To use ANSYS Fluent in your house, please use VDI (See below Link)
https://etc.engineering.uiowa.edu/help-desk/how-use/vdi-how-use-virtual-windows-desktop

Simulation of Turbulent Flow over the Ahmed Body

ME:5160 Intermediate Mechanics of Fluids
CFD LAB 4
(ANSYS 2023 R1; Last Updated: August 17, 2023)

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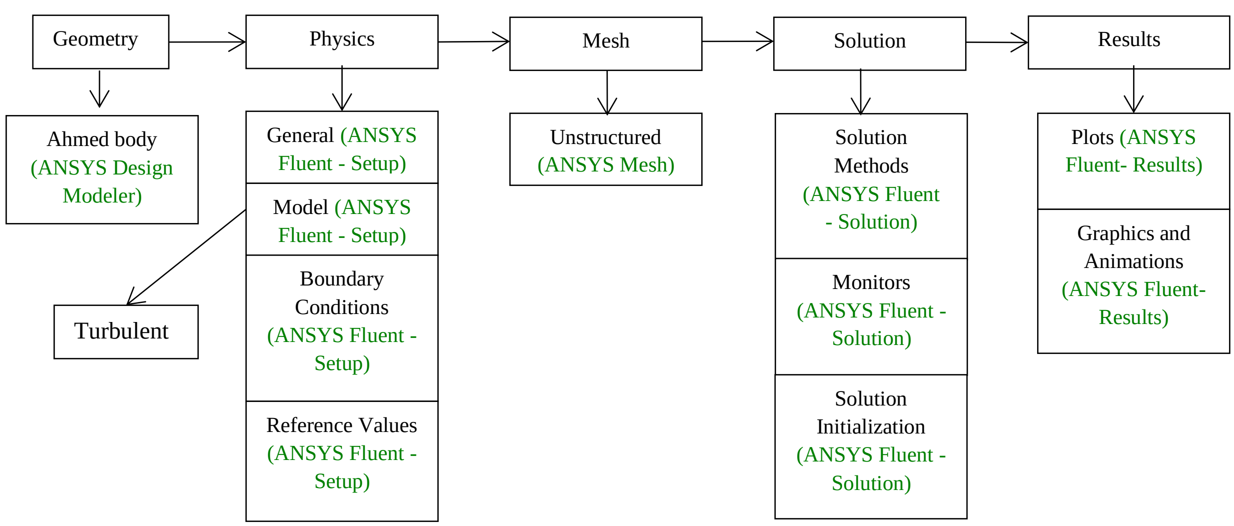
1. Purpose

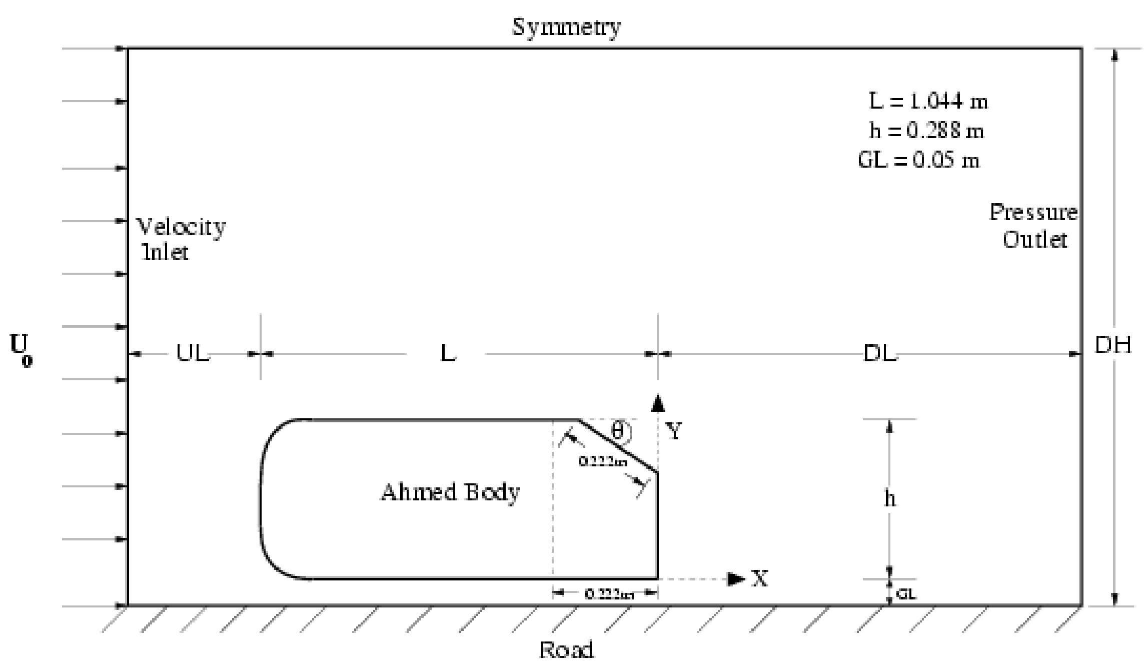
The Purpose of CFD Lab 4 is to simulate **unsteady turbulent** flows over the Ahmed body following the “CFD process” by an interactive step-by-step approach and conduct verifications using CFD Educational Interface ANSYS. Students will have “hands-on” experiences using ANSYS to **predict drag coefficients and axial velocity for slant angle 25 degrees and compare them with EFD 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 EFD and present results in a CFD Lab report.



Flow Chart for “CFD Process” for ahmed body

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.



For CFD Lab4, all EFD data can be found under the "CFD Lab4: Ahmed Car" section on the class website: http://www.engineering.uiowa.edu/~me_160/.

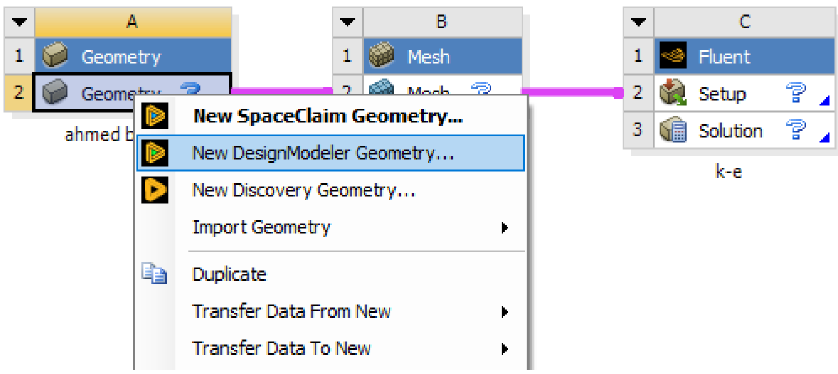
3. Opening ANSYS Workbench Software

3.1. Start > **All Programs** > **ANSYS 2021 R2** > **Workbench 2021 R2**

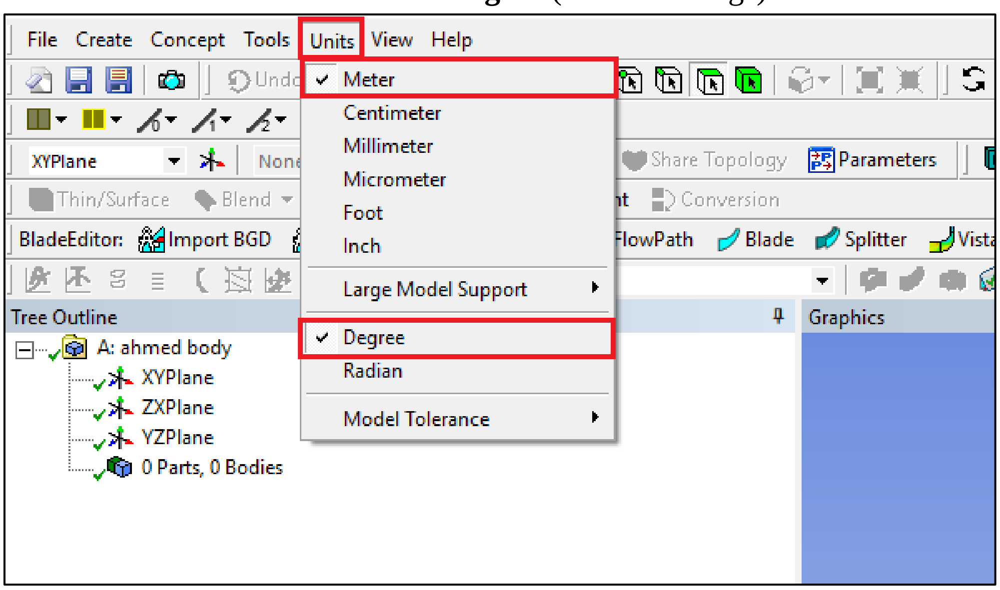
3.2. Drag and drop three component into the **Project Schematic**, name the components and create connections between components as per below.

4. Geometry Creation

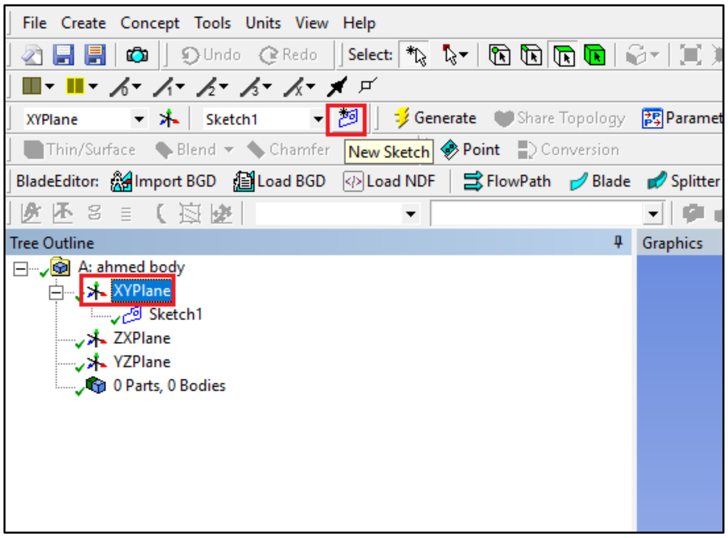
4.1. From the **Project Schematic** right click **Geometry** and select **New DesignModeler Geometry….**



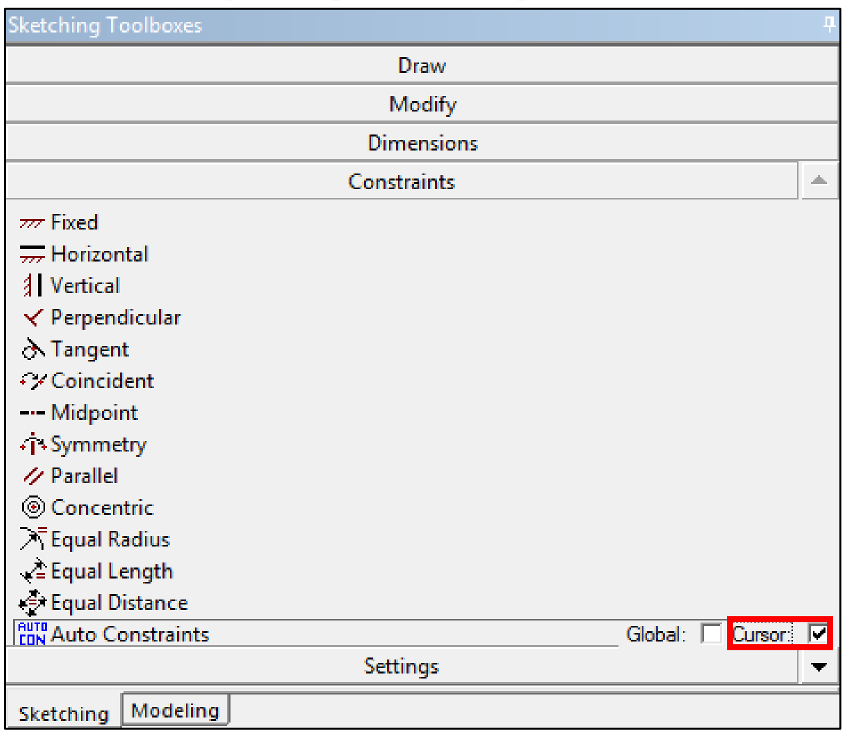
4.2. Make sure that Unit is set to **Meter** and **Degree** (default settings).



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

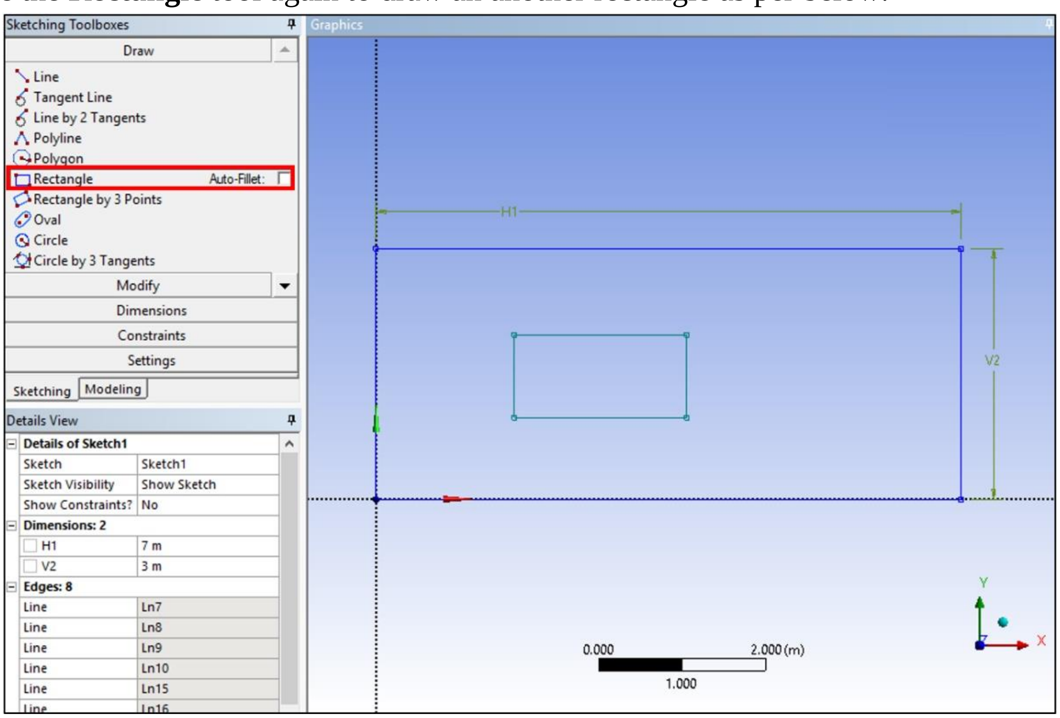


4.4. Enable the auto constraints option to pick the exact point as below

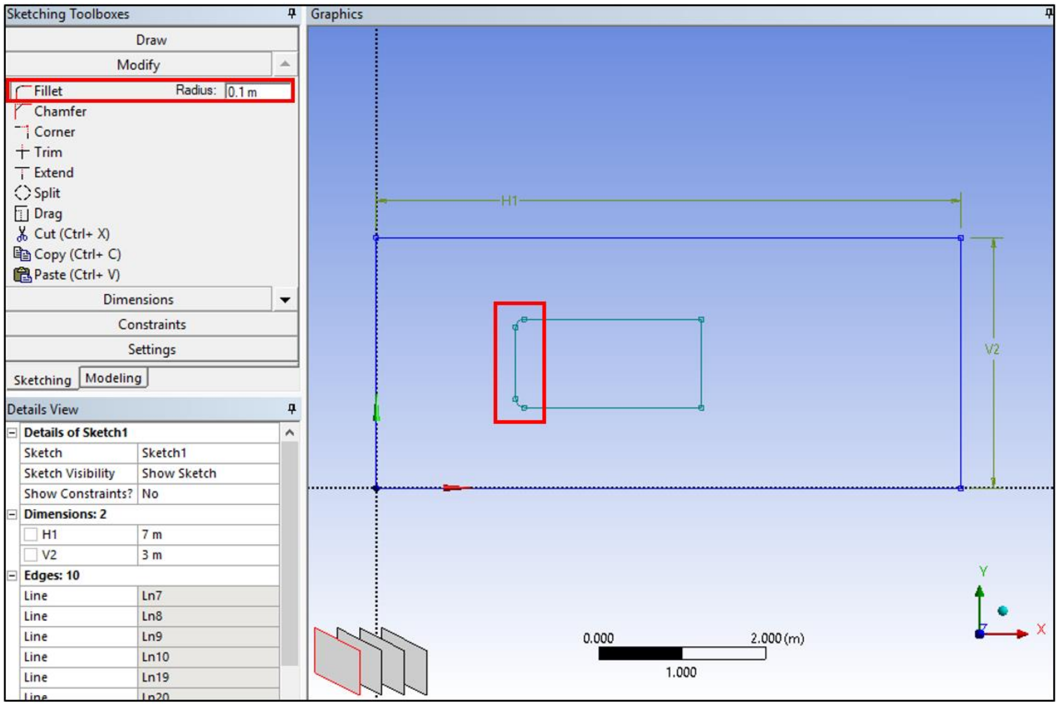


4.5. Use the **Rectangle** tool under **Draw** to make a rectangle starting from the origin and ending inside the first quadrant. Dimension it using **General** dimension as per below. (Click the z arrow of the 3D orientation located at the bottom right to make the view perpendicular to xy-plane. Make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

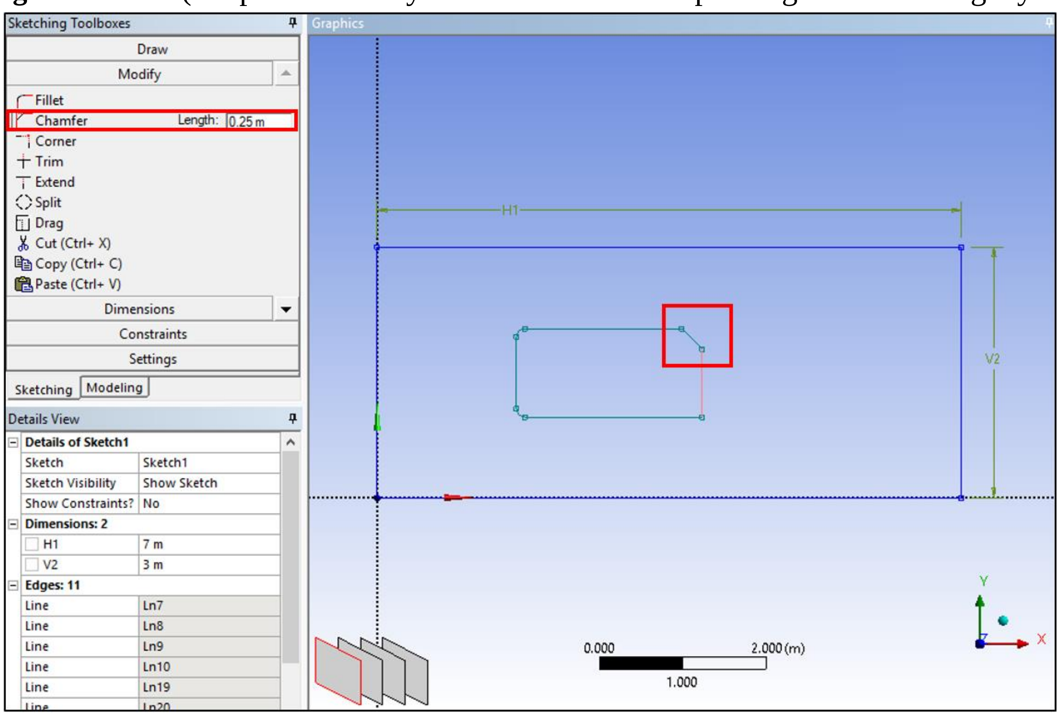
4.6. Use the **Rectangle** tool again to draw an another rectangle as per below.



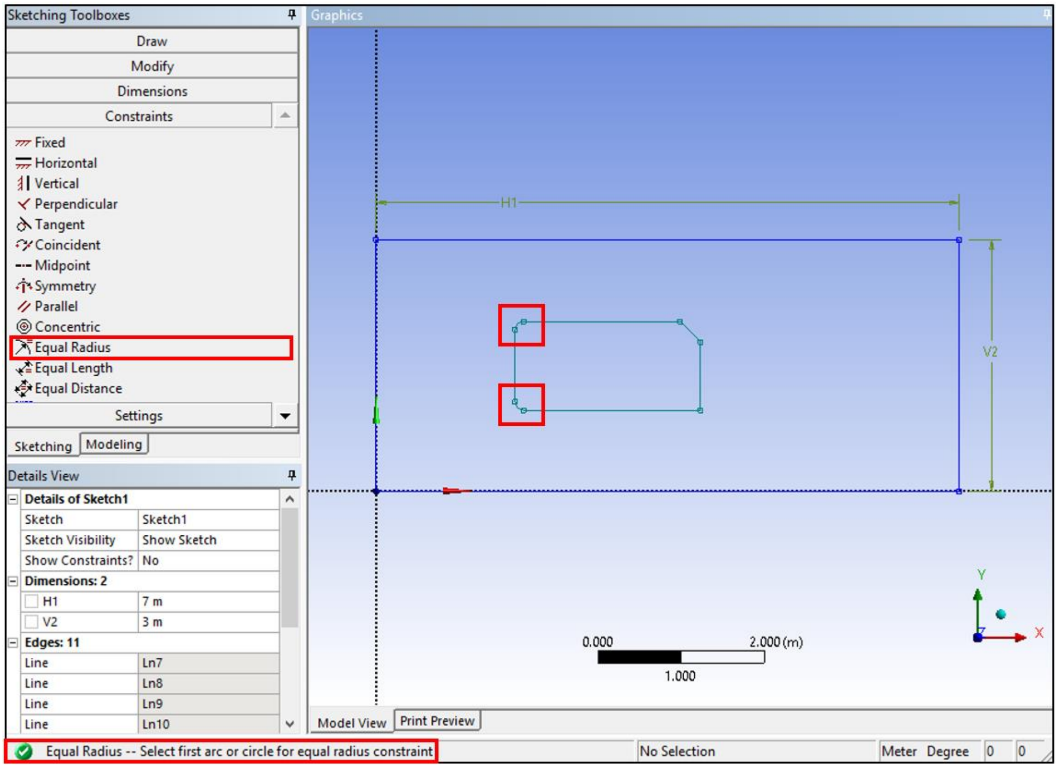
4.7. Use the **Fillet** tool in **Modify** to put a radius on the front corners of the Ahmed Car as per below. Use the **Radius** size of 0.1m. After changing the value, click the front corners.



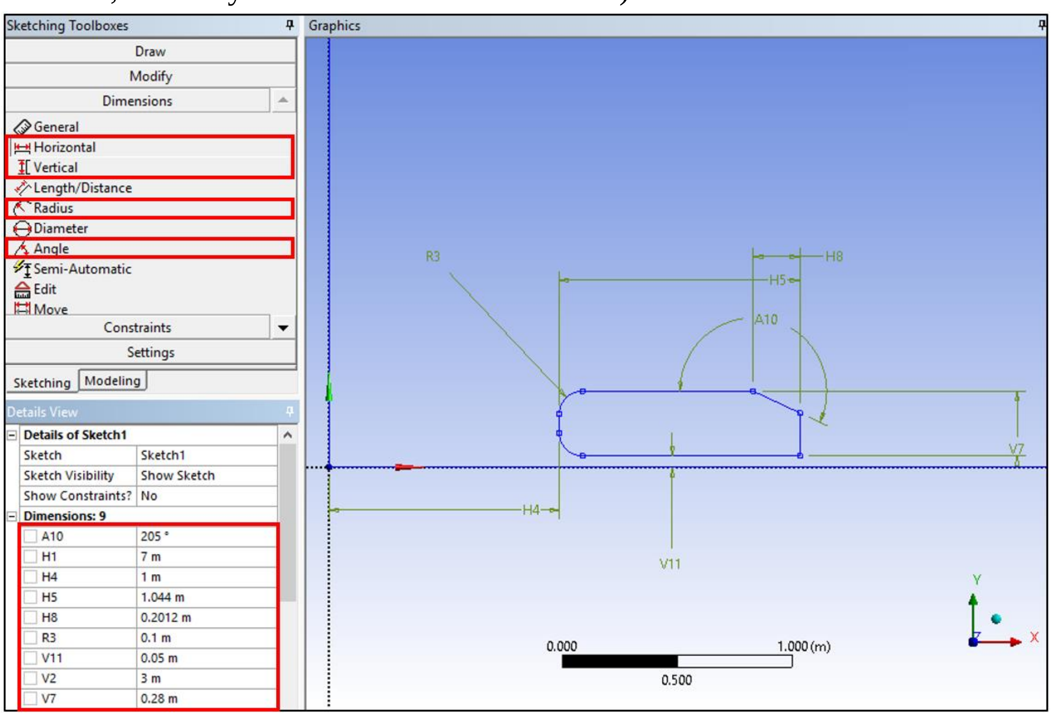
4.8. Use the **Chamfer** tool to put a chamfer on the back of the Ahmed Car as per below. Use the **Length** of 0.25m. (Shape of the body could be different depending on the rectangle you made)



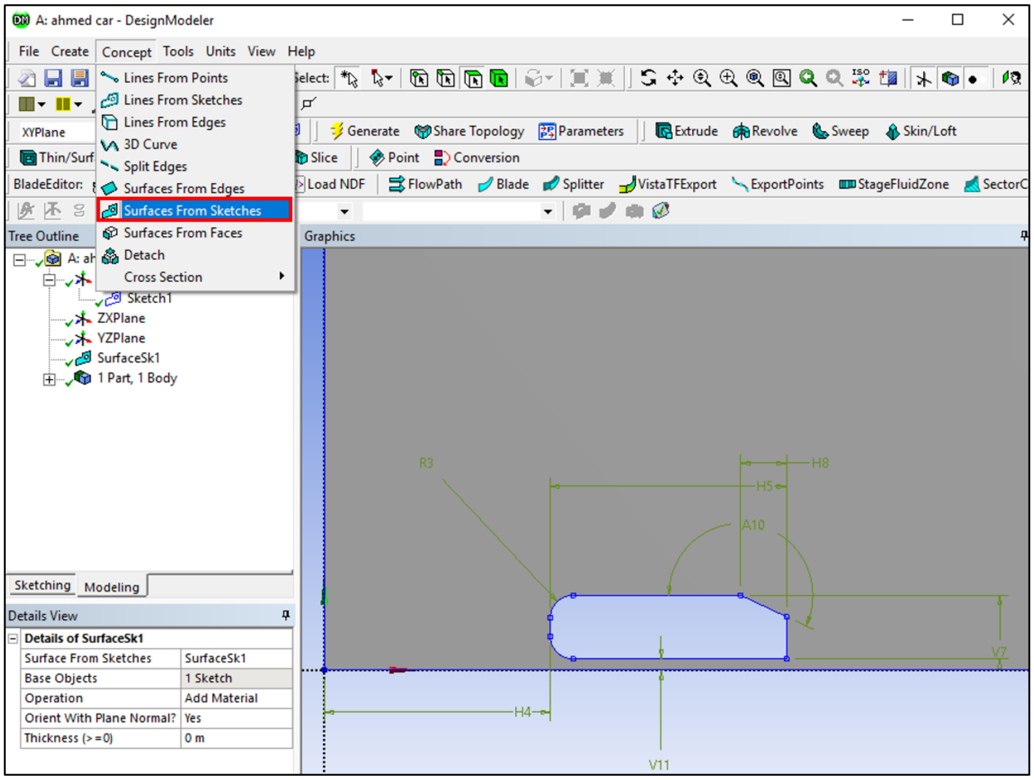
4.9. Put a constraint on the two radii using the **Equal Radius** tool in **Constraints**. (Note: in the bottom left corner next to the checkmark in a green circle is the note on how to use a tool)



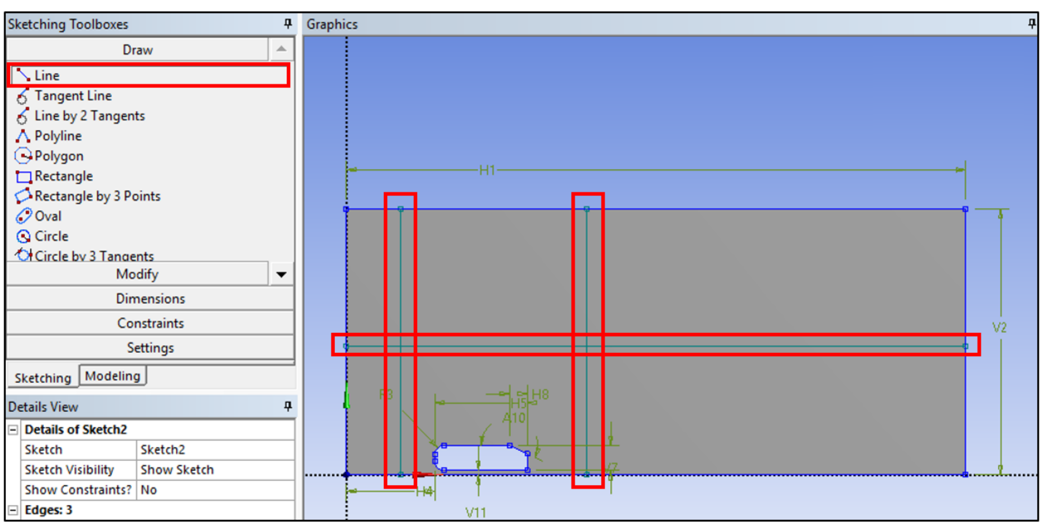
4.10. Dimension the body inside the rectangle as per below using **Horizontal**, **Vertical**, **Radius**, and **Angle** under **Dimensions**. (The name of each dimension will be followed by the order you make it, so it may be different from the manual)



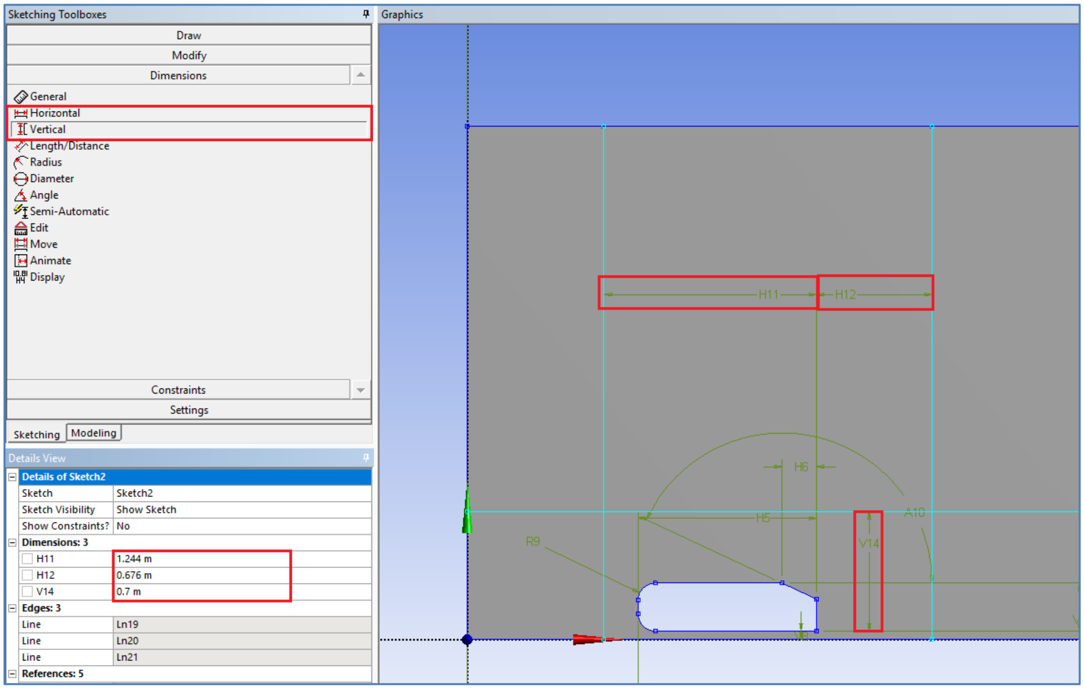
4.11. **Concept** > **Surface From Sketches**. Select the sketch you just created under the tree outline and click **Apply**. Click **Generate**.



