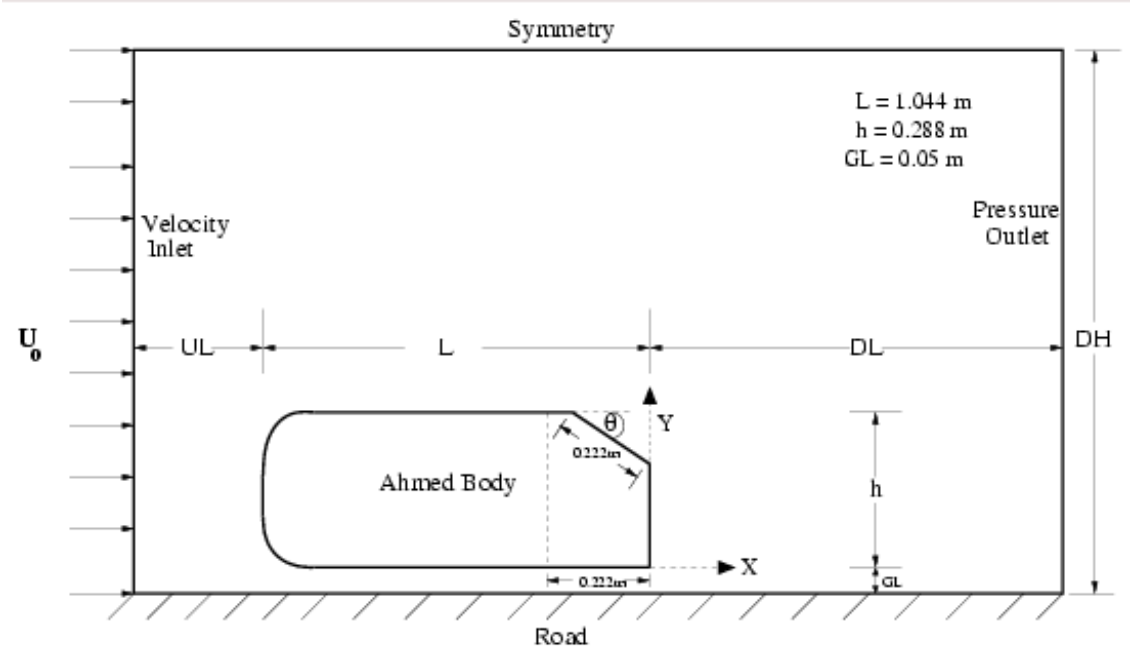
Simulation of Turbulent Flow over the Ahmed Body

1. Purpose

The Purpose of Task6 is to simulate **unsteady turbulent** flows over the Ahmed body following the "CFD process" by an interactive step-by-step approach and conduct verifications using ANSYS Fluent. Students will have "hands-on" experiences using ANSYS to **predict drag coefficients and axial velocity for slant angle 25 degrees and compare them with experimental data.** Students will use post-processing tools (streamlines, velocity vectors, contours, animations) to **visualize the mean and instantaneous flow fields and compute the non-dimensional shedding frequency (Strouhal number)**. Students will analyze the differences between CFD and experimental data and present results in a report.

2. Simulation Design

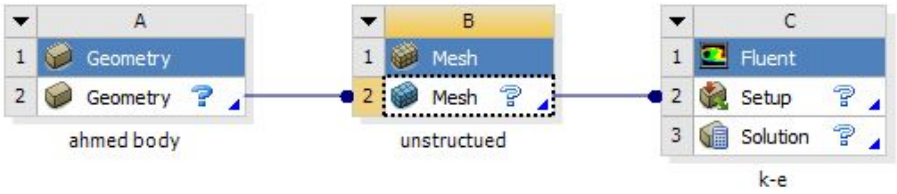
The problem to be solved is unsteady turbulent flows over the Ahmed body (2D). Reynolds number is around 768,000 based on inlet velocity and vehicle height (h). The following figure shows the sketch window you will see in ANSYS with definitions for all geometry parameters. The origin of the simulation is located at the rear of the body. θ is the slant angle. L is the length of the body and h is the height of the body. Uniform velocity specified at inlet and constant pressure specified at outlet. The top boundary of the simulation domain is regarded as "Symmetry" and there is a distance between the car body and road, GL.



3. Project Schematic in ANSYS Workbench

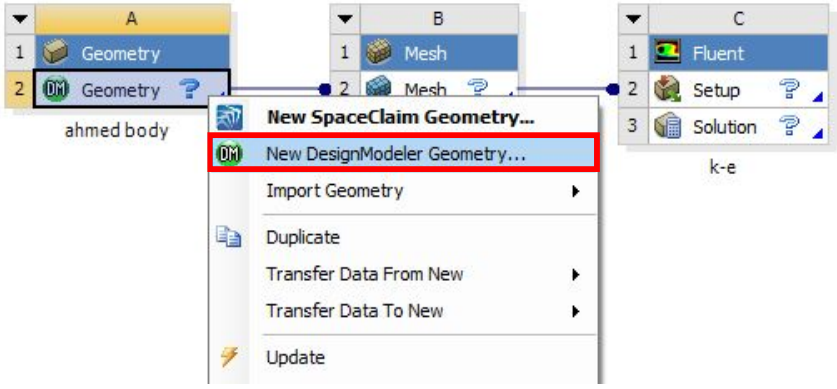
3.1. Start ANSYS **Workbench.**

3.2. Drag and drop three component into the **Project Schematic**, name the components and create connections between components as per below.

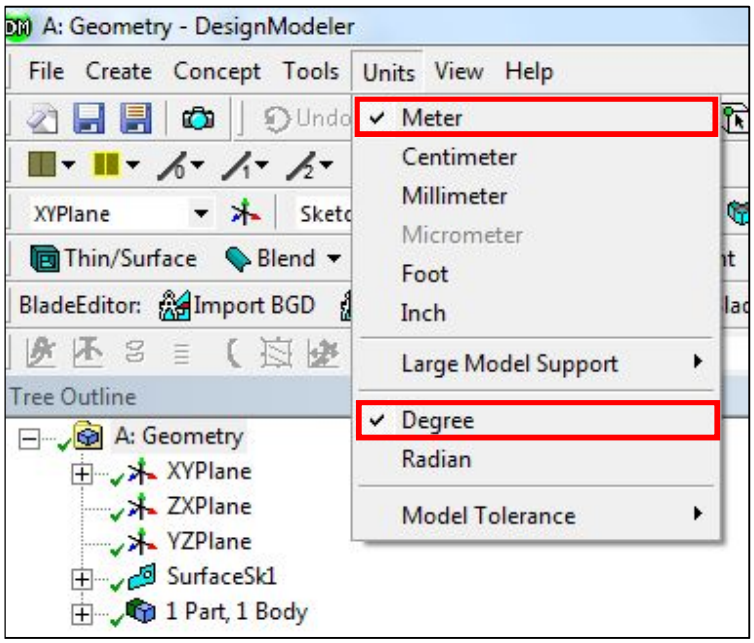


4. Geometry Creation

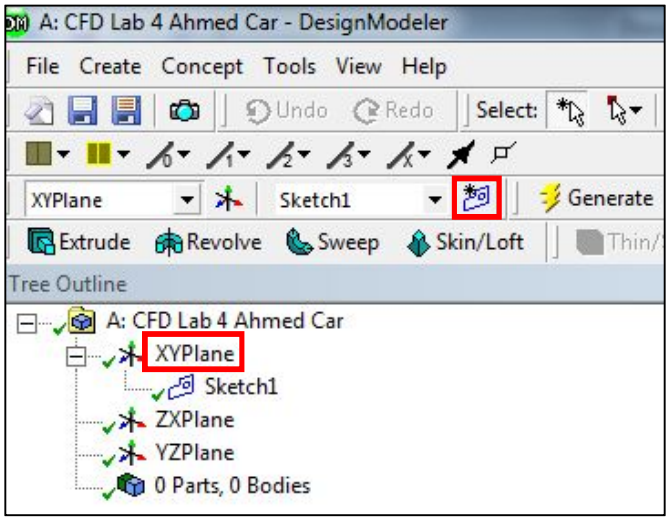
4.1. From the **Project Schematic** right click **Geometry** and select **New DesignModeler Geometry….**



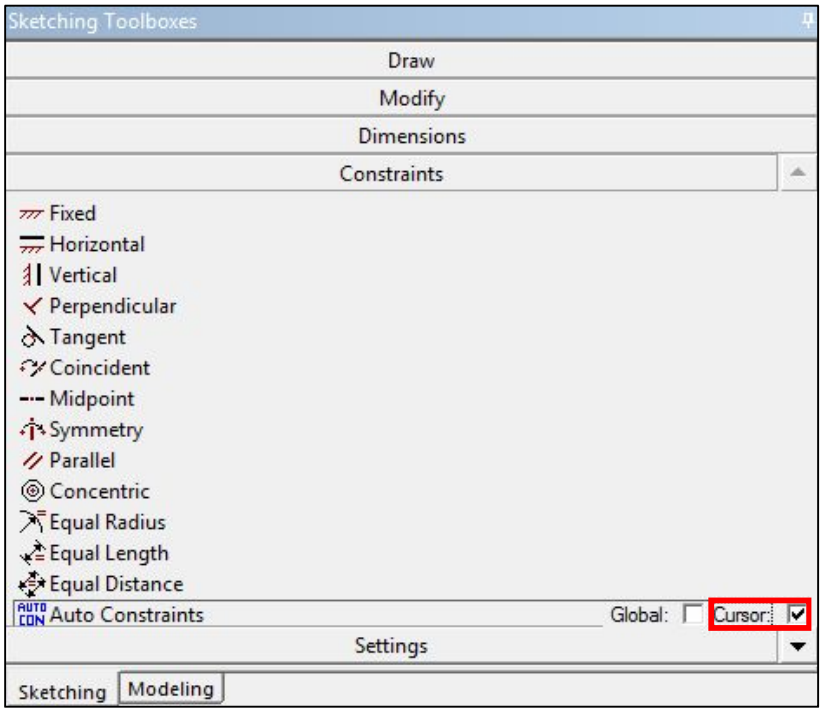
4.2. Make sure that Unit is set to **Meter** and **Degree** (default settings).



4.3. Select the **XYPlane** then click the **New Sketch** button.

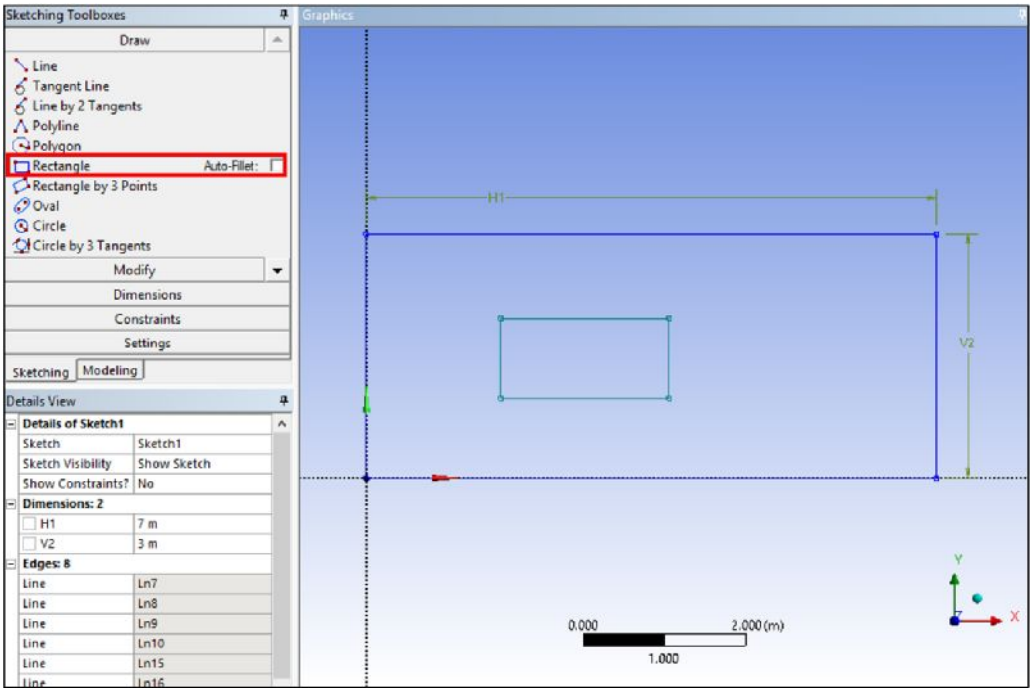


4.4. Enable the auto constraints option to pick the exact point as below

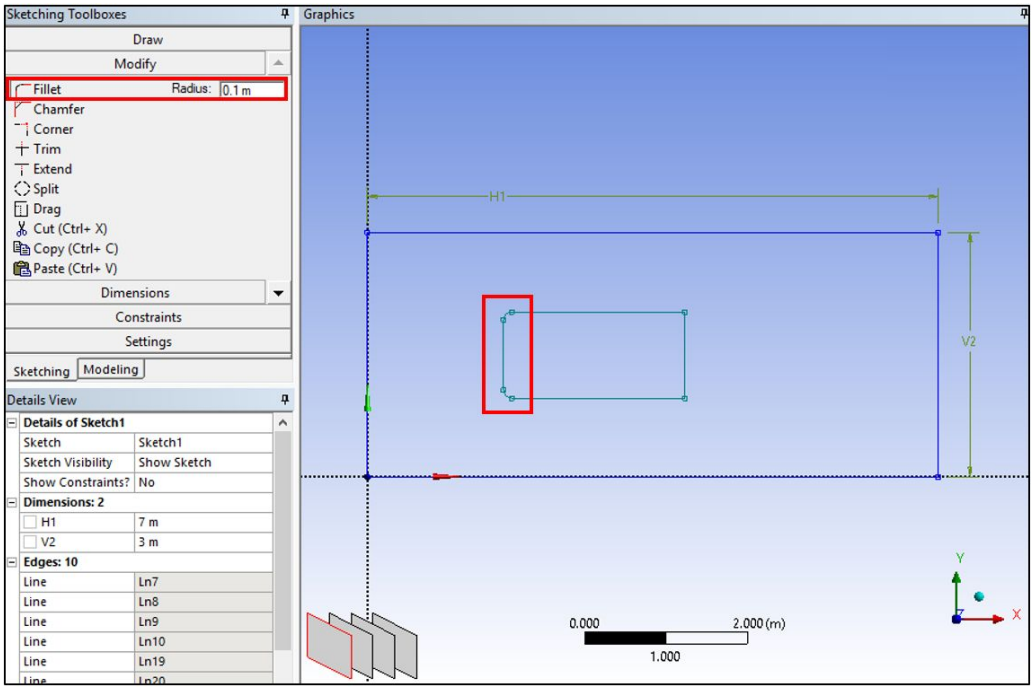


4.5. Use the **Rectangle** tool under **Draw** to make a rectangle starting from the origin and ending inside the first quadrant. Dimension it using **General** dimension as per below. (Click the z arrow of the 3D orientation located at the bottom right to make the view perpendicular to xy-plane. Make sure to click the origin when the mouse cursor is changed to “P”)

