LINEAR FINITE ELEMENT ANALYSIS & OPTIMIZATION OF A RACE CAR FRAME

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AUE- 8580 ADVANCED VEHICLE STRUCTURAL DESIGN

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CONTENTS

OBJECTIVE

The objective of this term project is to get hands-on experience with Hyperworks and insight into the design steps required to computationally assess and optimally design a Body in a White tubular space frame race car structure. The project will consist of two parts.

PART-1

Linear Static Finite Element Analysis-Baseline Design

Importing the model geometry:

The given space-frame tubular race car chassis is imported into HyperWorks.

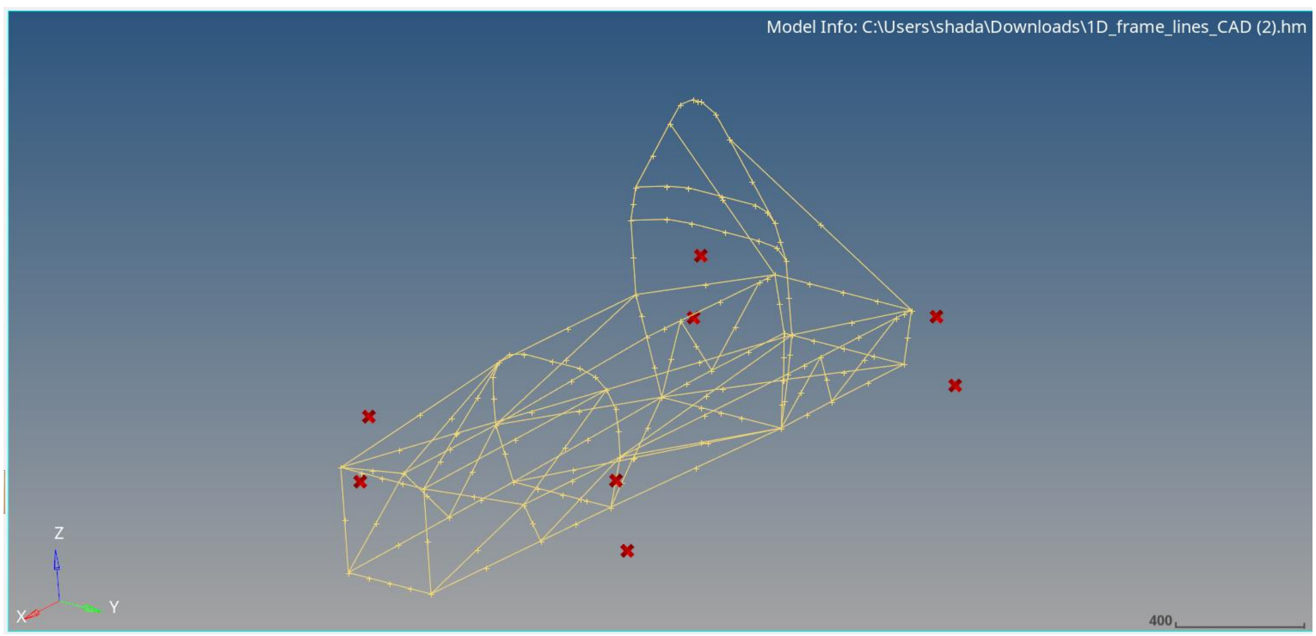

Figure-1 Imported Geometry

1-D Meshing:

To mesh the provided geometry, it was advised to utilize 100-size CBAR-type elements. Line meshing is done after assigning the element type to the space frame structure. After completing the line mesh, certain errors in the CAD geometry were discovered. Running the 1-D mesh check confirmed that three locations are of poor mesh quality because of disconnected nodes.

Three mesh errors were found after the line mesh. Therefore, we have joined the nodes to rectify the errors.

Figure-2 Mesh error-1

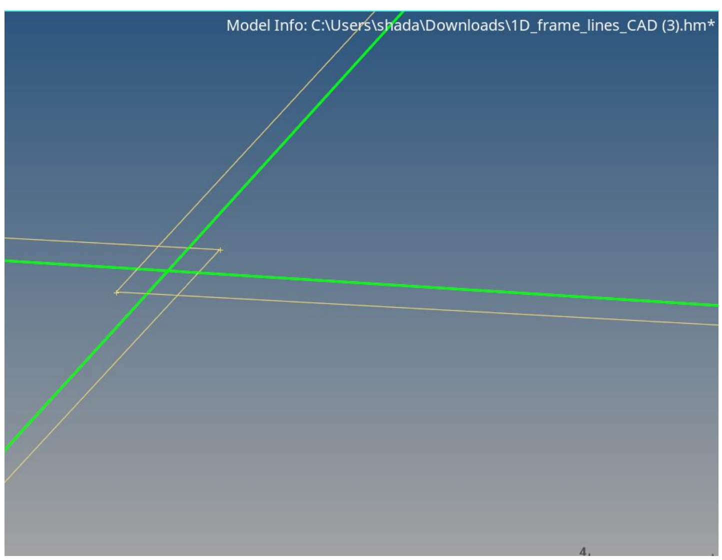

Figure-3 Mesh error-1 after correction

The mesh errors are rectified by using replace node option under the meshing tab in Hypermesh.