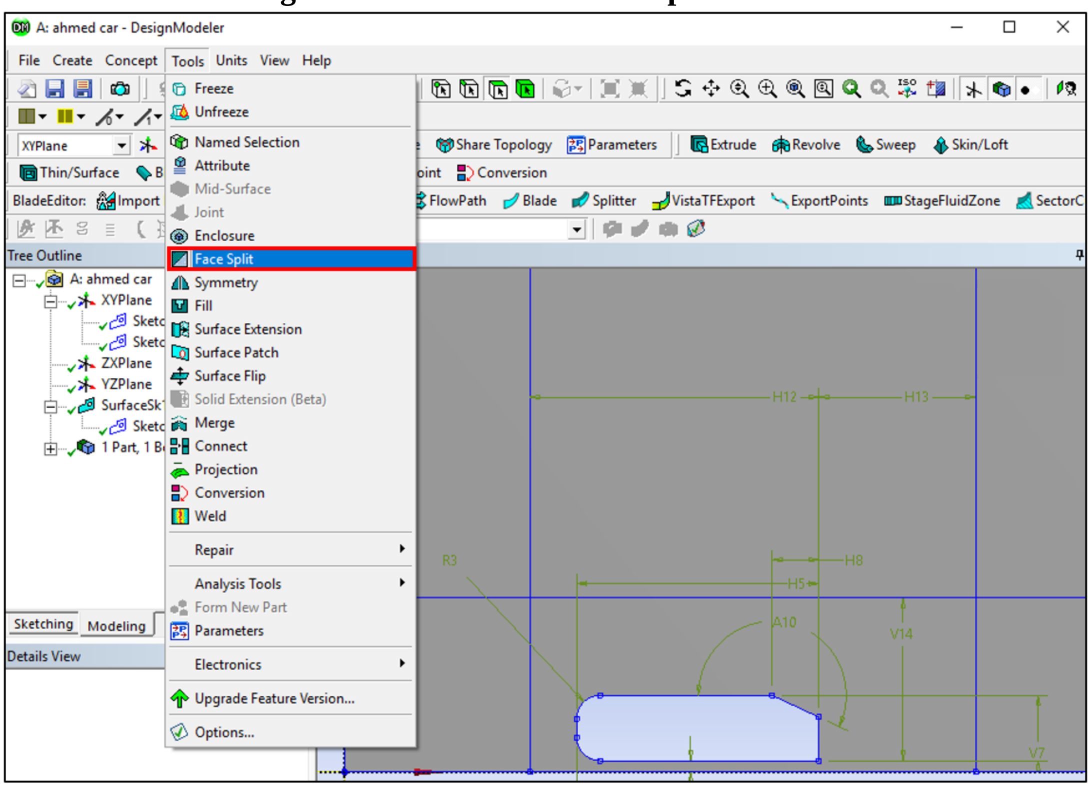
4.12. Select **XYPlane** and click the **New Sketch** button. In this new sketch, use the **Line** tool under **Draw** to make the lines as per below. Three lines will extend over the entire domain, horizontally or vertically. Make sure that the **C** appears when you are on the line and the **V/H**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



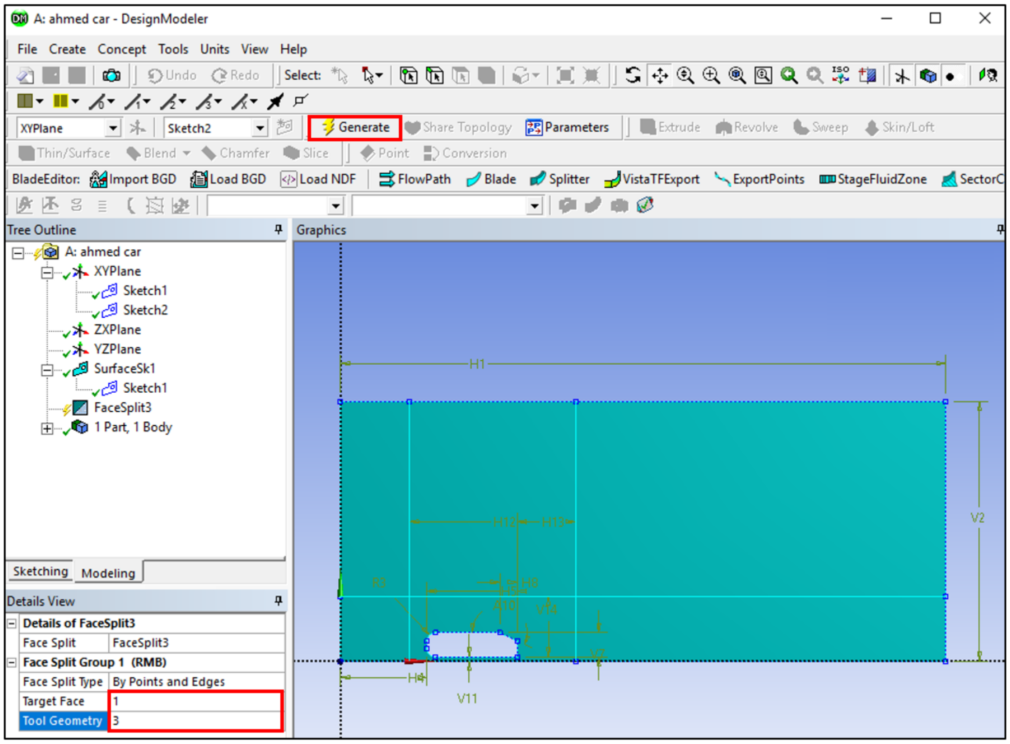
4.13. Use the **Horizontal** and **Vertical** dimension tool to dimension the lines as per below.



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

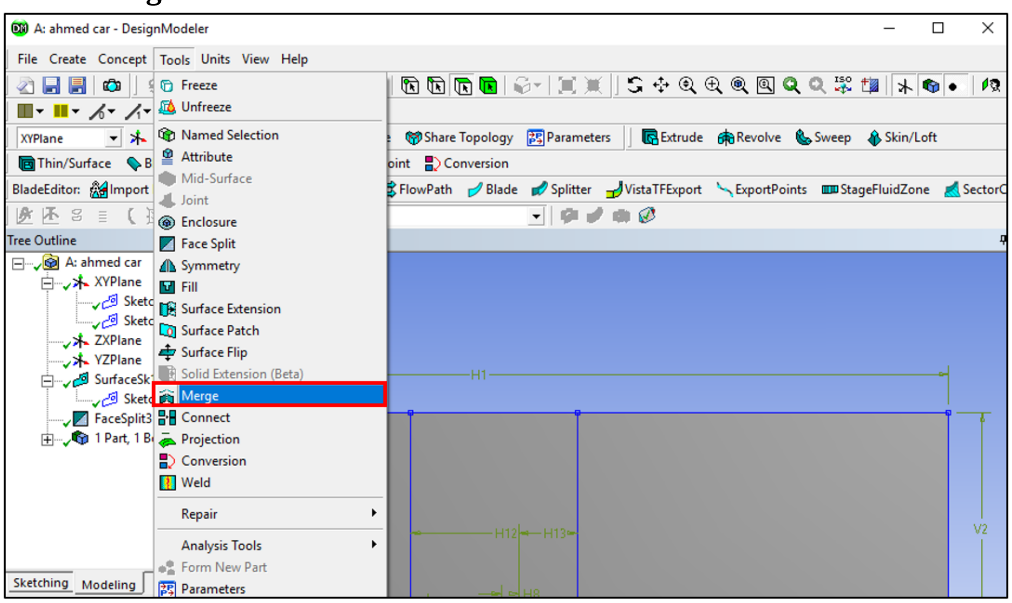


4.15. Select the gray surface for **Target Face** and click **Apply.** For **Tool Geometry** select two endpoints of the one line you just created while holding **Ctrl** then click **Apply**. Select **Tool Geometry** again and select two more endpoints of another line and click **Apply**. Repeat this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

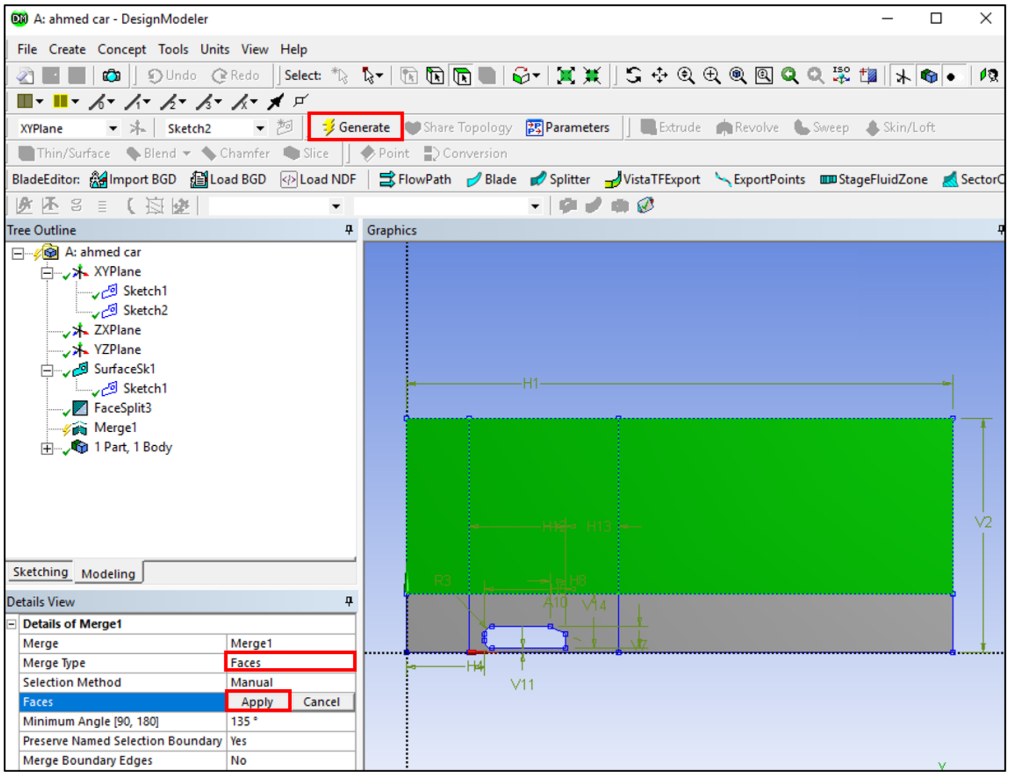


(The picture above was taken right before clicking 'Generate')

4.16. Tools > **Merge**.



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

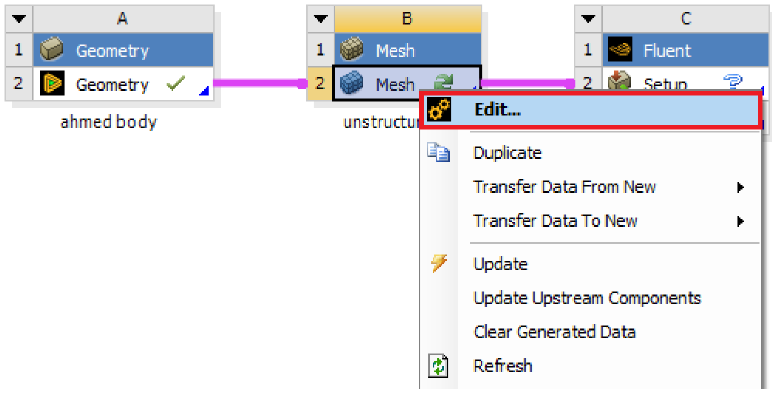


(The picture above was taken right before clicking 'Apply')

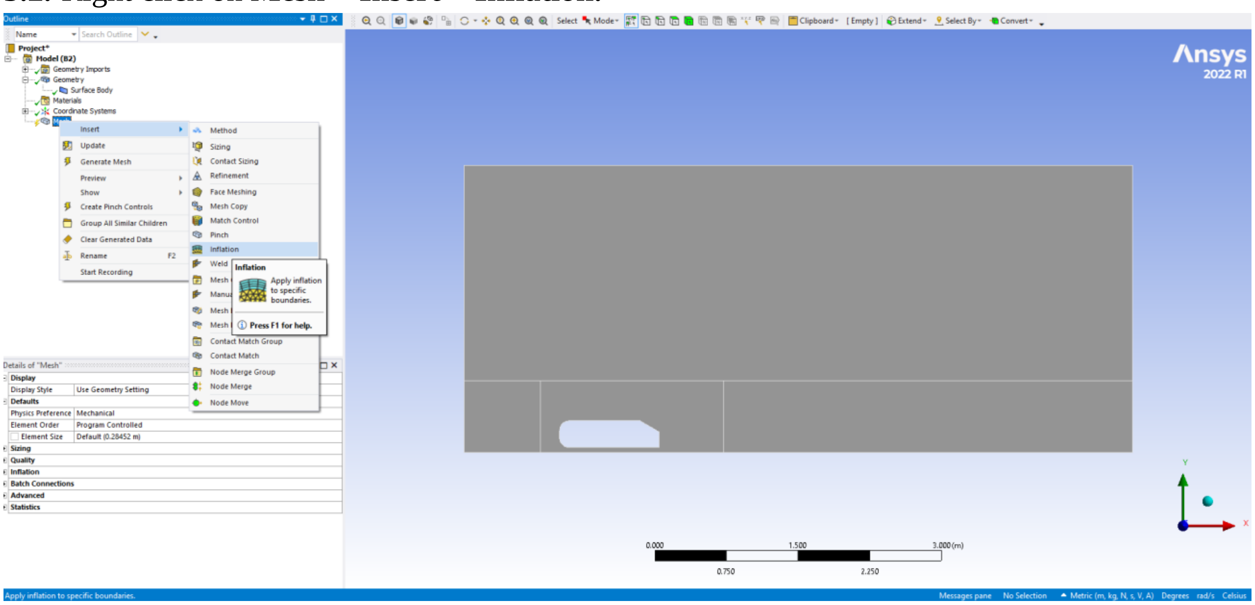
4.18. **File** > **Save Project**. Close the **Design Modeler** window.

5. Mesh

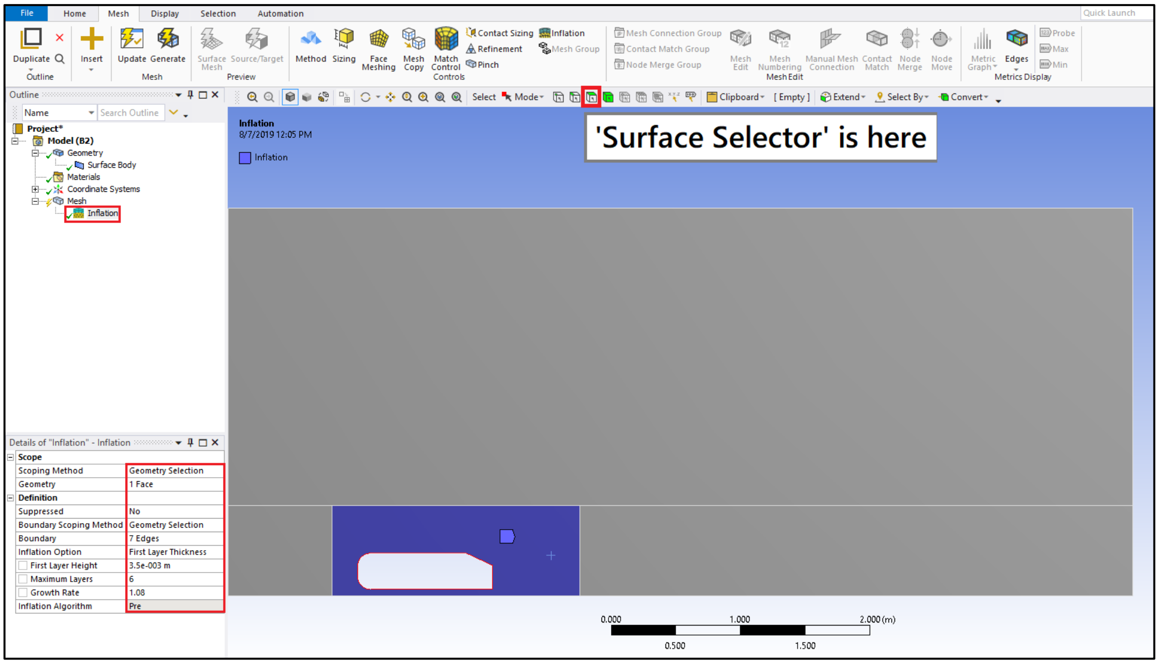
5.1. Right click **Mesh** and from the dropdown menu then select **Edit…**



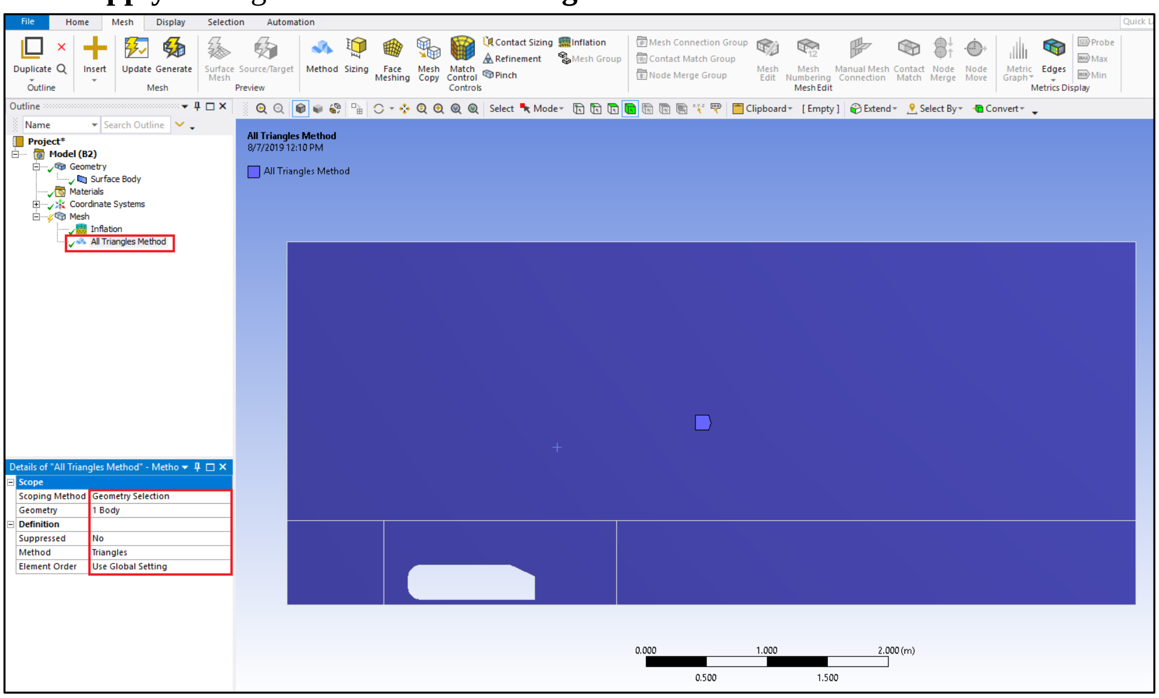
5.2. Right click on **Mesh** > **Insert** > **Inflation.**



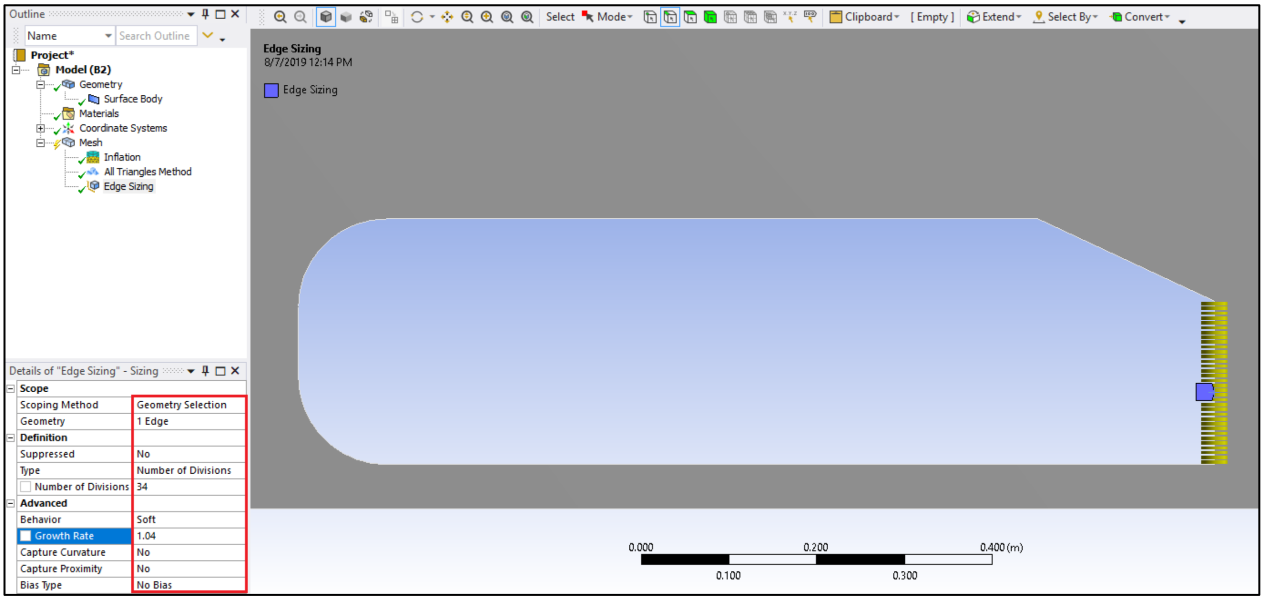
5.3. For **Geometry** option, select the surface of the domain which borders the Ahmed Car and click **Apply** (Change the cursor to 'Surface Selector' at upper region to select the surface). For the **Boundary**, select the edges of the Ahmed Car by holding **Ctrl** and selecting the edges and then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

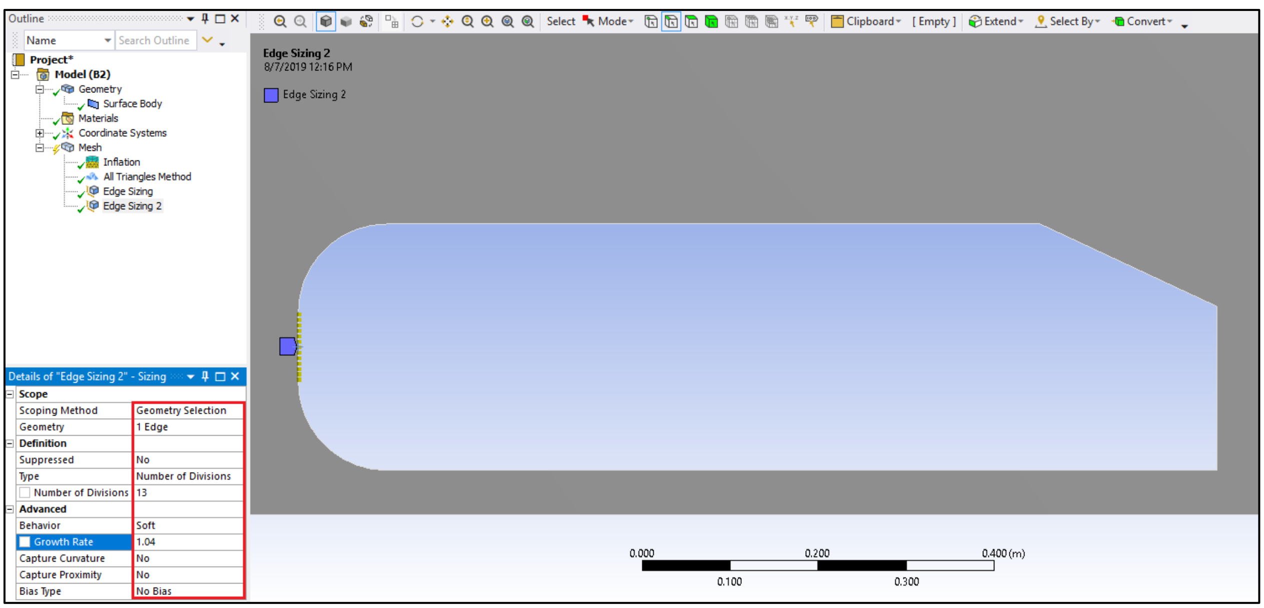


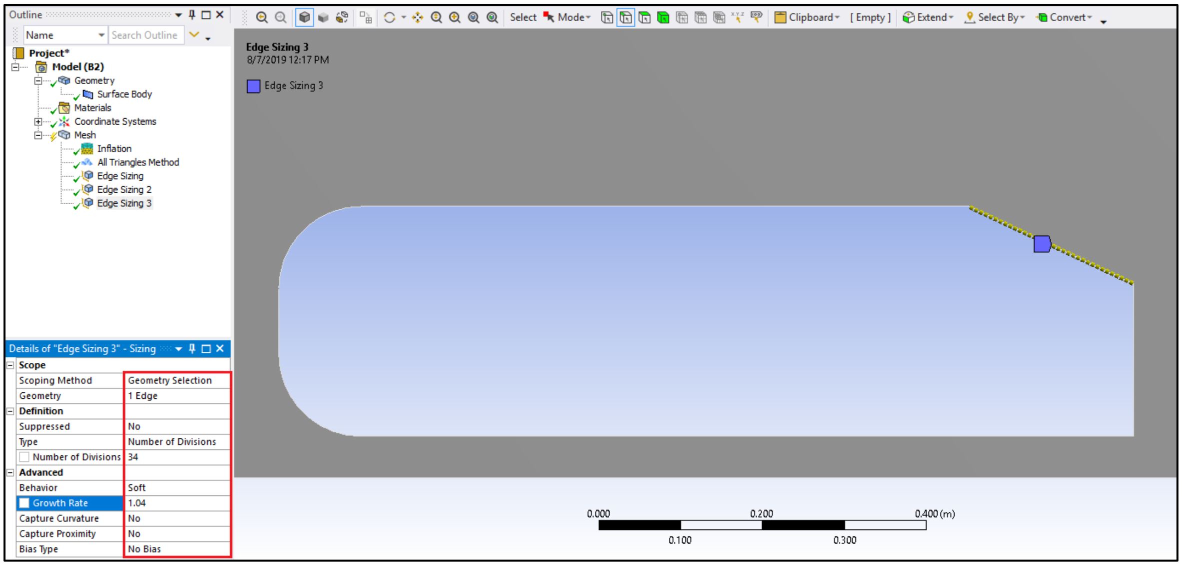
5.4. Right click **Mesh** > **Insert** > **Method**. Select the whole domain (surfaces) for Geometry and click **Apply**. Change the **Method** to **Triangles**.