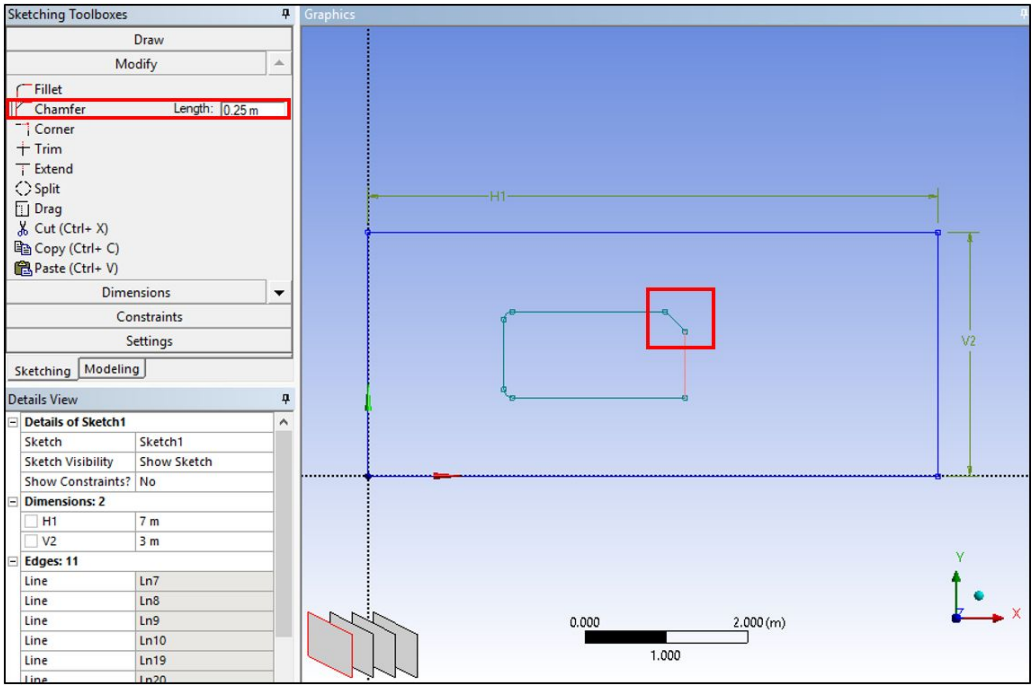
4.6. Use the **Rectangle** tool again to draw an another rectangle as per below.



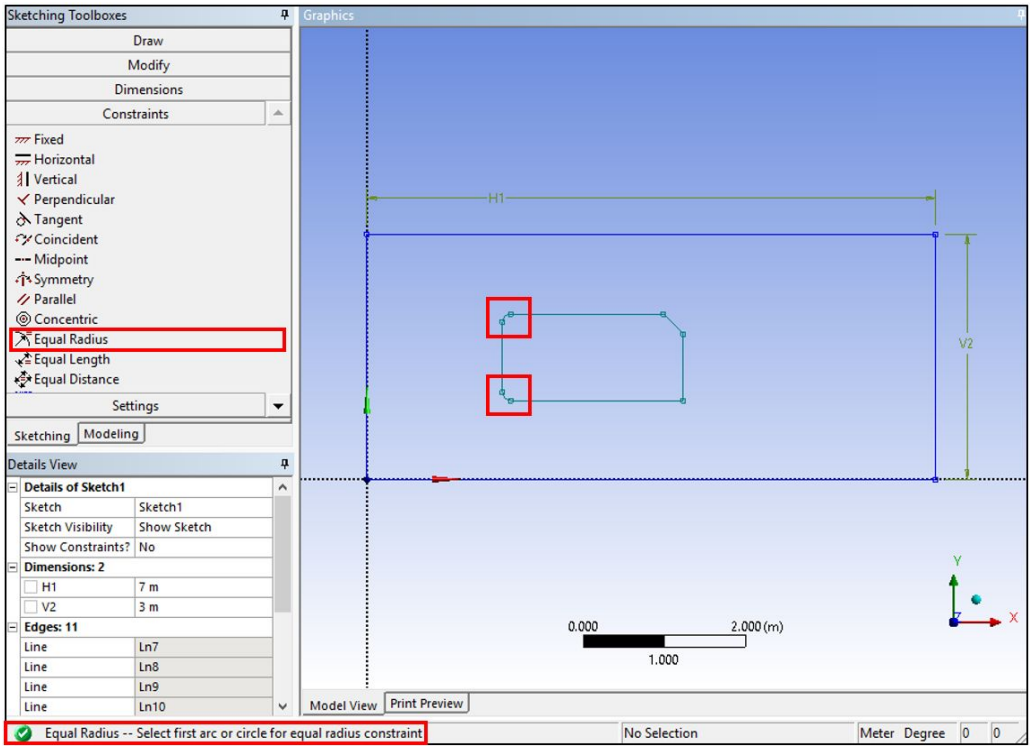
4.7. Use the **Fillet** tool in **Modify** to put a radius on the front corners of the Ahmed Car as per below. Use the **Radius** size of 0.1m. After changing the value, click the front corners.



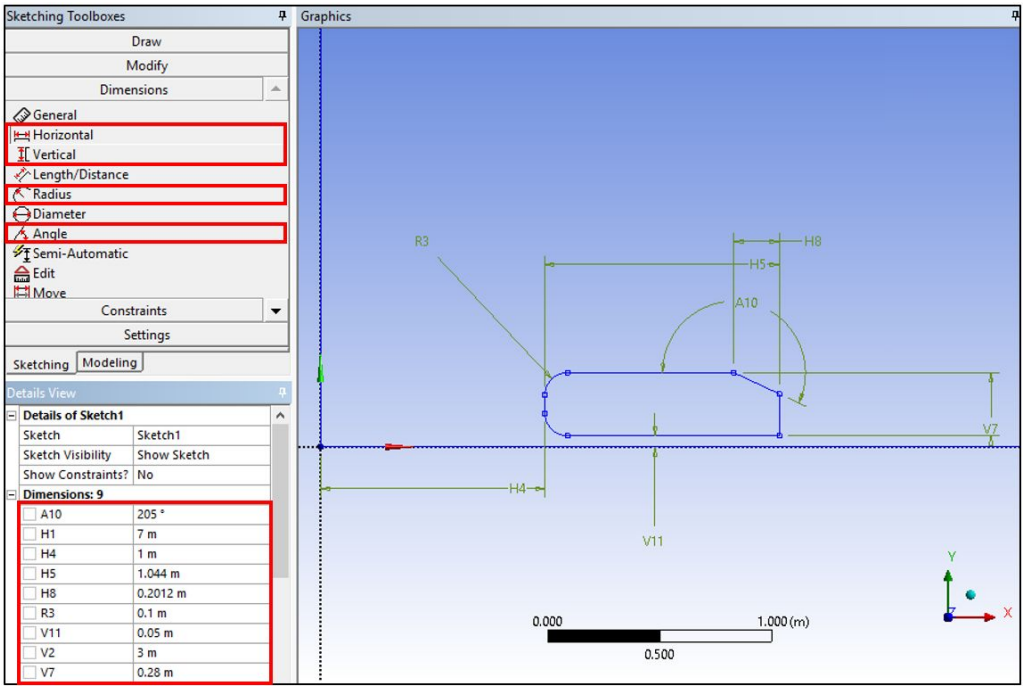
4.8. Use the **Chamfer** tool to put a chamfer on the back of the Ahmed Car as per below. Use the **Length** of 0.25m. (Shape of the body could be different depending on the rectangle you made)



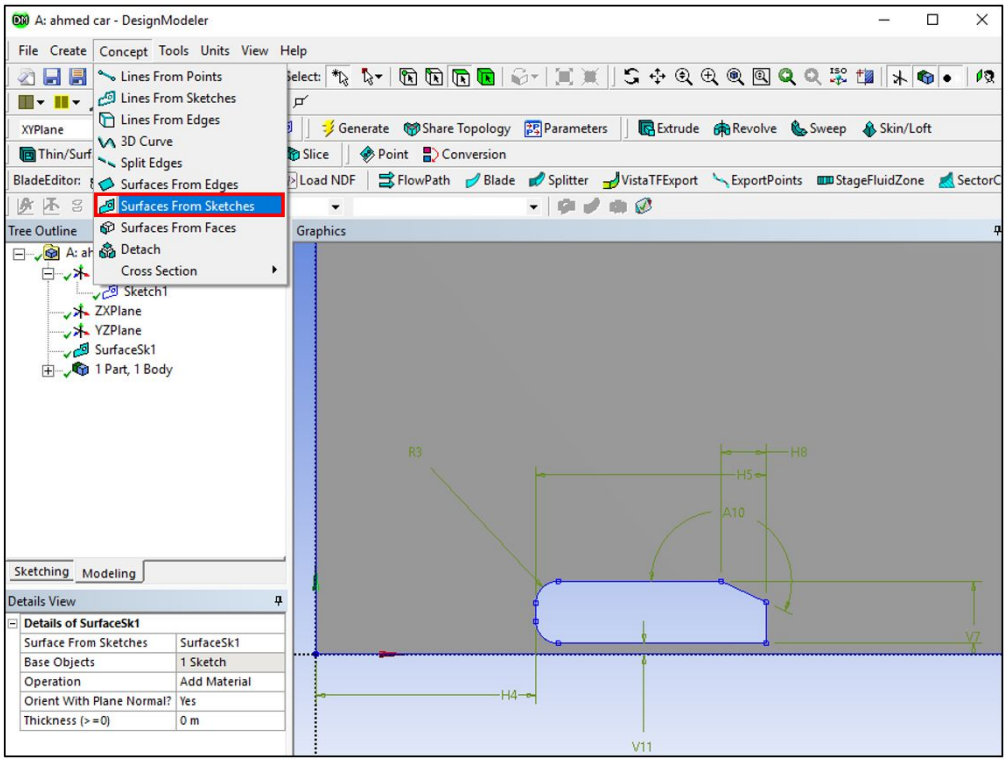
4.9. Put a constraint on the two radii using the **Equal Radius** tool in **Constraints**. (Note: in the bottom left corner next to the checkmark in a green circle is the note on how to use a tool)



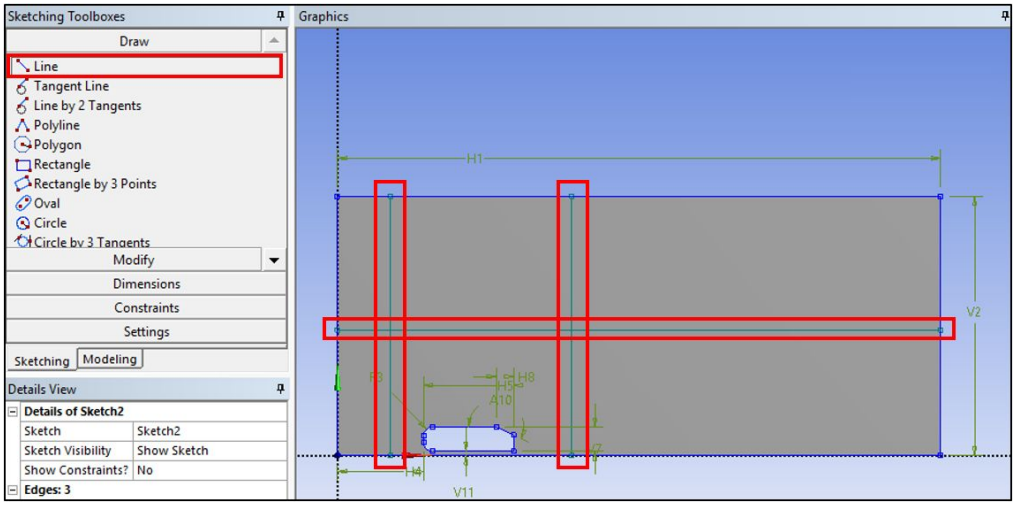
4.10. Dimension the body inside the rectangle as per below using **Horizontal**, **Vertical**, **Radius**, and **Angle** under **Dimensions**. (The name of each dimension will be followed by the order you make it, so it may be different from the manual)



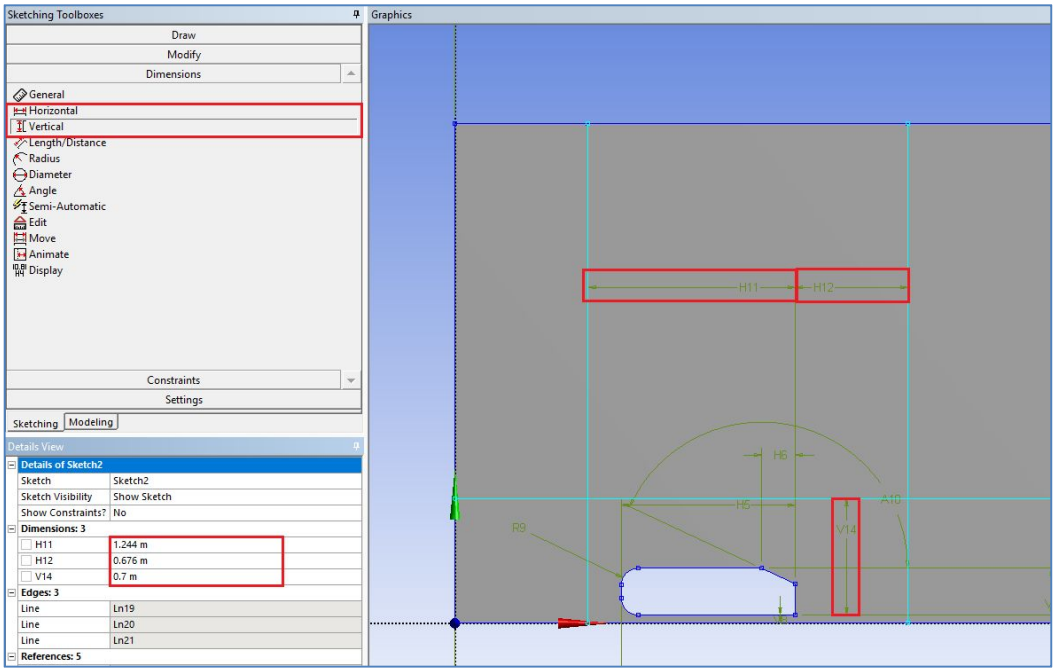
4.11. **Concept** > **Surface From Sketches**. Select the sketch you just created under the tree outline and click **Apply**. Click **Generate**.