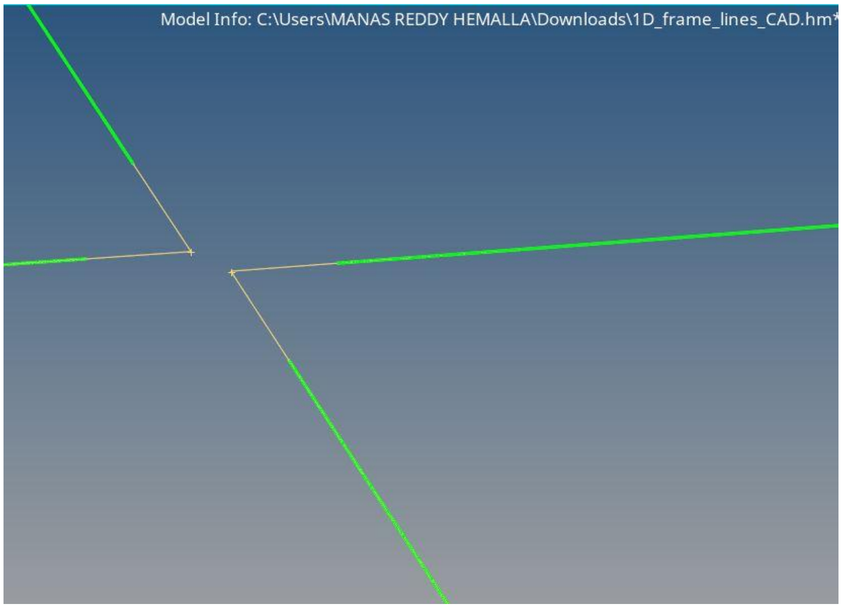

Figure-4 Mesh error-2

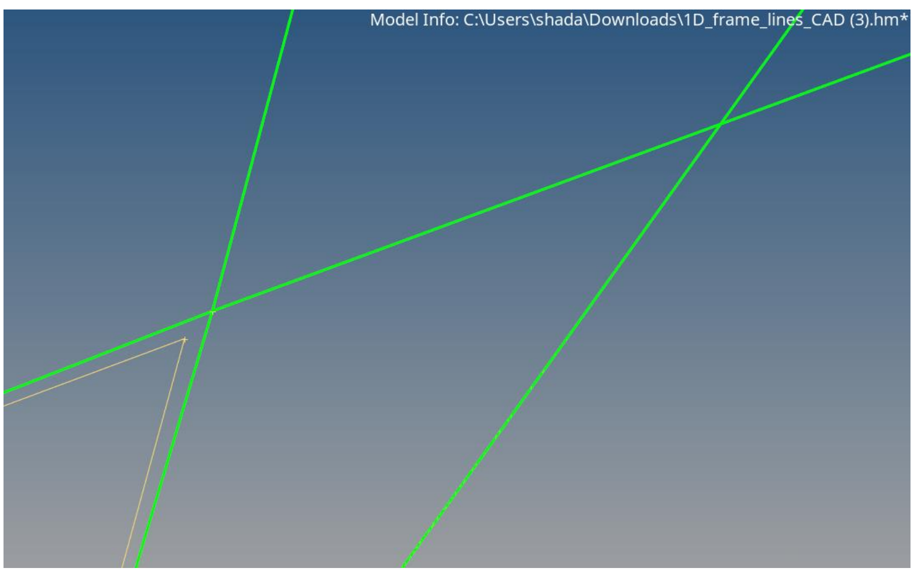

Figure-5 Mesh-2 after correction

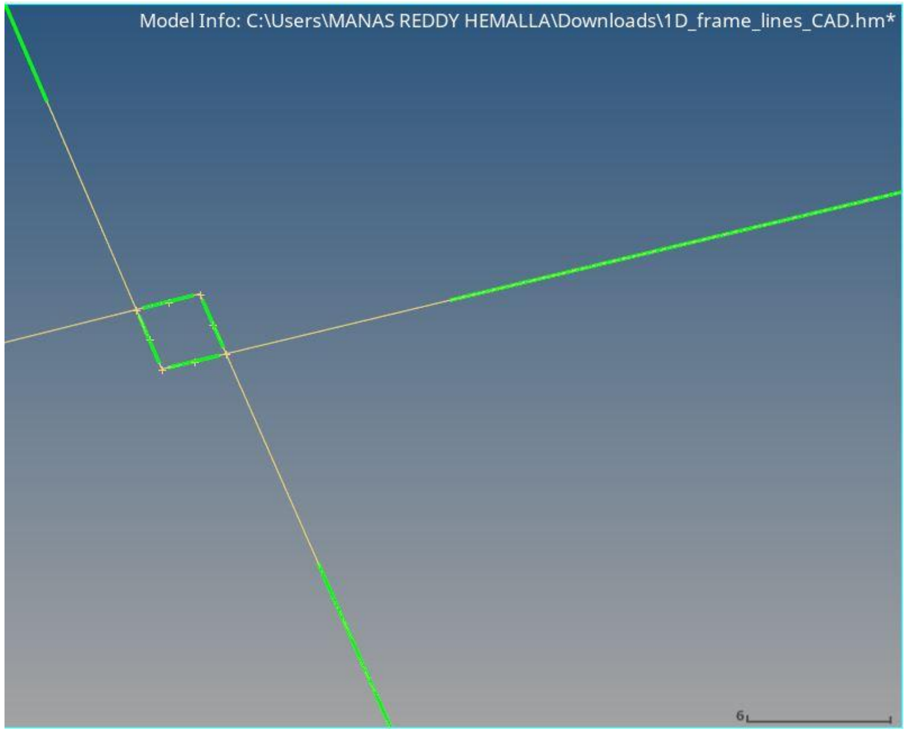

Figure-6 Mesh error 3

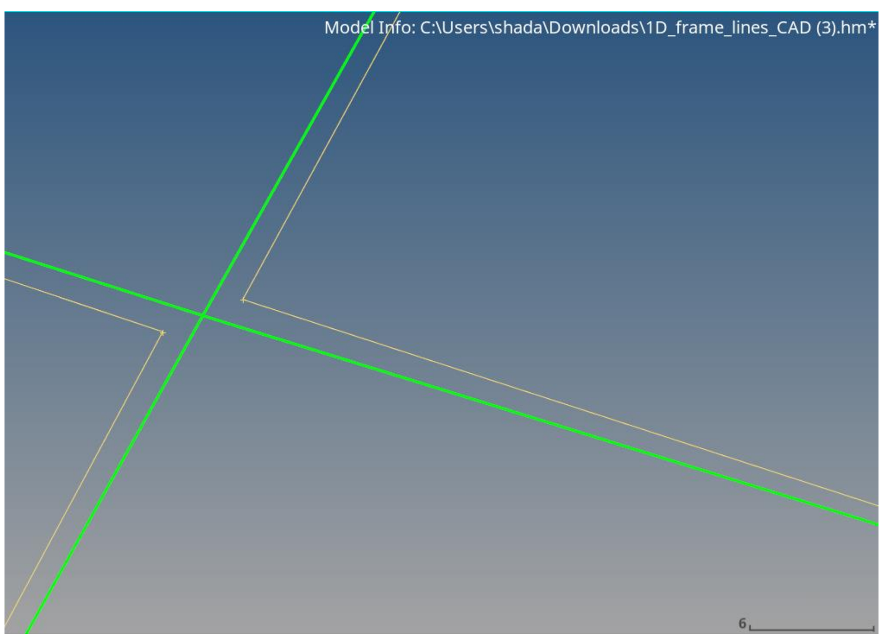

Figure-7 Mesh error-3 after correction

Material Definition:

Steel is used as the material of the tubular space frame chassis. Youngs Modulus = 2100000, Poisson’s ratio = 0.3, Density= 7900 kg/m^{3}, and the card image is set to MAT1.

Definition of frame properties:

A beam section of the Optistruct tube was selected by assigning the outer diameter and inner diameter as 12.5 mm and 10.5 mm, respectively.

Suspension model (Double wishbone structure):

RBE2 elements were used to produce the wheel suspension, with the nodes generated on the suspension points as independent nodes and the nodes on the tubular space frame serving as dependent nodes. Before this step, we created the nodes at the red cross marks provided in the geometry from the beginning. This suspension modeling approach is streamlined.