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
Details of "Edge Sizing 3" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
Number of Divisions | 34
Advanced
Behavior | Soft
Growth Rate | 1.04
Capture Curvature | No
Capture Proximity | No
Bias Type | No Bias
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Edge Sizing 3
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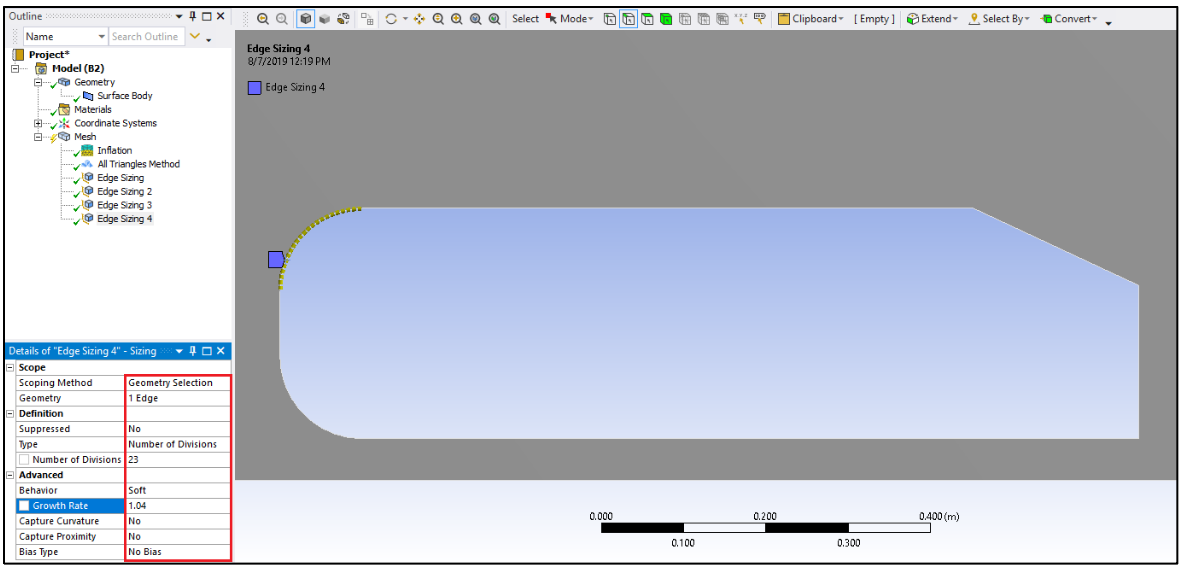
0.100
0.200
0.300
0.400 (m)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Materials
Coordinate Systems
Mesh
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All Triangles Method
Edge Sizing
Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Details of "Edge Sizing 4" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
Suppressed | No
Type | Number of Divisions
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Advanced
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Capture Curvature | No
Capture Proximity | No
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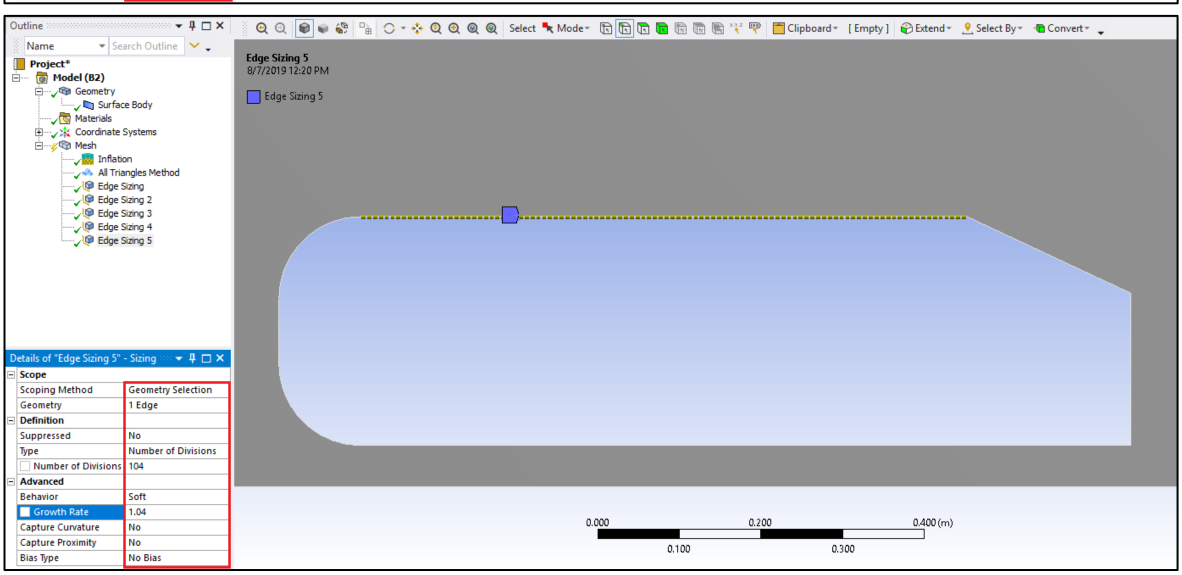
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Coordinate Systems
Mesh
Inflation
All Triangles Method
Edge Sizing
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Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
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Scope
Scoping Method | Geometry Selection
Geometry | 1 Edge
Definition
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Behavior | Soft
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Capture Proximity | No
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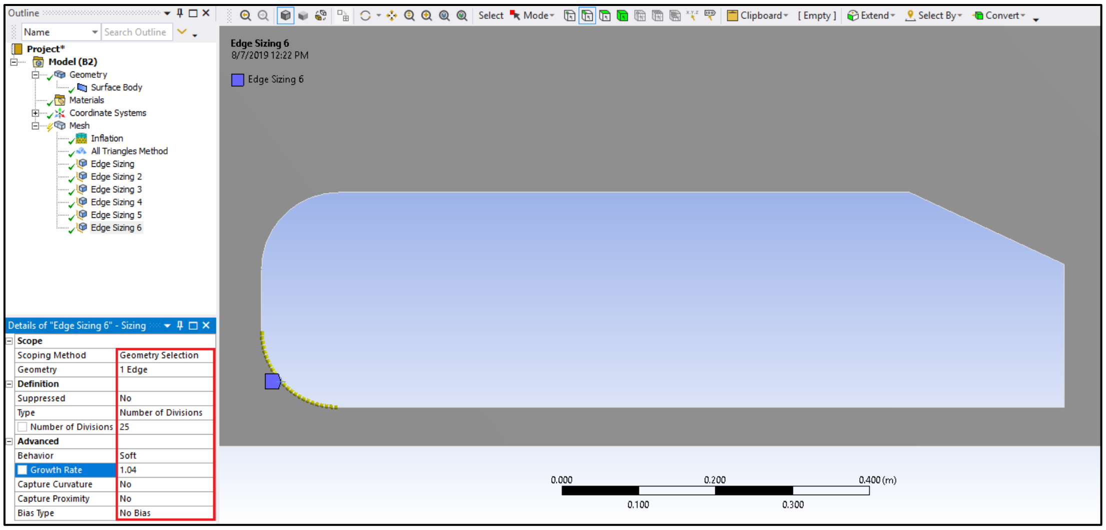
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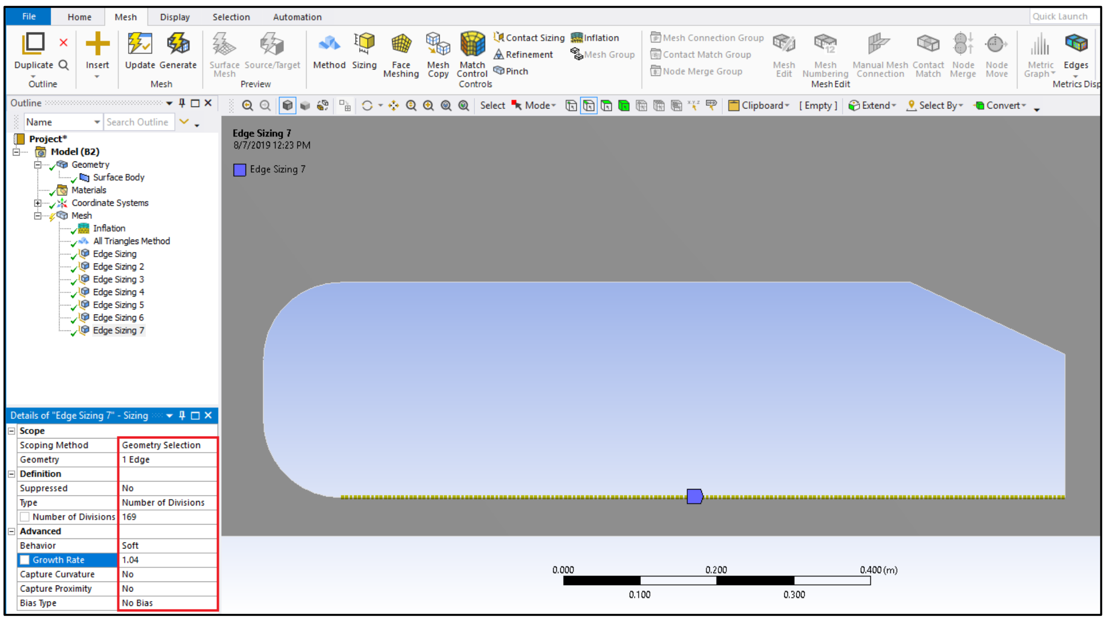
Capture Proximity No
Bias Type No Bias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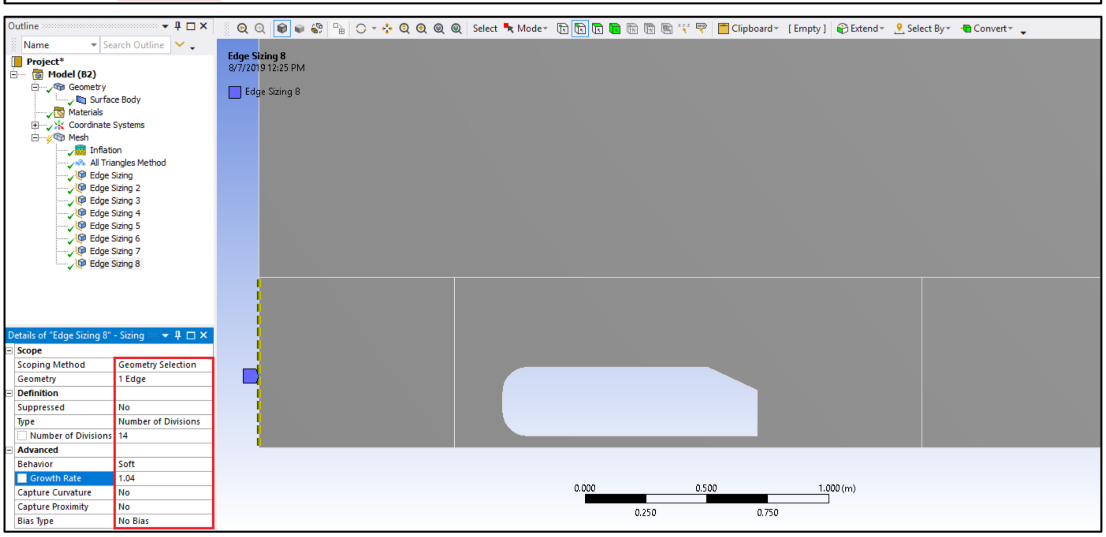
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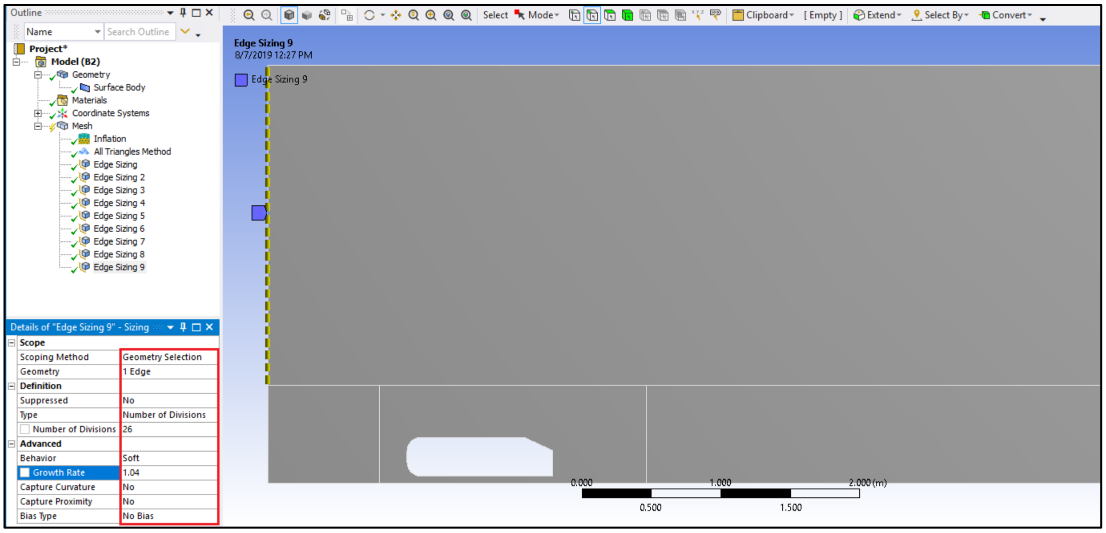
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Edge Sizing 7
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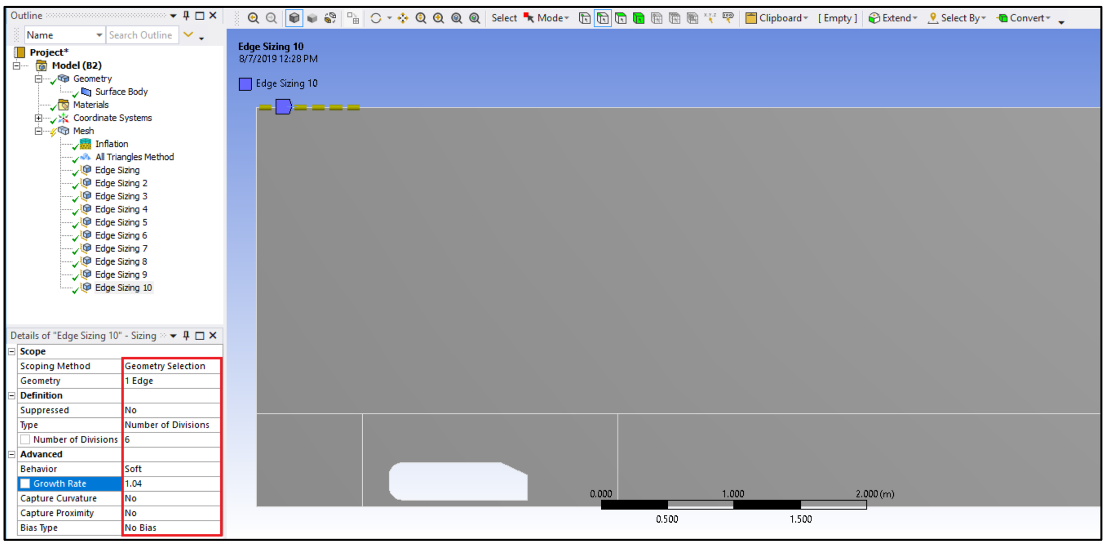
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Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
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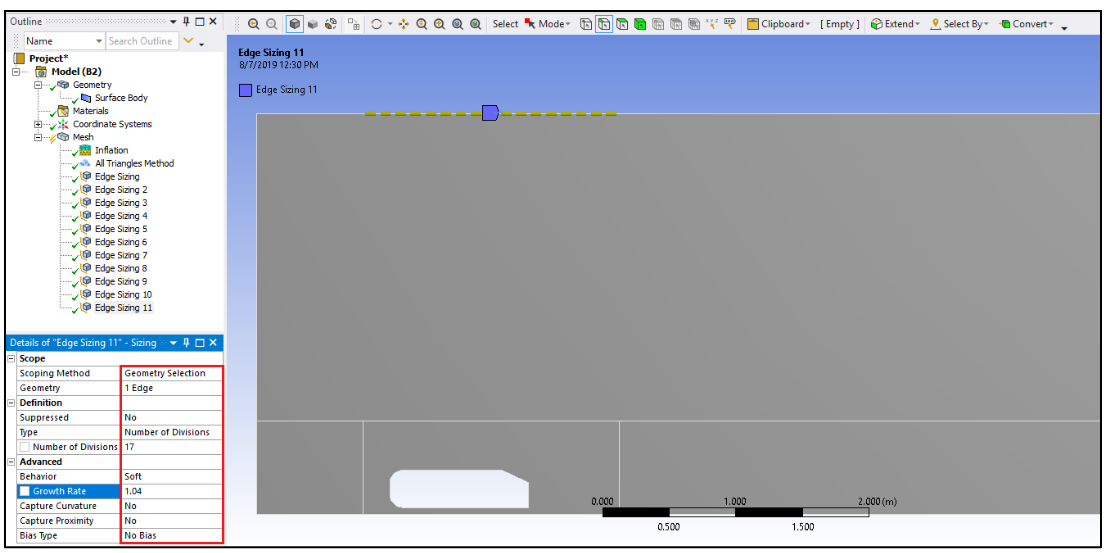
0.500 1.500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Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
Edge Sizing 11
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Definition
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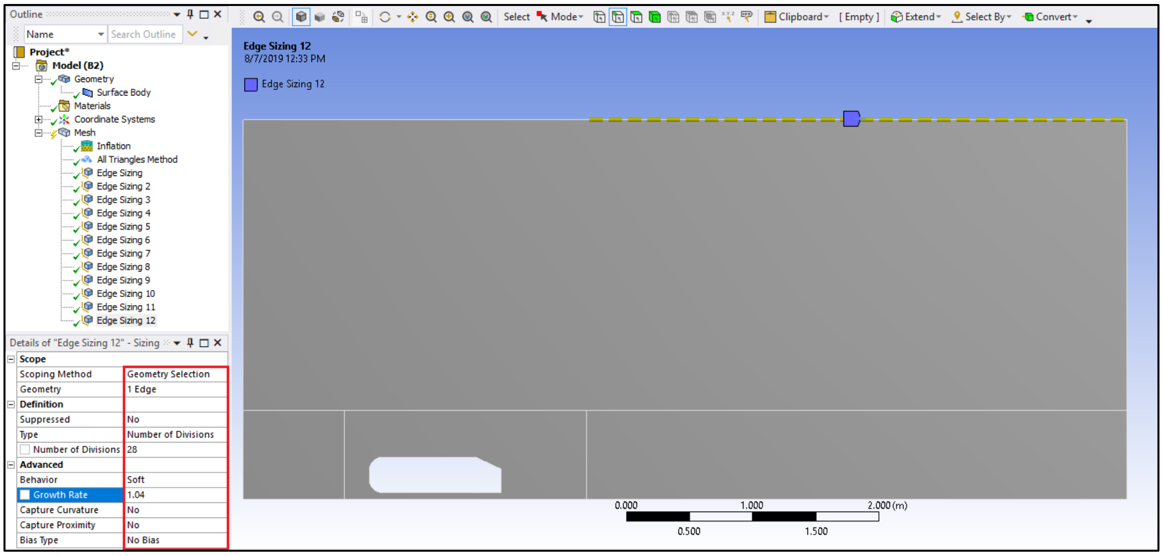
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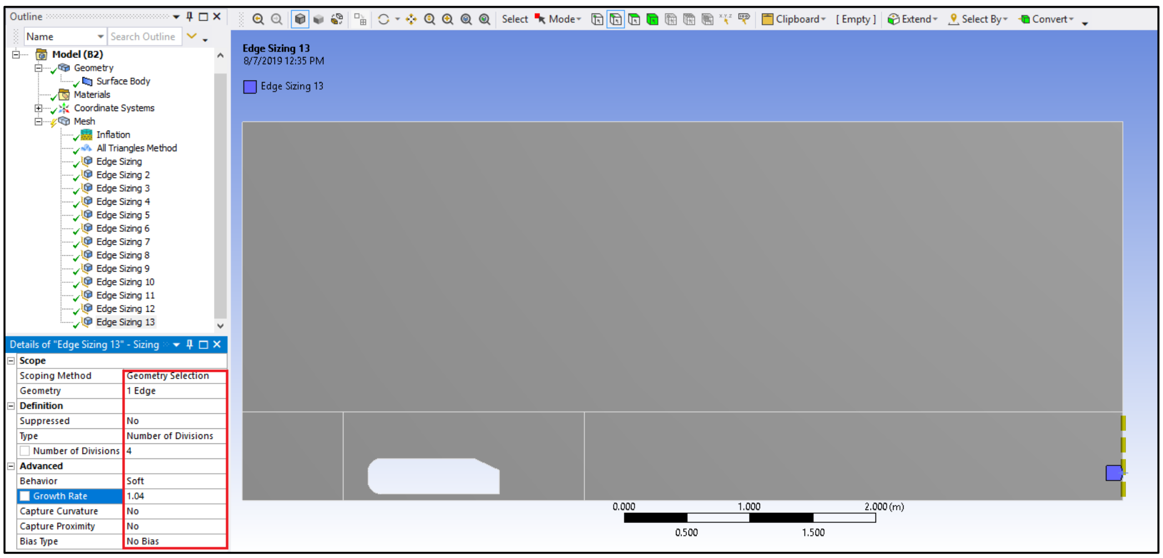
0.000 1.000 2.000 (m)
0.500 1.500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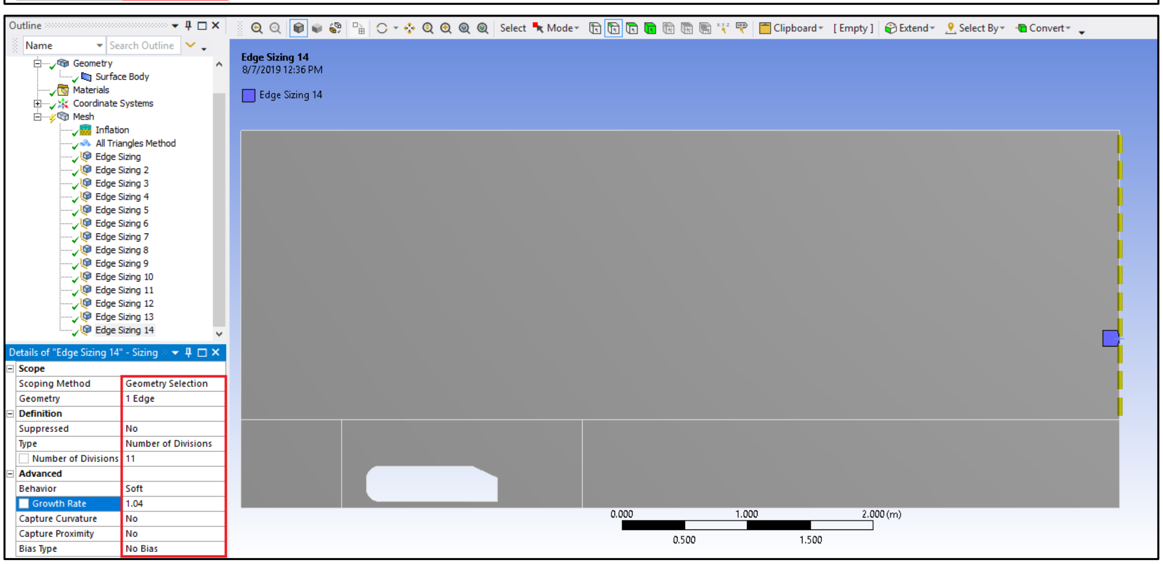
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Number of Divisions 11
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Capture Proximity No
Bias Type No Bias
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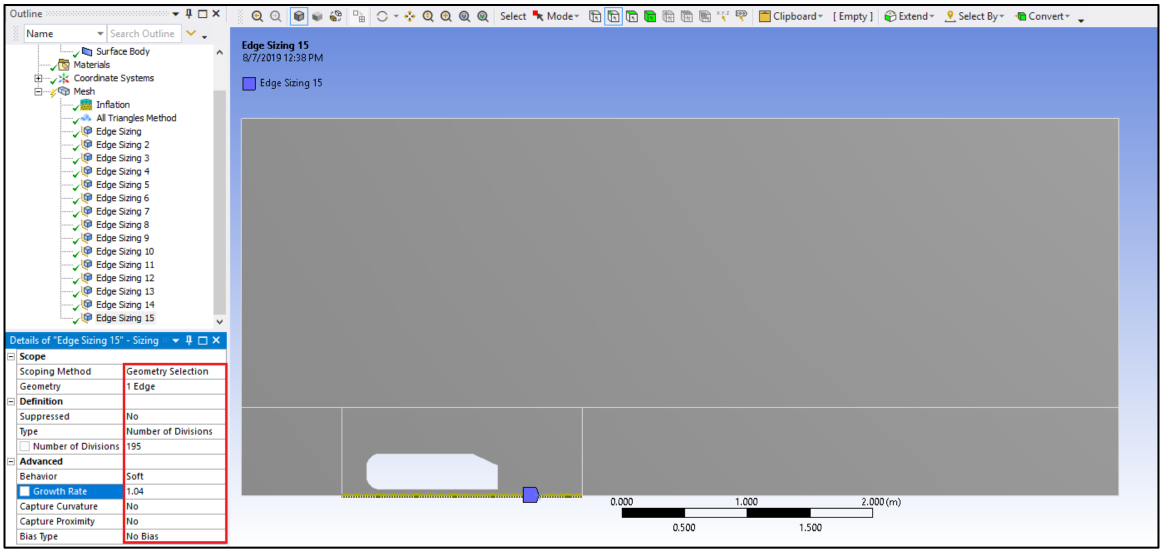
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Inflation
All Triangles Method
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Edge Sizing 3
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Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
Edge Sizing 11
Edge Sizing 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
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Type Number of Divisions
Number of Divisions 195
Advanced
Behavior Soft
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Capture Proximity No
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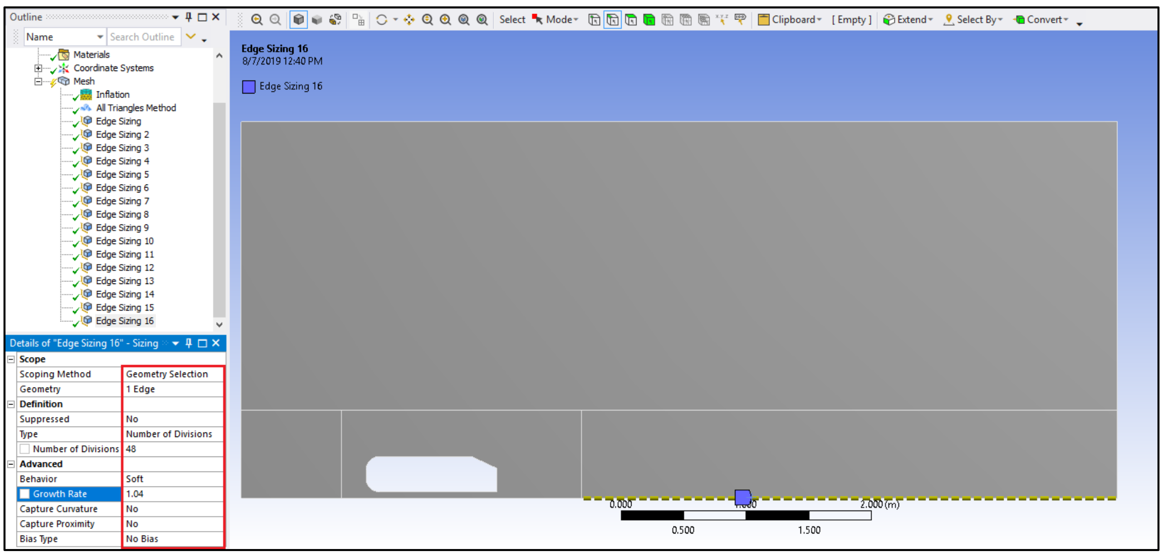
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Edge Sizing 11
Edge Sizing 12
Edge Sizing 13
Edge Sizing 14
Edge Sizing 15
Edge Sizing 16
Details of "Edge Sizing 16" - Sizing
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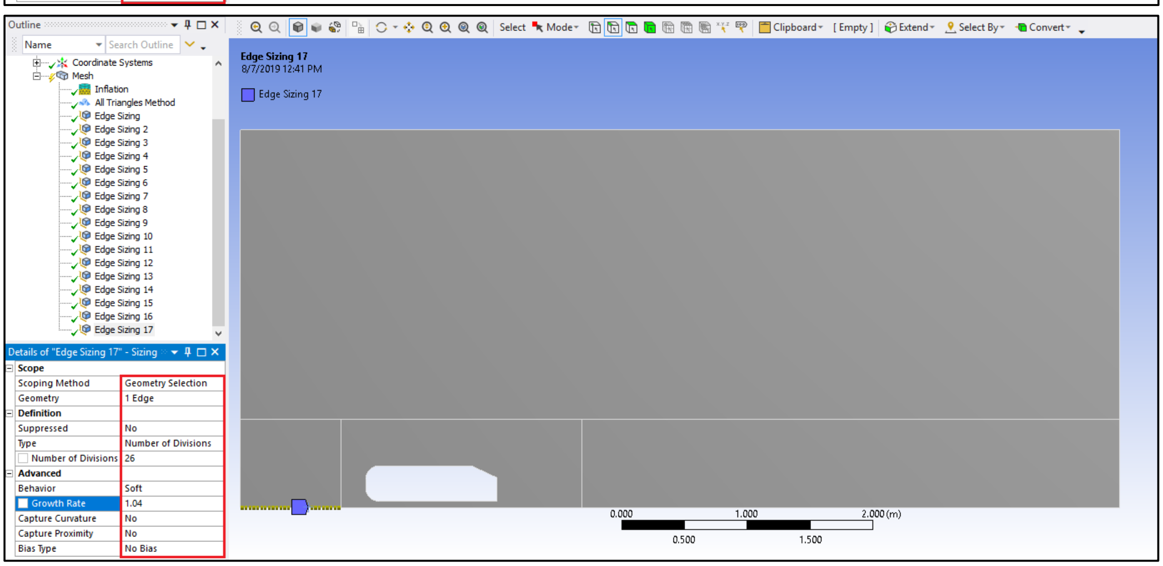
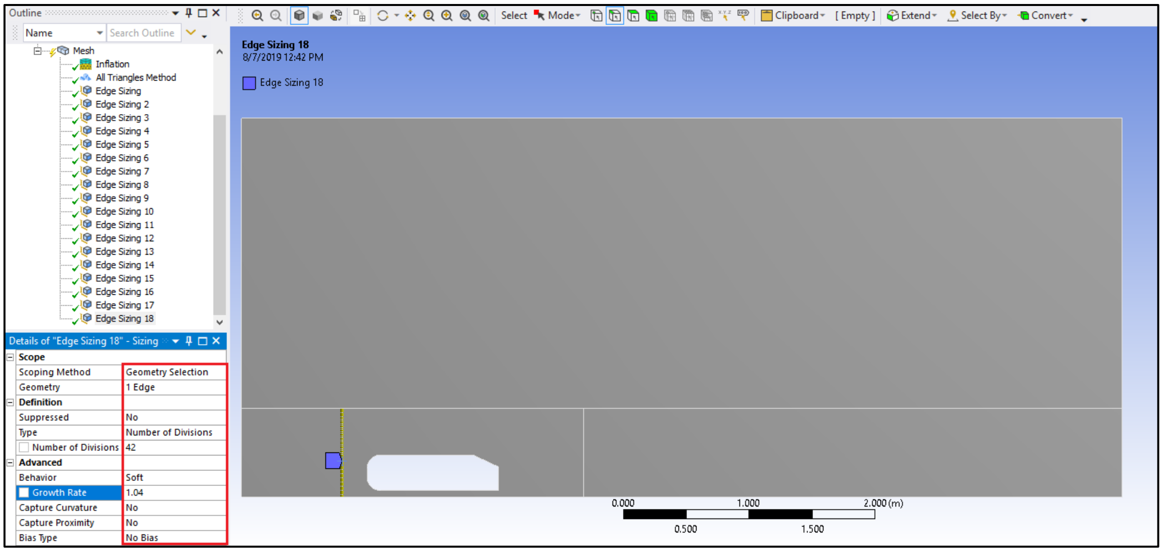
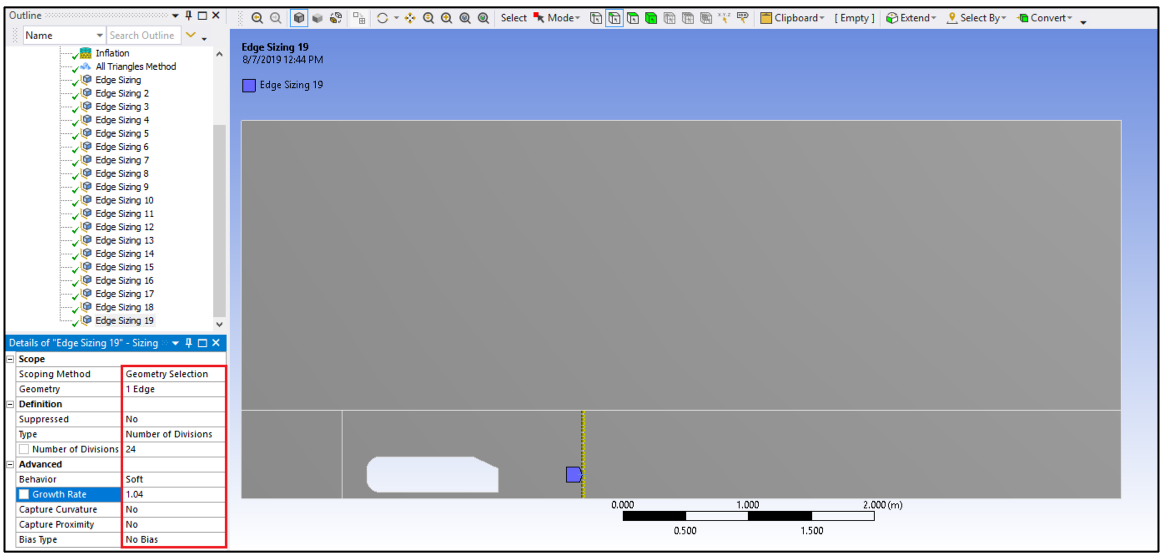
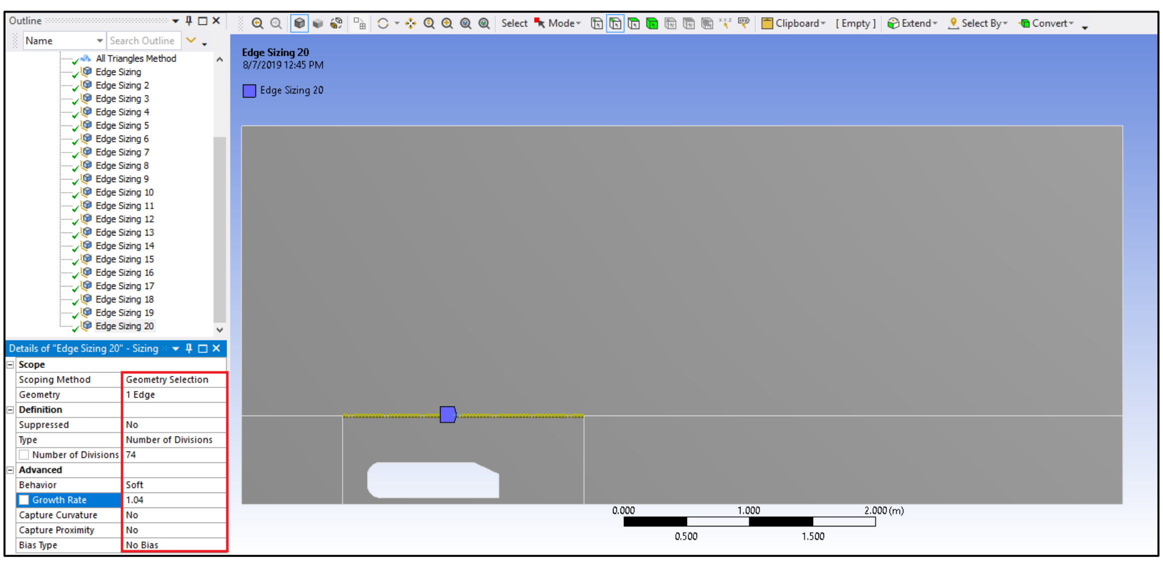
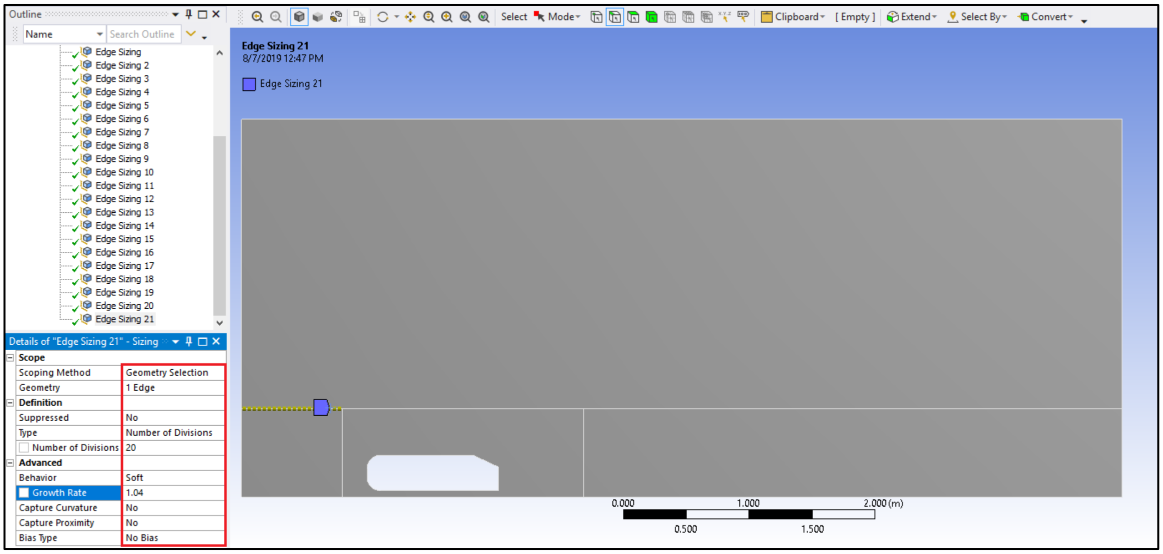
0.000 2.000 (m)
0.500 1.500