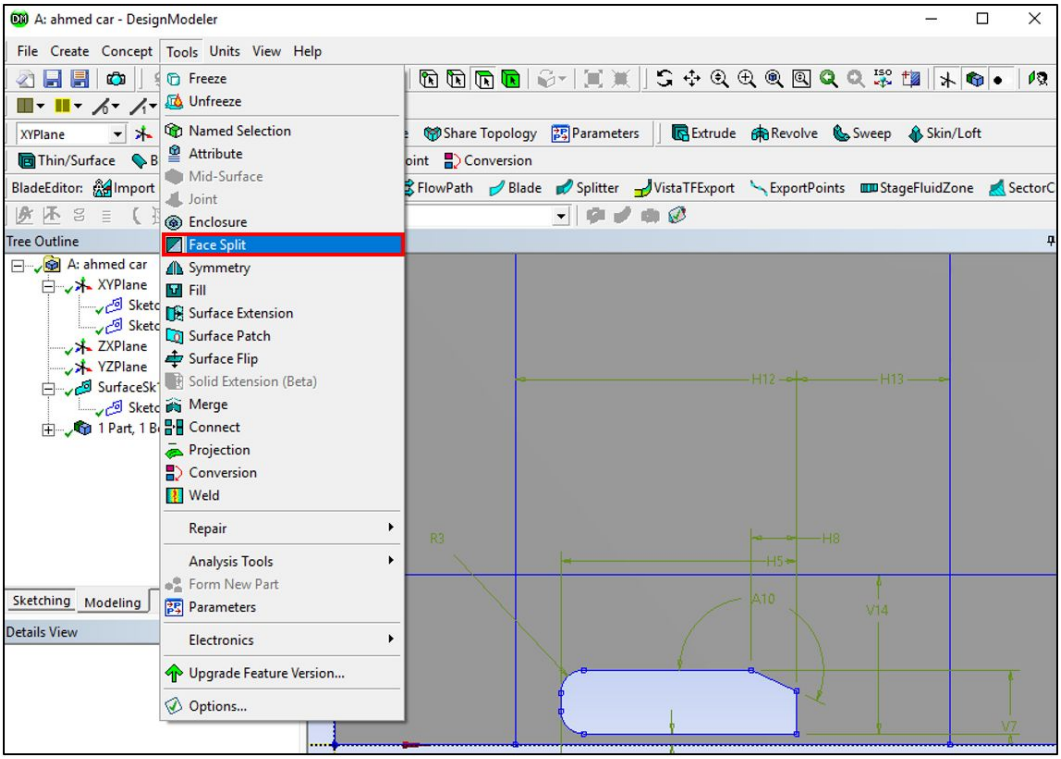
4.12. Select **XYPlane** and click the **New Sketch** button. In this new sketch, use the **Line** tool under **Draw** to make the lines as per below. Three lines will extend over the entire domain, horizontally or vertically. Make sure that the **C** appears when you are on the line and the **V/H** appears next to the line being created, ensuring that you are pointing on the edge and the line is vertical/horizontal.



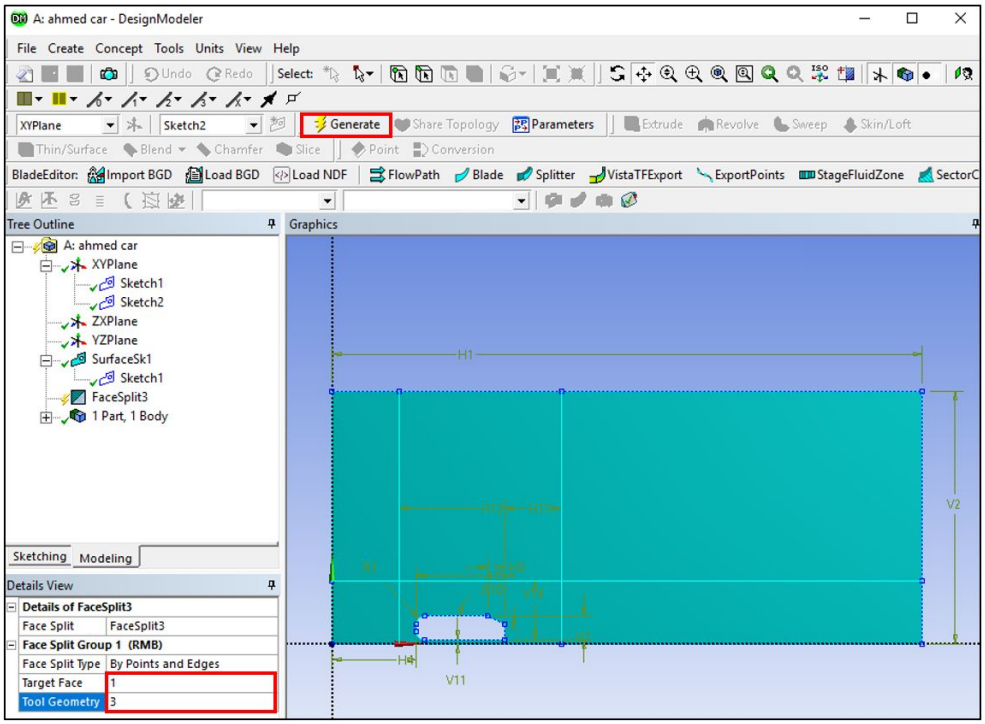
4.13. Use the **Horizontal** and **Vertical** dimension tool to dimension the lines as per below.



4.14. Go back to **Modeling** tab and then **Tools** > **Face Split**.

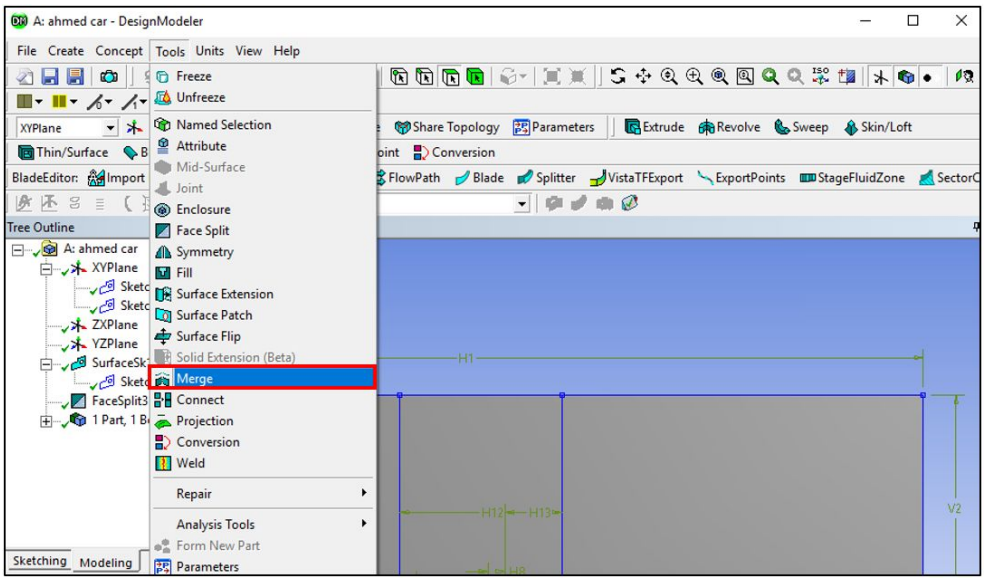


4.15. Select the gray surface for **Target Face** and click **Apply.** For **Tool Geometry** select two endpoints of the one line you just created while holding **Ctrl** then click **Apply**. Select **Tool Geometry** again and select two more endpoints of another line and click **Apply**. Repeat this process for the last line and click **Apply**. Click **Generate**. This splits the surface into six pieces.

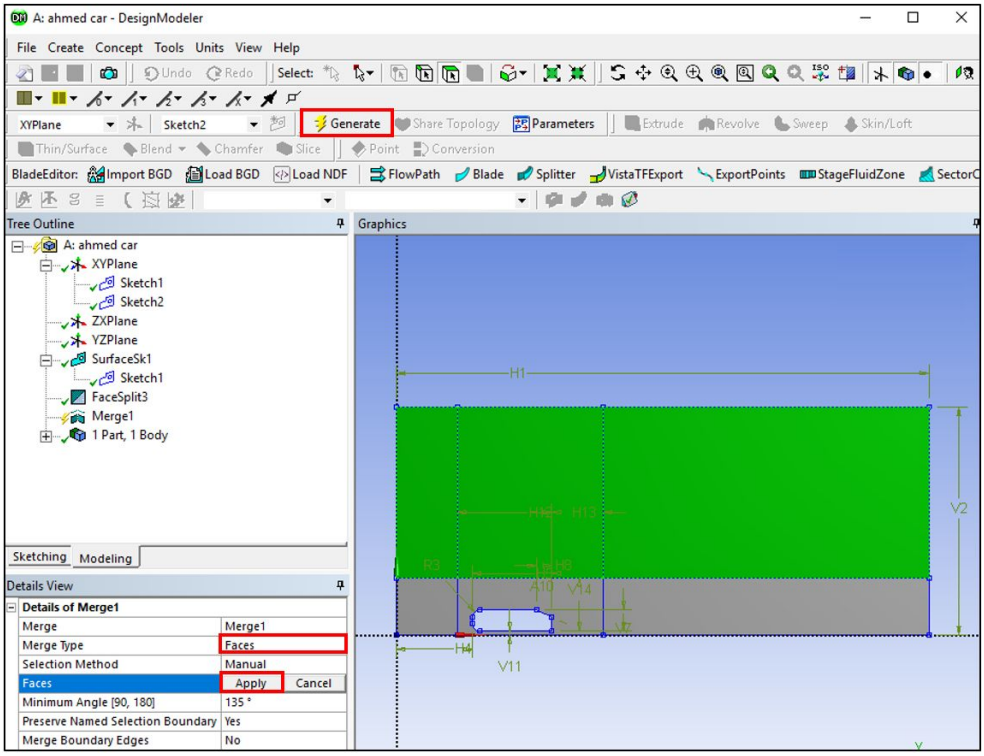


(The picture above was taken right before clicking 'Generate')

4.16. **Tools** > **Merge**.



4.17. Change the **Merge Type** to **Faces** and select the top three faces. Click **Apply** then **Generate**.

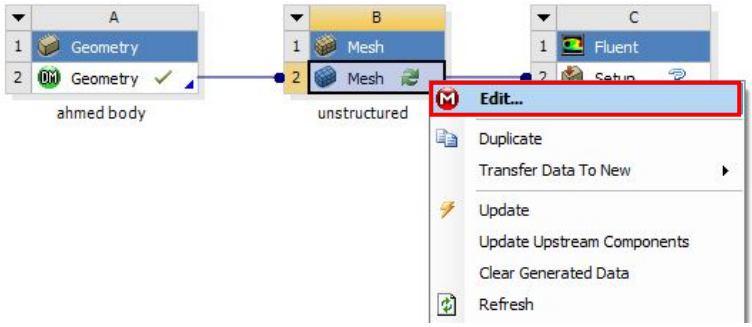


(The picture above was taken right before clicking 'Apply')

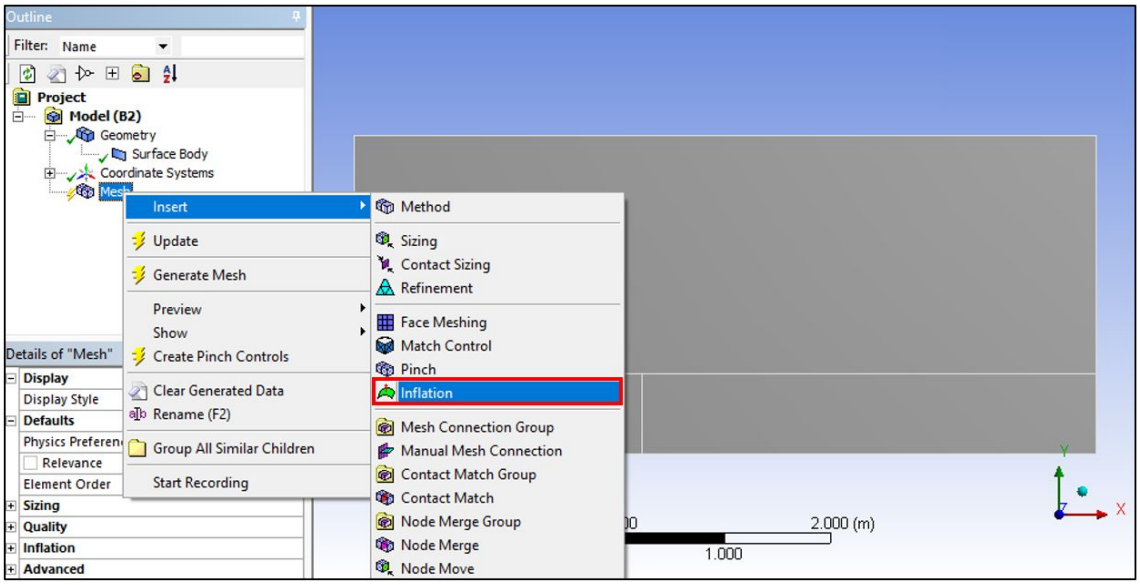
4.18. **File** > **Save Project**. Close the **Design Modeler** window.

