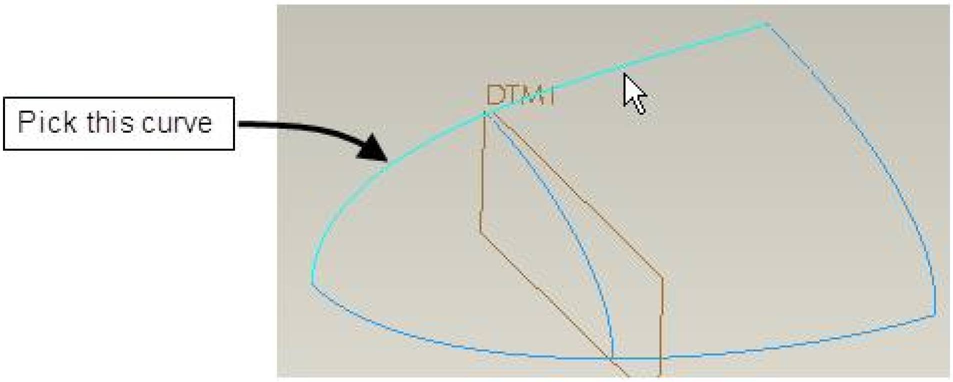
Pick Spline and sketch a two point spline whose end points lie on datum points. Then dimension as shown below.



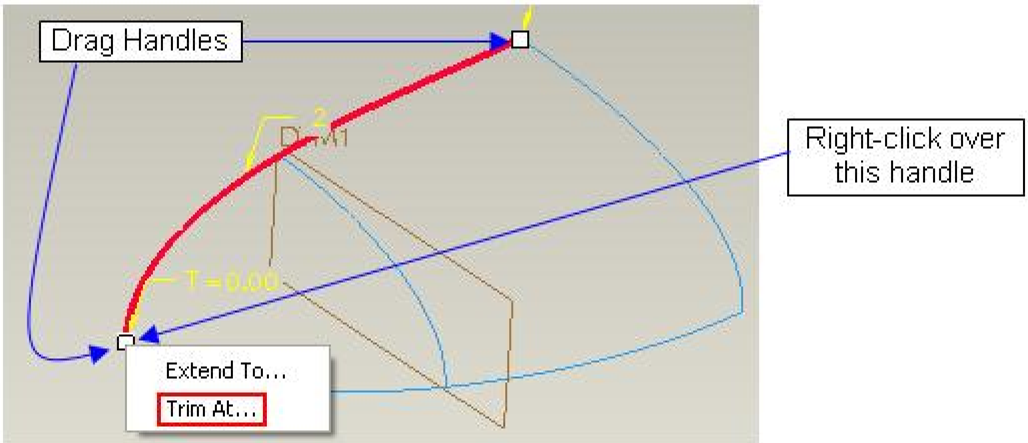
Note: The tangency dimensions (90 in the figure) are created by first picking spline, then reference plane and then the endpoint where the tangency is defined. After this you should pick middle mouse button to place the dimension.

Pick  after completing the sketch.

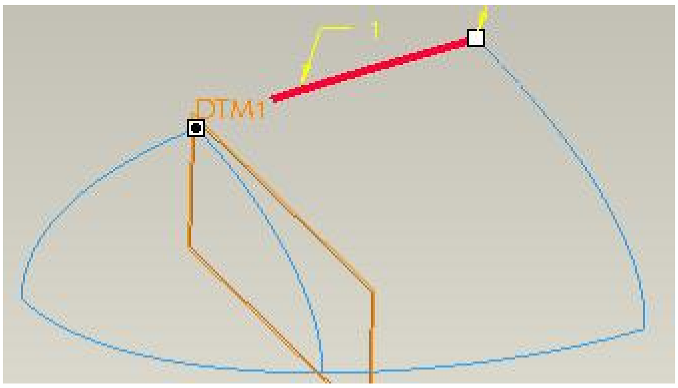
Pick  and select the curve shown in the figure below.



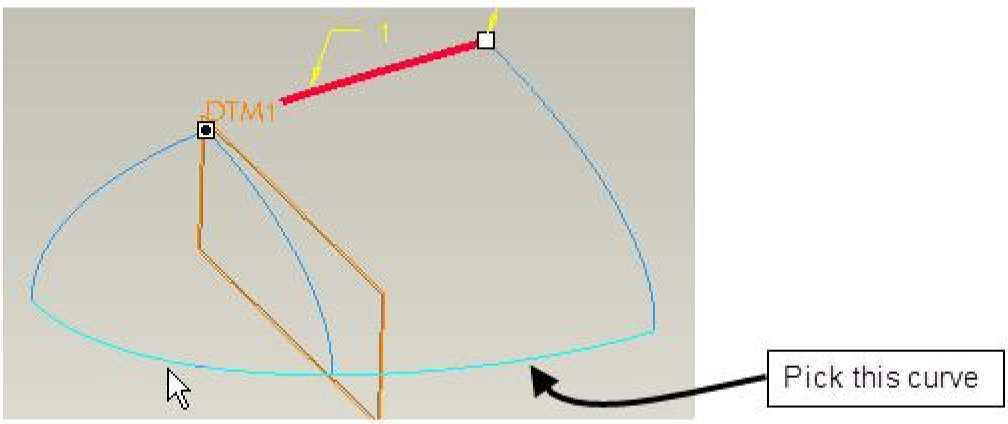
We need to trim the selected chain. So right-click over the left drag handle and pick **Trim At** as shown in the figure below.



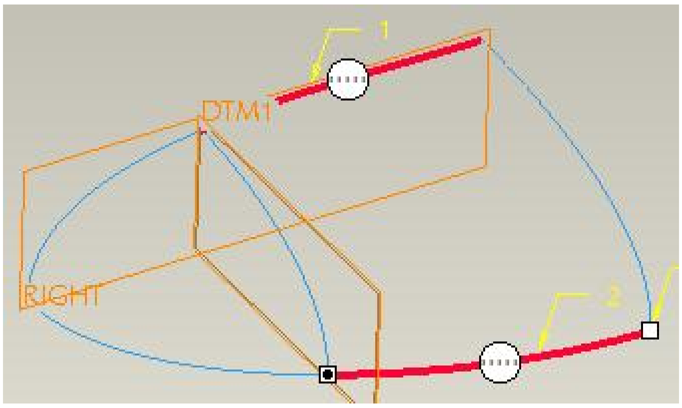
Select the **DTM1** as trimming reference and chain will appear as shown below.



Now hold down the Ctrl key and pick the following curve as second chain.

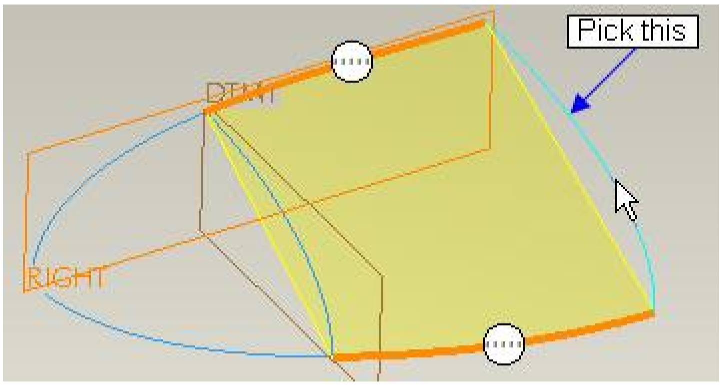


Trim this chain at DTM1 so that chains appear as shown below.

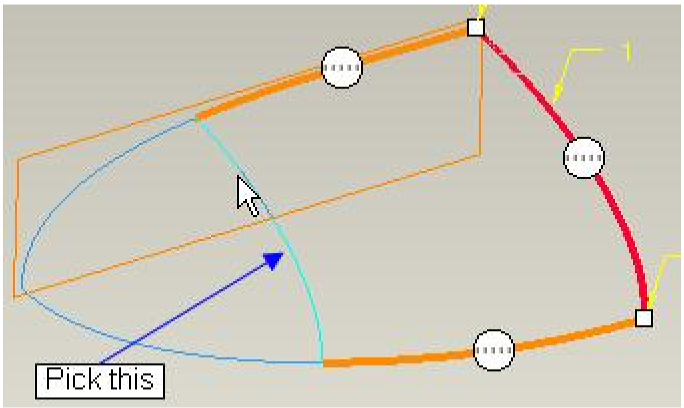


Pick in the Second Direction Collector to activate it.

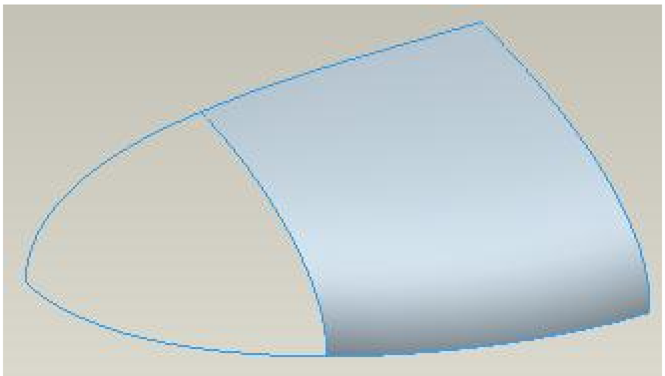
Select the curve shown in the figure below as first chain in second direction.



Hold down the Ctrl key and pick the following curve as second chain.

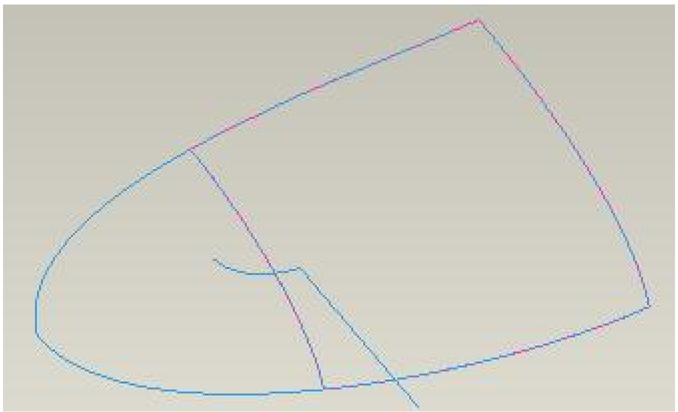


Pick  to complete the feature and it will appear as shown below.