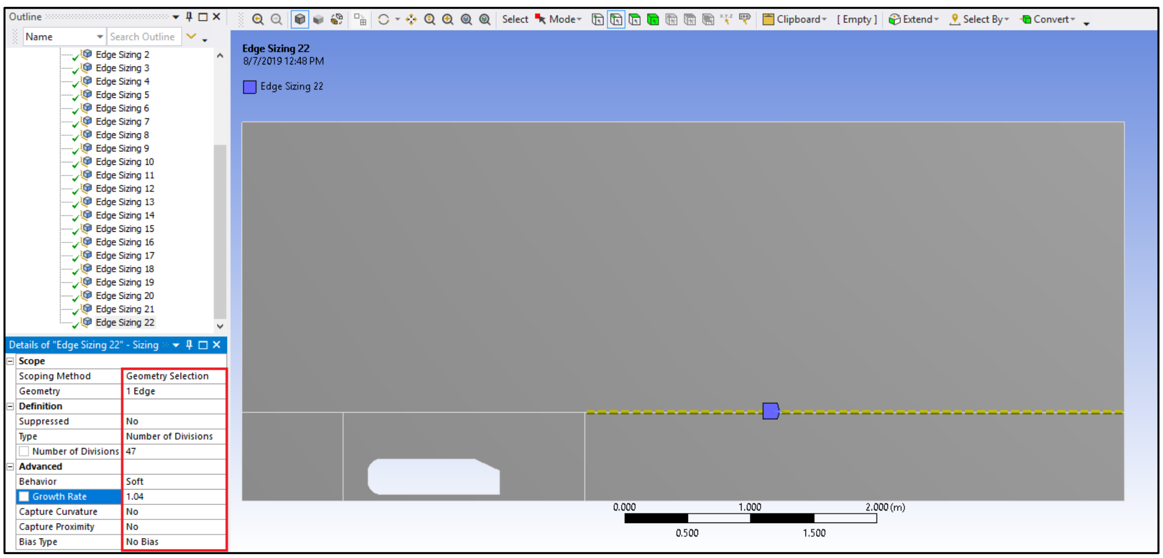

Outline
Coordinate Systems
Mesh
Inflation
All Triangles Method
Edge Sizing
Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
Edge Sizing 11
Edge Sizing 12
Edge Sizing 13
Edge Sizing 14
Edge Sizing 15
Edge Sizing 16
Edge Sizing 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 26
Advanced
Behavior Soft
Growth Rate 1.04
Capture Curvature No
Capture Proximity No
Bias Type No Bias
Edge Sizing 17
8/7/2019 12:41 PM
Edge Sizing 17
0.000 1.000 2.000 (m)
0.500 1.500


Edge Sizing 18
8/7/2019 12:42 PM
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
0.000 1.000 2.000 (m)
0.500 1.500

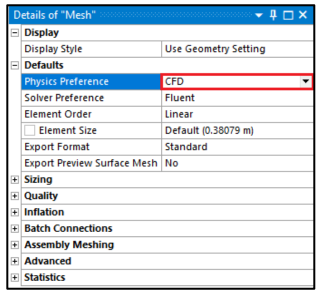

Edge Sizing 19
8/7/2019 12:44 PM
Details of "Edge Sizing 19" - Sizing
Scope
Scoping Method Geometry Selection
Geometry 1 Edge
Definition
Suppressed No
Type Number of Divisions
Number of Divisions 24
Advanced
Behavior Soft
Growth Rate 1.04
Capture Curvature No
Capture Proximity No
Bias Type No Bias
0.000 1.000 2.000 (m)
0.500 1.500


Edge Sizing 20
8/7/2019 12:45 PM
Details of "Edge Sizing 20" - Sizing
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
0.000 1.000 2.000 (m)
0.500 1.500

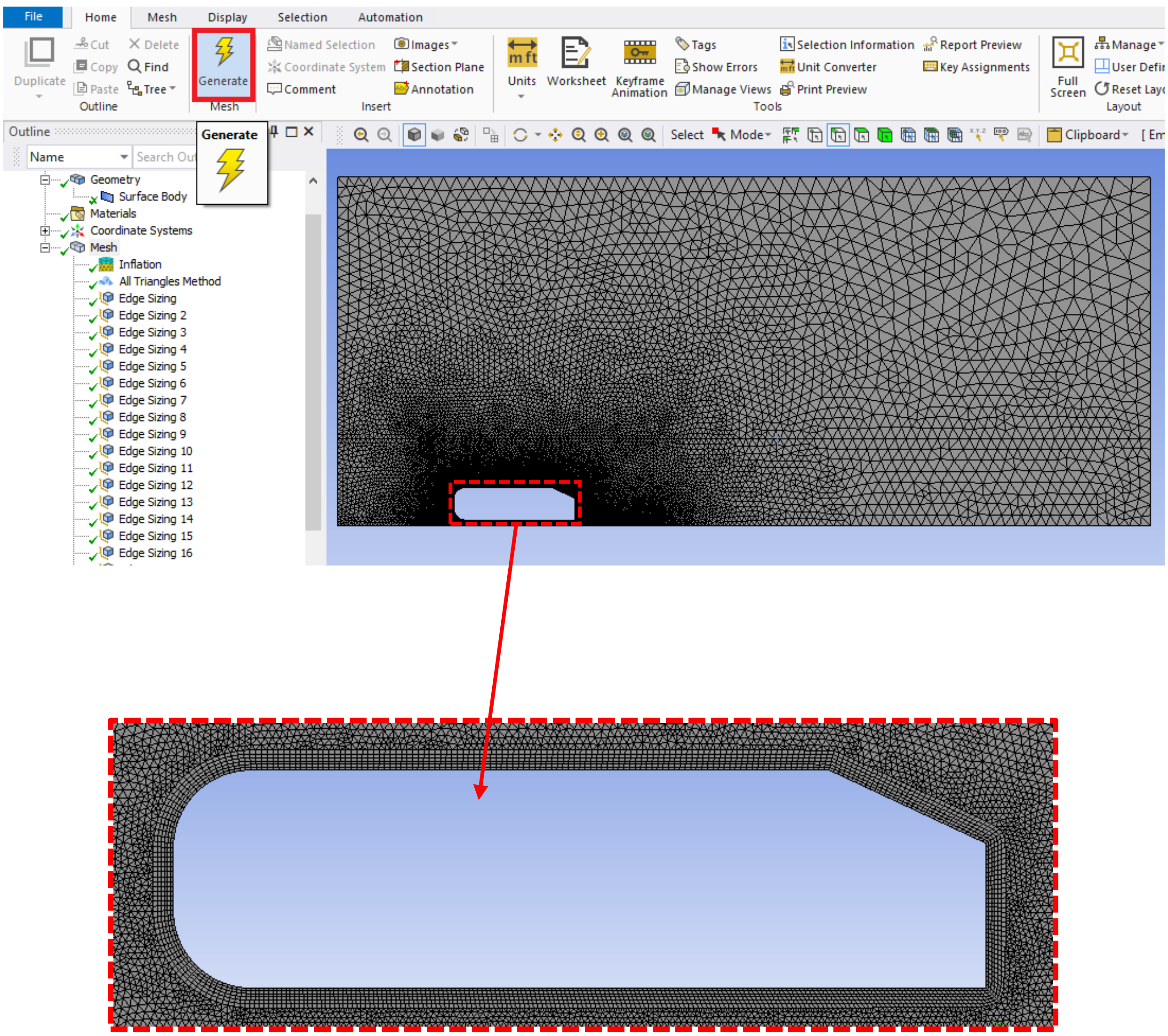

Outline
Edge Sizing
Edge Sizing 2
Edge Sizing 3
Edge Sizing 4
Edge Sizing 5
Edge Sizing 6
Edge Sizing 7
Edge Sizing 8
Edge Sizing 9
Edge Sizing 10
Edge Sizing 11
Edge Sizing 12
Edge Sizing 13
Edge Sizing 14
Edge Sizing 15
Edge Sizing 16
Edge Sizing 17
Edge Sizing 18
Edge Sizing 19
Edge Sizing 20
Edge 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
8/7/2019 12:47 PM
Edge Sizing 21
0.000
1.000
2.000 (m)
0.500
1.500


Outline
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
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
8/7/2019 12:48 PM
Edge Sizing 22
0.000
1.000
2.000 (m)
0.500
1.500

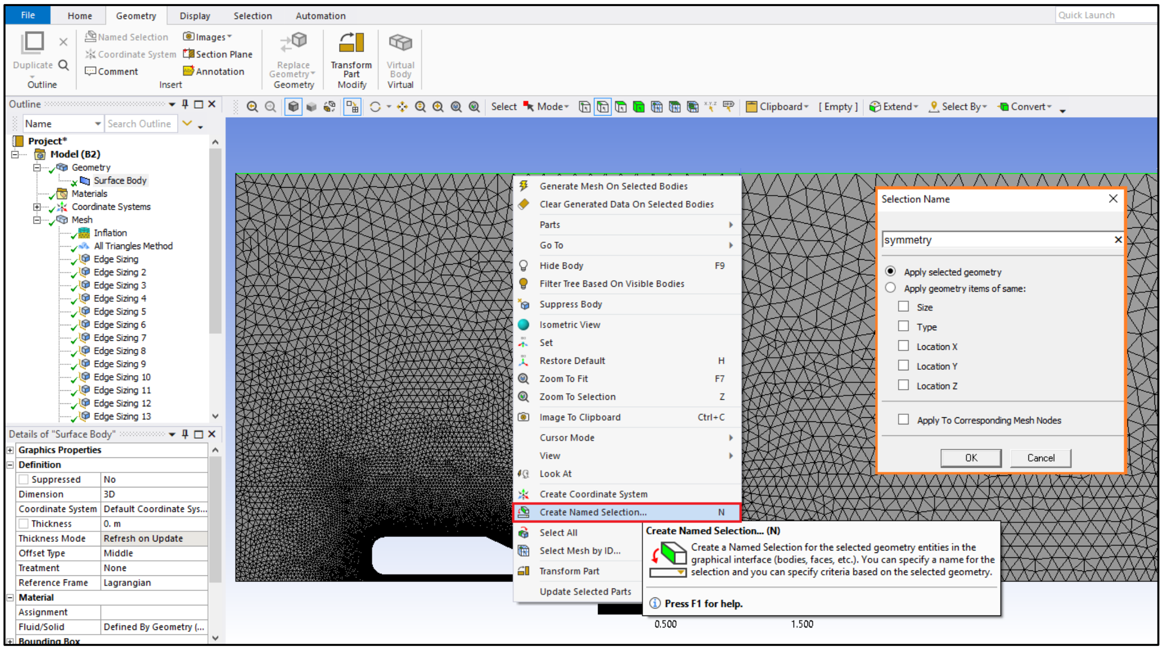
5.6. Click on **Mesh** under the **Outline** and change the **Physics Preference** to **CFD**.



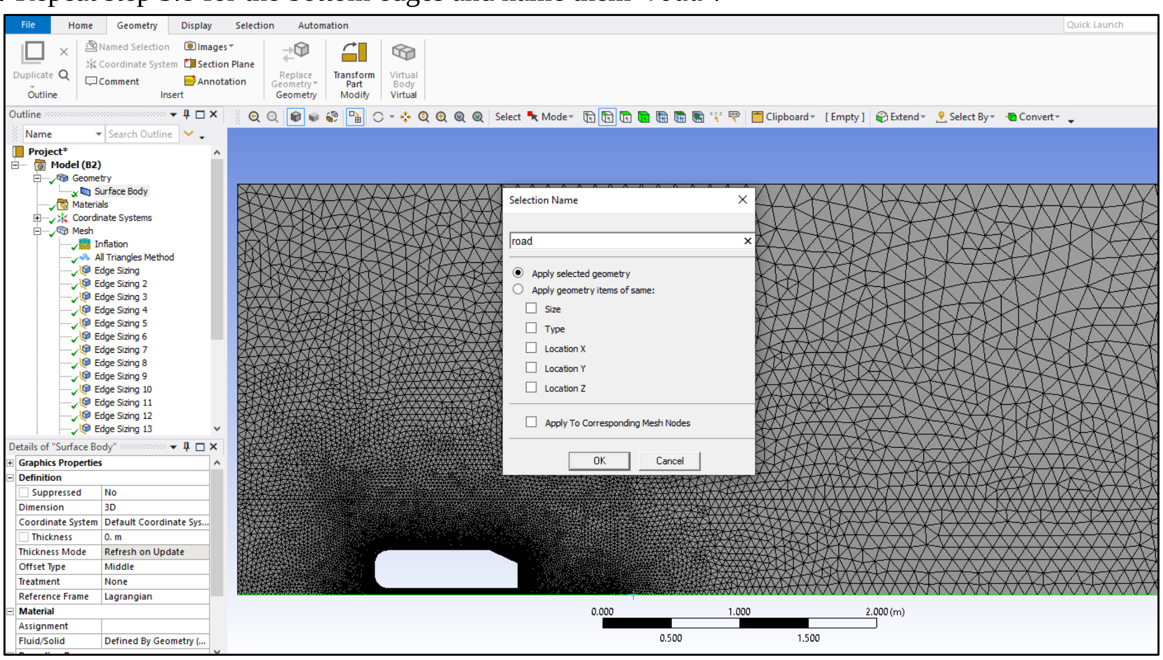
5.7. Click **Generate Mesh**.



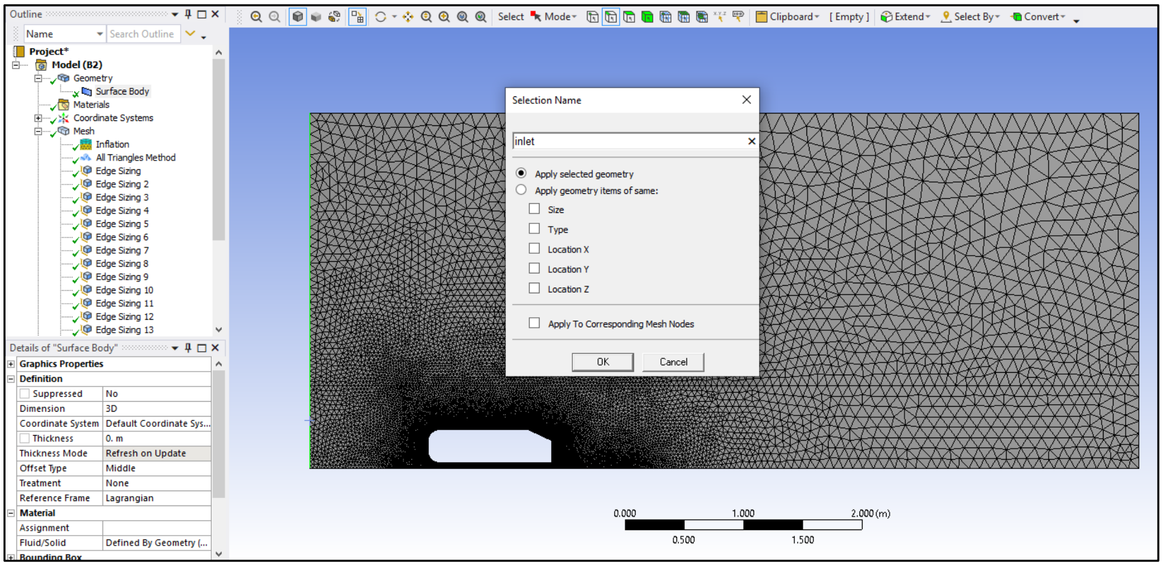
5.8. Select 'Edge Selector'. Select the top edges of the domain by holding **Ctrl** while selecting, right click, select **Create Named Selection** from the dropdown menu. Name the top edge *'symmetry'*.