5. Mesh

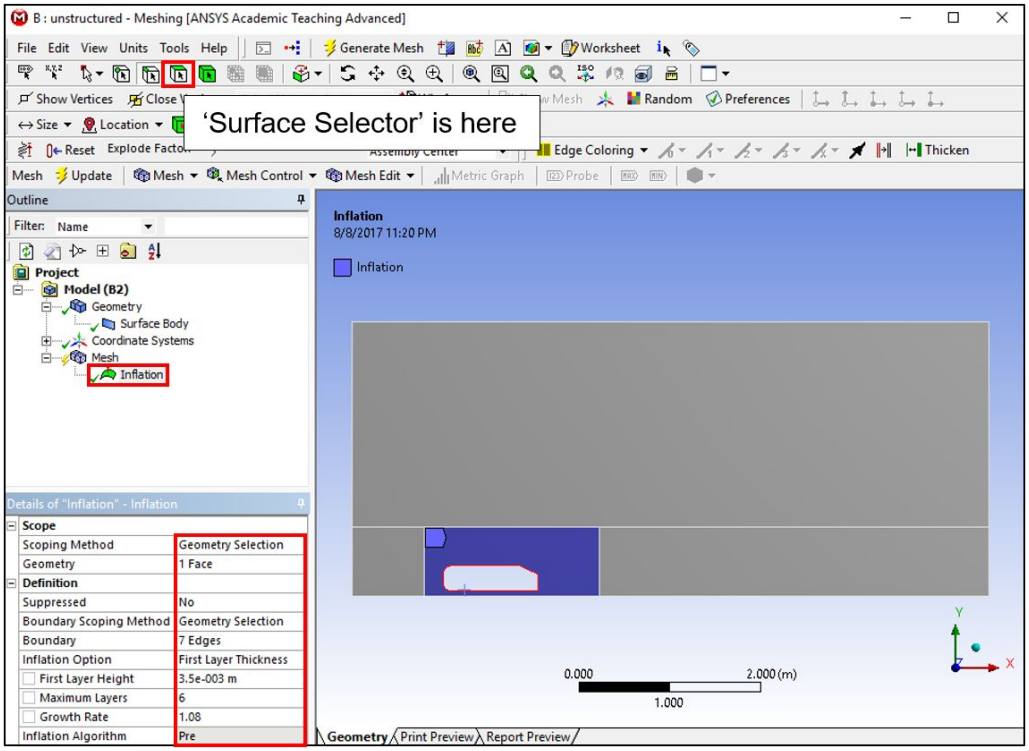
5.1. Right click **Mesh** and from the dropdown menu then select **Edit…**



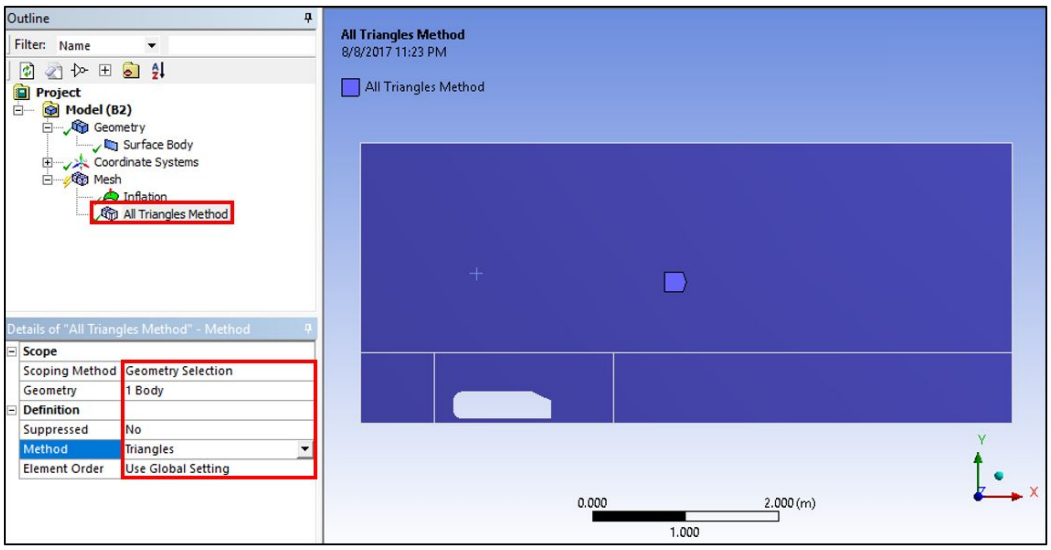
5.2. Right click on **Mesh** > **Insert** > **Inflation.**



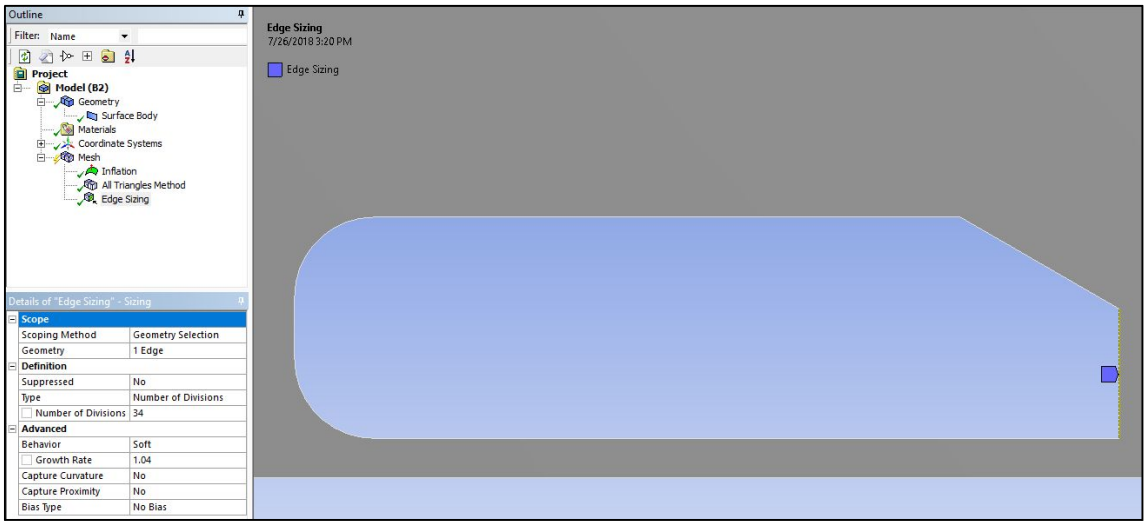
5.3. For **Geometry** option, select the surface of the domain which borders the Ahmed Car and click **Apply** (Change the cursor to 'Surface Selector' at upper region to select the surface). For the **Boundary**, select the edges of the Ahmed Car by holding **Ctrl** and selecting the edges and then click **Apply**. There should be seven edges selected for the **Boundary**. Change the parameters in **Details of "Inflation" – Inflation** as per below.

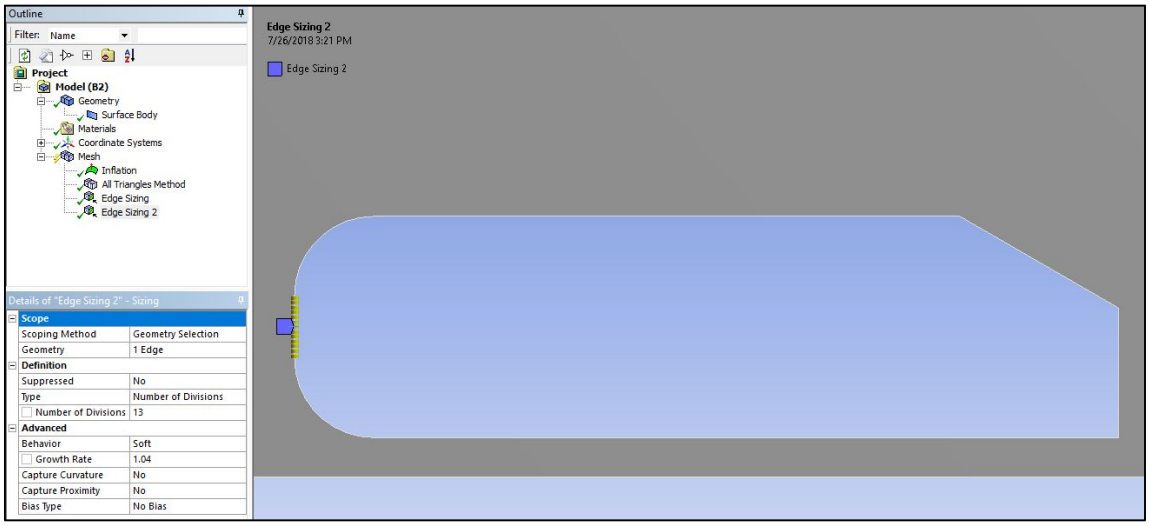


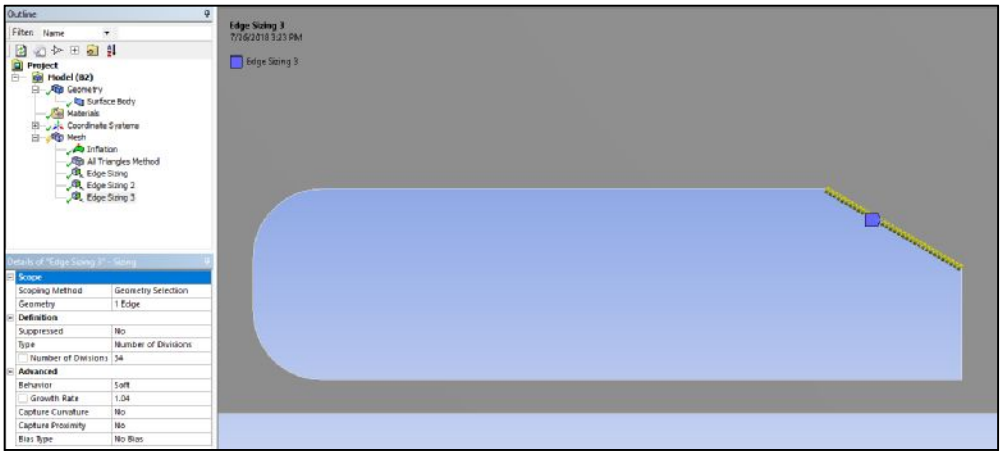
5.4. Right click **Mesh** > **Insert** > **Method**. Select the whole domain (surfaces) for Geometry and click **Apply**. Change the **Method** to **Triangles**.



5.5. Right click **Mesh** > **Insert** > **Sizing**. Select the line as per below and click **Apply**. Change the parameters of sizing as per below. Repeat this for the following figures below. There should be **22 edge sizings** in total. Change the cursor to “Edge Selector” to select the edges.