Now we will trim this surface in such a way that we can build another boundary blended surface with four chains. Datum curve required for trimming operation has already been created but it is hidden.

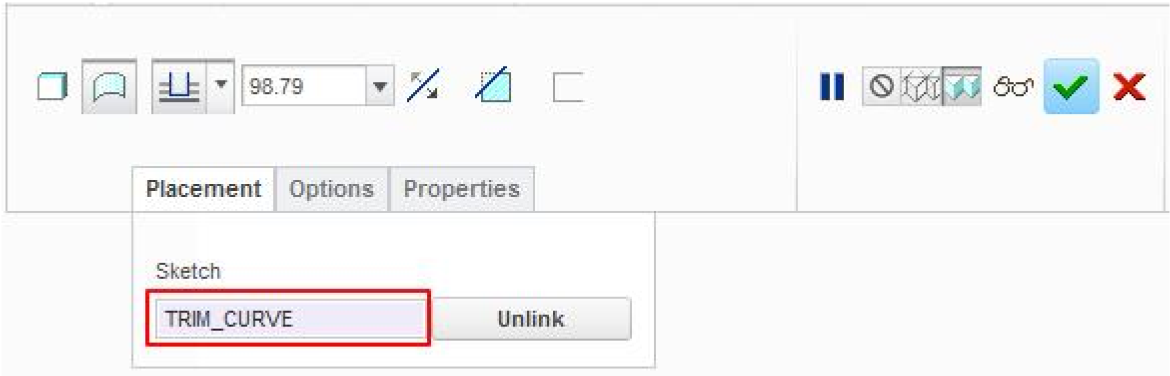
So Select the “TRIM_CURVE” feature in the model tree and pick **Show** and curve will appear on screen as shown below.



To trim the surface using Extrude tool, pick .

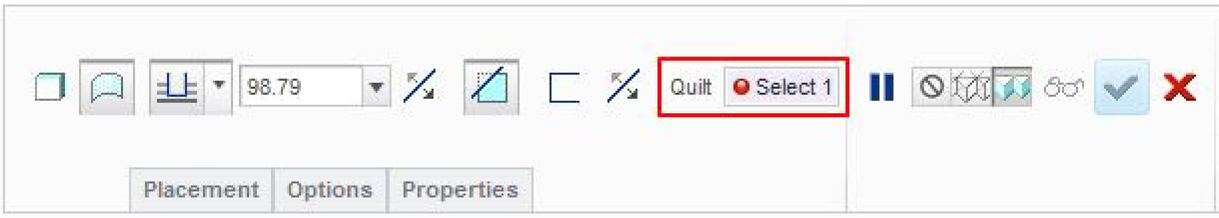
Pick “Extrude as Surface” tab () to create the feature as a surface.

Pick the TRIM_CURVE to be used as sketch.

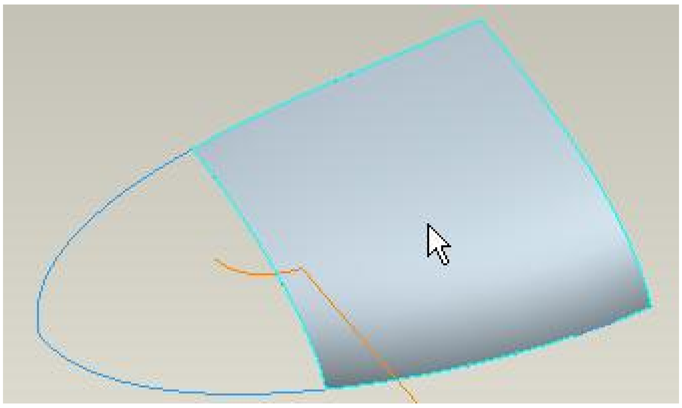


Pick icon to trim the existing surface.

System requires to know which surface or quilt we want to trim. So Quilt collector will appear on the dashboard and system will ask to select the quilt to be trimmed.

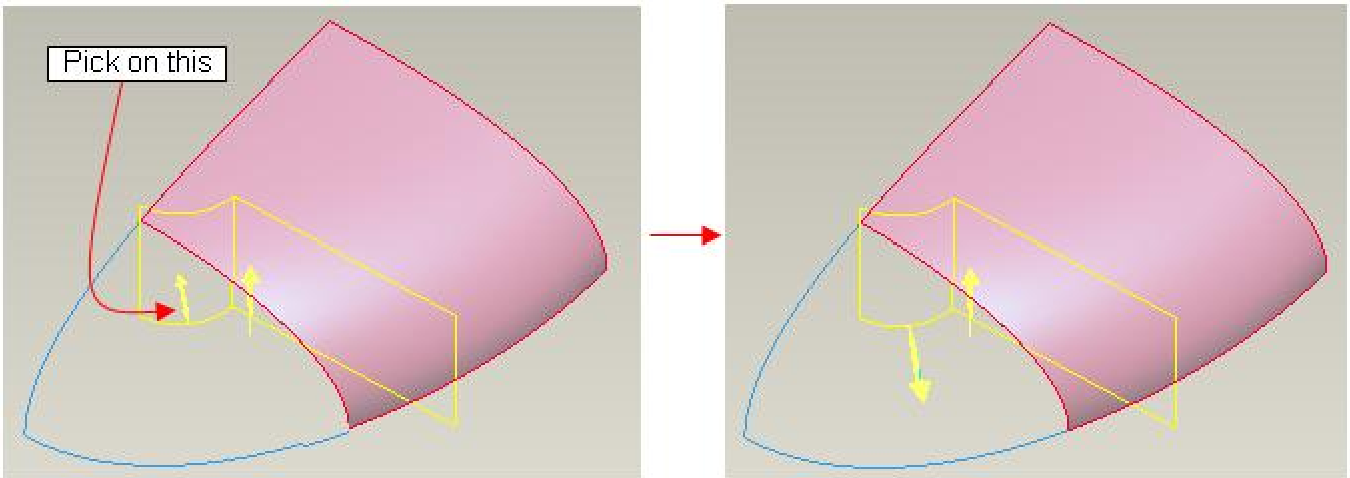


So select the boundary blended surface as shown below.

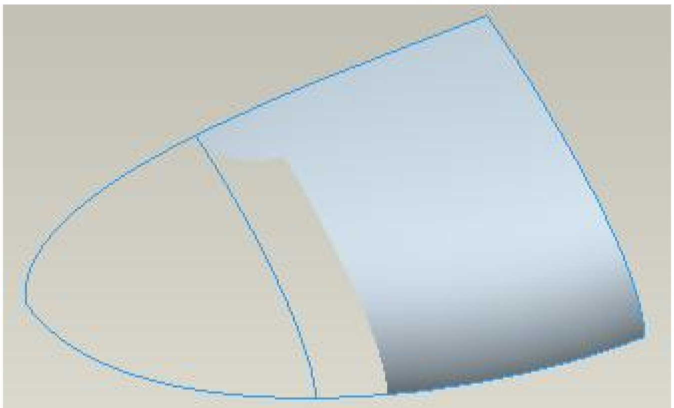


Change the depth option to **Through All** by picking the icon in the Depth options list.

Flip the direction of the arrow, by picking on the arrow, to remove the left side of the surface as explained below.

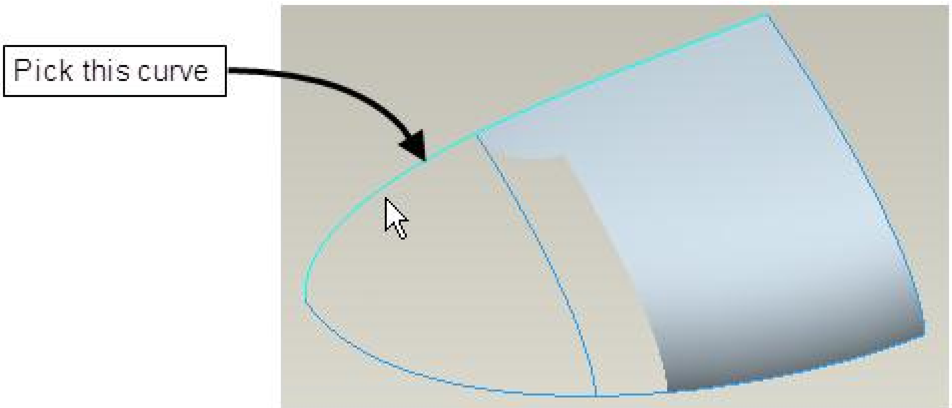


Pick  icon or middle-click to complete the feature and part will appear as shown below.

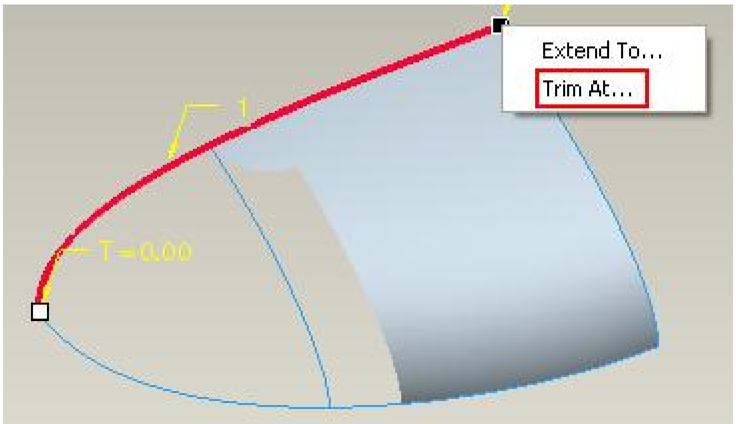


Now we will create another boundary blended surface to create the surface for remaining gap.