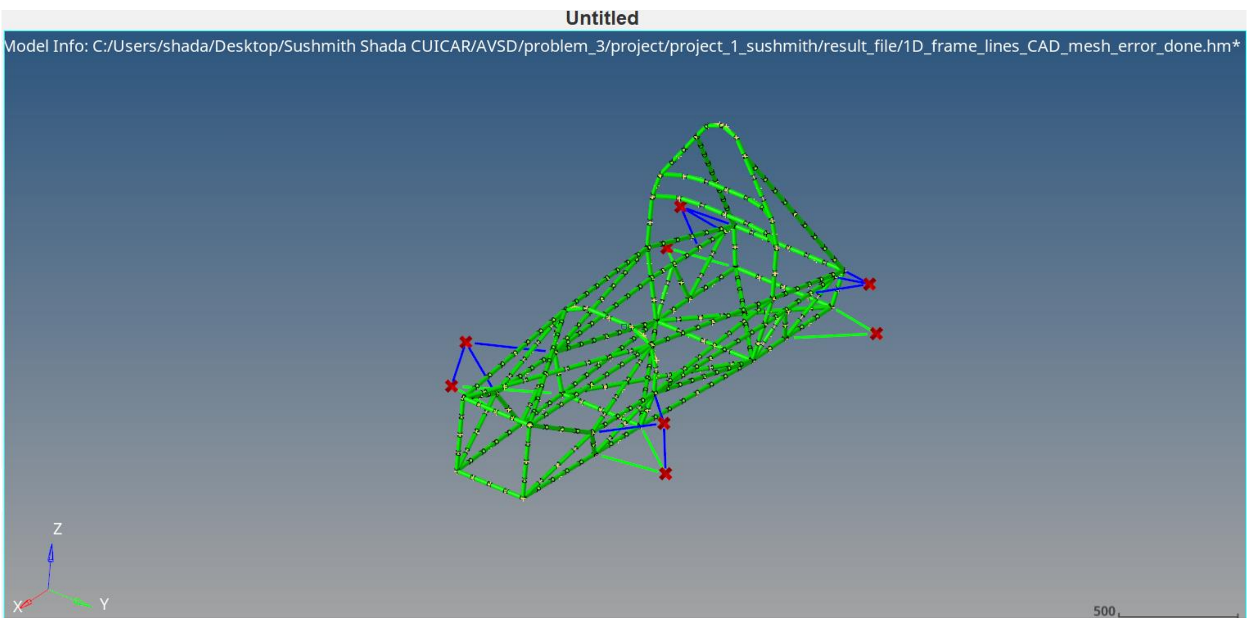

Figure-8 Suspension members

Boundary conditions and applying the load conditions:

As per the standard test procedure for torsion, bending, and shear, we have fixed the rear Double wishbone points of the chassis. The constraints are of all degrees of freedom, i.e. (123456), as shown in the figure.