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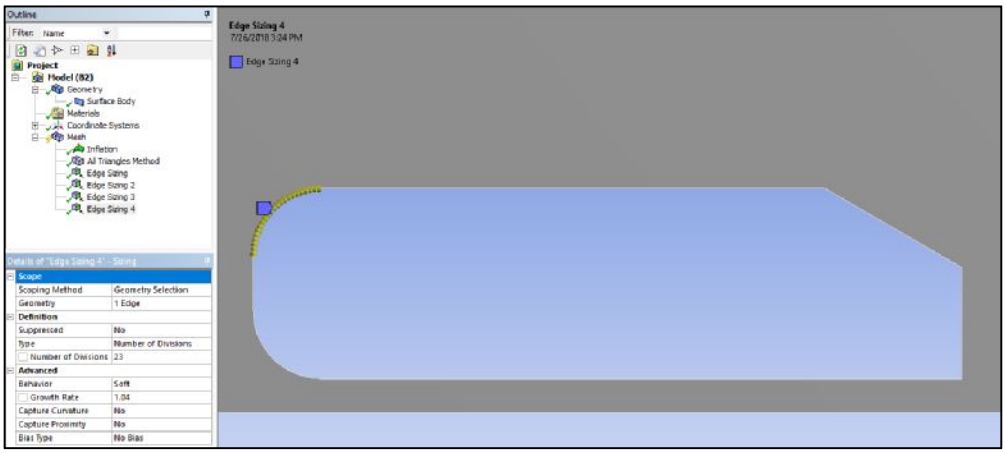
Geometry
Surface Body
Materials
Coordinate Systems
Mesh
Inflation
All Triangles Method
Edge Sizing
Edge Sizing 2
Edge Sizing 3
Edge Sizing 3
7/26/2018 3:23 PM
Edge Sizing 3
Details of "Edge Sizing 3" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
Number of Divisions | 54
Advanced
Behavior | Soft
Growth Rate | 1.04
Capture Curvature | No
Capture Proximity | No
Bias Type | No Bias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Surface Body
Materials
Coordinate Systems
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Inflation
All Triangles Method
Edge Sizing
Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Edge Sizing 4
7/26/2018 3:24 PM
Edge Sizing 4
Details of "Edge Sizing 4" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
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Advanced
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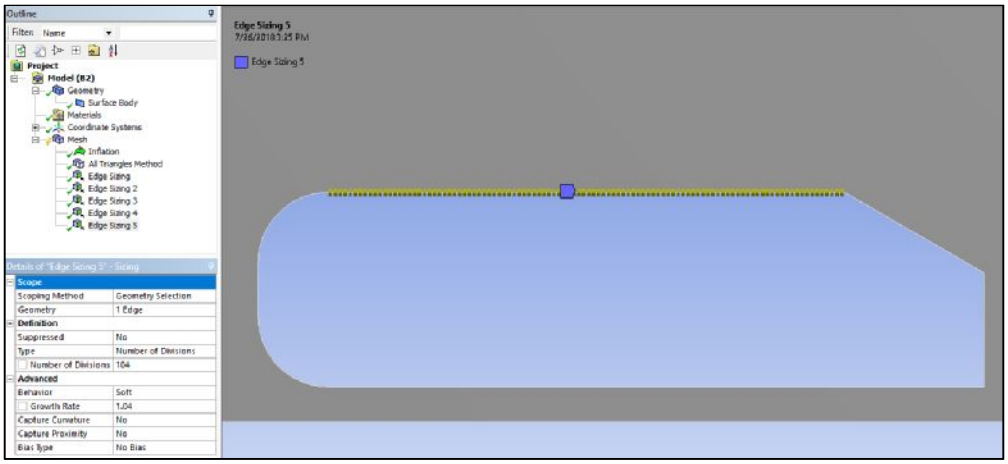
Bias Type | No Bias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Surface Body
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Coordinate Systems
Mesh
Inflation
All Triangles Method
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Edge Sizing 5
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Edge Sizing 5
Details of "Edge Sizing 5" - Sizing
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Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
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Behavior | Soft
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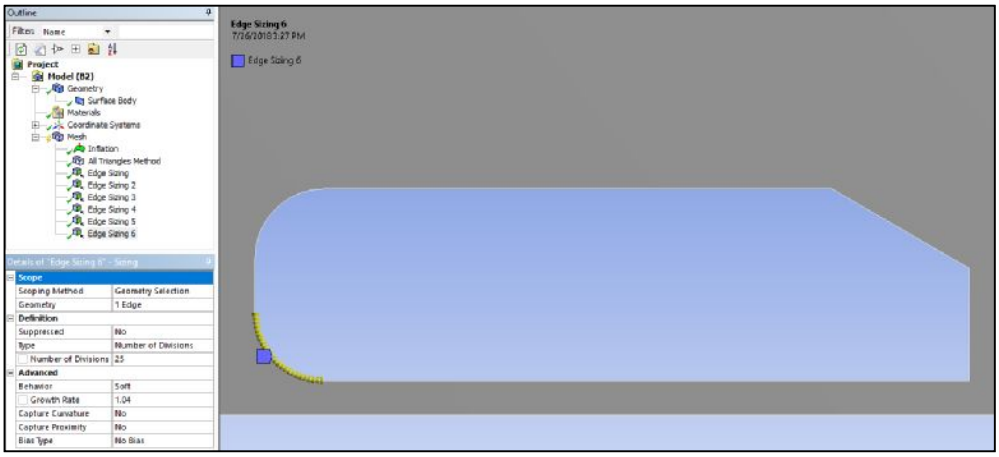
Capture Proximity | No
Bias Type | No Bias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Surface Body
Materials
Coordinate Systems
Mesh
Inflation
All Triangles Method
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Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Details of "Edge Sizing 6" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
Number of Divisions | 25
Advanced
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Capture Proximity | No
Bias Type | No Bias
Edge Sizing 6
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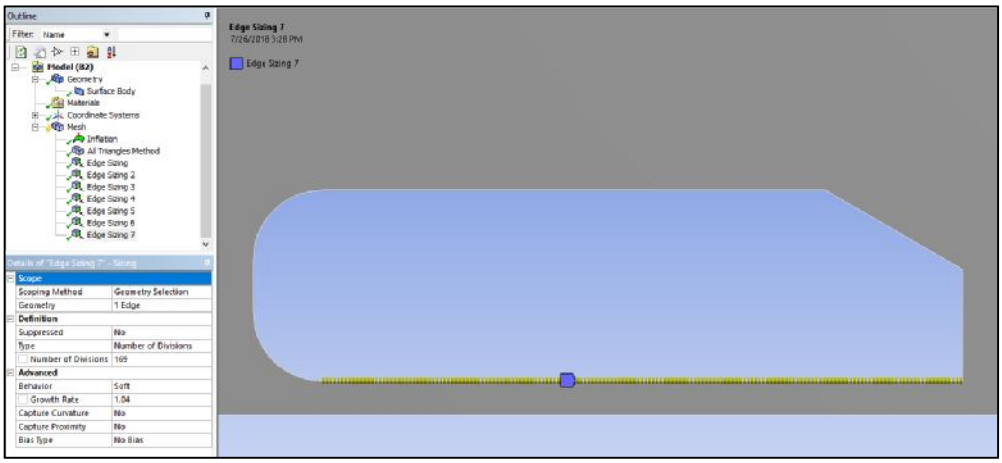
Edge Sizing 6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Materials
Coordinate Systems
Mesh
Inflation
All Triangles Method
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Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Edge Sizing 7
Details of "Edge Sizing 7" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
Number of Divisions | 169
Advanced
Behavior | Soft
Growth Rate | 1.04
Capture Curvature | No
Capture Proximity | No
Bias Type | No Bias
Edge Sizing 7
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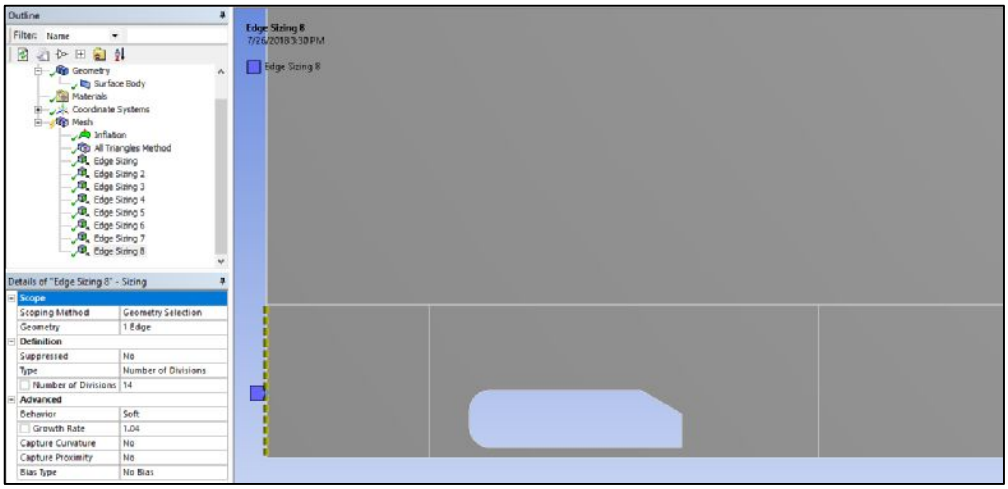
Edge Sizing 7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Materials
Coordinate Systems
Mesh
Inflation
All Triangles Method
Edge Sizing
Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Details of "Edge Sizing 8" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
Number of Divisions | 14
Advanced
Behavior | Soft
Growth Rate | 1.04
Capture Curvature | No
Capture Proximity | No
Bias Type | No Bias
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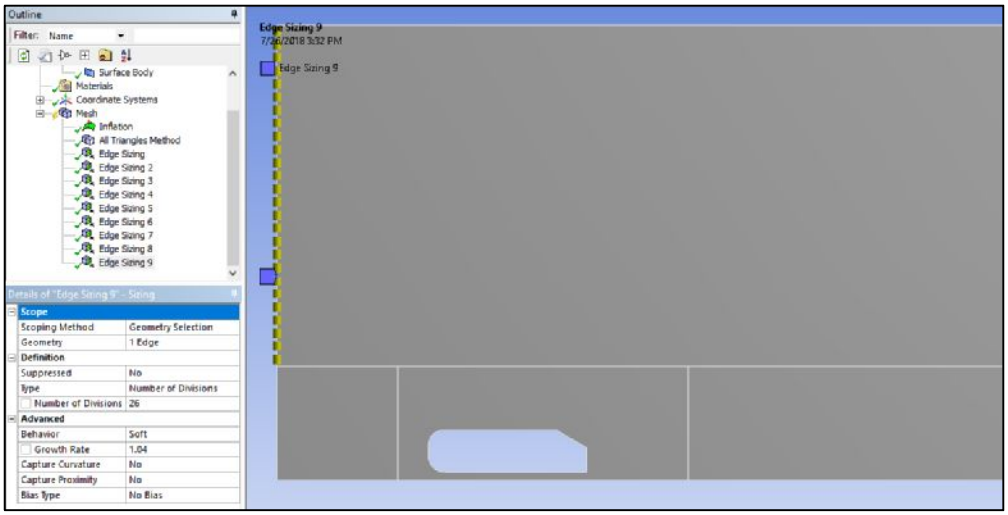
Edge Sizing 8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All Triangles Method
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Edge Sizing 3
Edge Sizing 4
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Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Details of "Edge Sizing 9" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
Number of Divisions | 26
Advanced
Behavior | Soft
Growth Rate | 1.04
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Capture Proximity | No
Bias Type | No Bias
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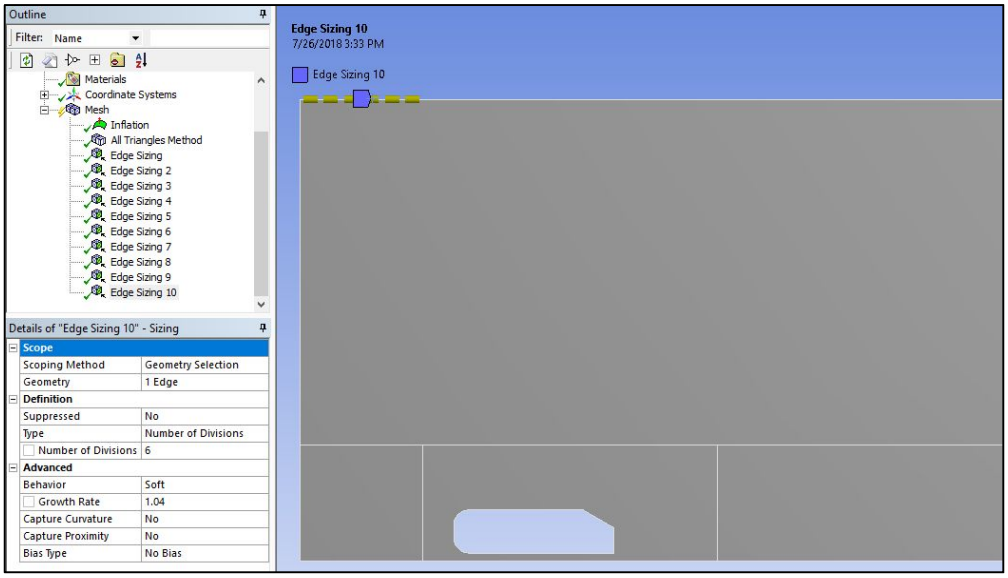
Edge Sizing 9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Mesh
Inflation
All Triangles Method
Edge Sizing
Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
Details of "Edge Sizing 10" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
Number of Divisions | 6
Advanced
Behavior | Soft
Growth Rate | 1.04
Capture Curvature | No
Capture Proximity | No
Bias Type | No Bias
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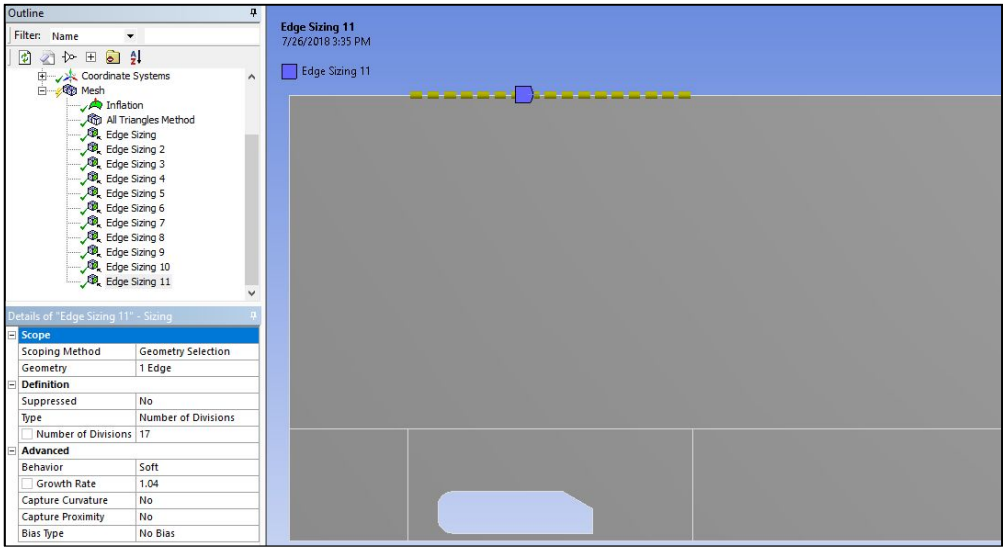
Edge Sizing 10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Coordinate Systems
Mesh
Inflation
All Triangles Method
Edge Sizing
Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
Edge Sizing 11
Details of "Edge Sizing 11" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
Number of Divisions | 17
Advanced
Behavior | Soft
Growth Rate | 1.04
Capture Curvature | No
Capture Proximity | No
Bias Type | No Bias
Edge Sizing 11
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Edge Sizing 11