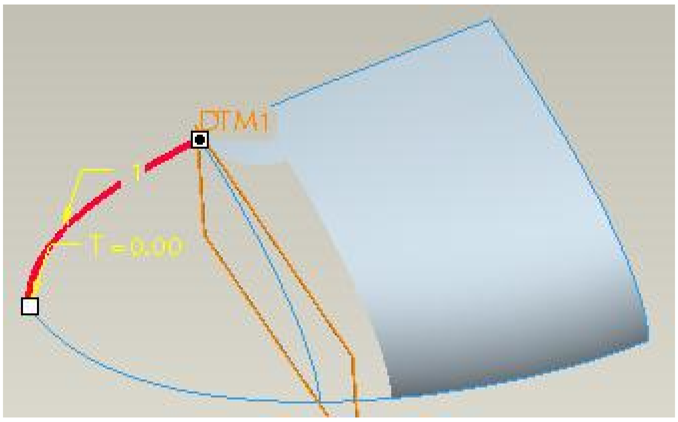
Pick  and select the curve shown in the figure below.



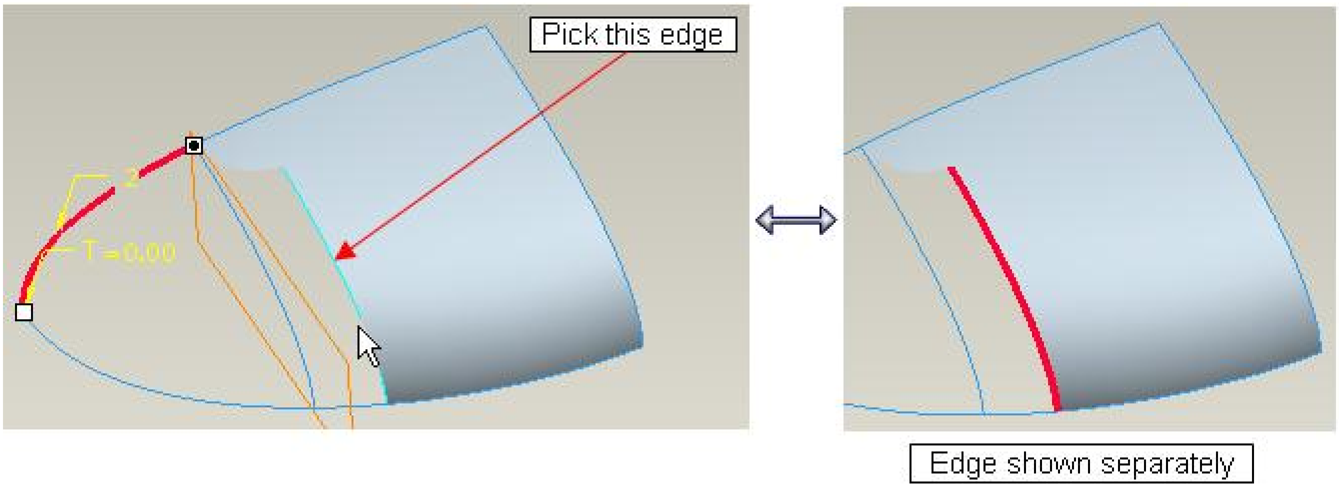
Right-click over the drag handle and pick **Trim At** as shown below.



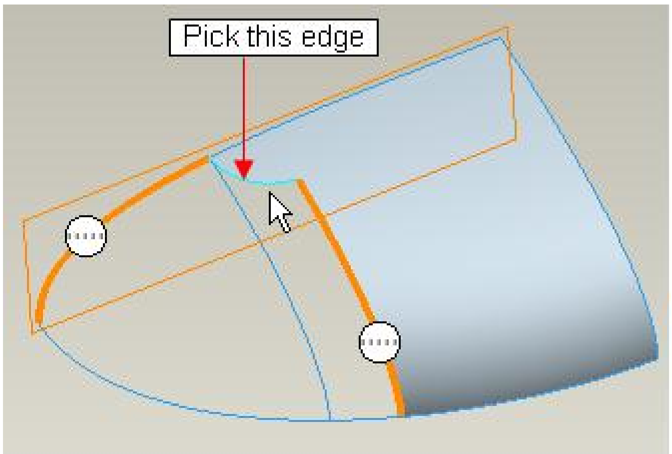
Select the **DTM1** as trimming reference and chain will appear as shown below.

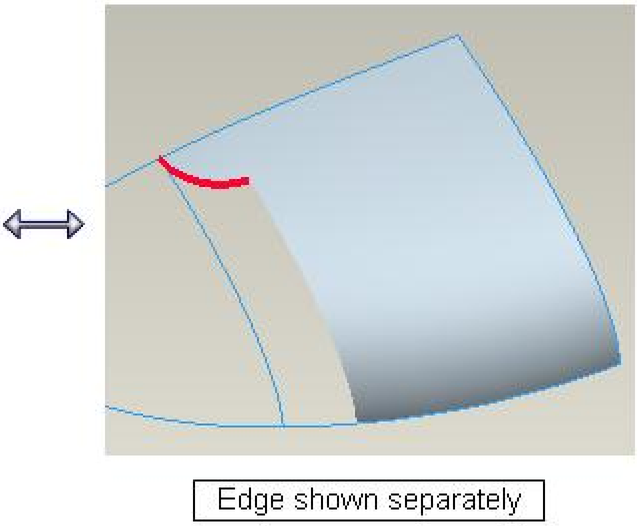


Now hold down the Ctrl key and pick the following edge as second chain.

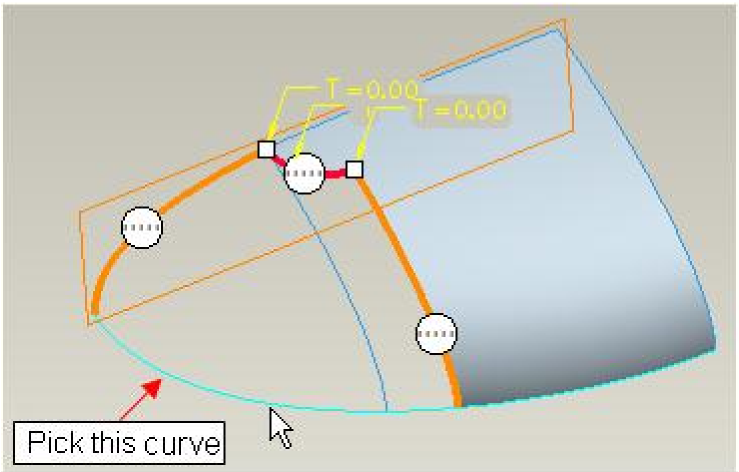


Pick in the **Second Direction Collector** to activate it and select the edge shown in the figure below as first chain in second direction.

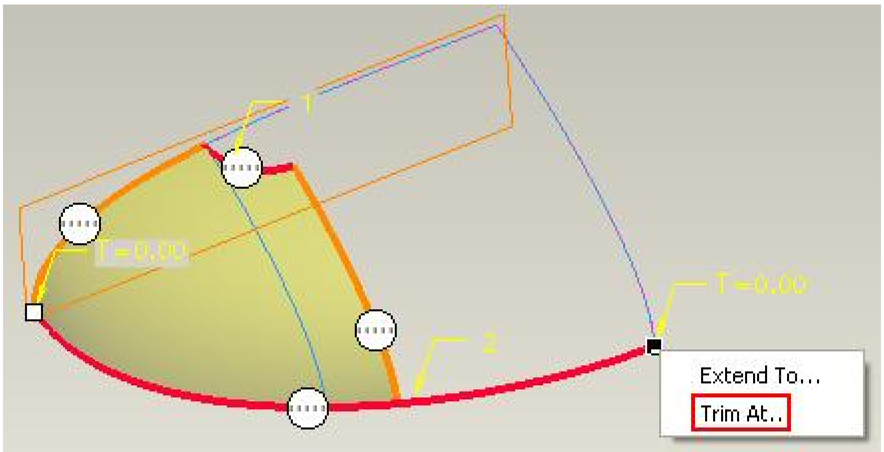




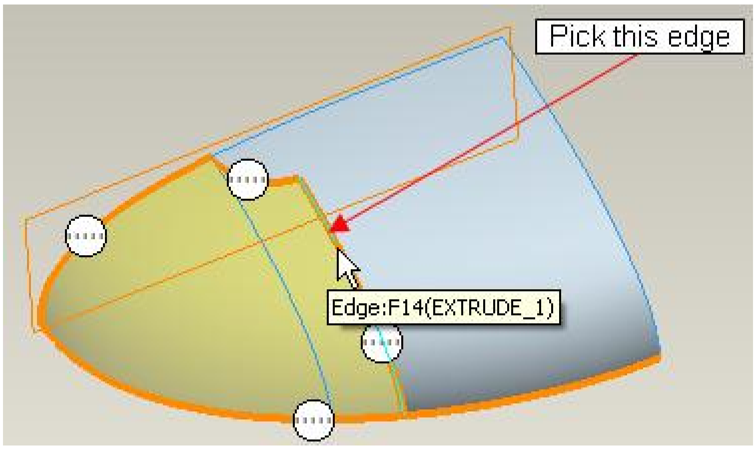
Hold down the Ctrl key and pick the following curve as second chain.



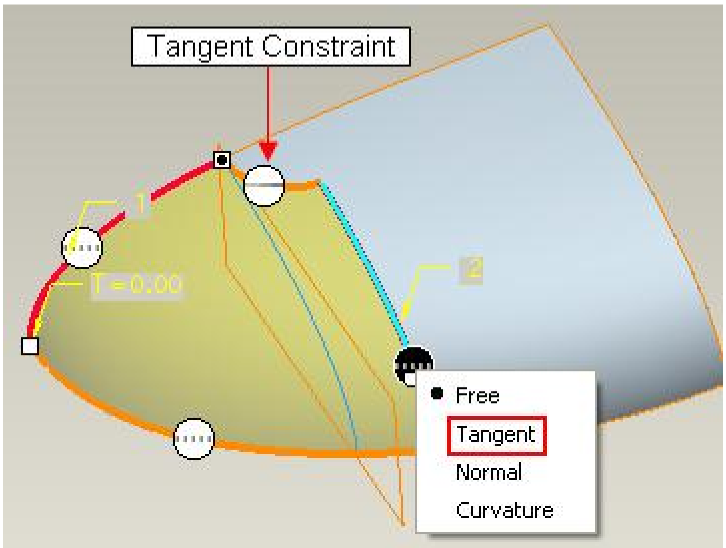
Right-click over the drag handle and pick **Trim At** as shown below.