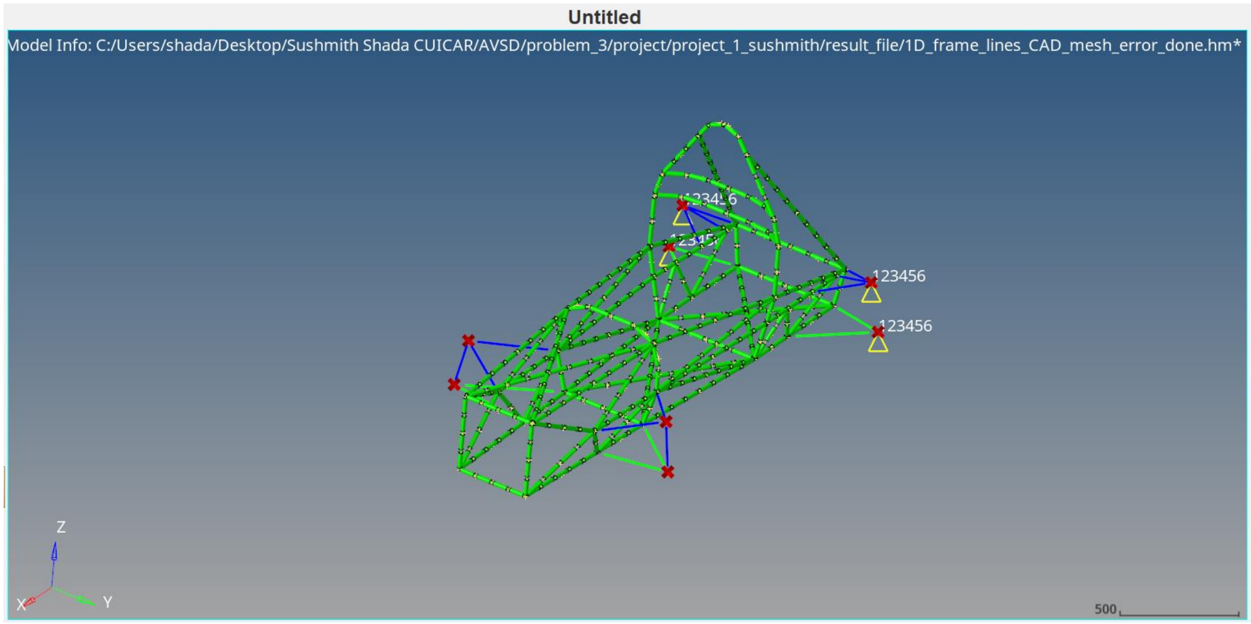

Figure-9 Constraints given

Loading conditions:

Torsion:

A couple of force was applied with vertically opposite directions on either side of the front axle double-wishbone points (each 1000 N), as shown in the figure below. The corresponding torsional load step was defined with constraint as the SPC.

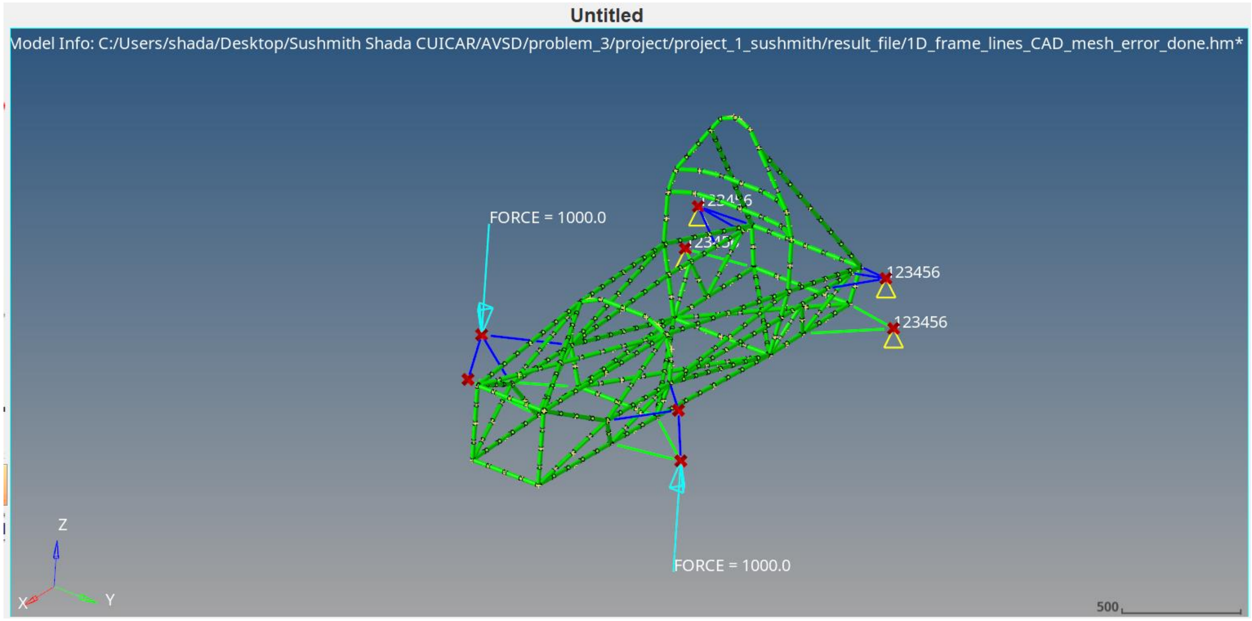

Figure-10 Torsion loading condition

Bending:

The bending load was applied with vertically upward forces, each 1000N on the front left upper and front right upper double wishbone points, as shown in the figure below. The corresponding bending load step was defined with constraint as the SPC.