Outline
Filter: Name
Mesh
Inflation
All Triangles Method
Edge Sizing
Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
Edge Sizing 11
Edge Sizing 12
Details of "Edge Sizing 12" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
Number of Divisions | 26
Advanced
Behavior | Soft
Growth Rate | 1.04
Capture Curvature | No
Capture Proximity | No
Bias Type | No Bias
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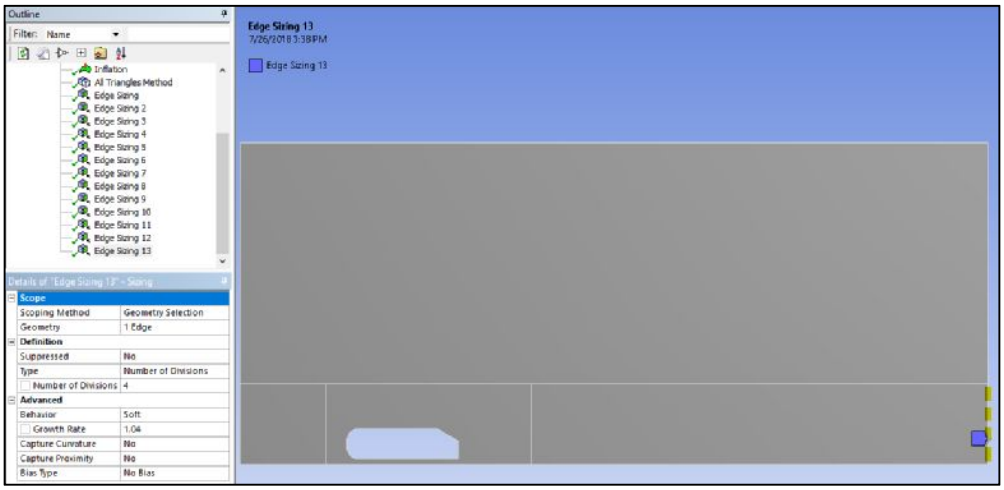
Edge Sizing 12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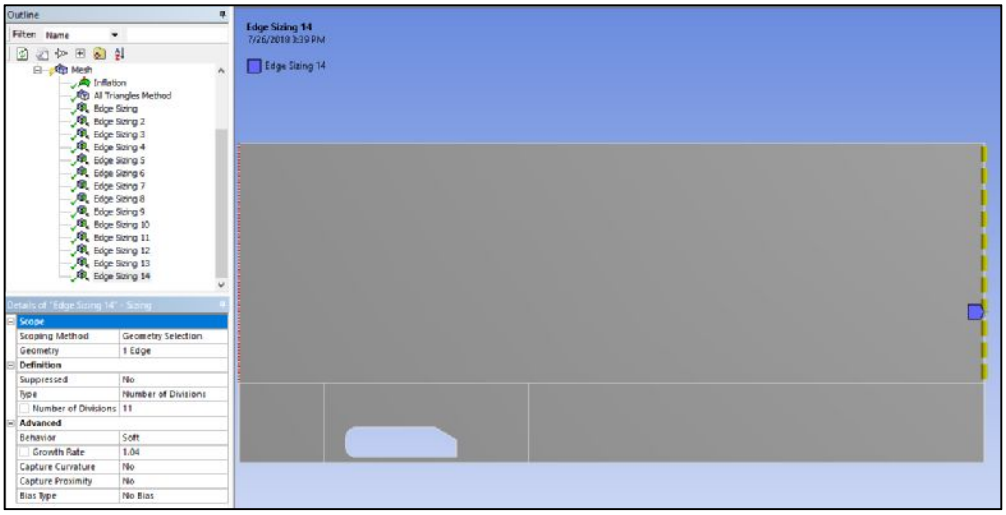
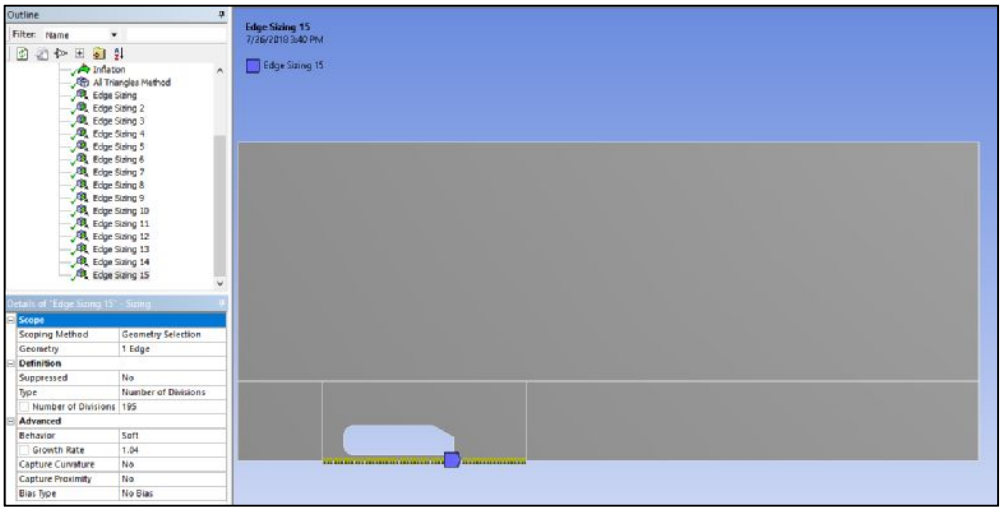
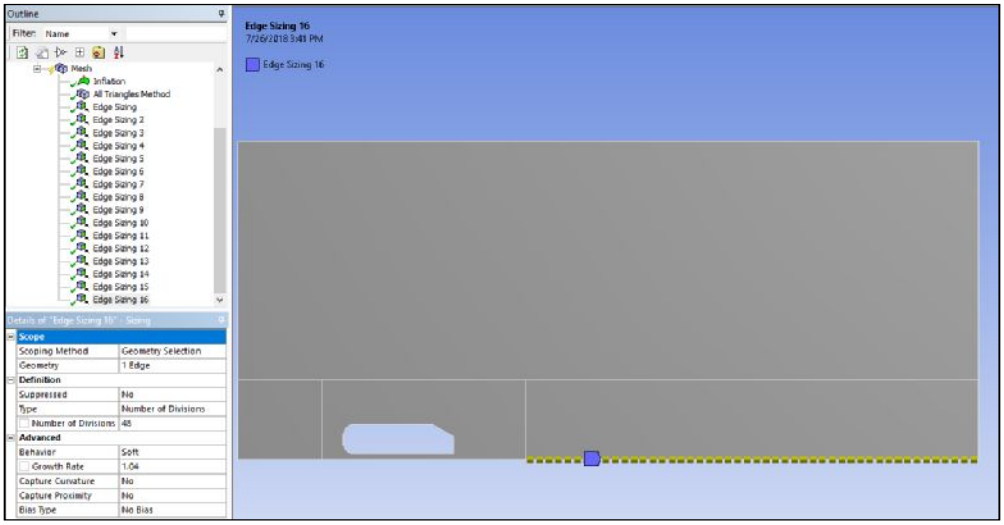
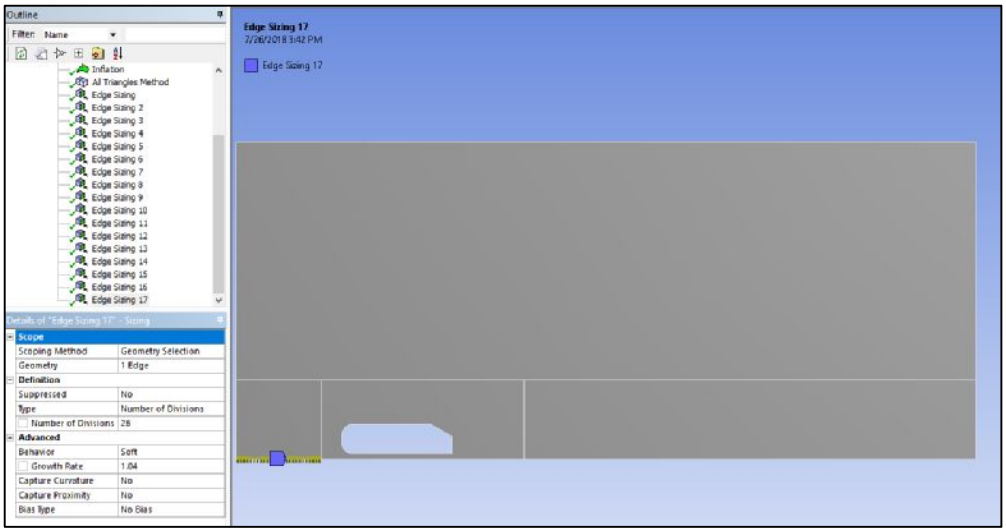
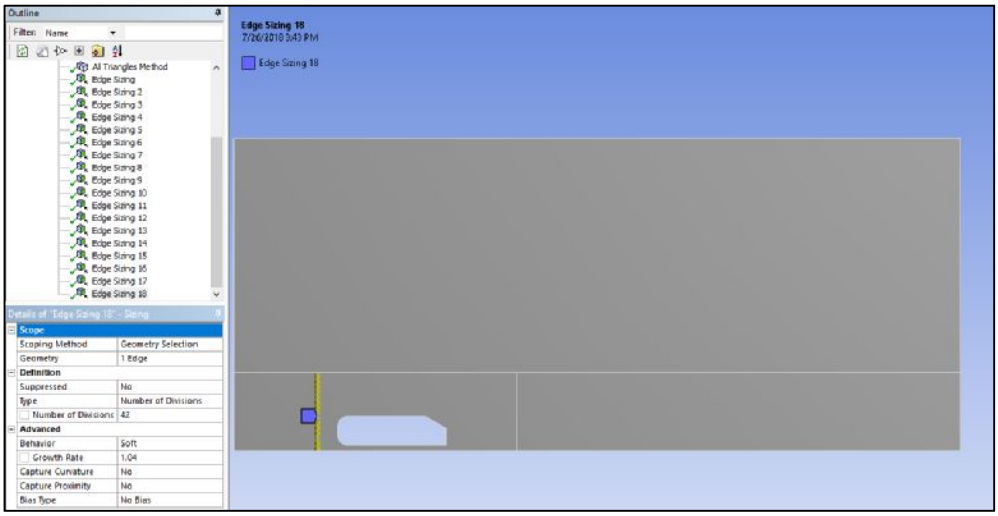
Inflation
All Triangles Method
Edge Sizing
Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
Edge Sizing 11
Edge Sizing 12
Edge Sizing 13
Details of "Edge Sizing 13" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
Number of Divisions | 4
Advanced
Behavior | Soft
Growth Rate | 1.04
Capture Curvature | No
Capture Proximity | No
Bias Type | No Bias
Edge Sizing 13
7/26/2018 3:38 PM
Edge Sizing 13

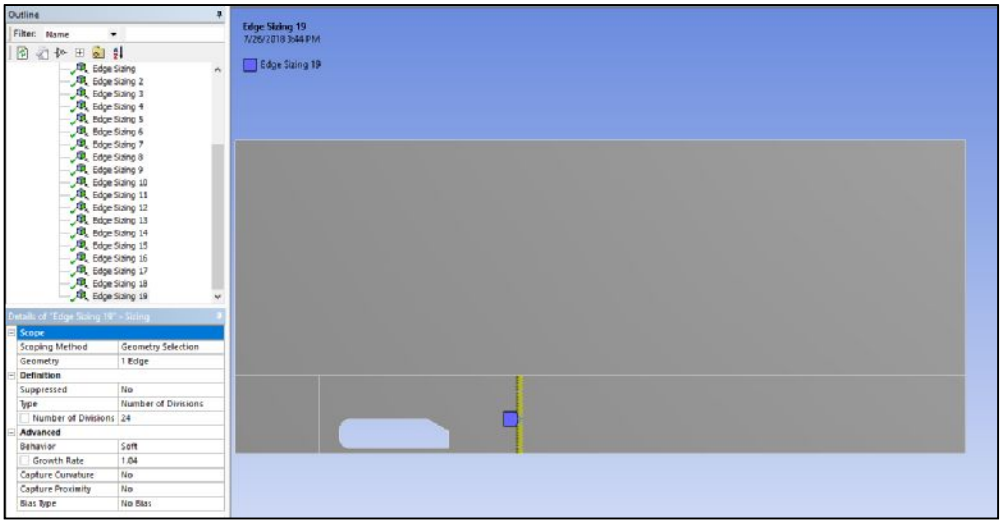

Outline
Filter: Name
Mesh
Inflation
All Triangles Method
Edge Sizing
Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
Edge Sizing 11
Edge Sizing 12
Edge Sizing 13
Edge Sizing 14
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
Number of Divisions | 11
Advanced
Behavior | Soft
Growth Rate | 1.04
Capture Curvature | No
Capture Proximity | No
Bias Type | No Bias
Edge Sizing 14
7/26/2018 3:39 PM
Edge Sizing 14

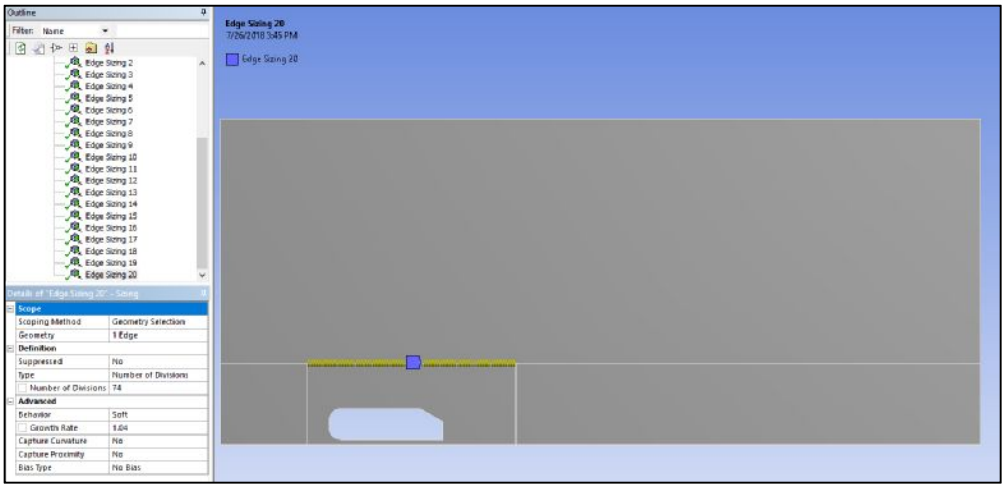

Outline
Filter: Name
Inflation
All Triangles Method
Edge Sizing
Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
Edge Sizing 11
Edge Sizing 12
Edge Sizing 13
Edge Sizing 14
Edge Sizing 15
Details of "Edge Sizing 15" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
Number of Divisions | 195
Advanced
Behavior | Soft
Growth Rate | 1.04
Capture Curvature | No
Capture Proximity | No
Bias Type | No Bias
Edge Sizing 15
7/26/2018 3:40 PM
Edge Sizing 15

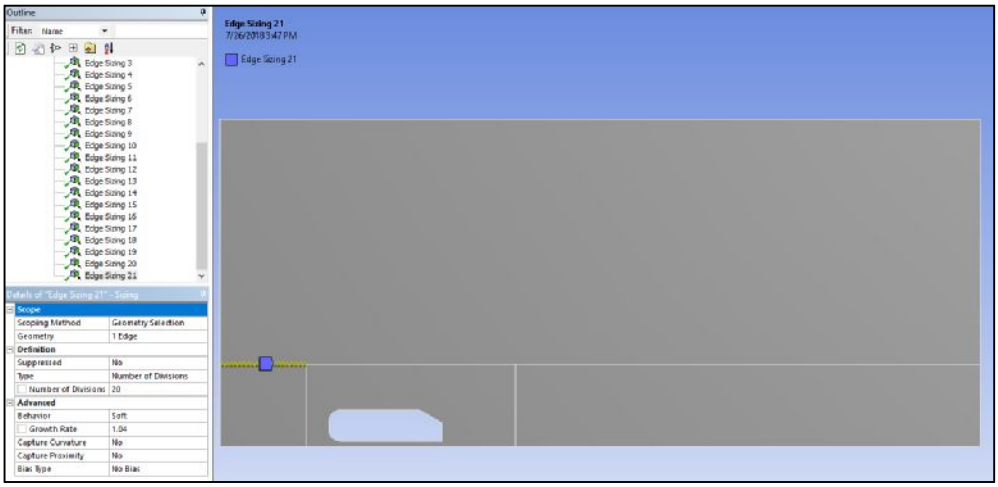

Outline
Filter: Name
Mesh
Inflation
All Triangles Method
Edge Sizing
Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
Edge Sizing 11
Edge Sizing 12
Edge Sizing 13
Edge Sizing 14
Edge Sizing 15
Edge Sizing 16
Details of "Edge Sizing 16" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
Number of Divisions | 48
Advanced
Behavior | Soft
Growth Rate | 1.04
Capture Curvature | No
Capture Proximity | No
Bias Type | No Bias
Edge Sizing 16
7/26/2018 3:41 PM
Edge Sizing 16