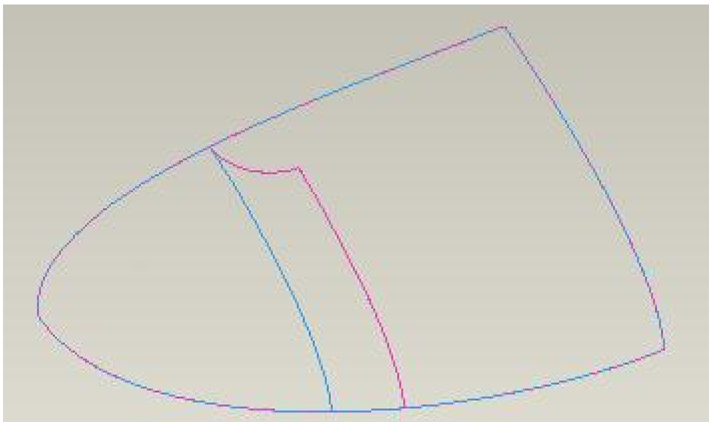
Select the edge shown in figure below.



Apply the Tangent constraints for the chains adjacent to existing surface as shown below.



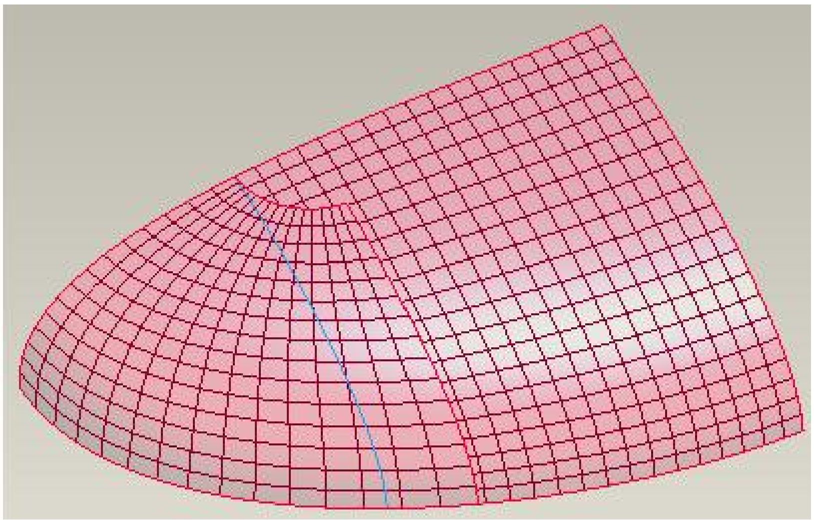
Pick to complete the feature and it will appear as shown below.



Now we will mesh the surface to view the grid line of surface.

Pick Mesh Surface on the Analysis tab to access the Mesh Surface tool.

Now select both surfaces and mesh will appear as shown below.



In the above figure you can see that there is no concentration of gridlines to a single point. These surfaces are considered to be of higher quality as compared to the previous one.

Pick Close to exit the dialog box.

Pick on the Graphics toolbar or press **Ctrl + R** on the keybaord to redraw the view to normal.

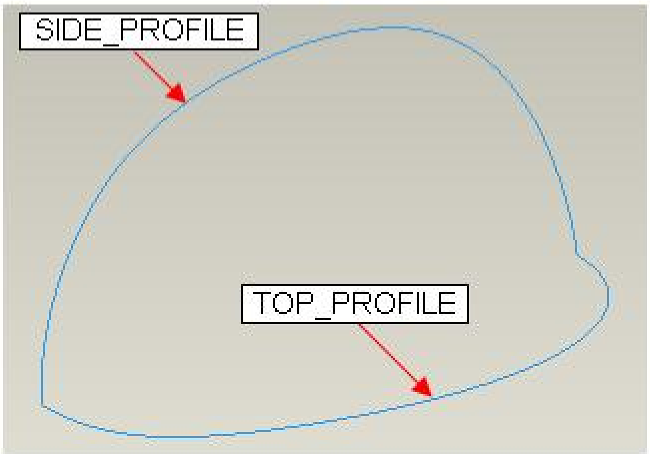
Select **File>Save** to save the work done so far.

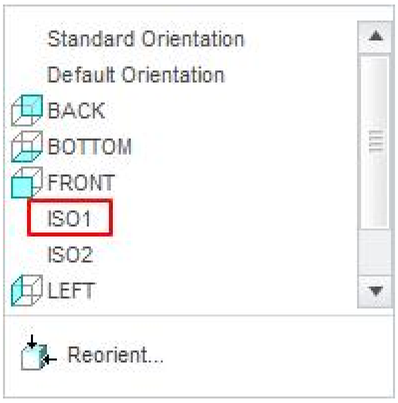
Exercise 2

In this exercise we will create a surface model for a helmet and learn to avoid singularity.

Set the working directory to the ANALYSIS folder and open the model HELMET.PRT

Set the view to **ISO1** and part will appear as shown below.

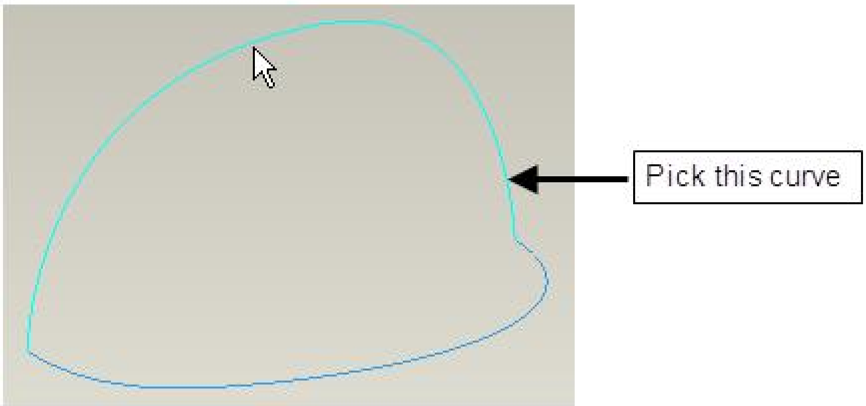




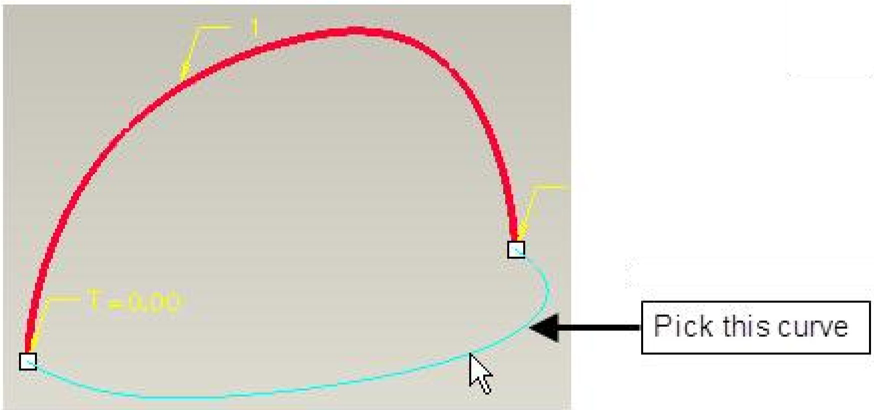
You should have a look at the names given to the curves in the model tree as we will refer to these curves, by name, to avoid any confusion.

First we will create a boundary blended surface that result in a singularity, just to show how intuitive this is.

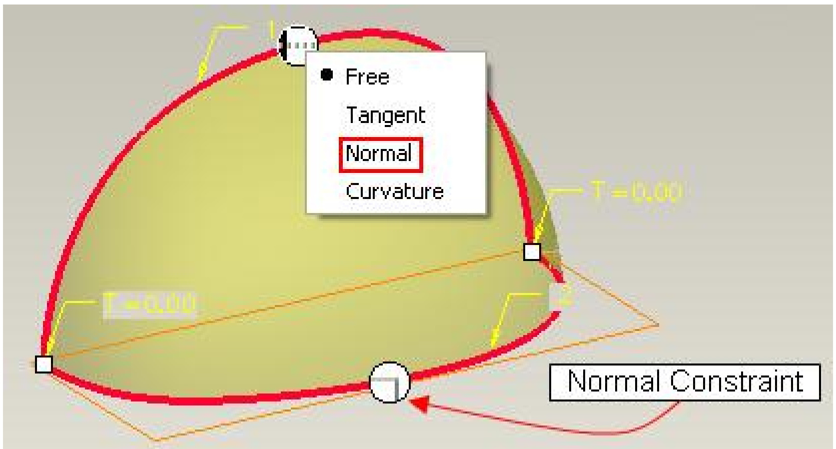
Pick  and select the SIDE_PROFILE curve shown in the figure below.



Now hold down the Ctrl key and pick the TOP_PROFILE curve as second chain.



Apply normal constraint for both chains as shown below.



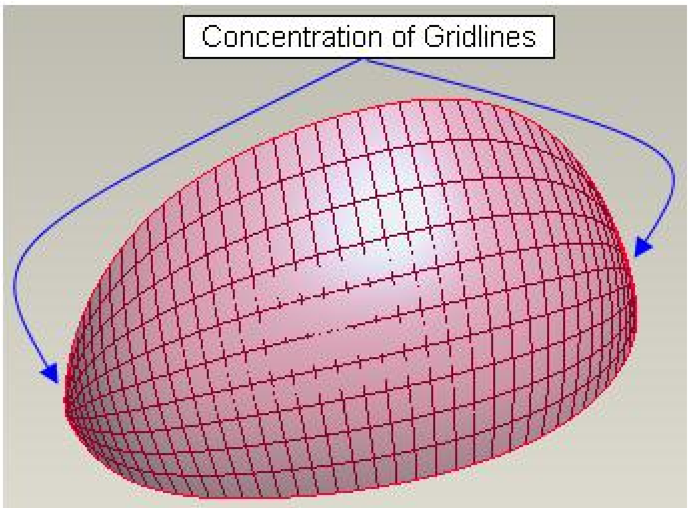
Pick  to complete the feature.

Now we will mesh the surface to create a grid line of surface.

Pick 

on the Analysis tab to access the Mesh Surface tool.

Now system will ask you to select a surface to be analyzed. So pick the newly created surface and system will mesh it as shown below.



In the above figure you can see that the grid lines merge to a single point. This usually makes the offset or shell operation very difficult.