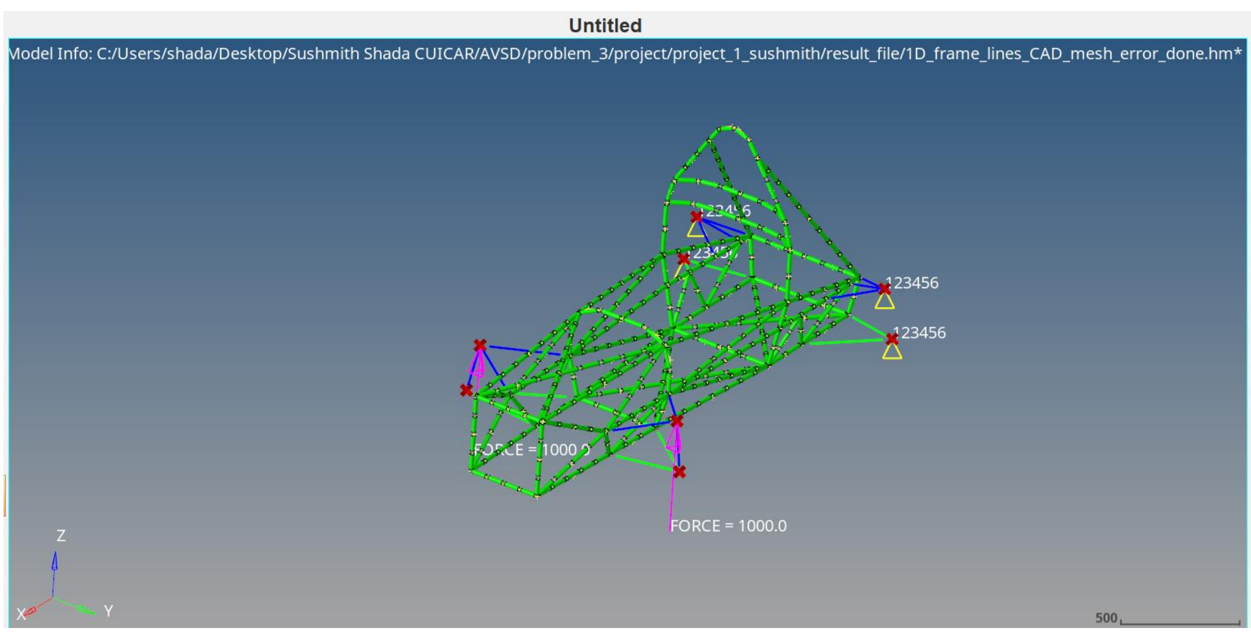

Figure-11 Bending condition

Shear:

The shear loads were applied in the positive Y direction on the front axle upper double wishbone points each 1000, as shown in the figure below. The corresponding shear load step was defined with constraint as the SPC.

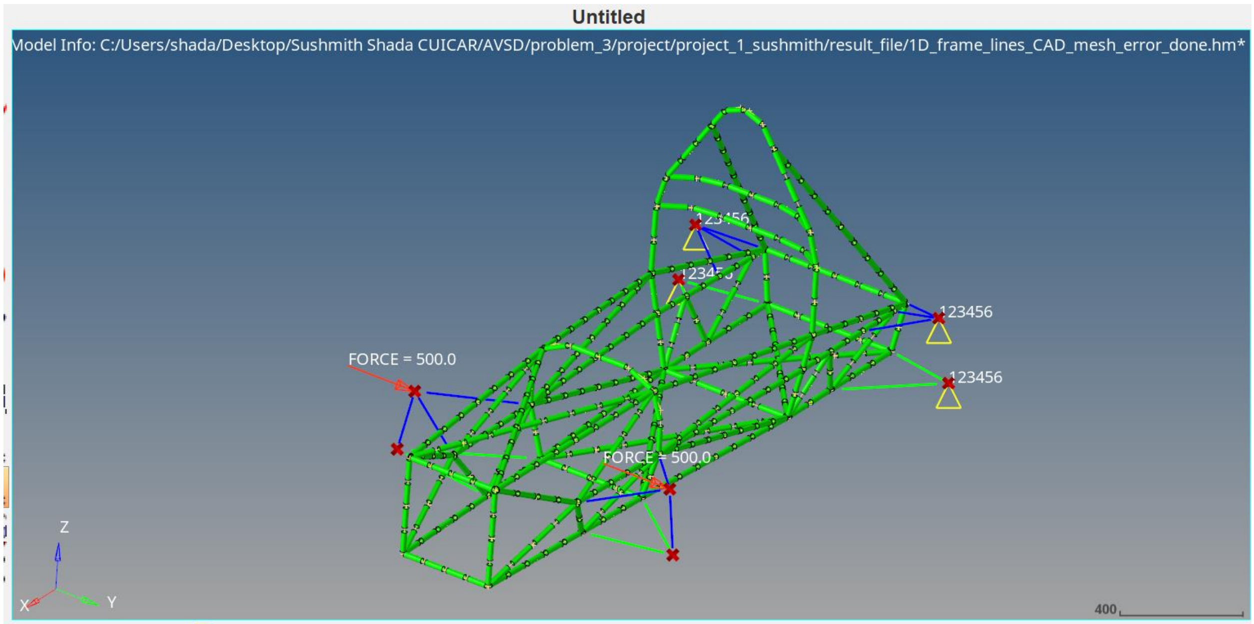

Figure-12 Shear Loading condition

Analysis:

The user profile was set to Optistruct, and Optistruct is selected from the analysis tab then, export options were toggled to all, and the run option is toggled to analysis. This is depicted in the figure below.