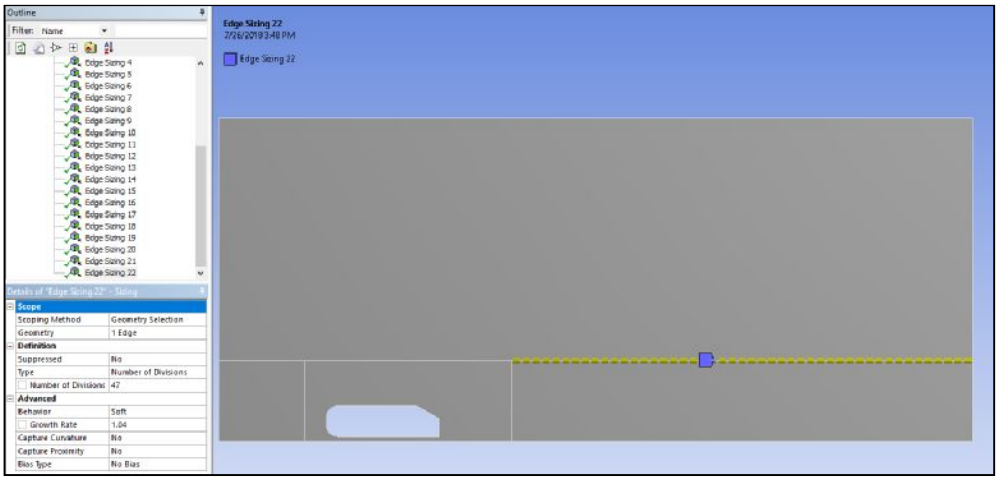

Outline
Filter: Name
Inflation
All Triangles Method
Edge Sizing
Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
Edge Sizing 11
Edge Sizing 12
Edge Sizing 13
Edge Sizing 14
Edge Sizing 15
Edge Sizing 16
Edge Sizing 17
Details of "Edge Sizing 17" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
Number of Divisions | 28
Advanced
Behavior | Soft
Growth Rate | 1.04
Capture Curvature | No
Capture Proximity | No
Bias Type | No Bias
Edge Sizing 17
7/26/2018 3:42 PM
Edge Sizing 17


Outline
Filter: Name
All Triangles Method
Edge Sizing
Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
Edge Sizing 11
Edge Sizing 12
Edge Sizing 13
Edge Sizing 14
Edge Sizing 15
Edge Sizing 16
Edge Sizing 17
Edge Sizing 18
Details of "Edge Sizing 18" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
Number of Divisions | 42
Advanced
Behavior | Soft
Growth Rate | 1.04
Capture Curvature | No
Capture Proximity | No
Bias Type | No Bias
Edge Sizing 18
7/26/2018 3:43 PM
Edge Sizing 18


Outline
Filter: Name
Edge Sizing
Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
Edge Sizing 11
Edge Sizing 12
Edge Sizing 13
Edge Sizing 14
Edge Sizing 15
Edge Sizing 16
Edge Sizing 17
Edge Sizing 18
Edge Sizing 19
Details of "Edge Sizing 19" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
Number of Divisions | 24
Advanced
Behavior | Soft
Growth Rate | 1.04
Capture Curvature | No
Capture Proximity | No
Bias Type | No Bias
Edge Sizing 19
7/26/2018 3:44 PM
Edge Sizing 19

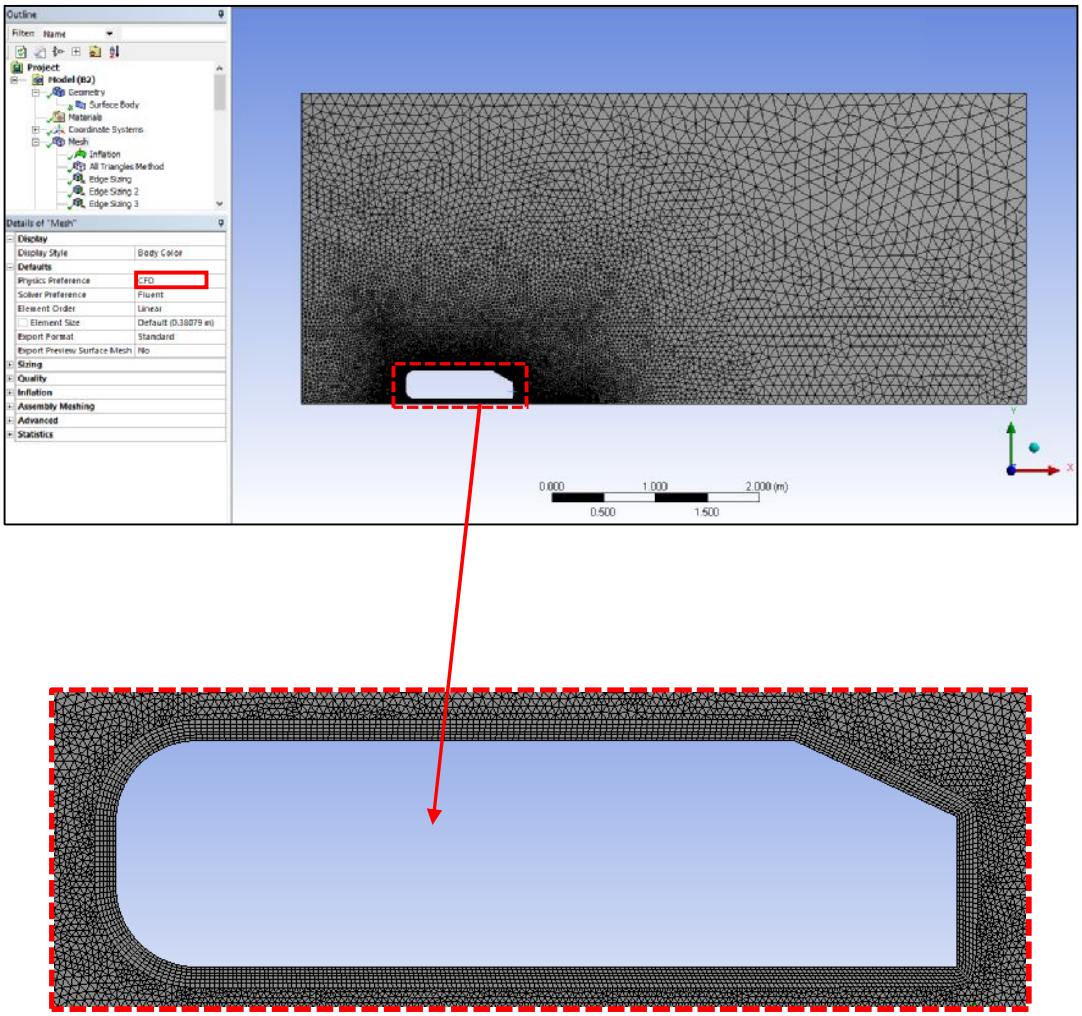

Outline
Filter: Name
Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
Edge Sizing 11
Edge Sizing 12
Edge Sizing 13
Edge Sizing 14
Edge Sizing 15
Edge Sizing 16
Edge Sizing 17
Edge Sizing 18
Edge Sizing 19
Edge Sizing 20
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
Number of Divisions | 74
Advanced
Behavior | Soft
Growth Rate | 1.04
Capture Curvature | No
Capture Proximity | No
Bias Type | No Bias
Edge Sizing 20
7/26/2018 3:45 PM
Edge Sizing 20


Outline
Filter: Name
Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
Edge Sizing 11
Edge Sizing 12
Edge Sizing 13
Edge Sizing 14
Edge Sizing 15
Edge Sizing 16
Edge Sizing 17
Edge Sizing 18
Edge Sizing 19
Edge Sizing 20
Edge Sizing 21
Details of "Edge Sizing 21" - Sizing
Scope
Scoping Method Geometry Selection
Geometry 1 Edge
Definition
Suppressed No
Type Number of Divisions
Number of Divisions 20
Advanced
Behavior Soft
Growth Rate 1.04
Capture Curvature No
Capture Proximity No
Bias Type No Bias
Edge Sizing 21
7/26/2018 3:47 PM
Edge Sizing 21

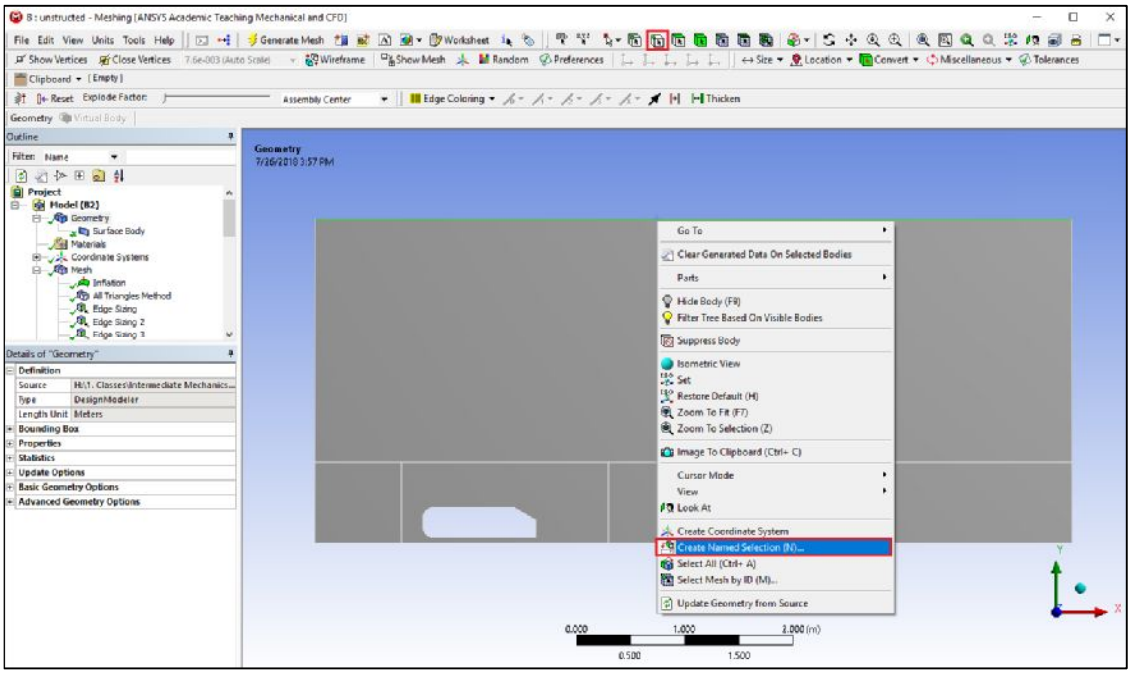

Outline
Filter: Name
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
Edge Sizing 11
Edge Sizing 12
Edge Sizing 13
Edge Sizing 14
Edge Sizing 15
Edge Sizing 16
Edge Sizing 17
Edge Sizing 18
Edge Sizing 19
Edge Sizing 20
Edge Sizing 21
Edge Sizing 22
Details of "Edge Sizing 22" - Sizing
Scope
Scoping Method Geometry Selection
Geometry 1 Edge
Definition
Suppressed No
Type Number of Divisions
Number of Divisions 47
Advanced
Behavior Soft
Growth Rate 1.04
Capture Curvature No
Capture Proximity No
Bias Type No Bias
Edge Sizing 22
7/26/2018 3:48 PM
Edge Sizing 22

5.6. Click on **Mesh** under the **Outline** and change the **Physics Preference** to **CFD**.

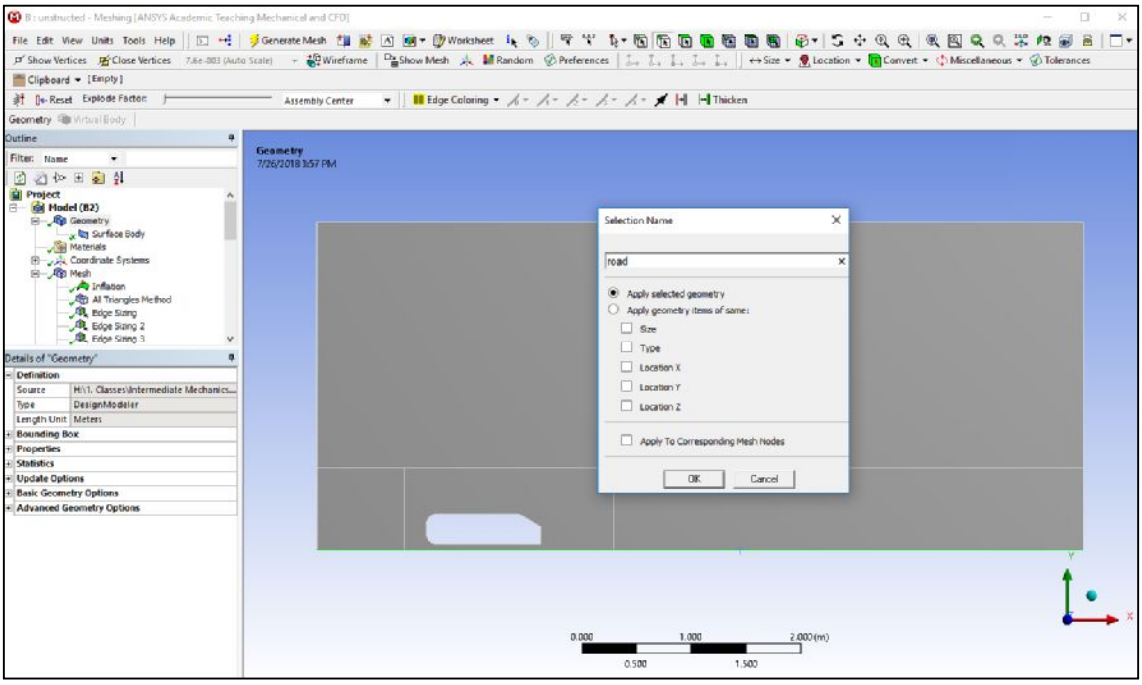
5.7. Click **Generate Mesh**.