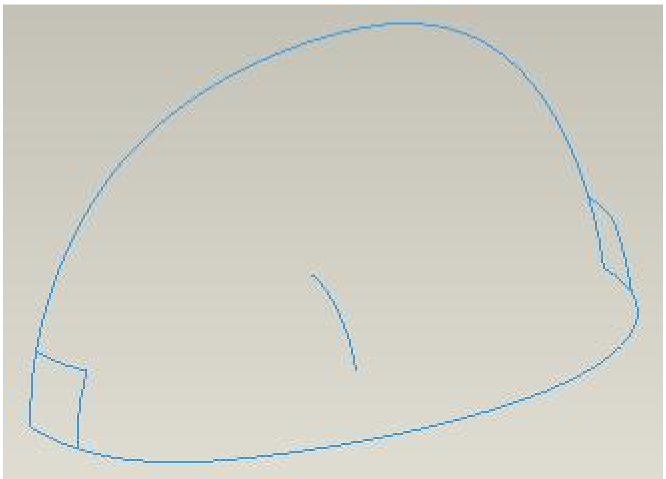
Pick  to exit the dialog box.

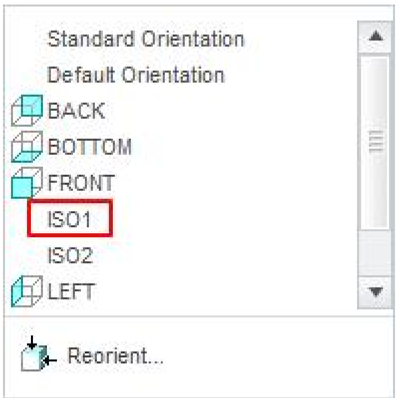
Pick  on the Graphics toolbar or press **Ctrl + R** on the keybaord to redraw the view to normal.

Now we will create the shape of the above surface using different technique that does not create singularity. Datum features required for this technique have already been created but are hidden. So first we will unhide them. Before that you should delete the existing boundary blended surface as we don't need it.

To delete the existing surface right-click the "Boundary Blend 1" feature and pick **Delete**.

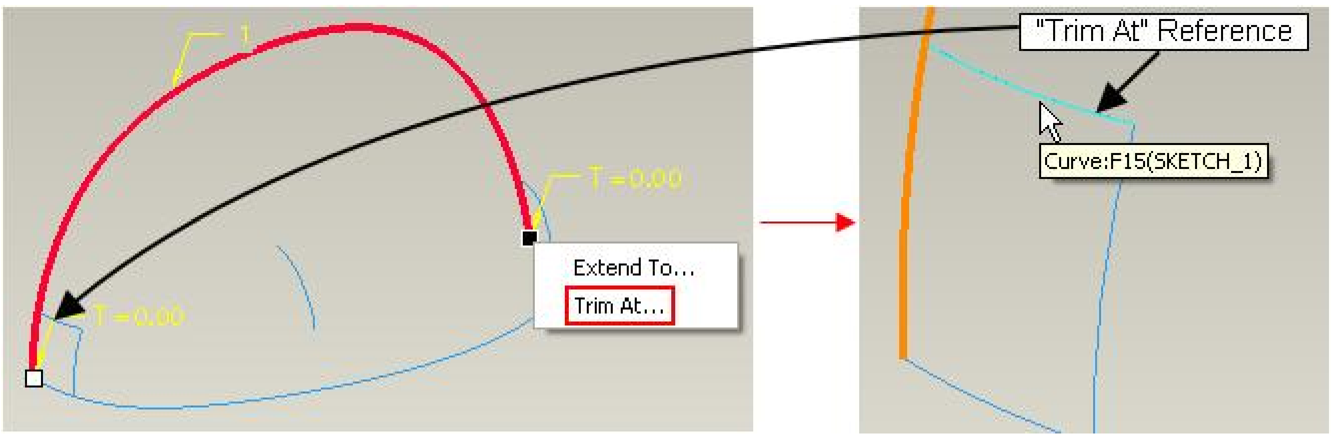
Select the "**Group 1**" feature in the model tree and pick **Show** and curves will appear on screen as shown below.



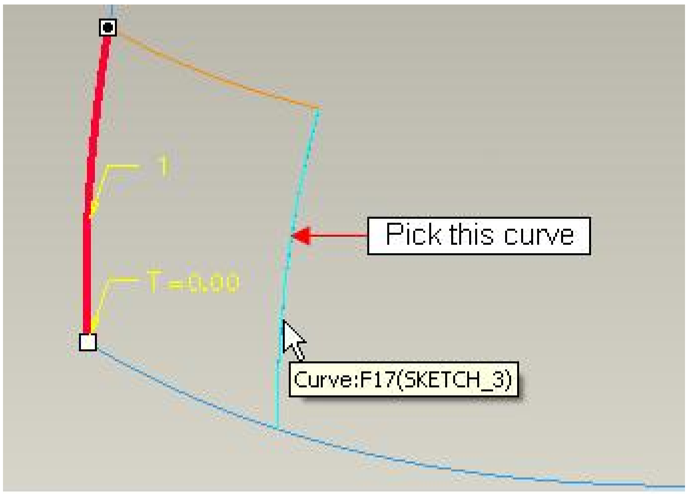


Now we will create two boundary blended surfaces and then trim them. You must set the view to ISO1 to avoid any confusion.

Pick  and select the SIDE_PROFILE curve as first chain and then trim it as shown in the figure below.

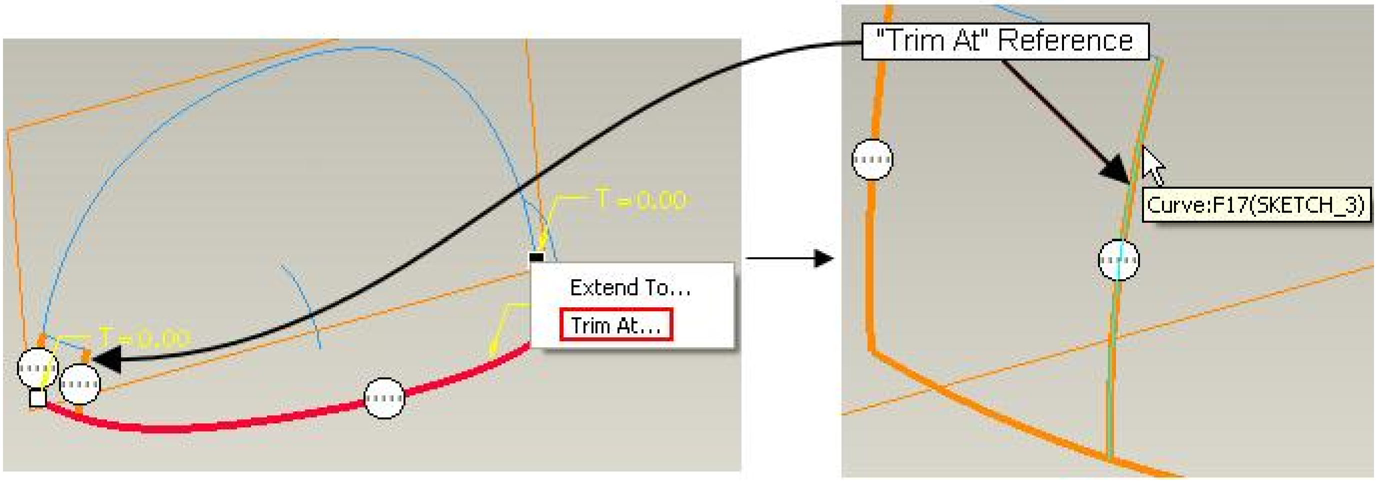


Now hold down the Ctrl key and pick the following curve as second chain.

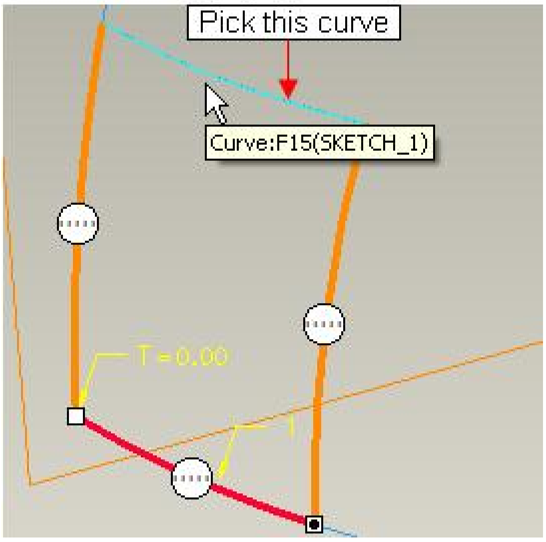


Pick in the Second Direction Collector to activate it.

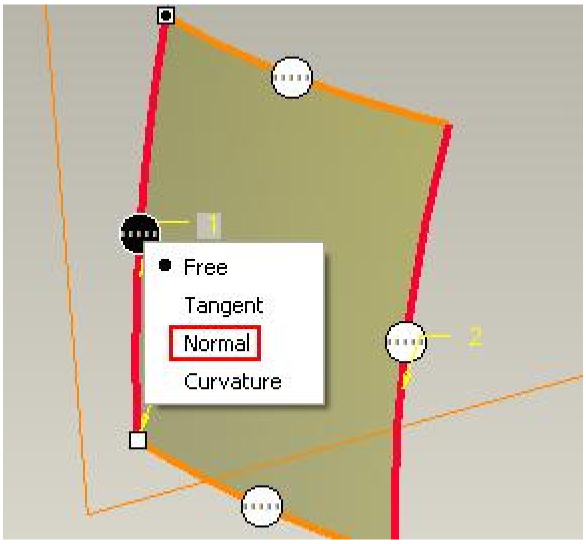
Select the TOP_PROFILE curve as first chain in second direction and then trim it as shown in the figure below.



Hold down the Ctrl key and pick the following curve as second chain.