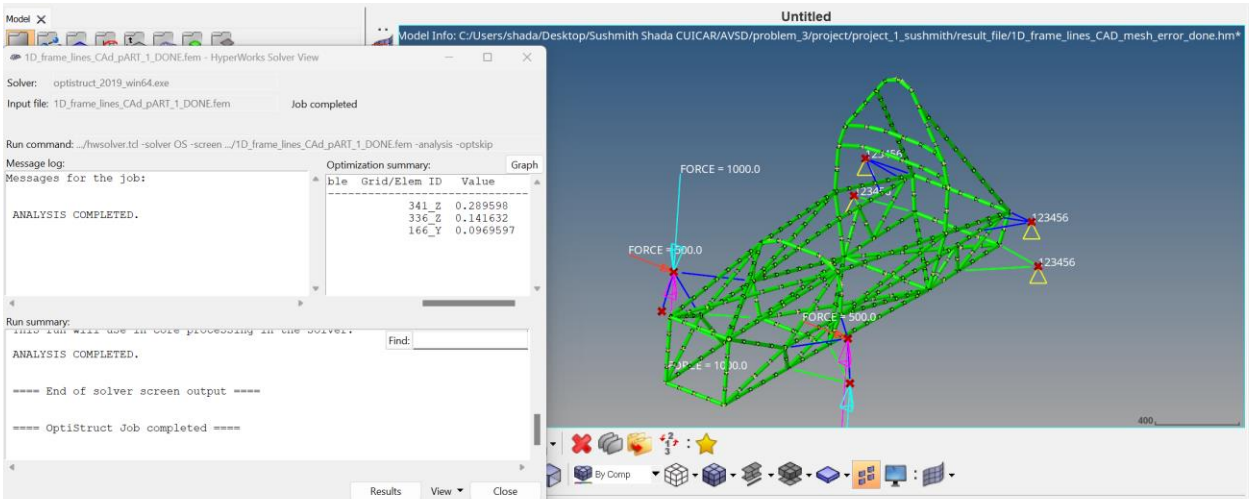

Figure-13 Analysis completed

Post Processing:

Loading conditions:

Torsion:

- Displacement of contour plot for the deformed frame under torsion loads
- Location of the node at which the maximum displacement is occurring is shown in the figure below. (i.e., at node 342).

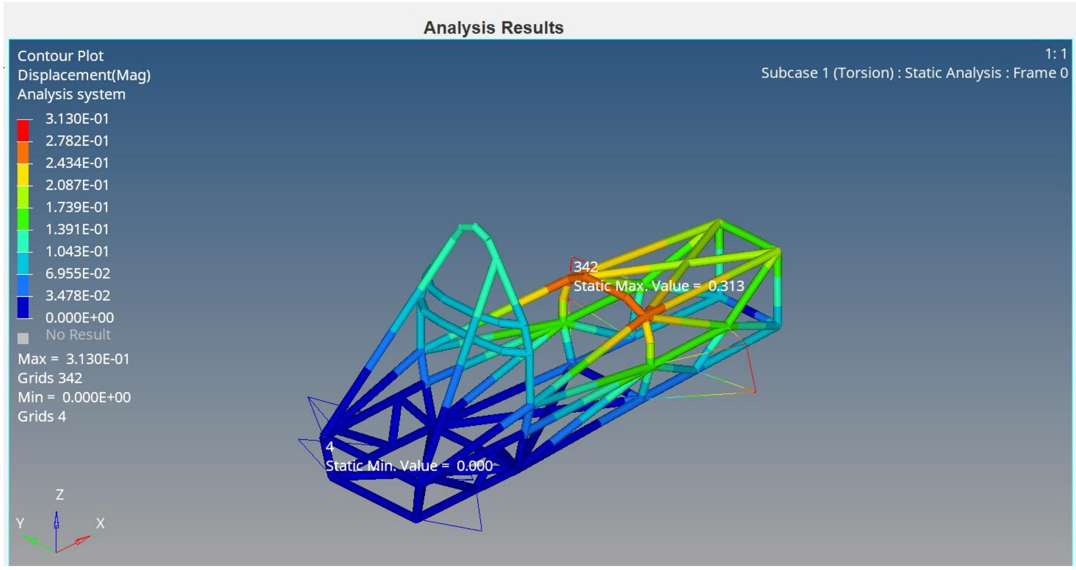

Figure-14 Displacement contour plot

Note: the displacements are scaled by a factor of 50 as instructed.