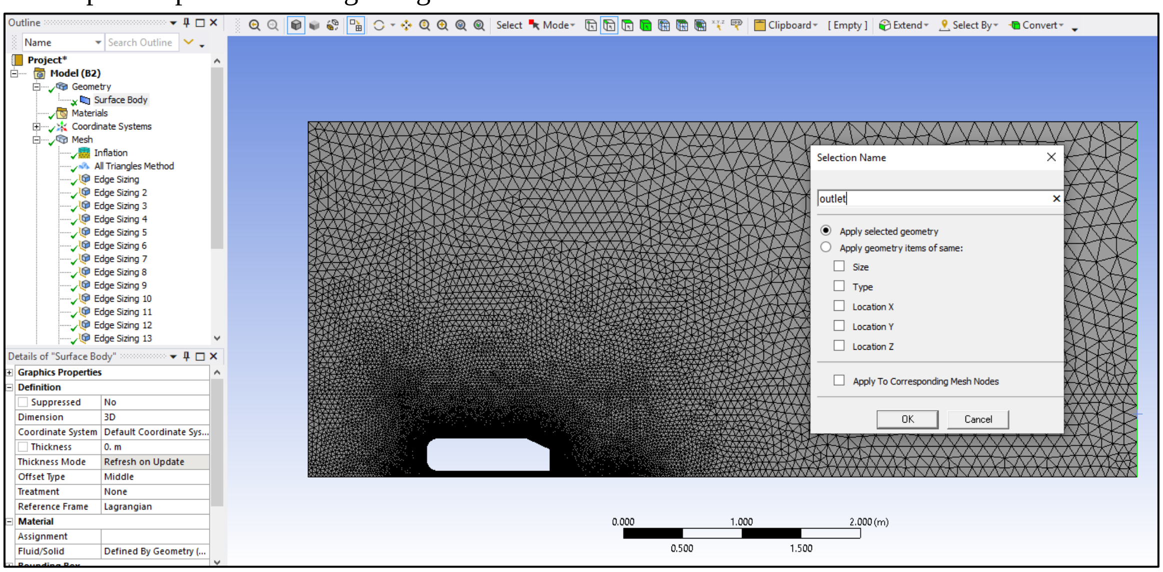
5.9. Repeat step 5.8 for the bottom edges and name them *'road'*.



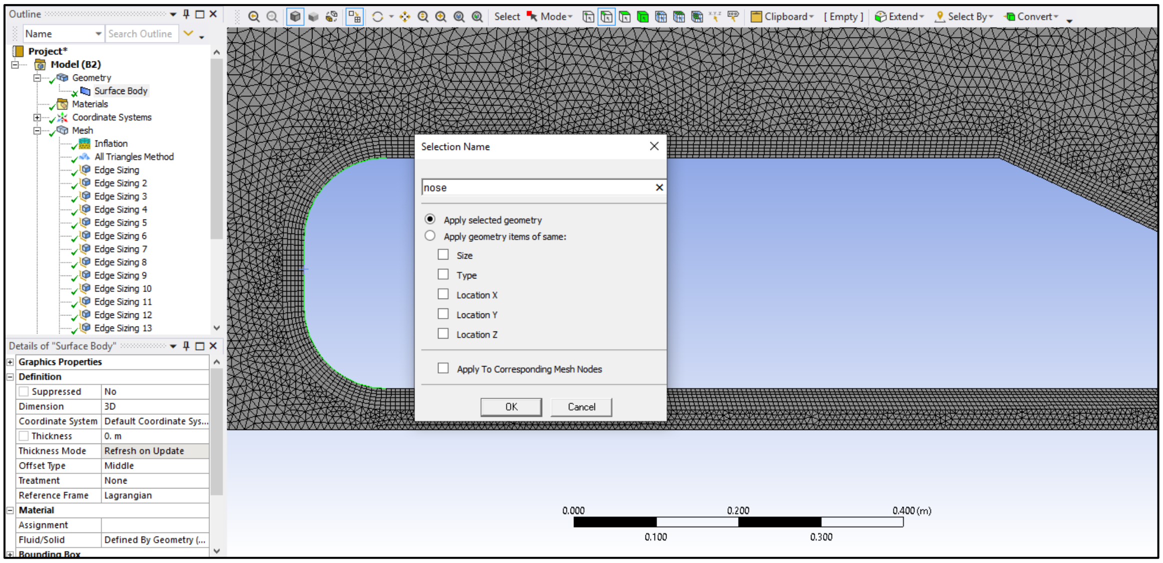
5.10. Repeat step 5.8 for the left edges and name them *'inlet'*.



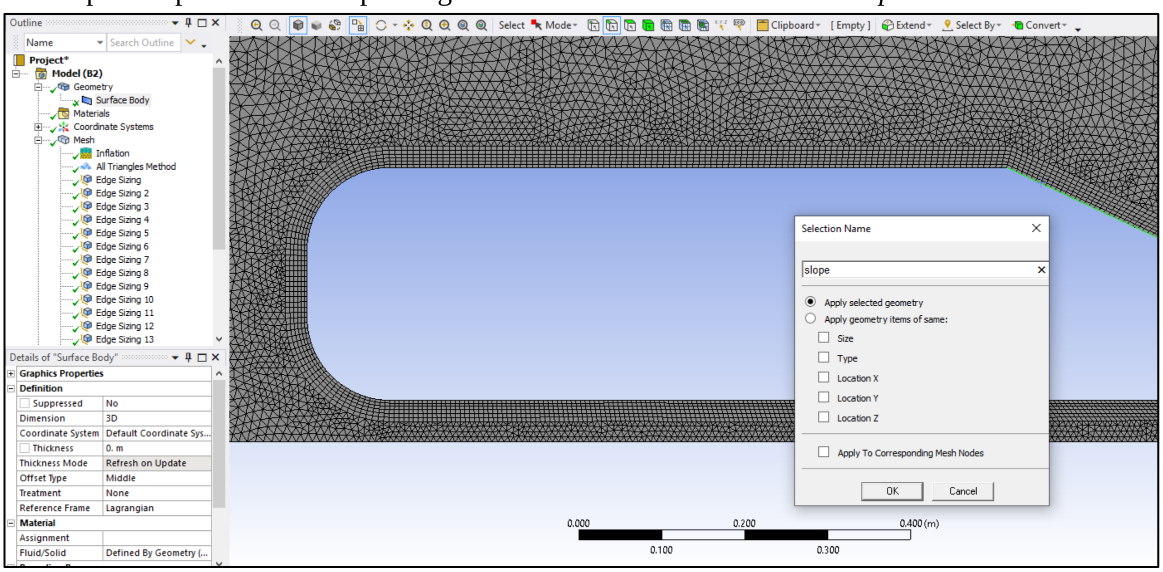
5.11. Repeat step 5.8 for the right edges and name them *'outlet'*.



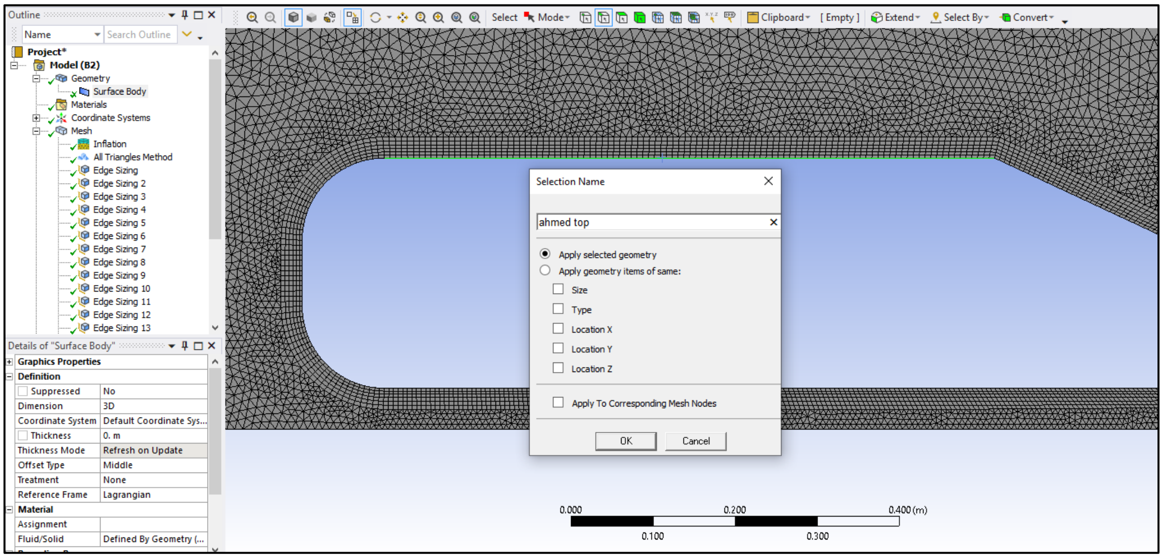
5.12. Repeat step 5.8 for the filleted corners and the straight segment that connects them and name them *'nose'*.



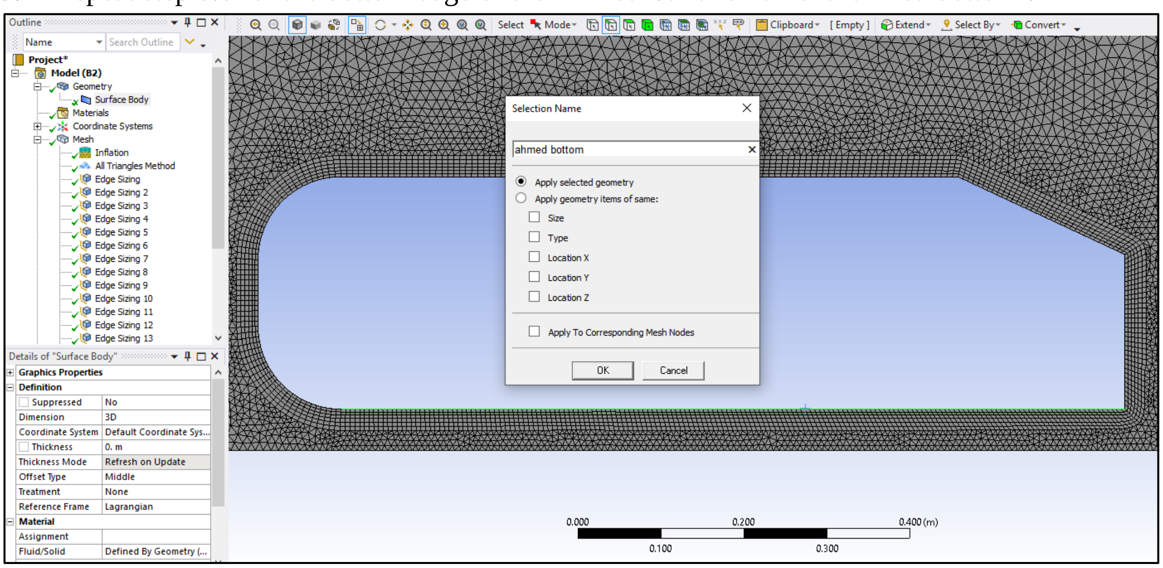
5.13. Repeat step 5.8 for the sloped edge of the Ahmed Car and name it *'slope'*.



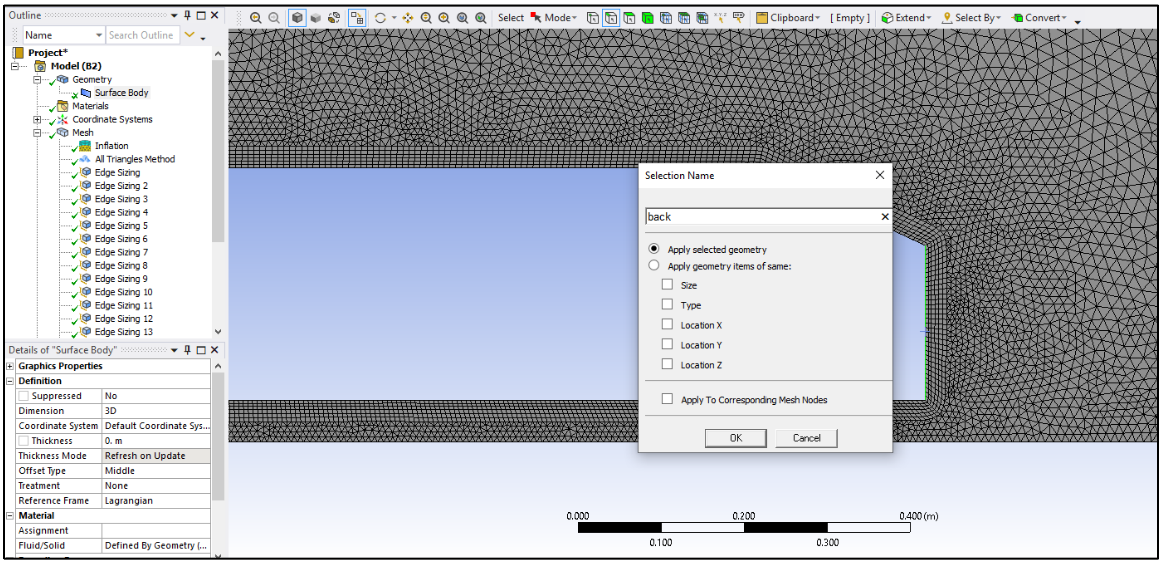
5.14. Repeat step 5.8 for the top edge of the Ahmed Car and name it *'ahmed top'*.



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

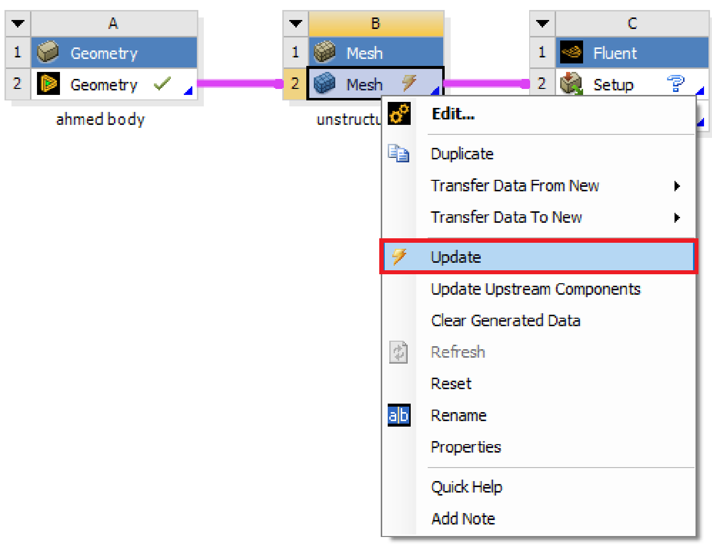


5.16. Repeat step 5.8 for the right vertical edge of the Ahmed Car and name it *back*.



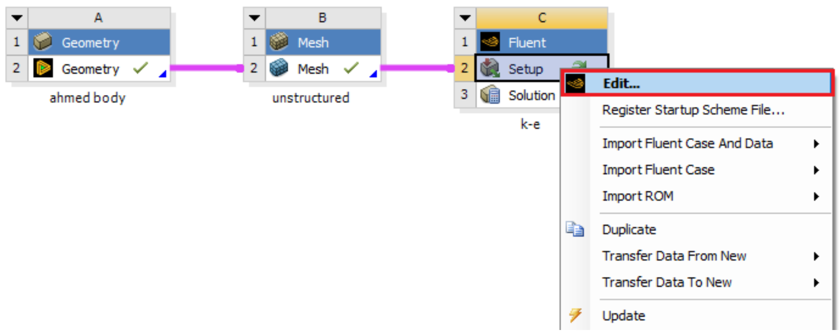
5.17. **File** > **Save Project**. Close **Meshing** window.

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

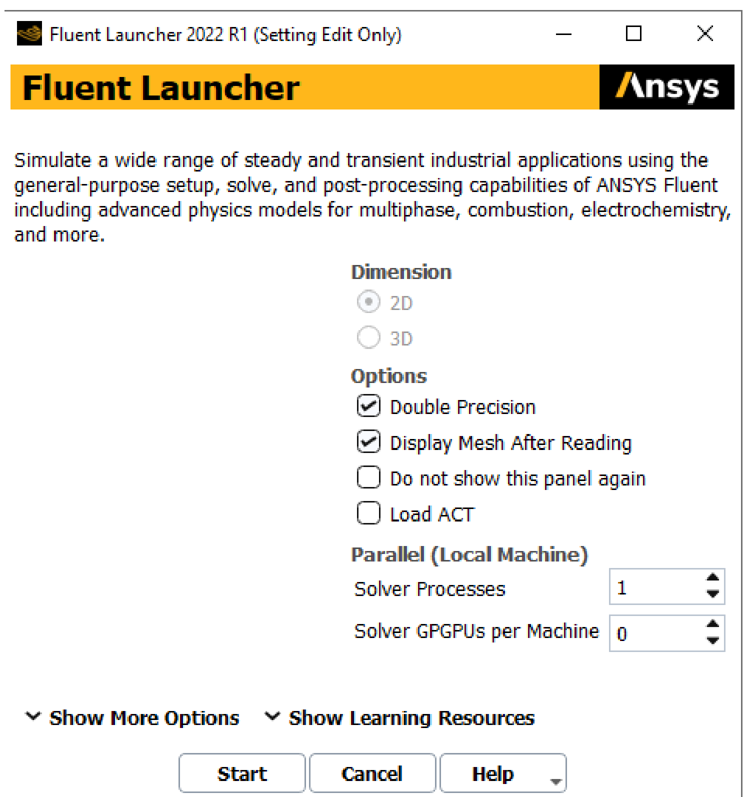


6. Setup

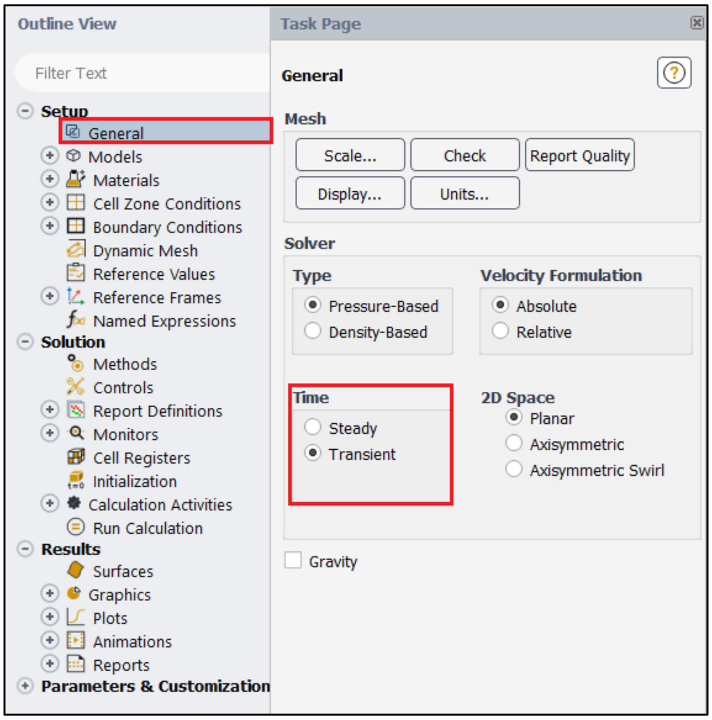
6.1. Right click **Setup** and select **Edit…**



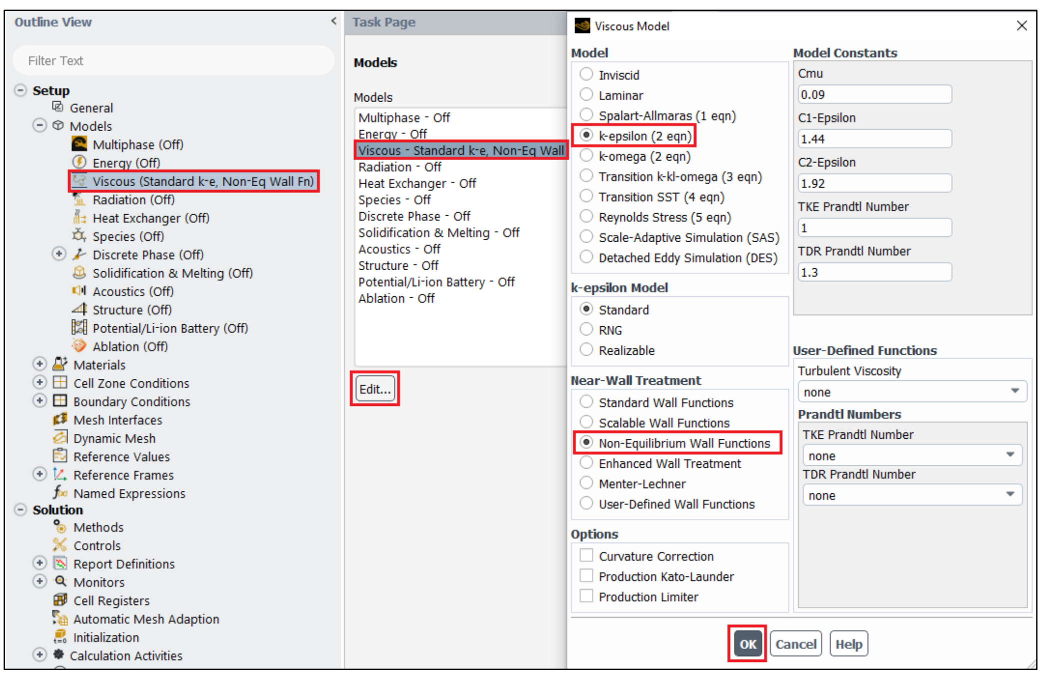
6.2. Select **Double Precision** and click **START.**



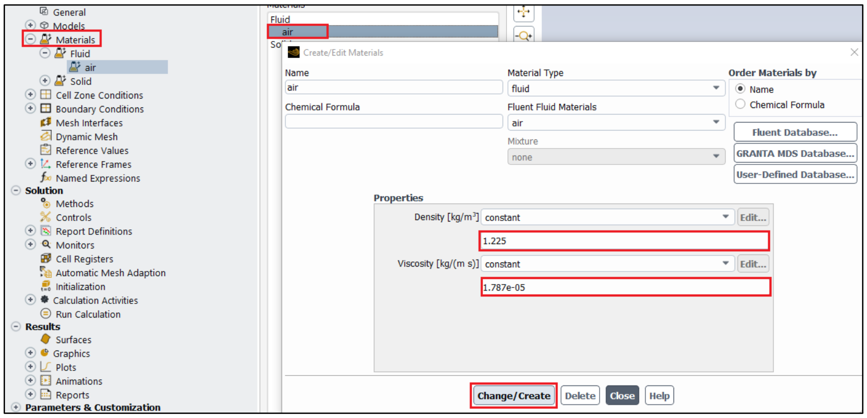
6.3. Setup > **General**. Change **Solver** to **Transient** as per below.



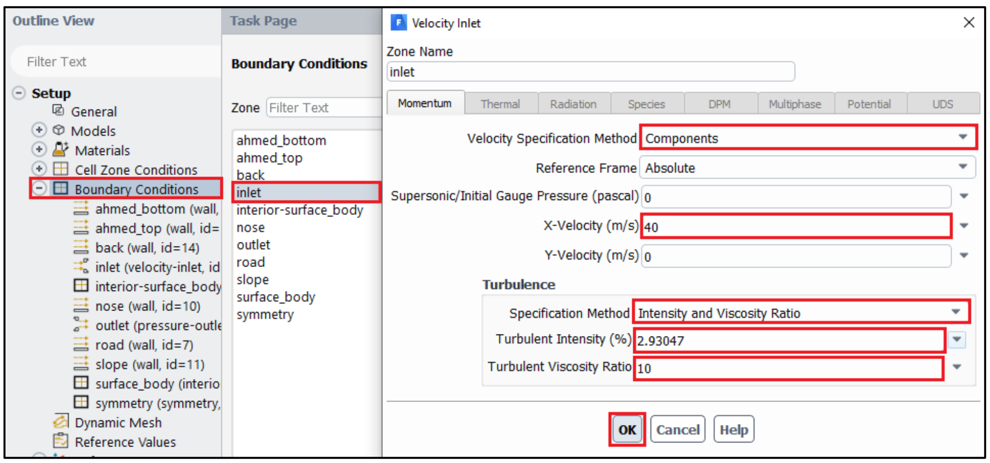
6.4. Setup > **Models** > **Viscous** > **Edit…** Change the turbulent model and near-wall treatment as per below.



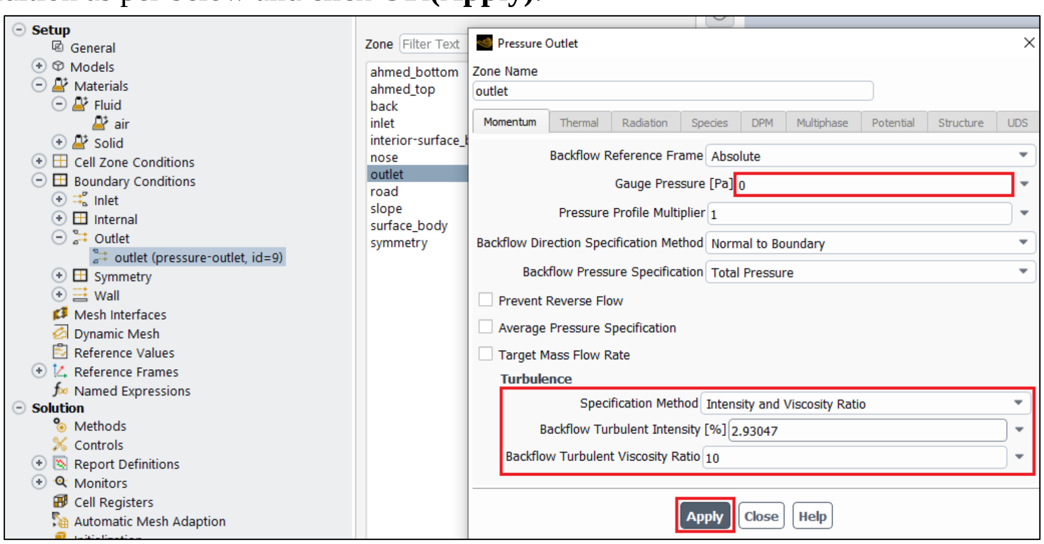
6.5. **Setup** > **Materials** > **Fluid** > **air** > **Create/Edit…** Change the air **Density** and **Viscosity** as per below and click **Change/Edit** then close the window.



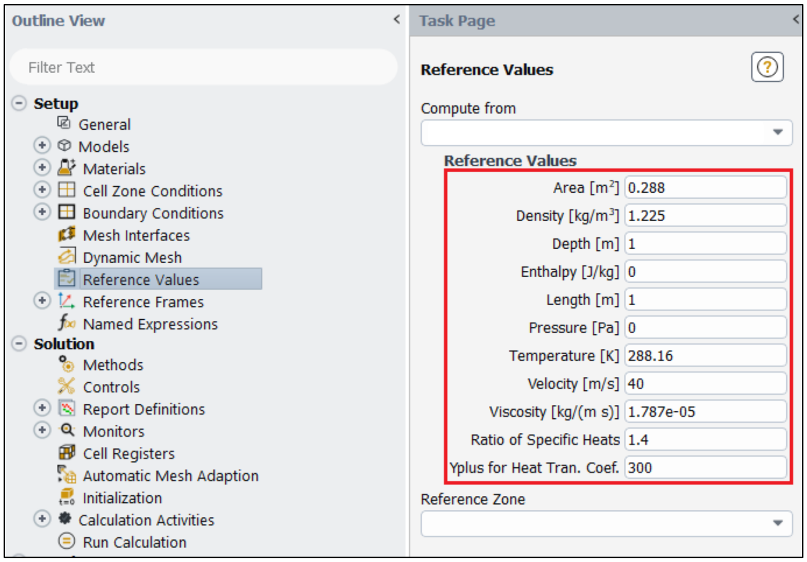
6.6. **Setup** > **Boundary Conditions** > **inlet** > **Edit…** Change the inlet boundary conditions as per below and click **OK(Apply)**.