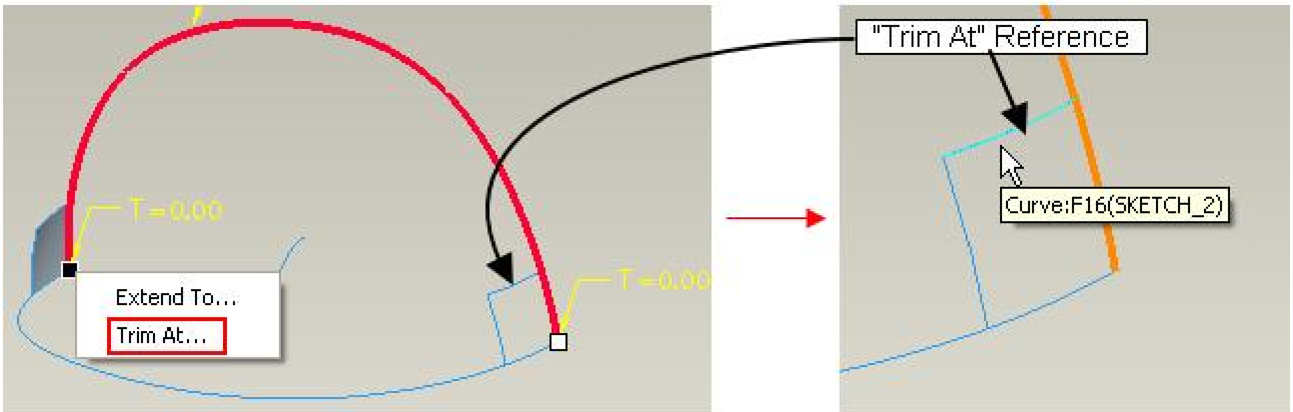
Apply normal constraint for first chain in first direction (i.e. SIDE_PROFILE curve) as shown below.



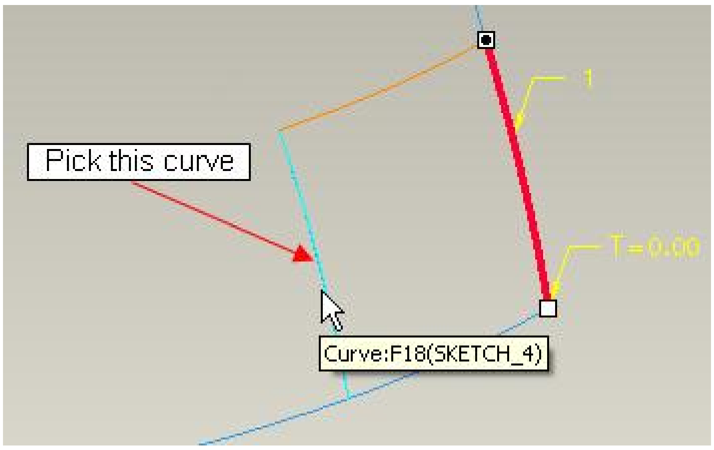
Pick  to complete the feature.

Now we will create second boundary blended surface but before that set the view to **ISO2** to avoid any confusion.

Again pick  and select the SIDE_PROFILE curve as first chain and then trim it as shown in the figure below.

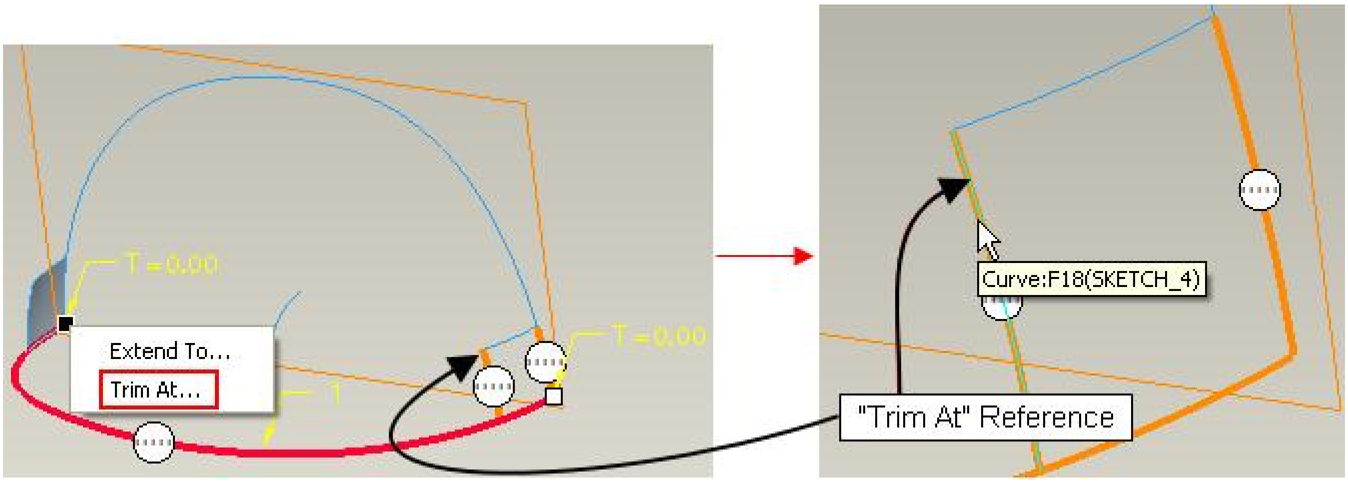


Now hold down the Ctrl key and pick the following curve as second chain.

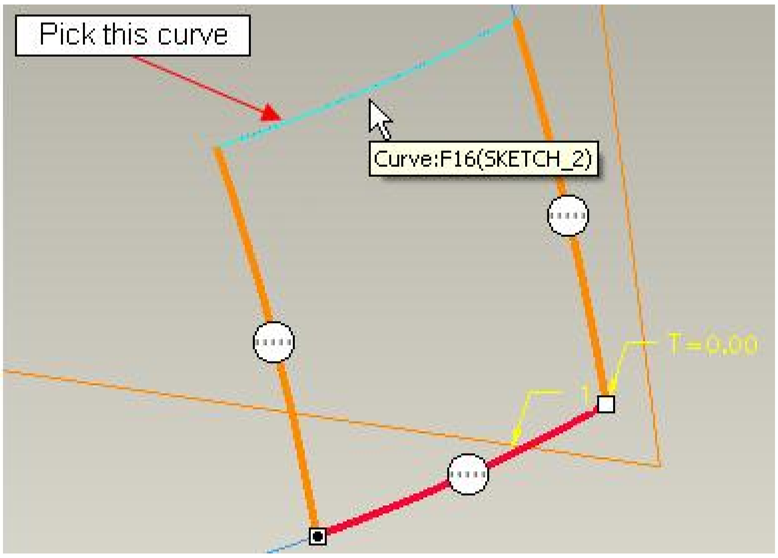


Pick in the Second Direction Collector to select chains for second direction.

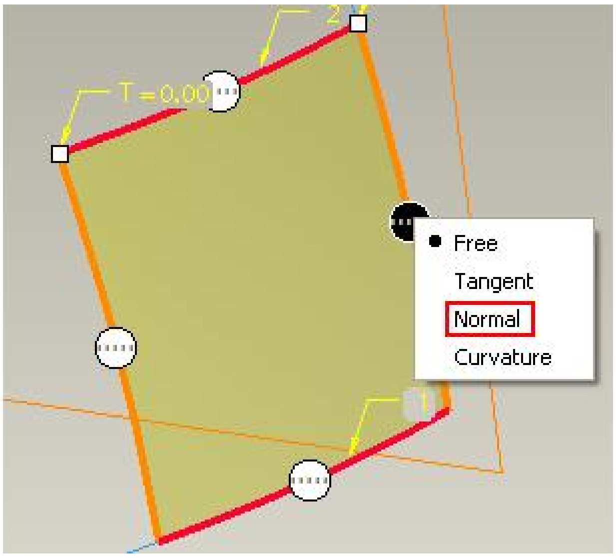
Select the TOP_PROFILE curve as first chain in second direction and then trim it as shown in the figure below.



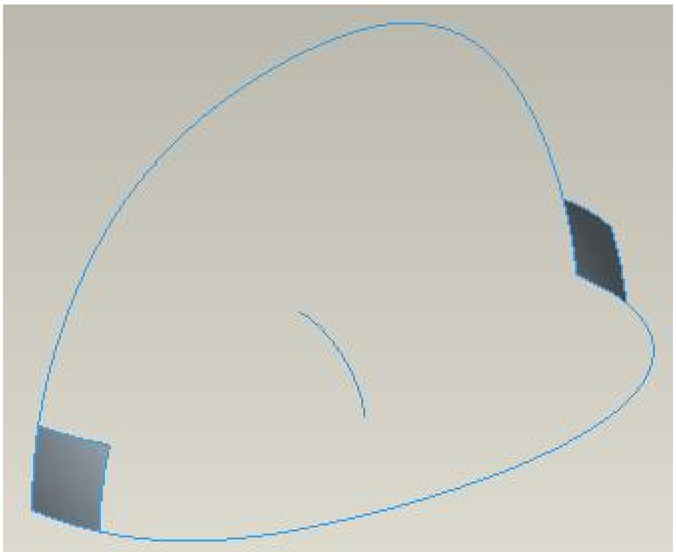
Hold down the Ctrl key and pick the following curve as second chain.



Apply normal constraint for first chain in first direction (i.e. SIDE_PROFILE curve) as shown below.



Pick  to complete the feature and part will appear as shown below.

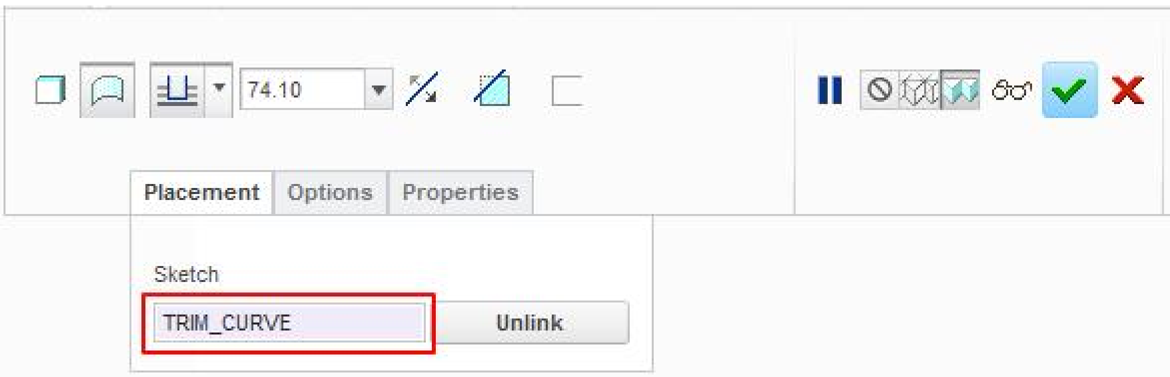


Now we will trim these surfaces in such a way that we can build another boundary blended surface with four chains. Datum curve required for trimming operation has already been created.