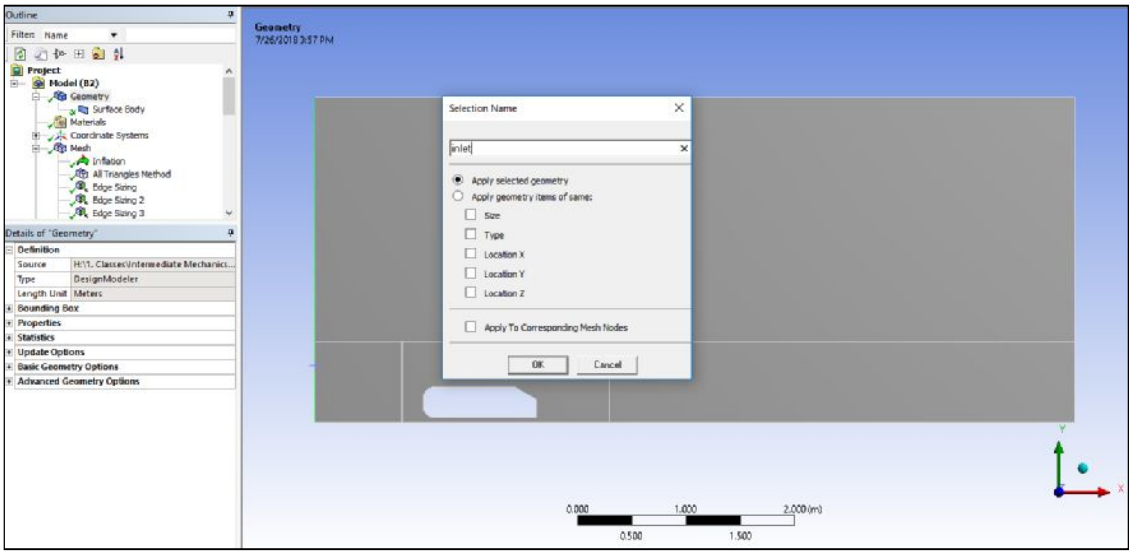
5.8. Select ‘Edge Selector’. Select the top edges of the domain by holding **Ctrl** while selecting, right click, select **Create Named Selection** from the dropdown menu. Name the top edge *‘symmetry’*.



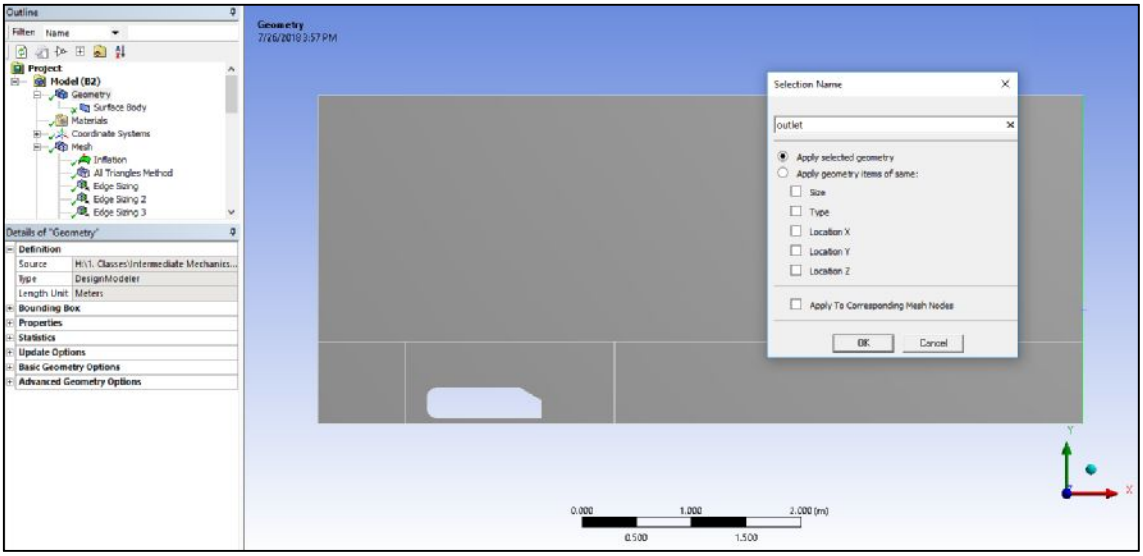
5.9. Repeat step 5.8 for the bottom edges and name them *‘road’*.



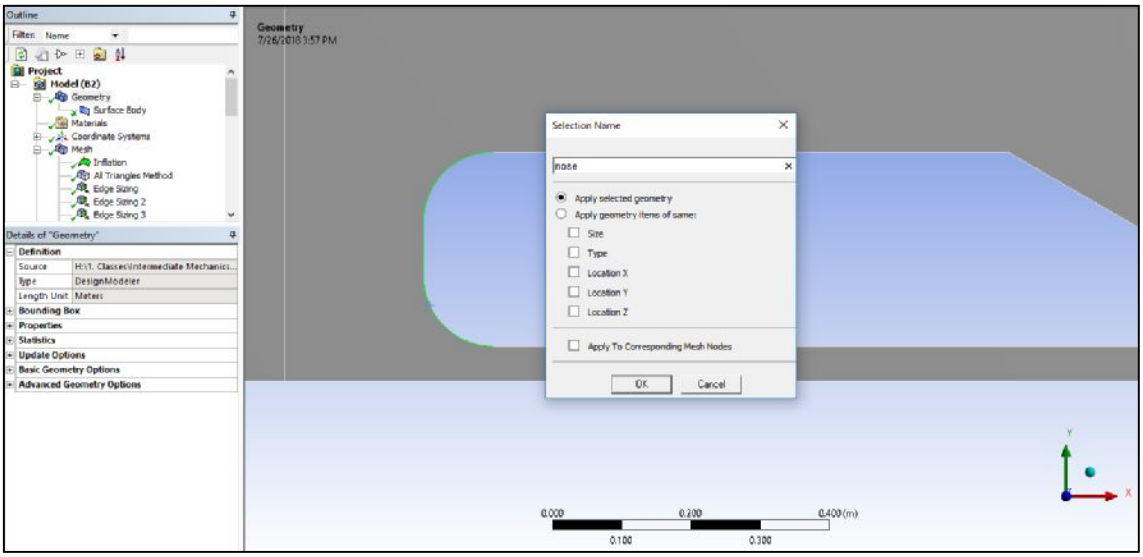
5.10. Repeat step 5.8 for the left edges and name them *'inlet'*.



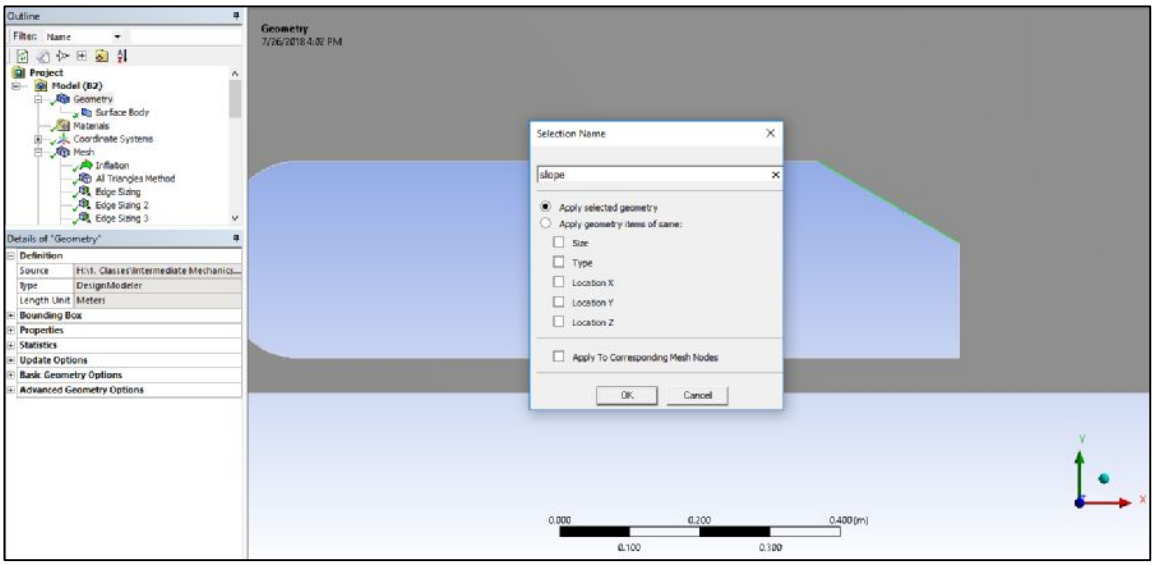
5.11. Repeat step 5.8 for the right edges and name them *'outlet'*.



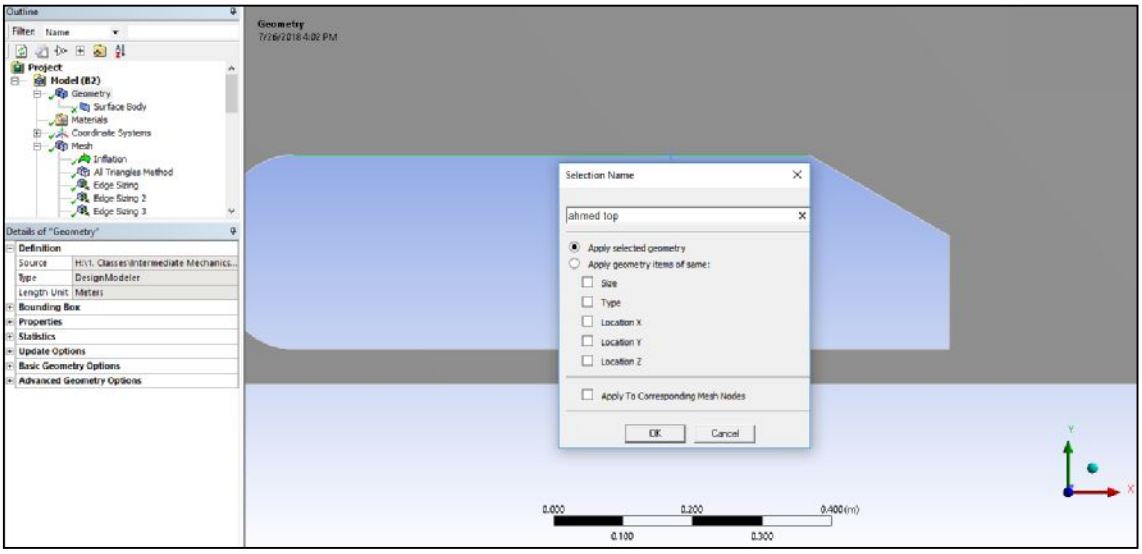
5.12. Repeat step 5.8 for the filleted corners and the straight segment that connects them and name them *'nose'*.



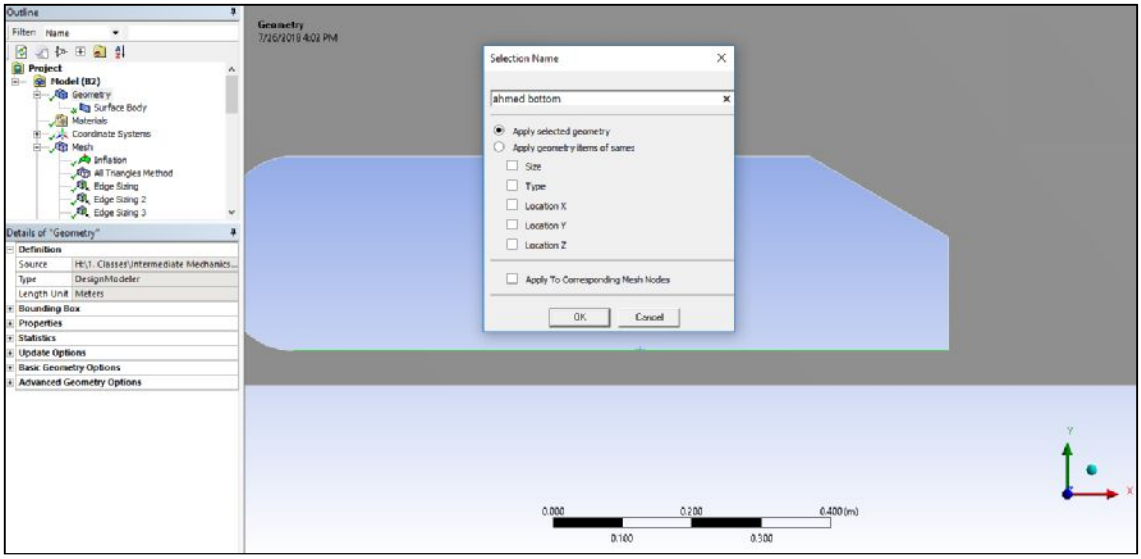
5.13. Repeat step 5.8 for the sloped edge of the Ahmed Car and name it *'slope'*.



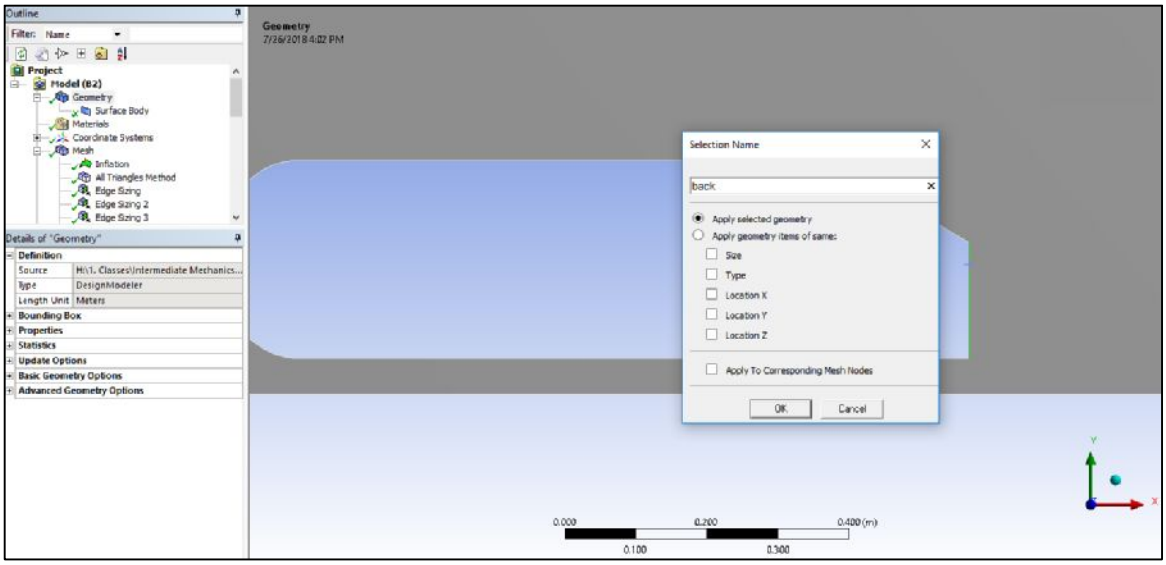
5.14. Repeat step 5.8 for the top edge of the Ahmed Car and name it *'ahmed top'*.



5.15. Repeat step 5.8 for the bottom edge of the Ahmed Car and name it *'ahmed bottom'*.



5.16. Repeat step 5.8 for the right vertical edge of the Ahmed Car and name it *back.*



5.17. **File** > **Save Project**. Close **Meshing** window.

5.18. Update the mesh by right clicking **Mesh** and from the dropdown menu select **Update**.