6.7. **Setup** > **Boundary Conditions** > **Zone** > **outlet** > **Edit…** Change the outlet boundary condition as per below and click **OK(Apply)**.

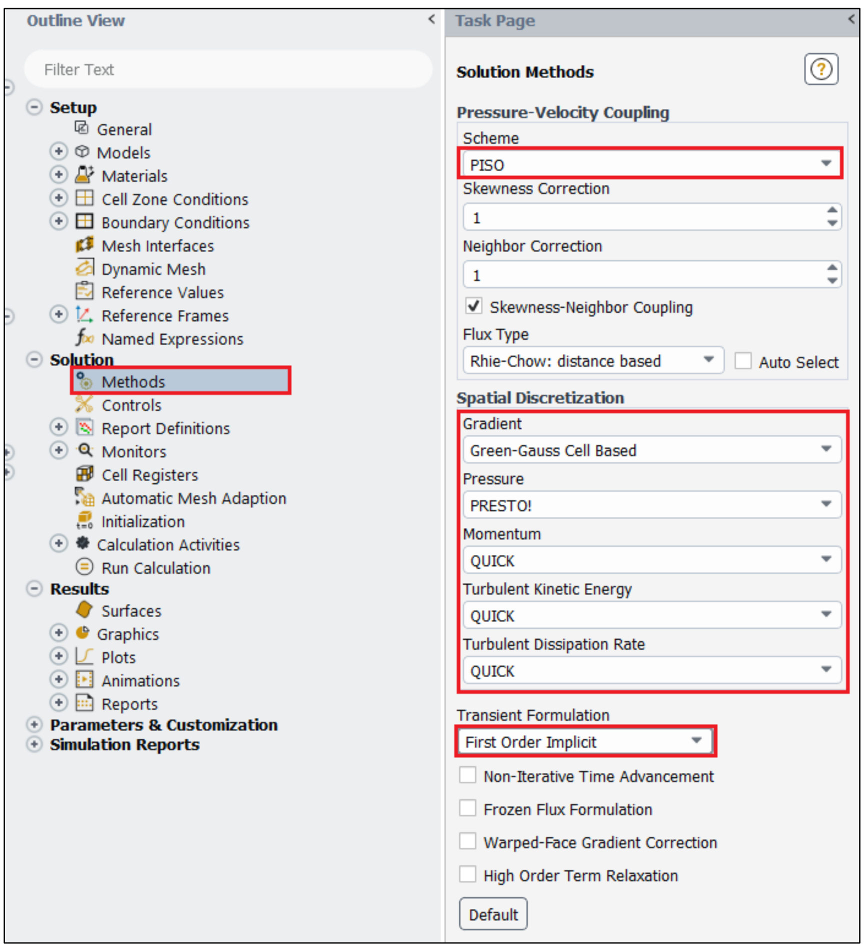


6.8. Setup > **Reference Values**. Change the reference values as per below.

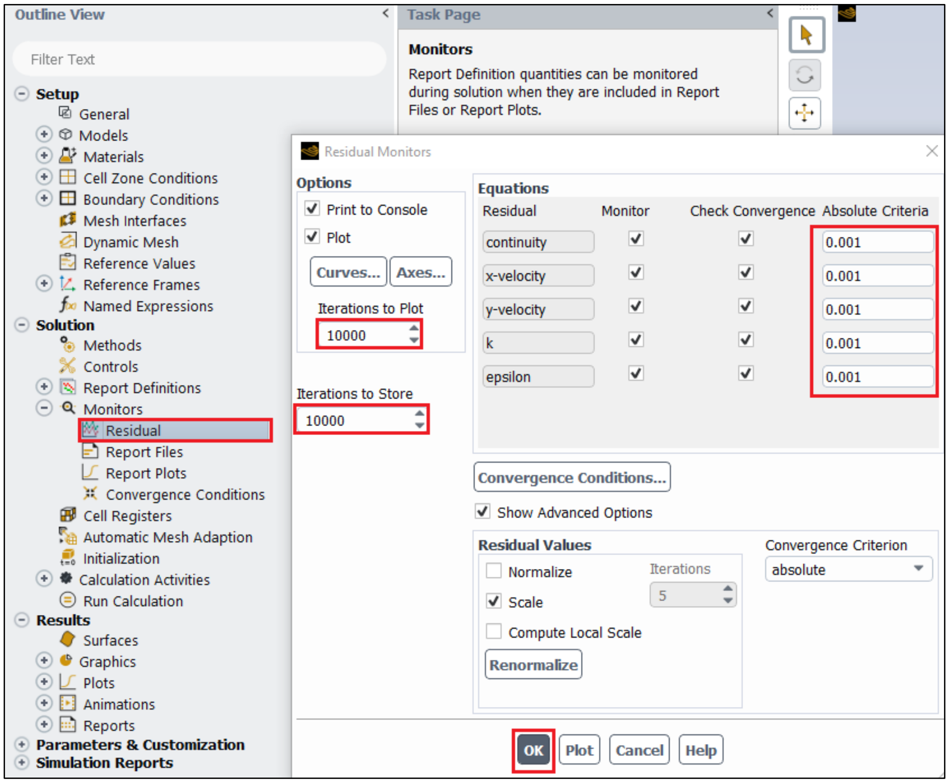


In case of '*Yplus for Heat Tran. Coef*' leave it as a default value (300)

6.9. Solution > **Methods**. Change solutions methods as per below.

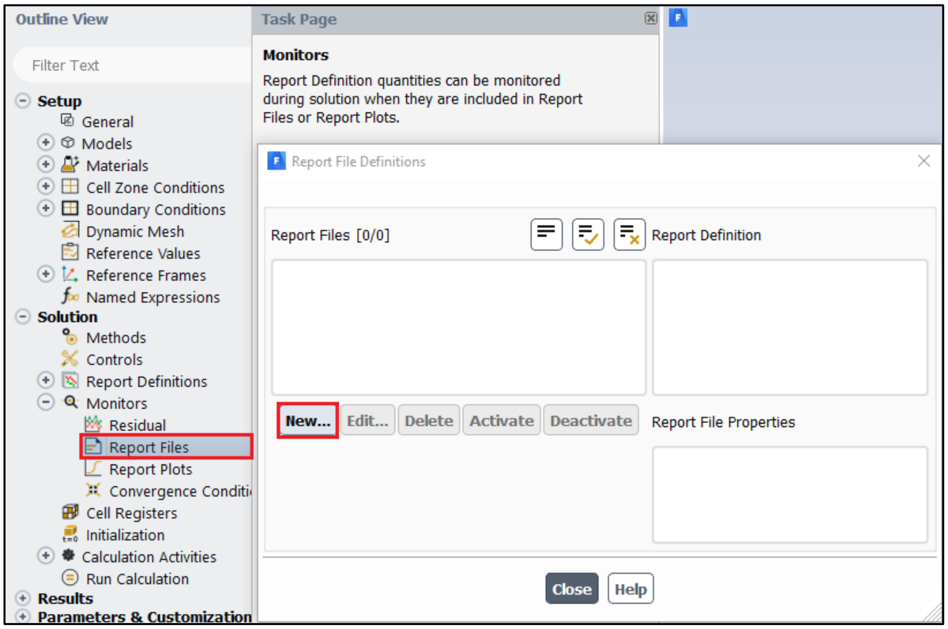


6.10. Solution > **Monitors** > **Residuals.** Change the parameters as per below and click ok.

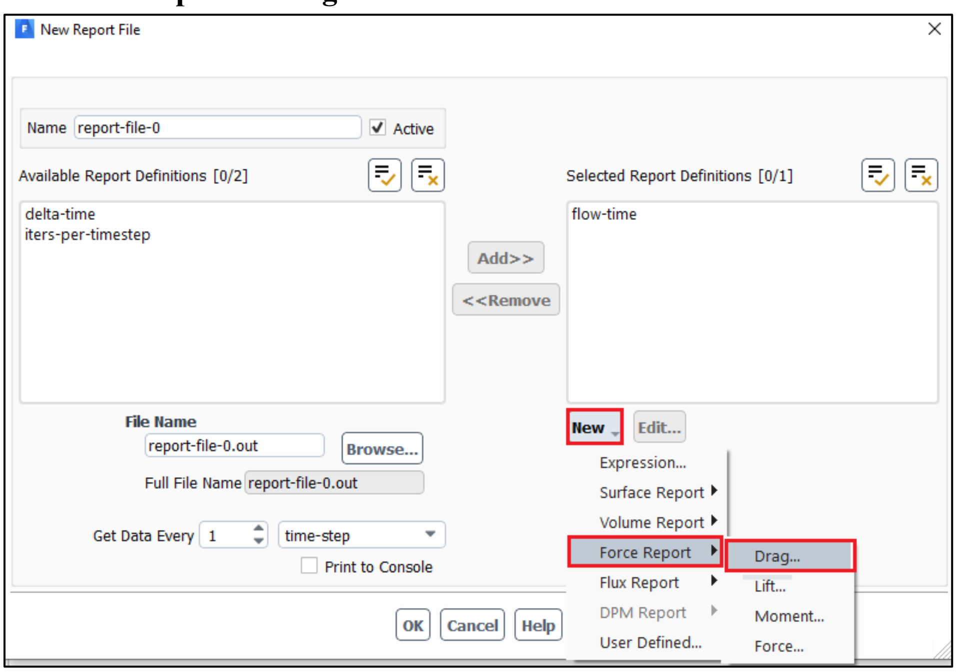


*Step 6.11~6.14 is for saving the time history file of the total drag coefficient.

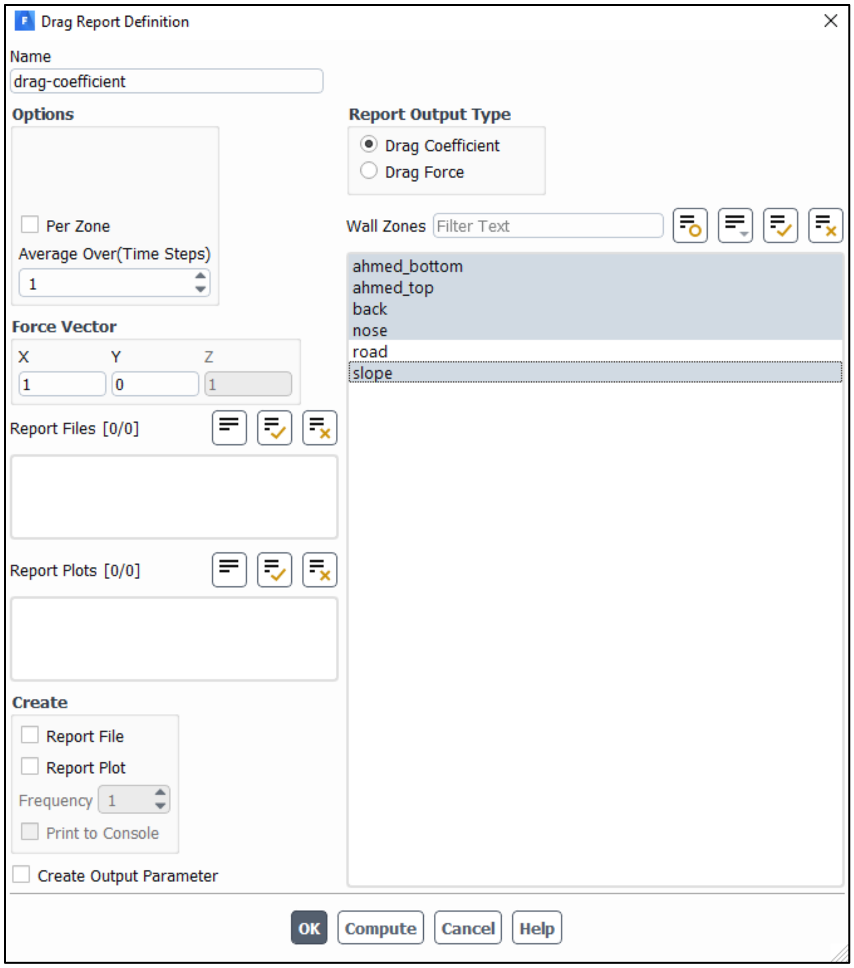
6.11. Solution > Monitors > Report Files > New…



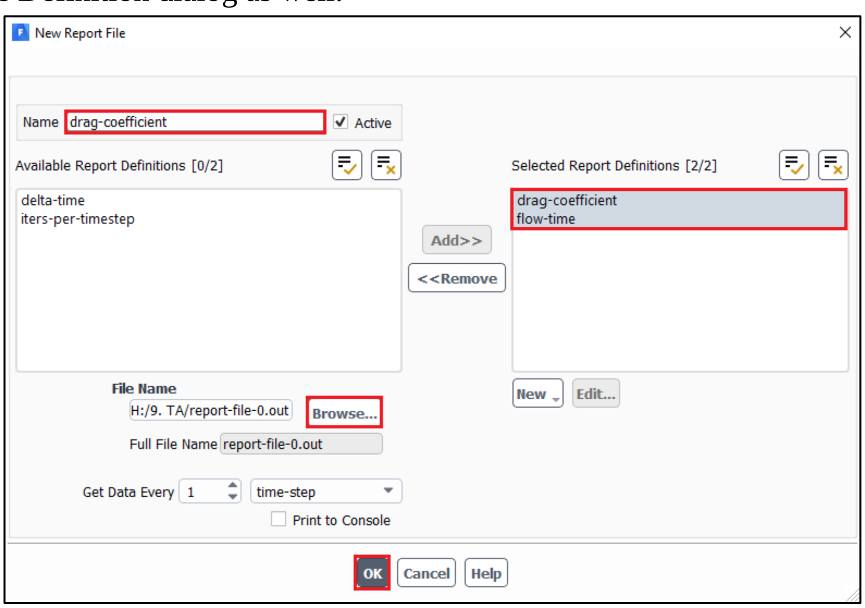
6.12. New > Force Report > Drag….



6.13. Change name, select wall zones as below and click **OK(Apply)** to exit.

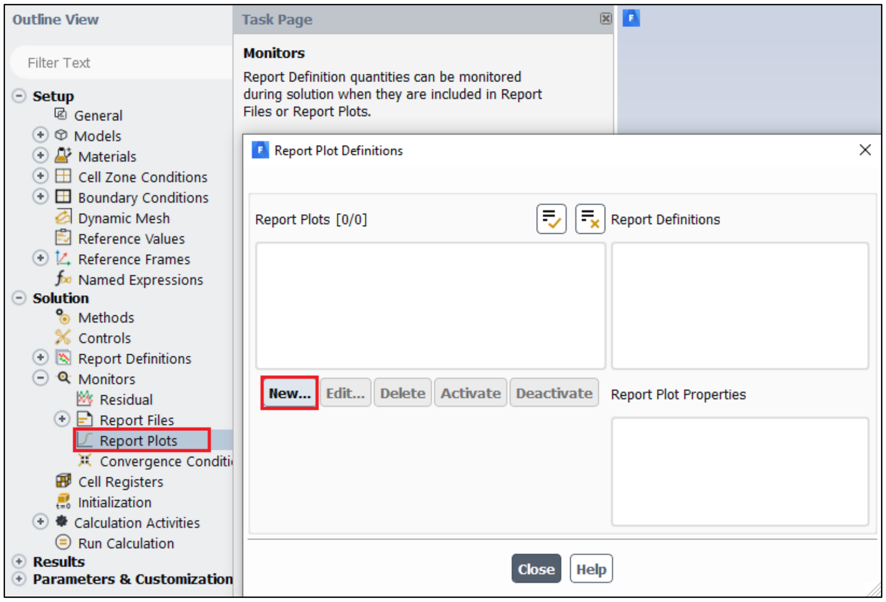


6.14. Change name and click **Browse** to locate the file. Click **OK(Apply)** to exit. Exit the Report File Definition dialog as well.

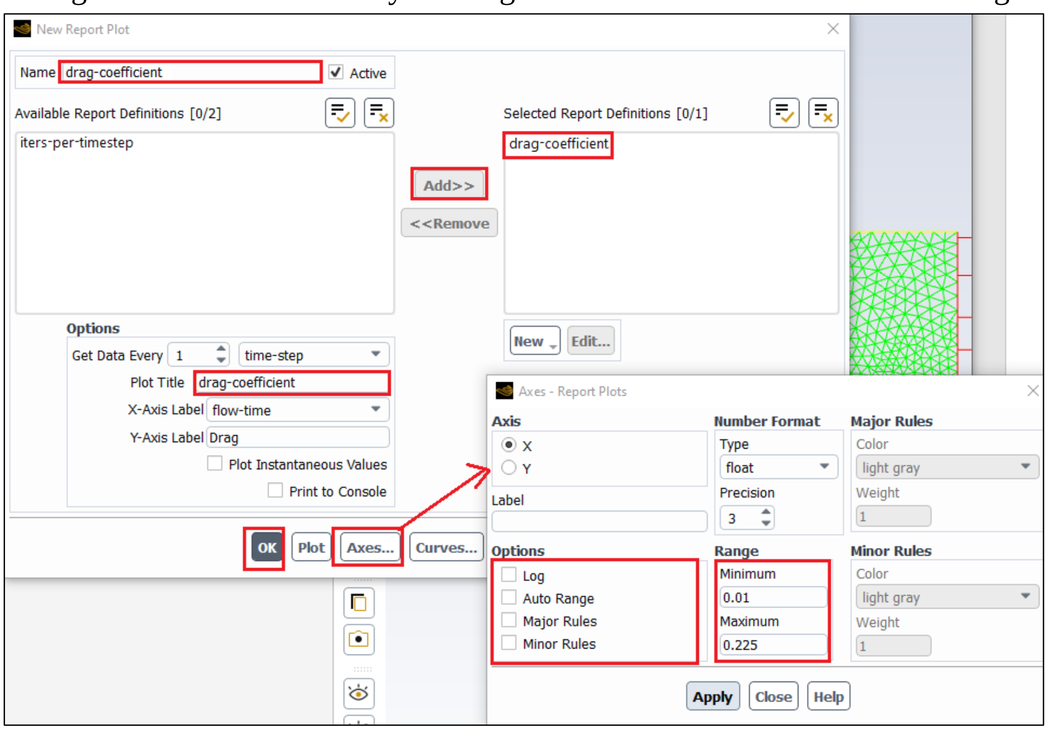


*Step 6.15~6.16 is for the plotting of the time history of the total drag coefficient during the computation.

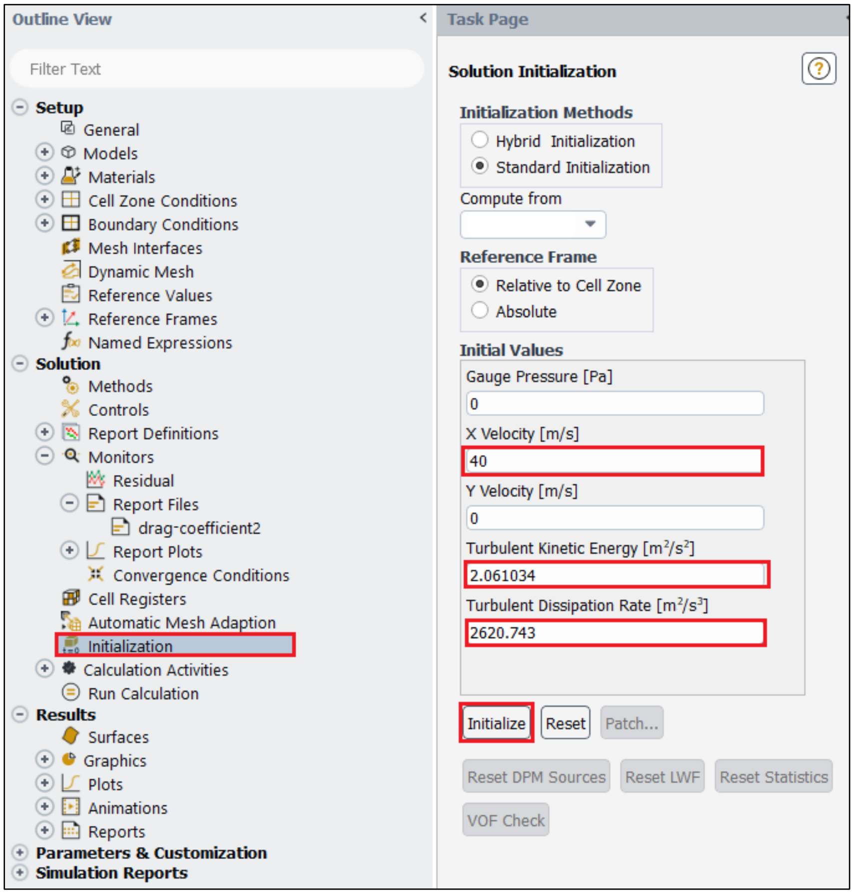
6.15. Solution > Monitors > Report Plots > New…



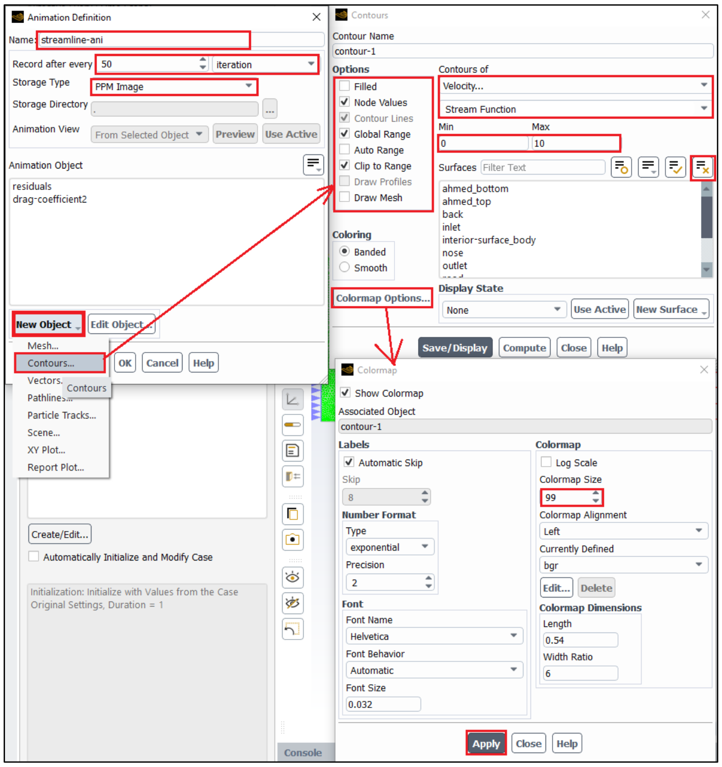
6.16. Select drag-coefficient generated from step 6.12~6.13 and **add** to right. Name the plot and change the x-axis condition by clicking **Axes…** as below. Exit from all dialogs.



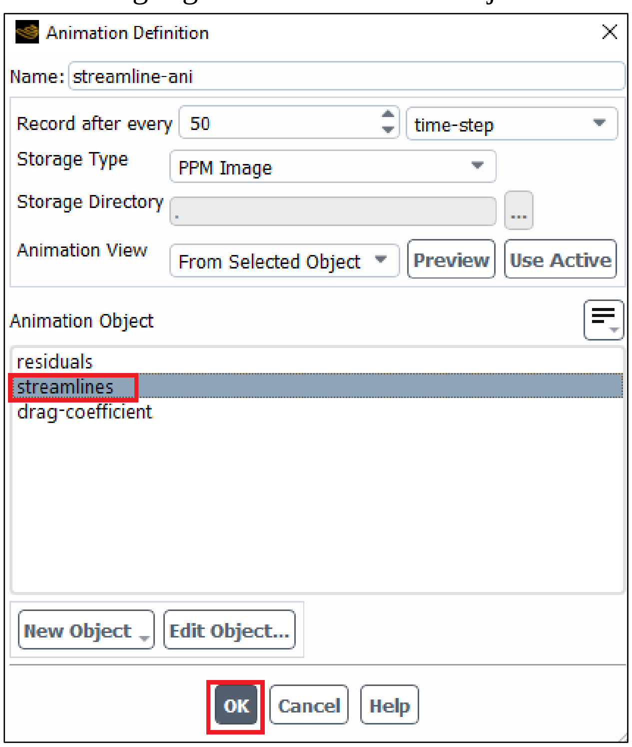
Solution > **Initialization**. Change **X-Velocity** and turbulent parameters as per below. Click **Initialize.**



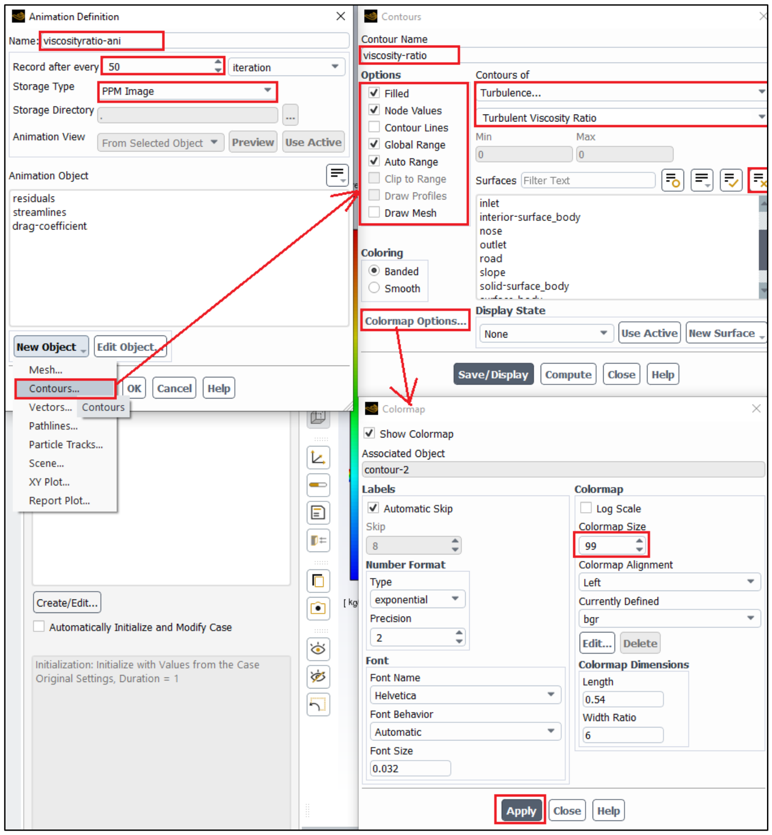
6.17. **Solution** > **Calculation Activities** > **Solution Animations** (right click) > **New...** Change the parameters as per below.



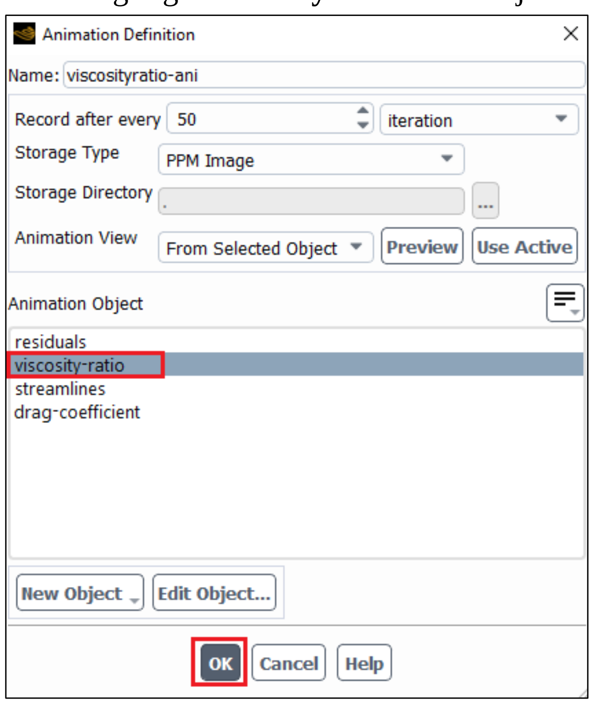
6.18. After 6.18, make sure to highlight **streamline** as an object and then close by clicking **OK**.