To trim the surface pick 

Pick "Extrude as Surface" tab () to create the feature as a surface.

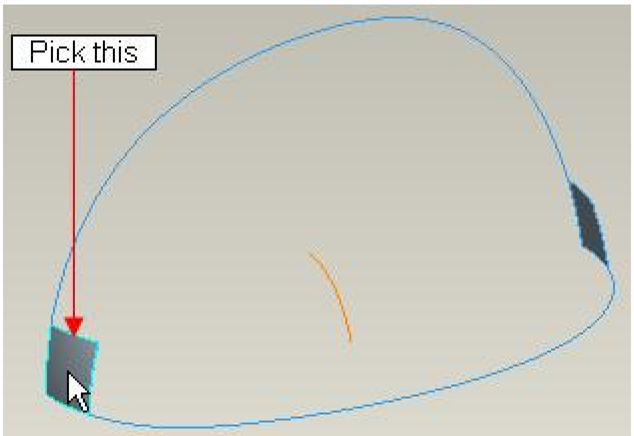
Pick the TRIM_CURVE in the model tree (located in "Group 1") to be used as sketch.

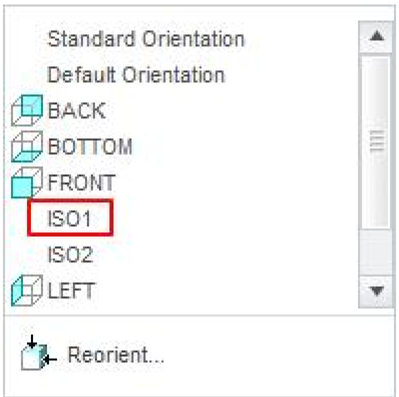


Pick  icon to trim the surface.

System requires to know which surface or quilt we want to trim. So Quilt collector will appear on the dashboard and system will ask to select the quilt to be trimmed.

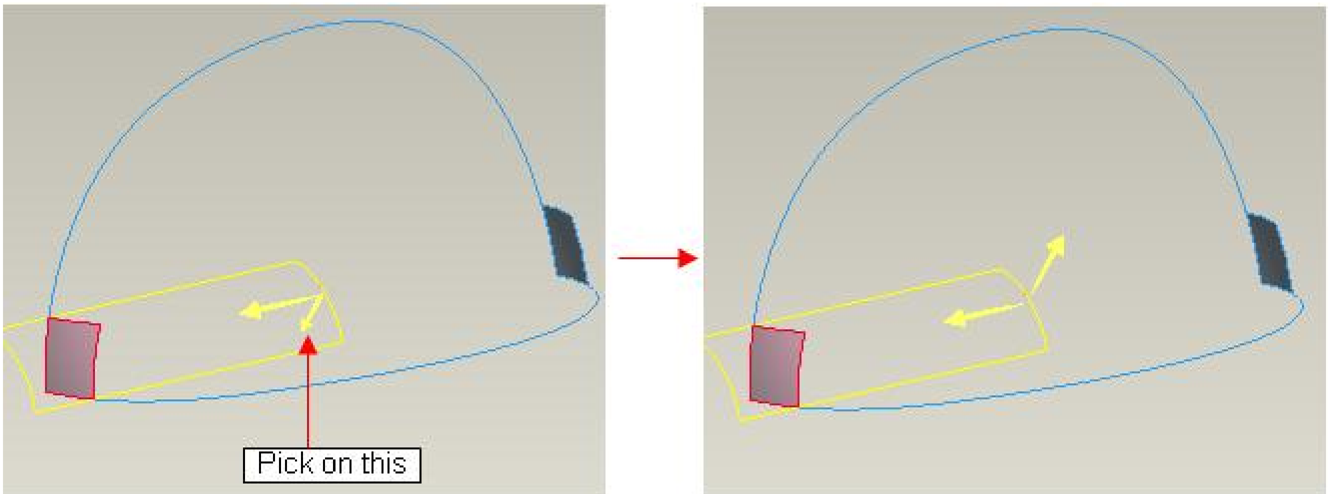
So select the boundary blended surface as shown below.



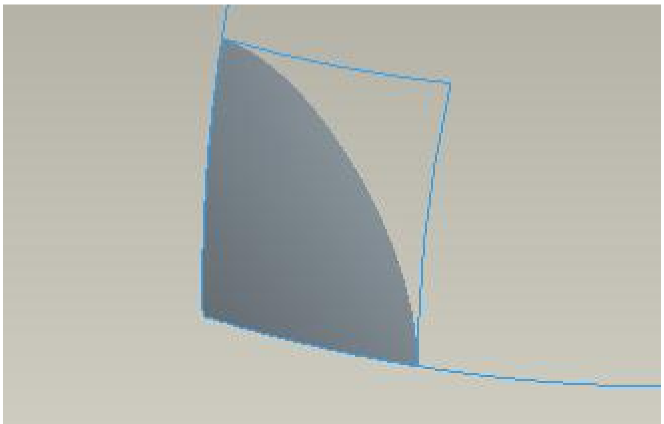


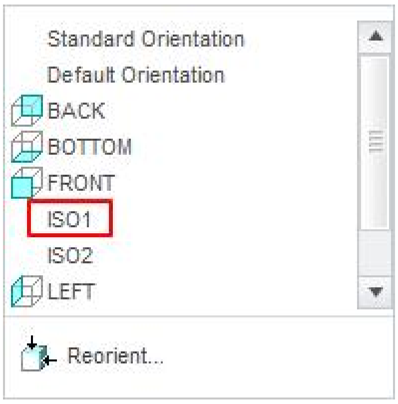
Change the depth option to **Through All** by picking the  icon in the Depth options list.

Flip the direction of the arrow, by picking on the arrow, to remove the outer side of the surface as explained below.



Pick  icon or middle-click to complete the feature and trimmed surface will appear as shown below.





Now we will trim second boundary blended surface so pick 

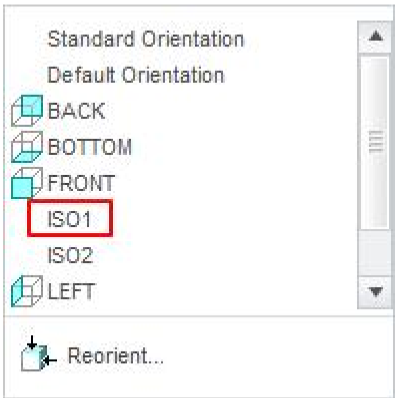
Pick “Extrude as Surface” tab () to create the feature as a surface.

Pick the TRIM_CURVE in the model tree (located in “Group 1”) to be used as sketch.

Pick the  icon to reverse the direction of feature creation.

Pick  icon to trim the surface.

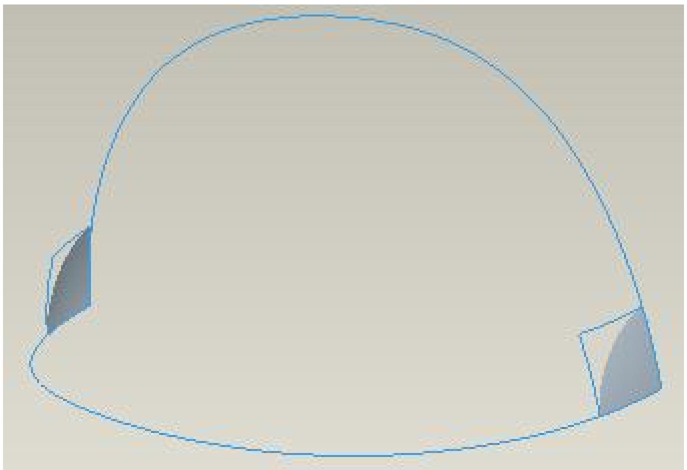
As Quilt collector is active so select the boundary blended surface for trim operation as shown below.



Change the depth option to **Through All** by picking the  icon in the Depth options list.

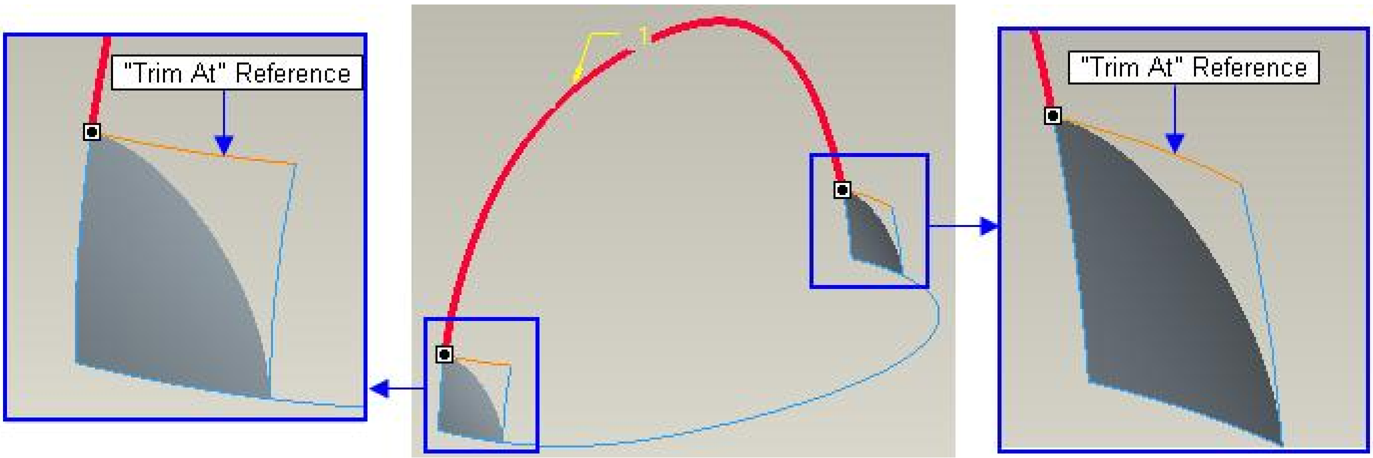
Flip the direction of the arrow to remove the outer side of the surface.