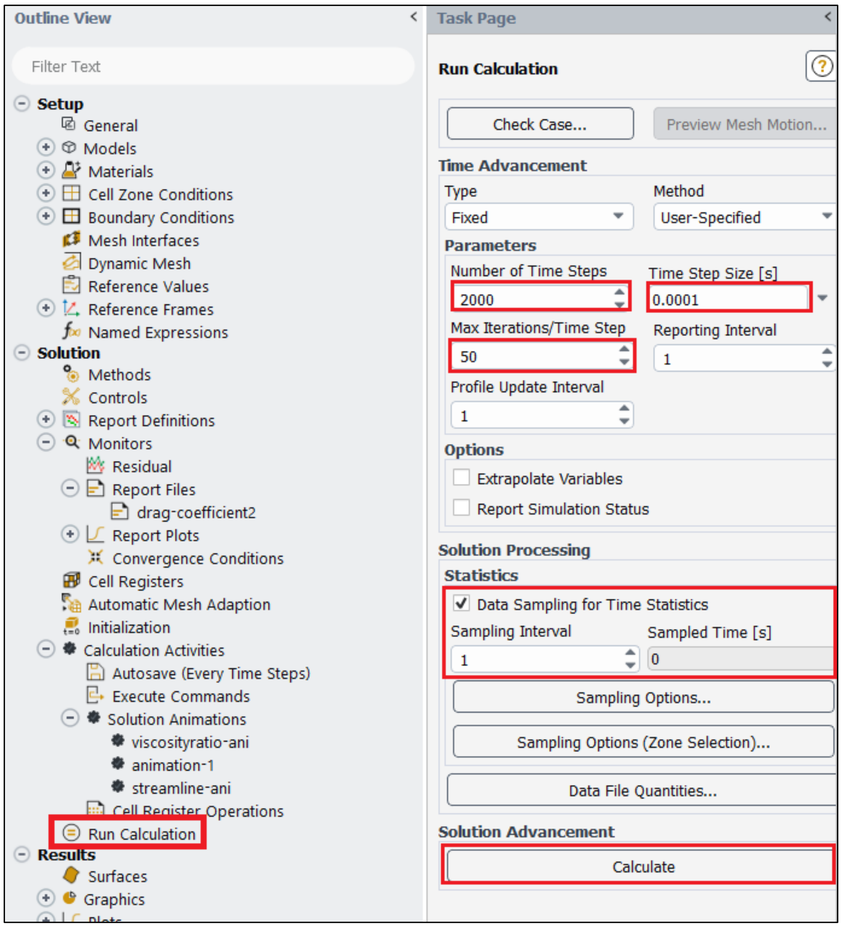
6.19. **Solution** > **Calculation Activities** > **Solution Animations** (right click) > **New...** Change the parameters as per below.



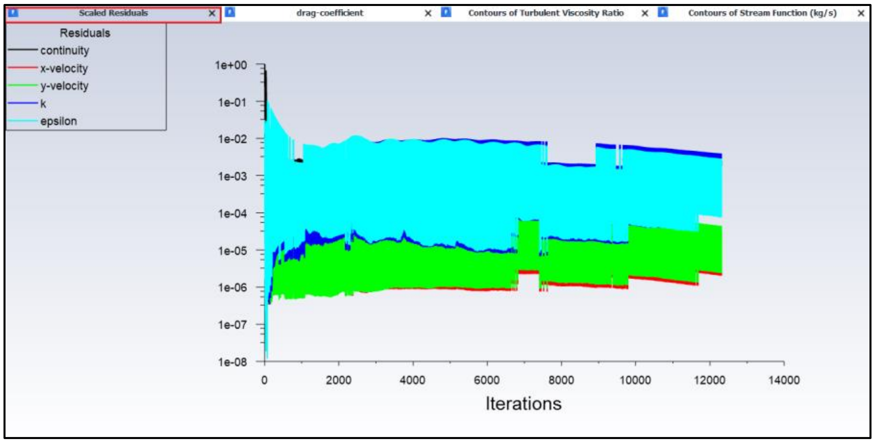
6.20. After 6.20, make sure to highlight **viscosity-ratio** as an object and then click **OK**.

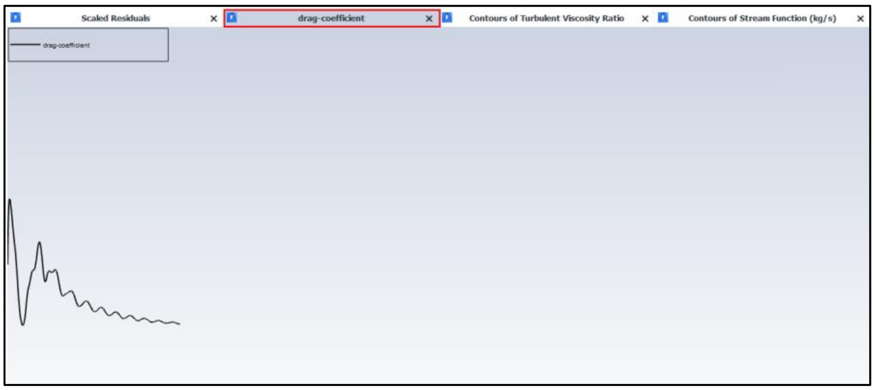


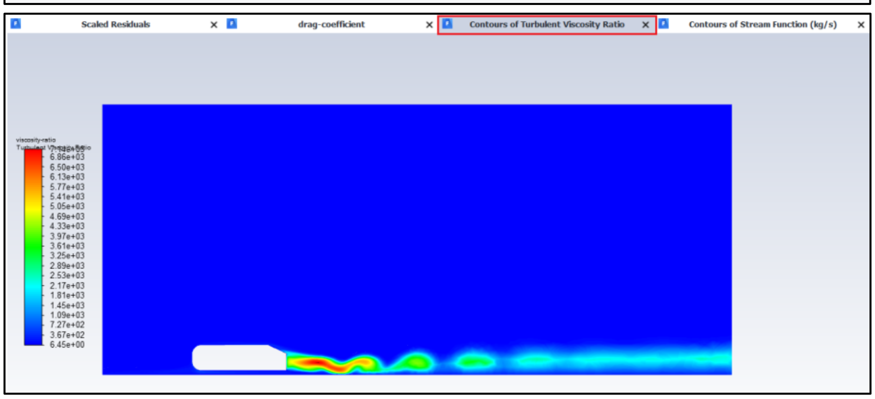
6.21. **Solution** > **Run Calculation**. Change parameters as per below and click **Calculate**. If you have the correct setup you should see four tabs on the upper sides of the display. You can change what the window shows by changing the tab. Tab 1-4 shows the residuals, streamlines, turbulent viscosity ratio and time-history of drag coefficient. After running for about 0.05 flow time you should see vortices at the back of the ahmed car on tab 2 and 3. **NOTE: This simulation could take up to an hour depending on the computer performance. Please make sure your setup is correct before running the simulation! If you close <u>Fluent window</u> after running the simulation, the data for the post-process is not lost, but harder to access. If at all possible, finish post-processing after solving. Accessing the time-history of drag coefficient and post processing videos after the Fluent window is closed will be explained in later sections.**

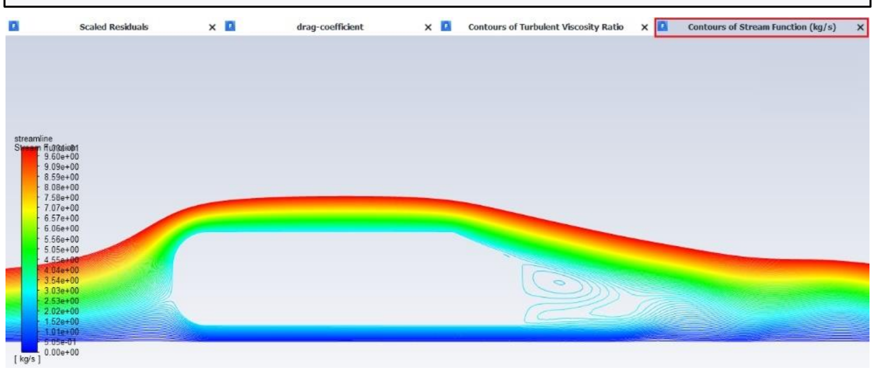


After the computation, you should see the images below:





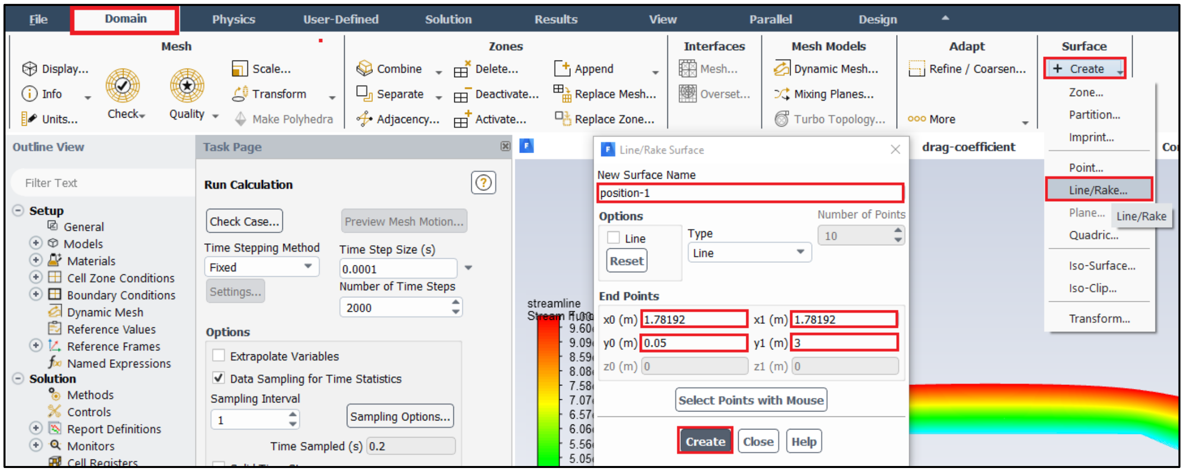




7. Results

7.1. Creating lines to plot modified TKE and modified U.

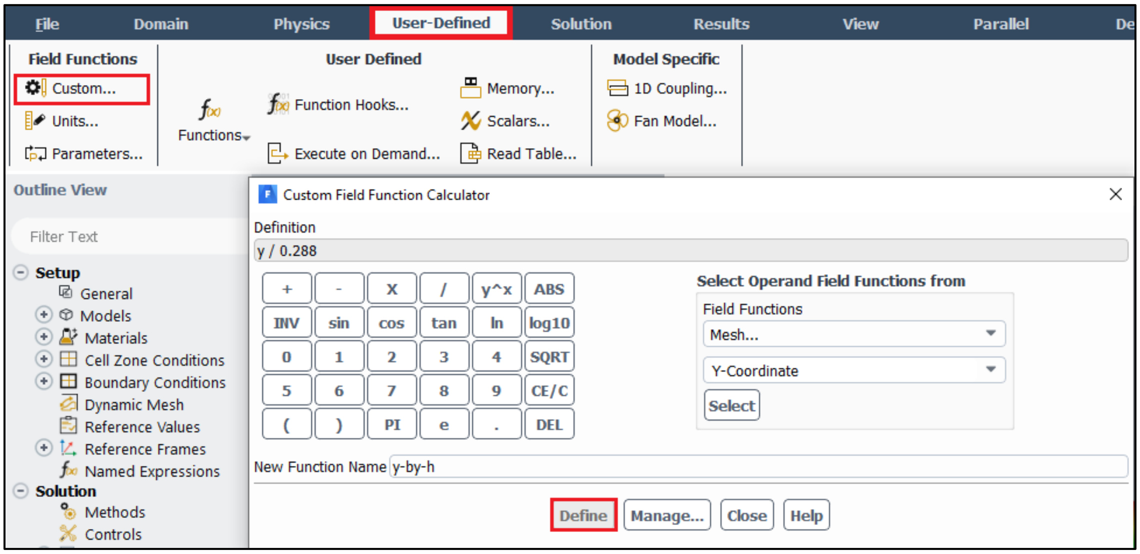
Setting Up Domain > **Surface** > **Create** > **Line/Rake**. Create 10 lines at the locations given at the table below.



Surface Name	x0	y0	x1	y1
position-1	1.78192	0.05	1.78192	3
position-2	1.932	0.05	1.932	3
position-3	1.98208	0.05	1.98208	3
position-4	2.03191	0.05	2.03191	3
position-5	2.08201	0	2.08201	3
position-6	2.13212	0	2.13212	3
position-7	2.23206	0	2.23206	3
position-8	2.332	0	2.332	3
position-9	2.482	0	2.482	3
position-10	2.6819	0	2.6819	3

7.2. Creating custom function

User-Defined > **Field Functions > Custom**. Create custom field functions and click **Define**. You will need to create three custom field functions shown in the table below.



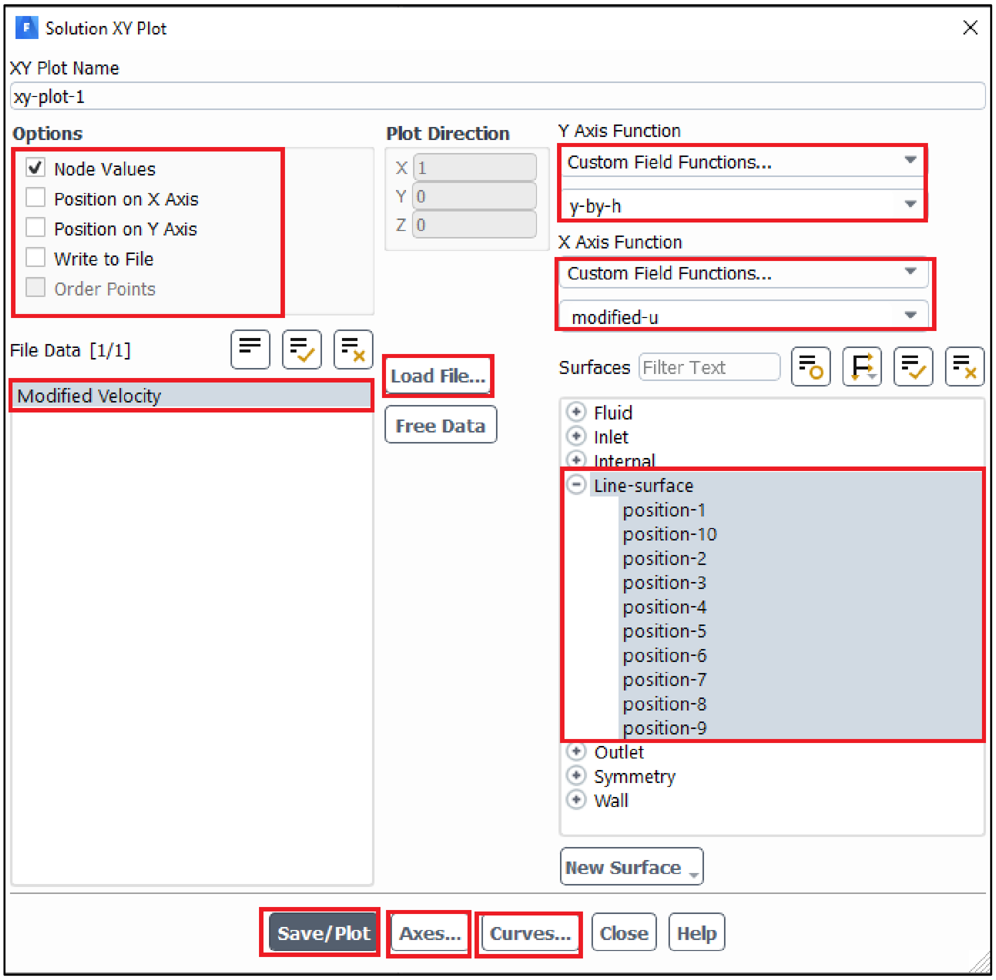
Function Name	Definition
y-by-h	y / 0.288
Modified-U	(mean-x-velocity / 120) + (x / 0.288)
Modified-TKE	(turb-kinetic-energy / 500) + (x / 0.288)

Operand field function including x and y position, mean-x-velocity and turb-kinetic-energy can be found in the following table:

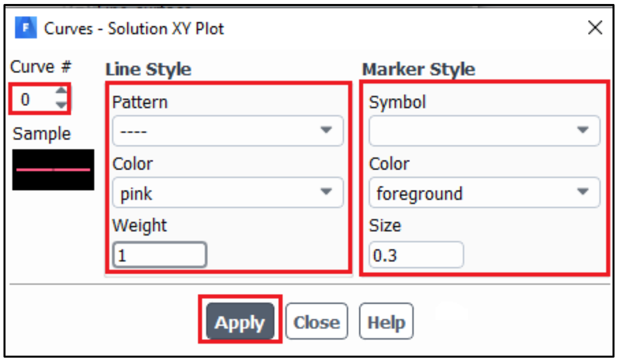
Operand field function	From field functions
x, y	Mesh
Mean-x-velocity	Unsteady statistics
Turb-kinetic-energy	Turbulence

7.3. Plotting values along the lines created

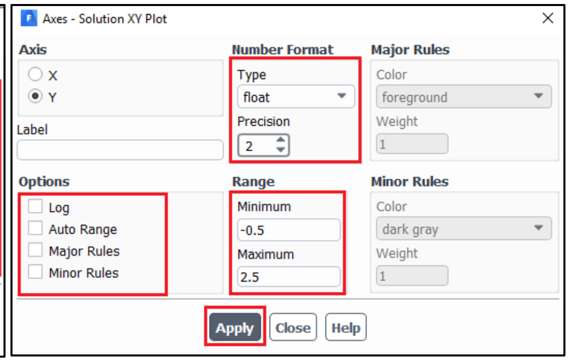
Results > **Plots** > **XY Plot** > **Set Up**. Click **Load File…** and load the experimental data. Select the lines you created (position-1 through position-10) and experimental data then click **Plot**. (Note: You can download the 'Modified_u_slant25.xy' file from the class website for plotting the *'Modified-u vs. y-by-h'* figure. For *'Modified-TKE vs. y-by-h'* figure, please plot CFD values only)



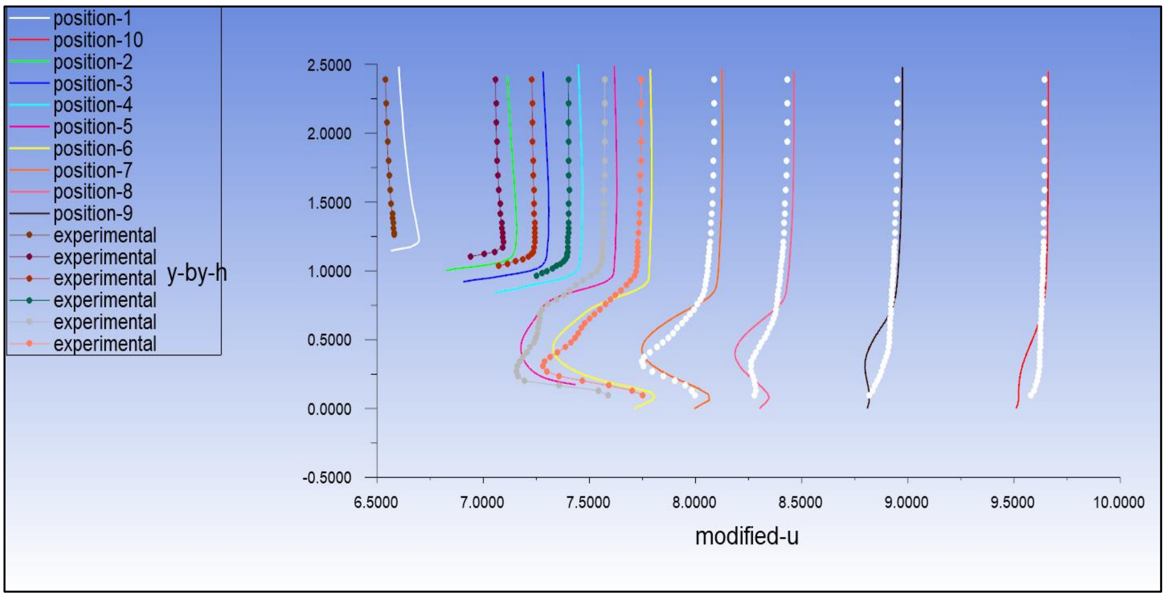
Note: You can change the style and color of the data by clicking **Curves** button and changing the parameters below then clicking **Apply**. Click **Axes…** and adjust the Y axis maximum to 2.5 and minimum to -0.5.


Curves - Solution XY Plot
Curve #
0
Sample
Line Style
Pattern

Color
pink
Weight
1
Marker Style
Symbol
Color
foreground
Size
0.3
Apply
Close
Help

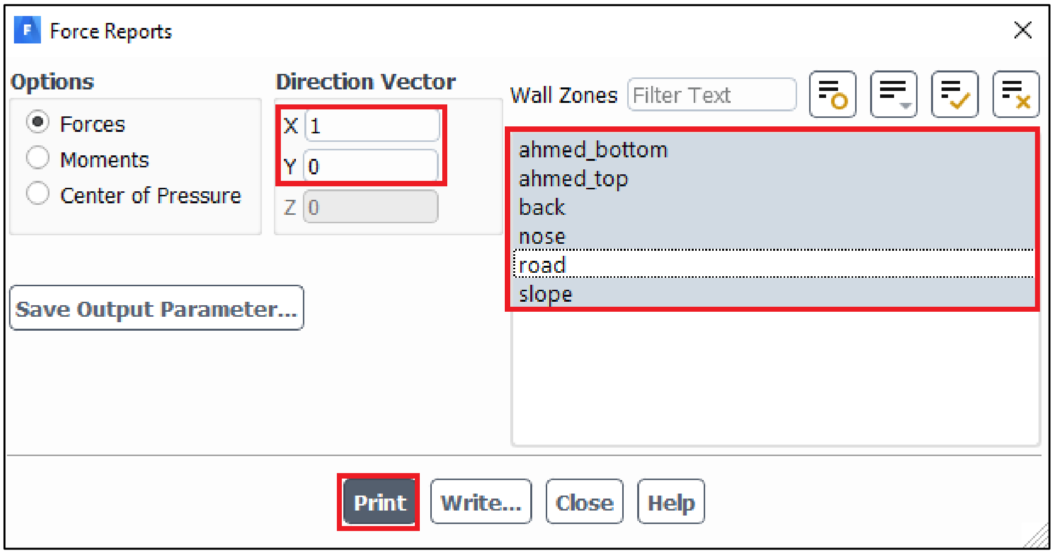

Axes - Solution XY Plot
Axis
X
Y
Label
Number Format
Type
float
Precision
2
Major Rules
Color
foreground
Weight
1
Options
Log
Auto Range
Major Rules
Minor Rules
Range
Minimum
-0.5
Maximum
2.5
Minor Rules
Color
dark gray
Weight
1
Apply
Close
Help

Result:


position-1
position-10
position-2
position-3
position-4
position-5
position-6
position-7
position-8
position-9
experimental
experimental
experimental
experimental
experimental
experimental
y-by-h
2.5000
2.0000
1.5000
1.0000
0.5000
0.0000
-0.5000
6.5000
7.0000
7.5000
8.0000
8.5000
9.0000
9.5000
10.0000
modified-u

7.4. Printing drag coefficient components

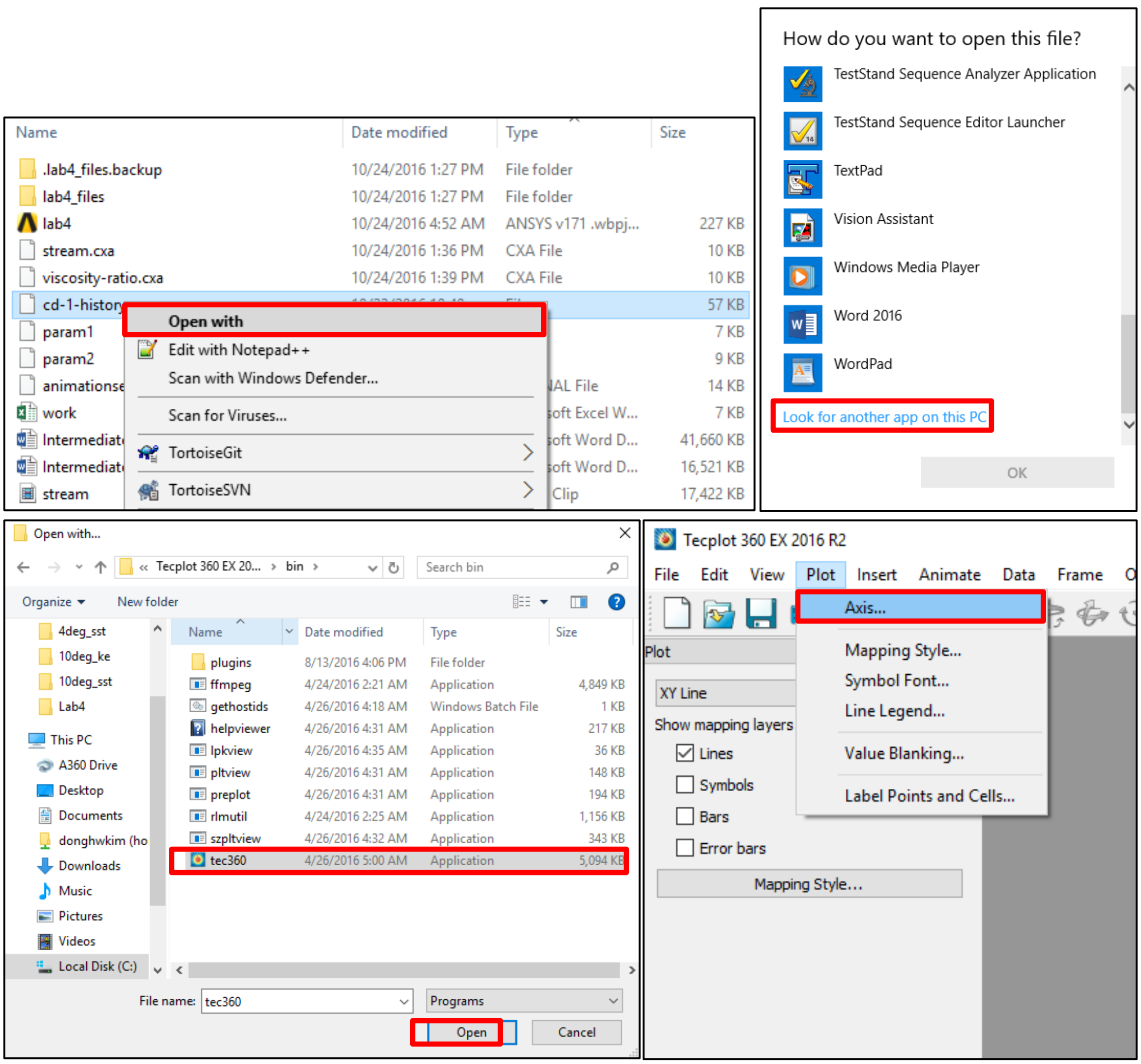
Results > **Reports** > **Forces**. Select the region where you want to calculate the drag coefficient under wall zone then click print.



7.5. Plotting time-history of total drag coefficient in Tecplot

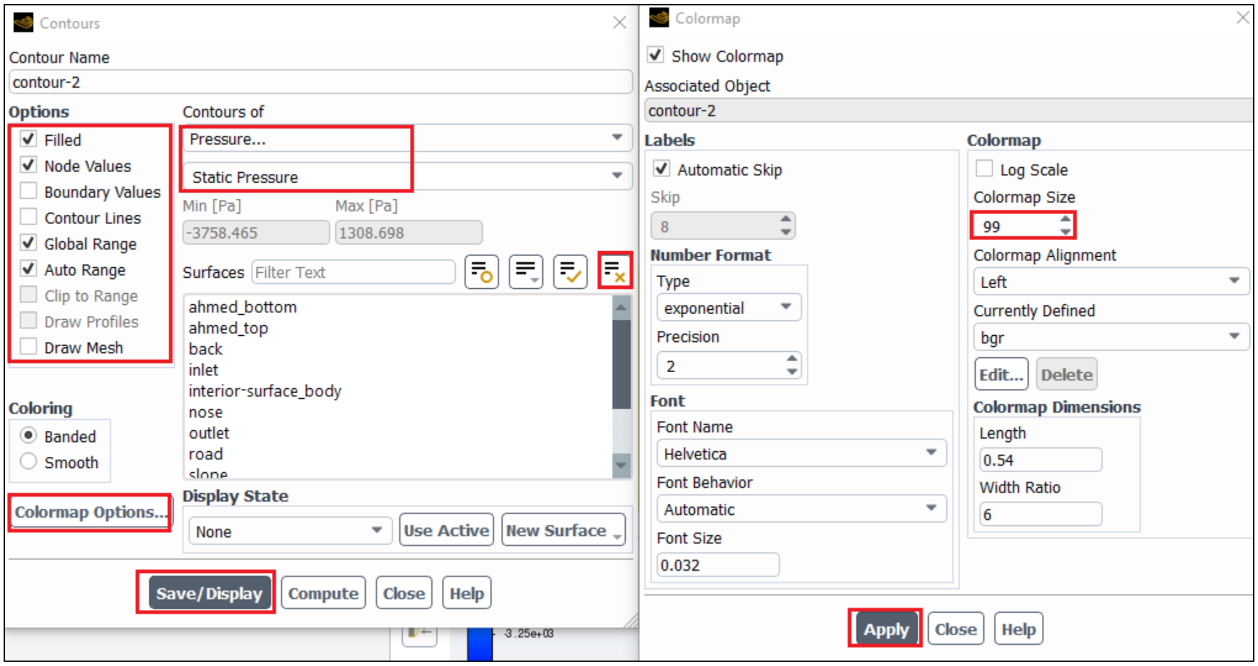
Note: If you closed Fluent without first plotting and saving drag coefficient time history, navigate to "\Lab 4 Project File_files\dp0\FLU\Fluent" and find an ascii file named as "cd-1-history". **You can choose either Excel or Tecplot for plotting with this file:**

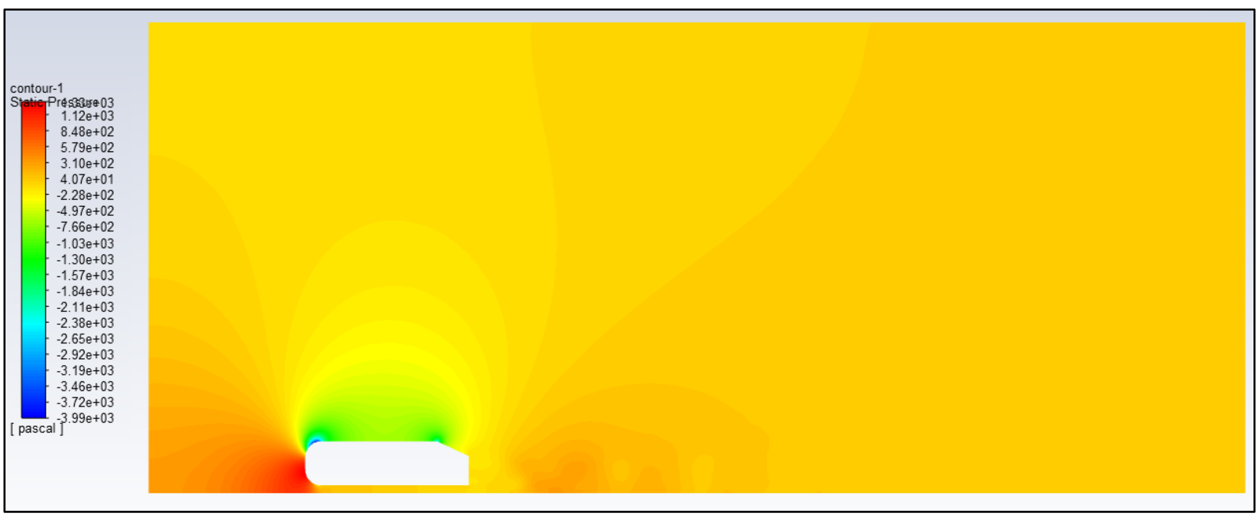
Plotting with Tecplot: Right click on file *cd-1-history* and select **Open** again click **Open** when window asking if you would like to open this file comes up. Click **Browse (or Look for another app in this PC)**, and navigate to C:\Program Files\Tecplot\Tecplot 360 EX 2016 R2\bin and select **tec360** and click **Open,** and in *Open With* window click **Ok** and in *Open File* window click **Open**. Change vertical Range by clicking Plot > Axis…, select Y1 from top axis icons and change range to 0 for min and 1 for max. Further refine that range to properly capture curve. Change axis names by clicking Plot > Axis…, select Title tab, at bottom select **Use text** and enter axis title as **Cd** for vertical axis and **Flow Time** for horizontal axis**.** Save picture by **File > Export… >** change *Export format* to **JPEG** and save as **Cd-history.jpg**. If you have questions, please see TA in office hours.



7.6. Plotting Pressure Contours

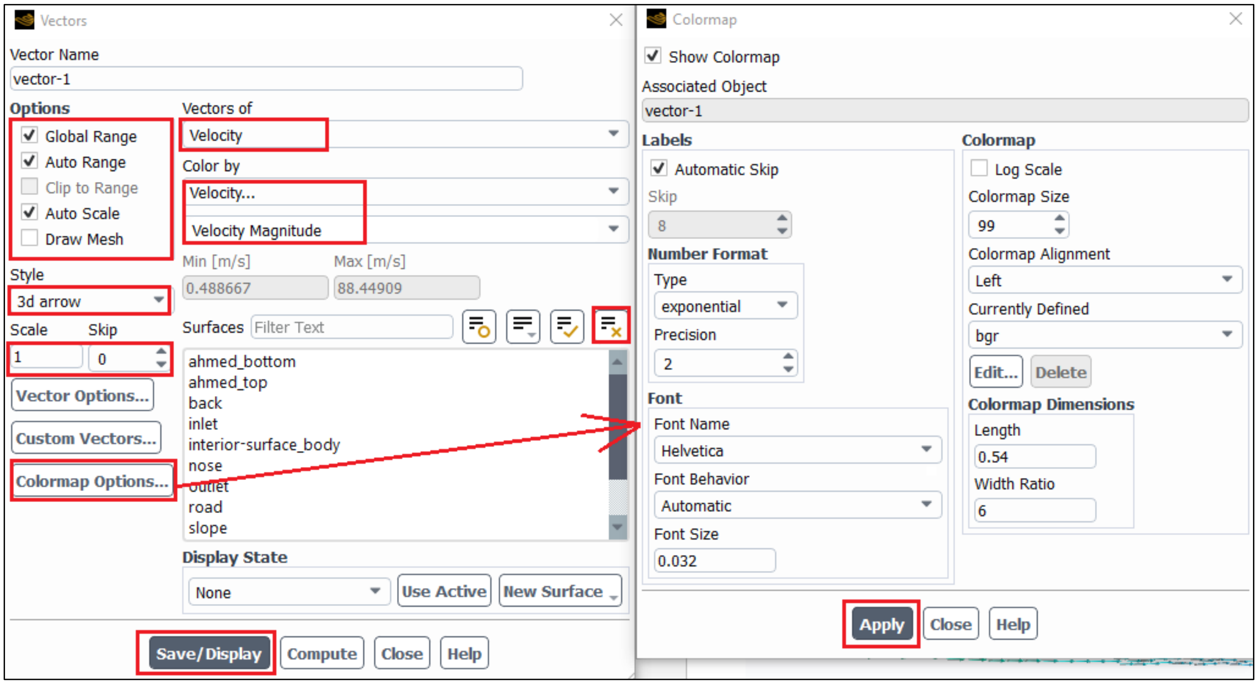
Results > **Graphics** > **Contours**. Change parameters as per below and click **Display**.

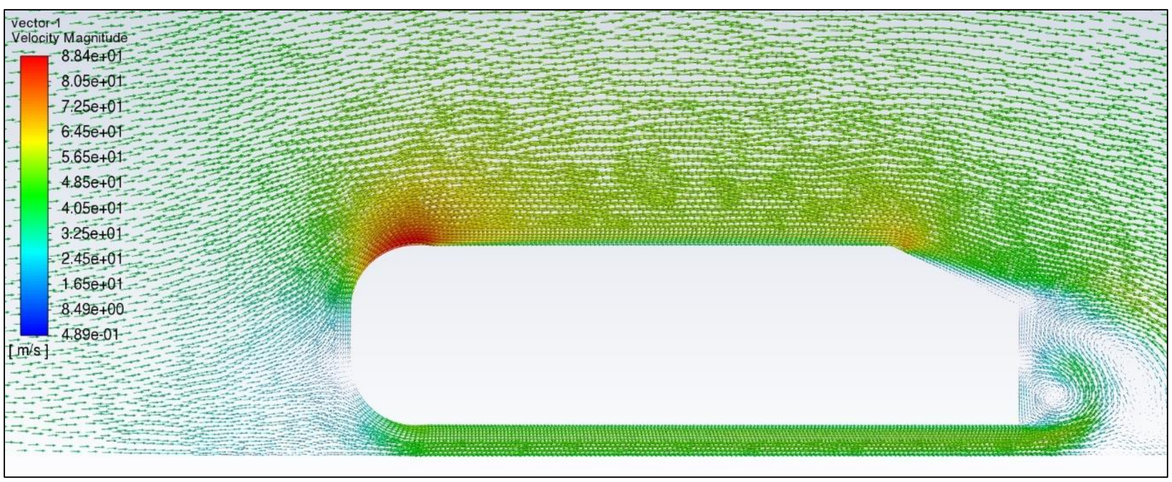




7.7. Plotting Velocity Vectors

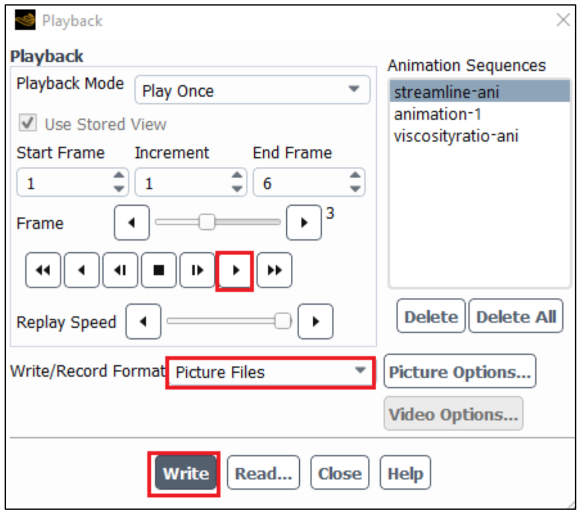
Results > **Graphics** > **Vectors** > **Set Up…** Change parameters as per below and click **Display**.

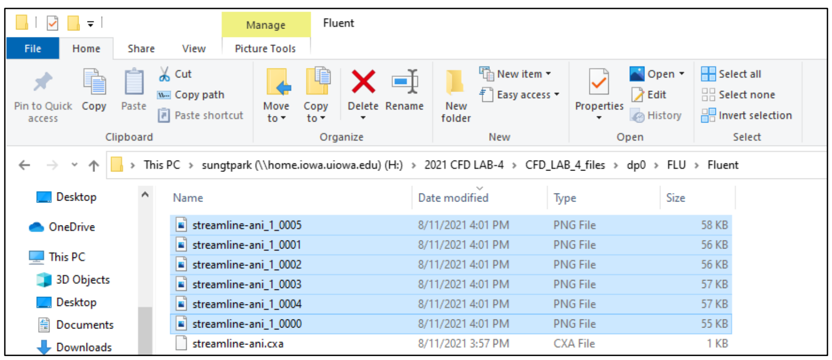


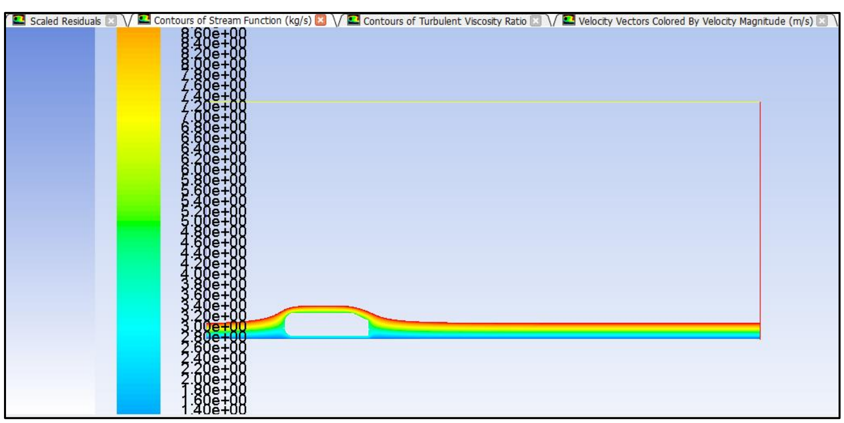


7.8. Creating videos

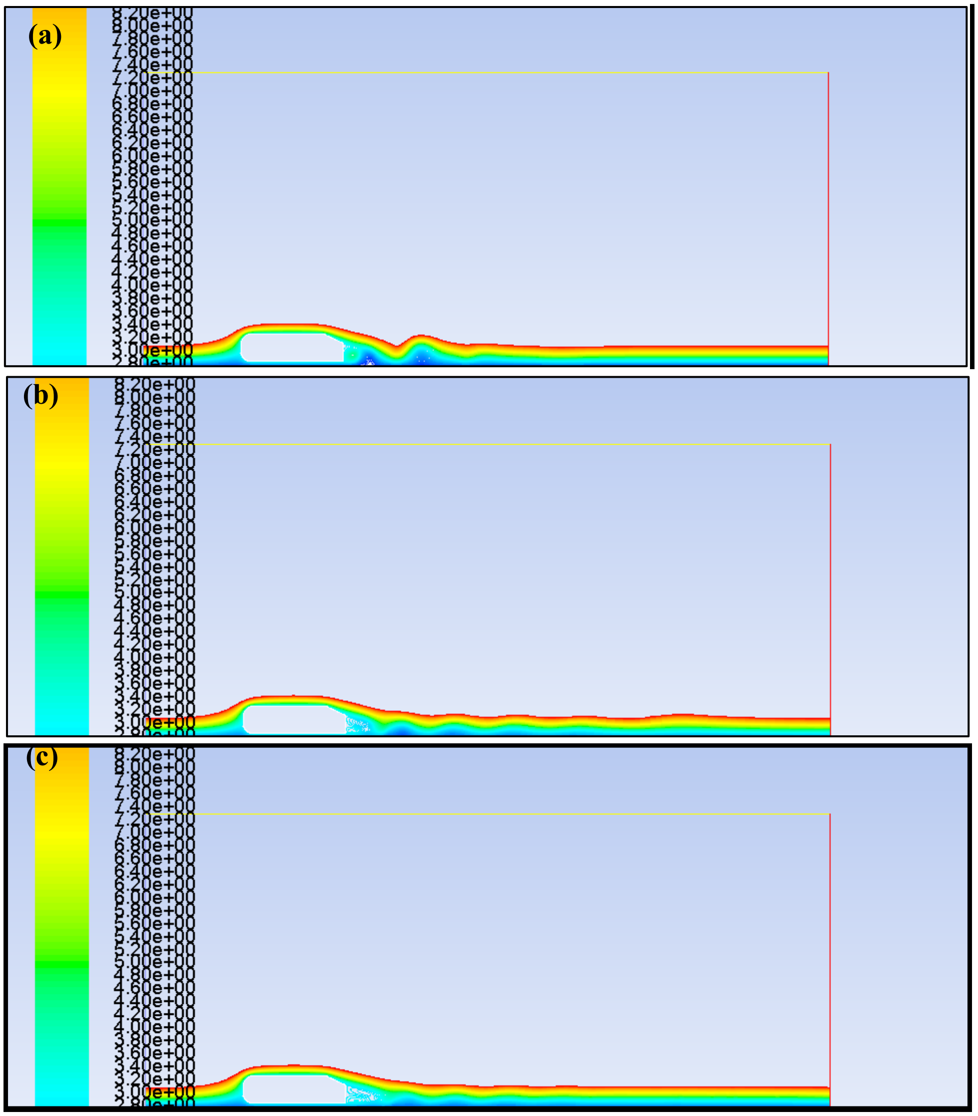
Results > **Animations** > **Playback**. Change the window to streams or viscous ratio then click play button to see the animation. Select the "Picture Files" and click the "Write" button. The picture files will be saved below directory, and it would used to make the Video clip.



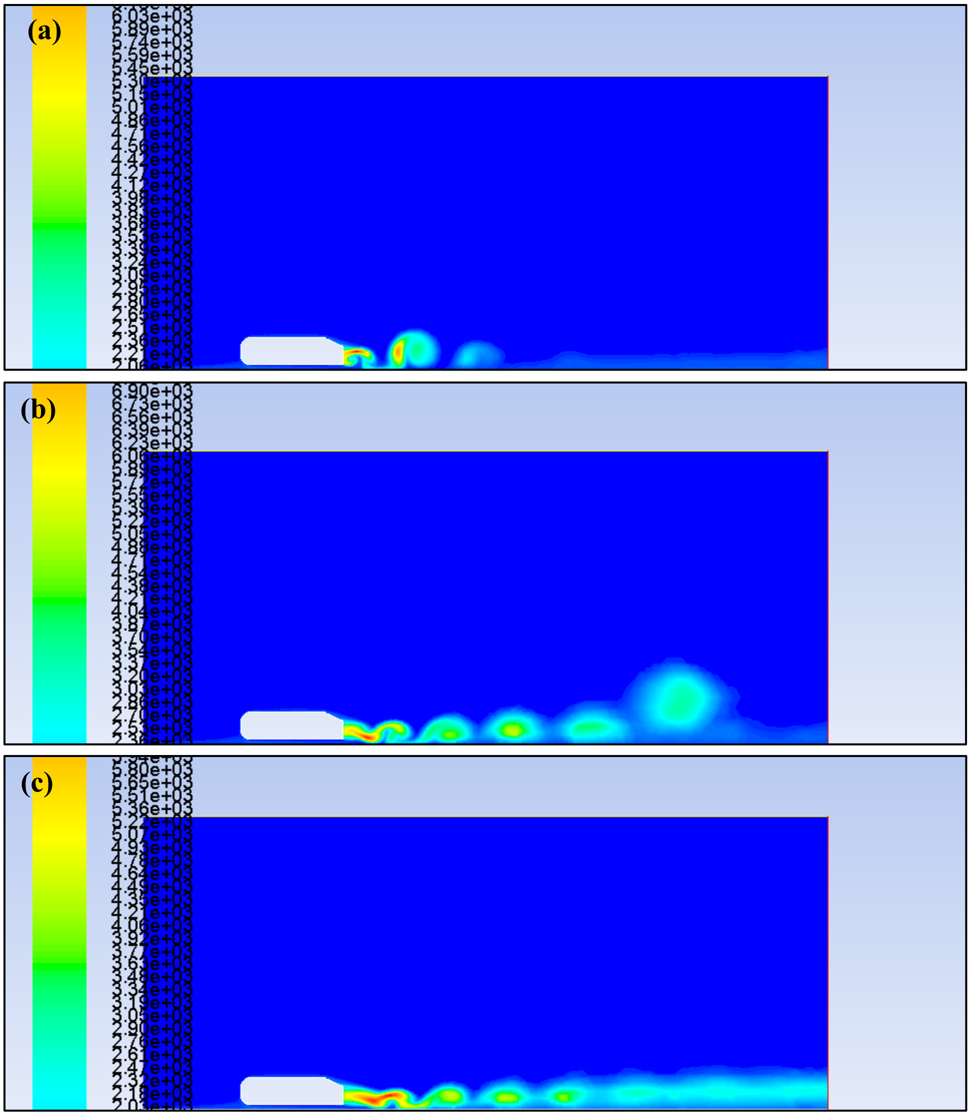




Once the figure files are saved correctly, return to the first time-step, change the **Write/Record Format** to **Picture Files** and click **Write**. Please go through the same procedure for viscosity-ratios.

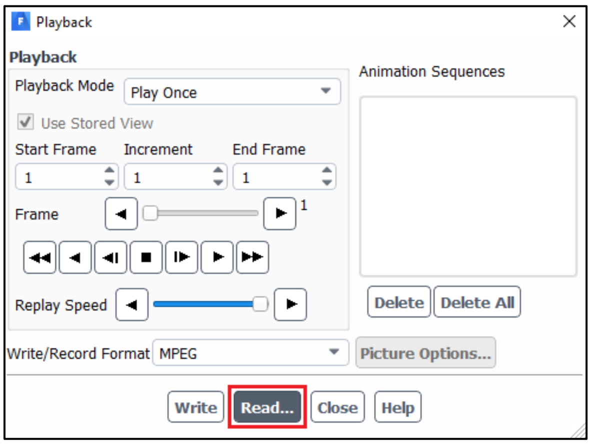


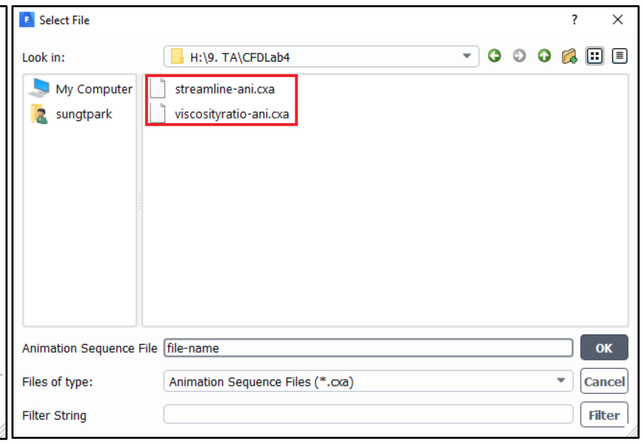
Pictures of streamline for ahmed car: (a) frame=100; (b) frame=200; (c) frame=300



Pictures of turbulent viscosity ratio for ahmed car: (a) frame=100; (b) frame=200; (c) frame=300

If you have closed the Fluent after the calculation, there could be no ‘streamline’ or ‘viscosity-ratio’ under the Animation Sequence in Animation Playback when you reopen it (select **solution** instead **setup** in the workbench when you reopen). You need to read the set-up file to bring back those options. If this is the case, click **Read** and read the ‘*.cxa’ file saved in the location you assigned at the animation part. Select both streamline and viscosity-ratio files (one at each time). Once the options appear under the Animation Sequence, save video files like the beginning of this section (section 7.8). Please note that the setup files (*.cxa) can be modified by opening it with notepad or any ascii readers. Please change the options according to your needs.






```
AnimationSequence1.0
NAME: .\\stream
WINID: 2
STORAGE: 4
FRAMES: 250
Frame 0 4 stream_0000.ppm 2
Frame 1 4 stream_0001.ppm 2
Frame 2 4 stream_0002.ppm 2
Frame 3 4 stream_0003.ppm 2
Frame 4 4 stream_0004.ppm 2
Frame 5 4 stream_0005.ppm 2
Frame 6 4 stream_0006.ppm 2
Frame 7 4 stream_0007.ppm 2
Frame 8 4 stream_0008.ppm 2
Frame 9 4 stream_0009.ppm 2
Frame 10 4 stream_0010.ppm 2
Frame 11 4 stream_0011.ppm 2
```

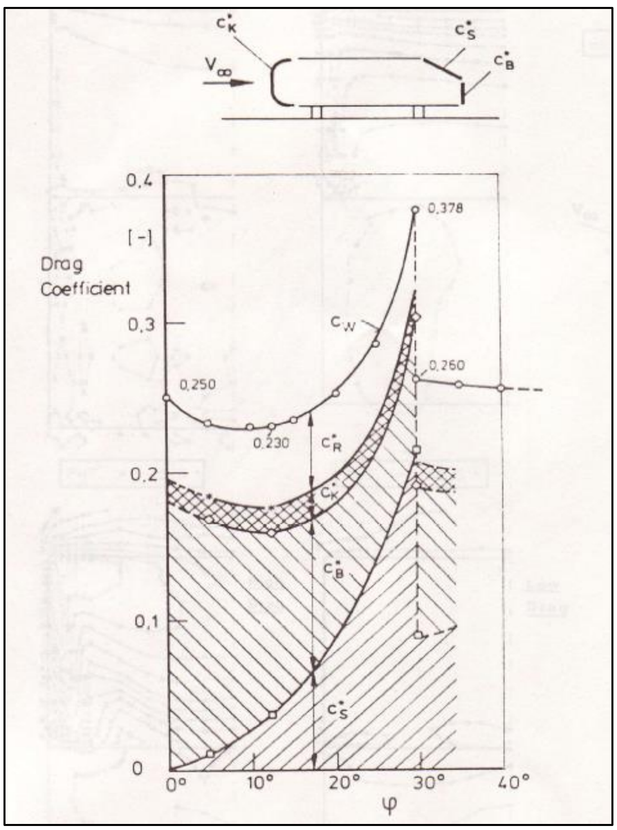
```
AnimationSequence1.0
NAME: .\\viscosity-ratio
WINID: 3
STORAGE: 4
FRAMES: 250
Frame 0 4 viscosity-ratio_0000.ppm 2
Frame 1 4 viscosity-ratio_0001.ppm 2
Frame 2 4 viscosity-ratio_0002.ppm 2
Frame 3 4 viscosity-ratio_0003.ppm 2
Frame 4 4 viscosity-ratio_0004.ppm 2
Frame 5 4 viscosity-ratio_0005.ppm 2
Frame 6 4 viscosity-ratio_0006.ppm 2
Frame 7 4 viscosity-ratio_0007.ppm 2
Frame 8 4 viscosity-ratio_0008.ppm 2
Frame 9 4 viscosity-ratio_0009.ppm 2
Frame 10 4 viscosity-ratio_0010.ppm 2
Frame 11 4 viscosity-ratio_0011.ppm 2
```

8. Data Analysis and Discussion

You need to complete the following assignments and present results in your lab reports following the lab report instructions.

8.1. Simulation of turbulent flows over Ahmed body (slant angle=25 deg) (+24):

Fill in the table for the four drag coefficients and compute the relative error between CFD and EFD (Ahmed data), EFD data for C_k, C_B, and C_s can be found from the figure below. Where $C_k = C_k^*$, $C_B = C_B^*$, and $C_s = C_s^*$. The definitions of the drag coefficients are: C_k is the forebody pressure drag coefficient, C_B is the vertical based pressure drag coefficient, C_R is the friction drag coefficient, C_s is the slant surface pressure drag coefficient, and $C_w = C_D$ is the total drag coefficient. So, $C_w = C_D = C_S + C_B + C_k + C_R$



	C_k	C_B	C_S	C_D
Ahmed (EFD)				0.289
k-e				
Error (%)				

Questions (+21):

- Do you observe separations in the wake region (use streamlines)? If yes, where is the location of separation point?
- What is the Strouhal number based on the shedding frequency (C_D vs. time), the height of the Ahmed body and the inlet velocity? Note: the shedding frequency f=1/T where T is the typical period of the oscillation of C_D that can be evaluated using the peaks between 0.1<time<0.14.
- **Figures need to be reported:** (1) XY plots for residual history, (2) modified U vs. y-by-h (with EFD), (3) Modified-TKE vs. y-by-h, (4) time history of drag coefficient, (5) Contour of pressure, (6) contour of velocity magnitude, (7) velocity vectors, (8) 3 or 4 snapshots of animations for turbulent-viscosity-ratio and streamlines (hints: you can use <<**Alt+print Screen**>> during the play of the animations).
- **Data need to be reported:** the above table with values.

9. Grading scheme for CFD Lab Report

(Applied to all CFD Lab reports)

Section		Points
1	**Title Page**	5
	1.1 Course Name	
	1.2 Title of report	
	1.3 Submitted to "Instructor's name"	
	1.4 Your name (with email address)	
	1.5 Your affiliation (group, section, department)	
	1.6 Date and time lab conducted	
2	**Test and Simulation Design**	10
	Purpose of CFD simulation	
3	**CFD Process**	20
	Describe in your own words how you implemented CFD process	
	(Hint: CFD process block diagram)	
4	**Data Analysis and Discussion** **←Section 8 (Page# 54) for CFD Lab 4**	45
	Answer questions given in **Exercises** of the CFD lab handouts	
5	**Conclusions**	20
	Conclusions regarding achieving purpose of simulation	
	Describe what you learned from CFD	
	Describe the "hands-on" part	
	Describe future work and any improvements	
	Total	100

Additional Instructions:

1. Each student is required to hand in individual lab report.
2. Conventions for graphical presentation (**CFD**):
   ***** Color print of figures recommended but not required
3. Reports will not be graded unless section 1 is included and complete