Pick  icon or middle-click to complete the feature and trimmed surface will appear as shown below.

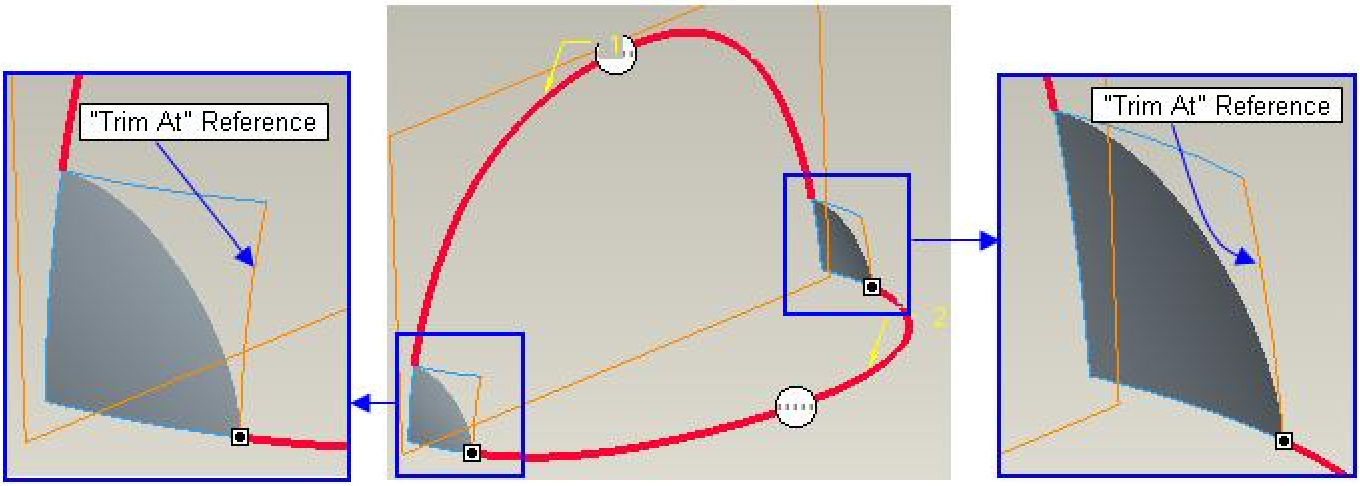


Now we will create another boundary blended surface to create the surface for remaining gap.

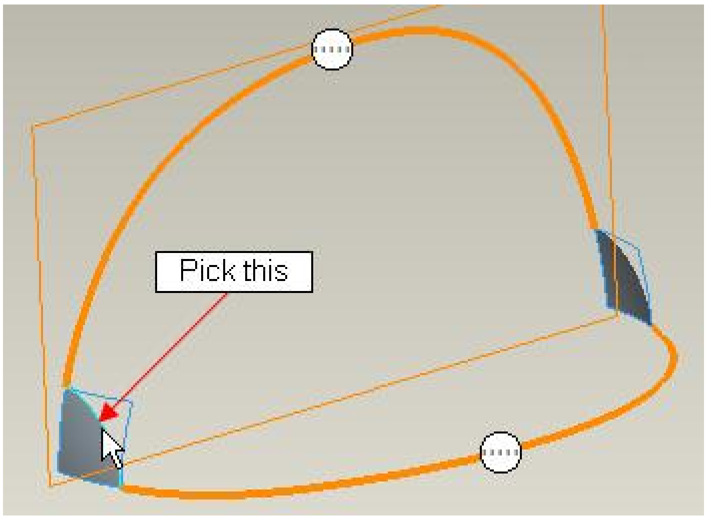
Pick  and select the SIDE_PROFILE curve and trim it at both ends as shown in the figure below.



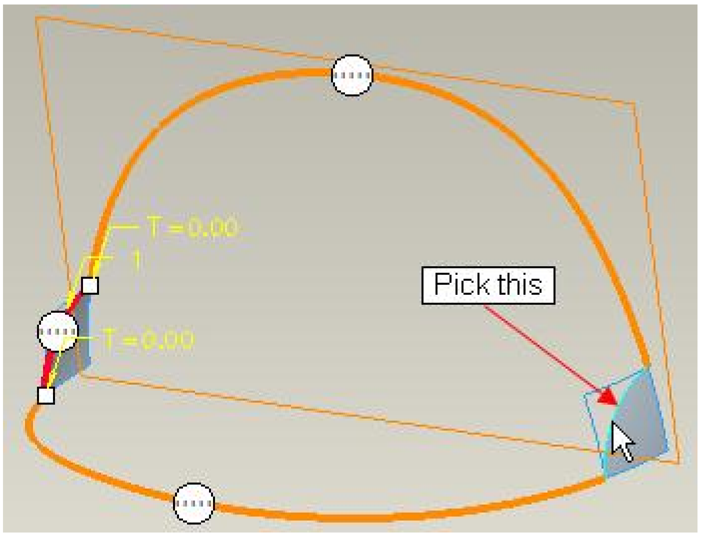
Now hold down the Ctrl key and pick the TOP_PROFILE curve, then trim it at both ends as shown in the figure below.



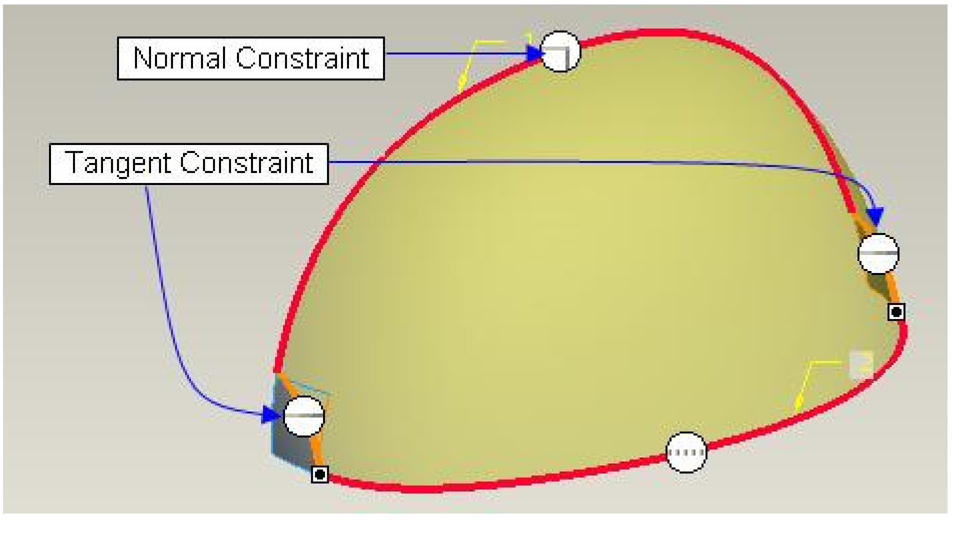
Pick in the **Second Direction Collector** to activate it and select the edge shown in the figure below as first chain in second direction.

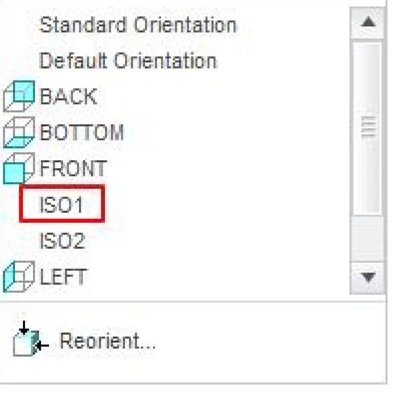


Hold down the Ctrl key and pick the following curve as second chain.

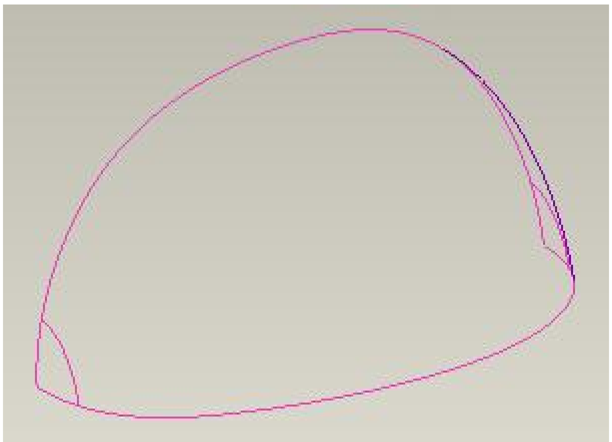


Apply the Normal and Tangent constraints as shown below.





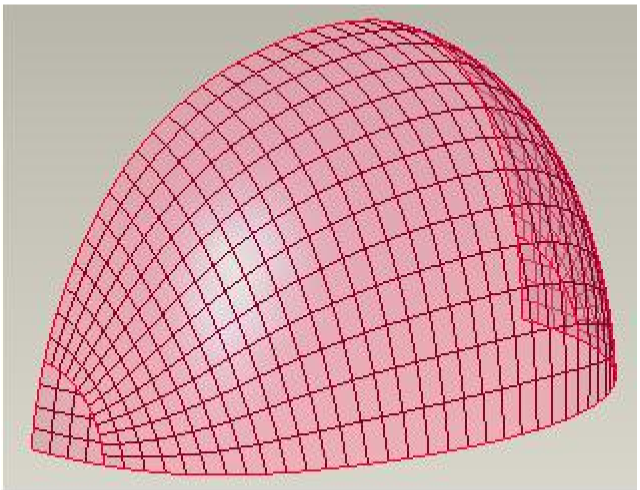
Pick  to complete the feature and it will appear as shown below.



Now we will mesh the surface to view the grid line of surface.

Pick Mesh Surface on the Analysis tab to access the Mesh Surface tool.

Now select both surfaces and mesh will appear as shown below.



In the above figure you can see that there is no concentration of gridlines to a single point. These surfaces are considered to be of high quality as compared to the previous one.

Pick Close to exit the dialog box.

Pick  on the Graphics toolbar or press **Ctrl + R** on the keybaord to redraw the view to normal.

Select **File>Save** to save the work done so far.