- Max element von mises of the contour plot

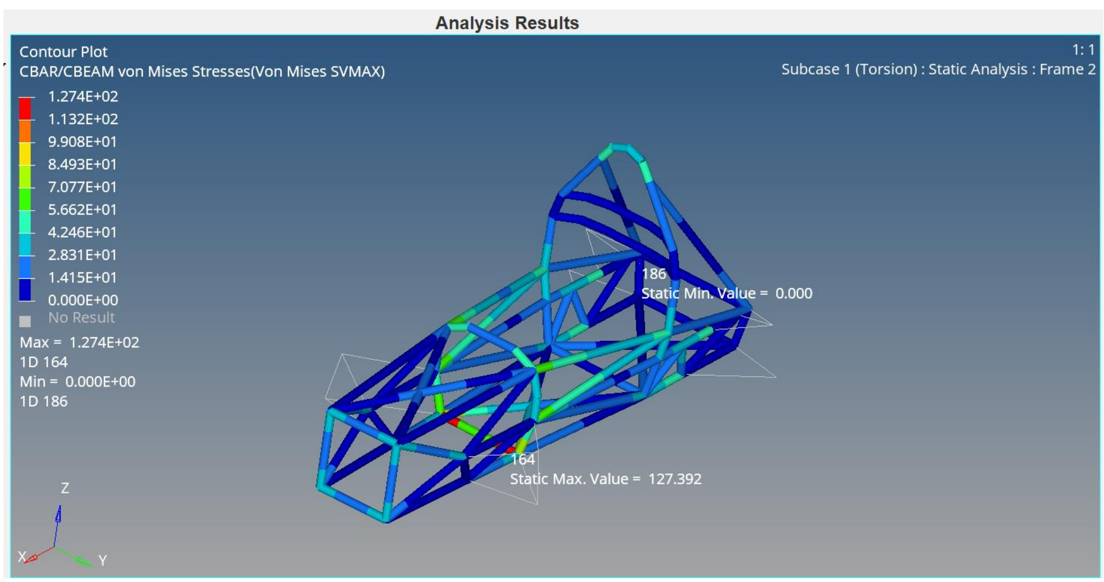

Figure-15 Von-mises stresses contour plot

Bending:

- Displacement of contour plot for the deformed frame under Bending

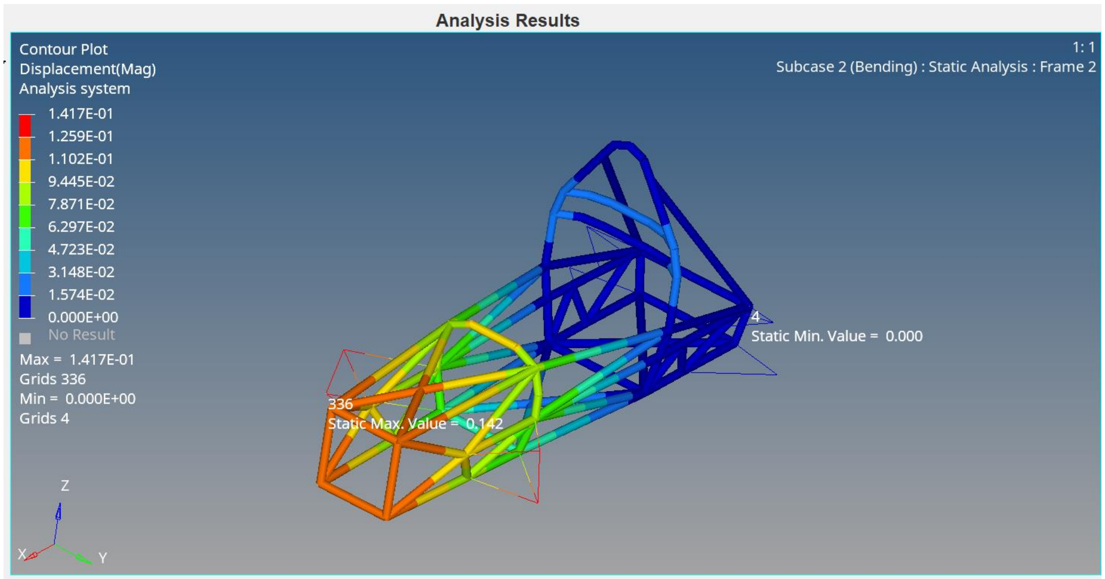

Figure-16 Displacement contour for Bending load

- Max element von mises of the contour plot

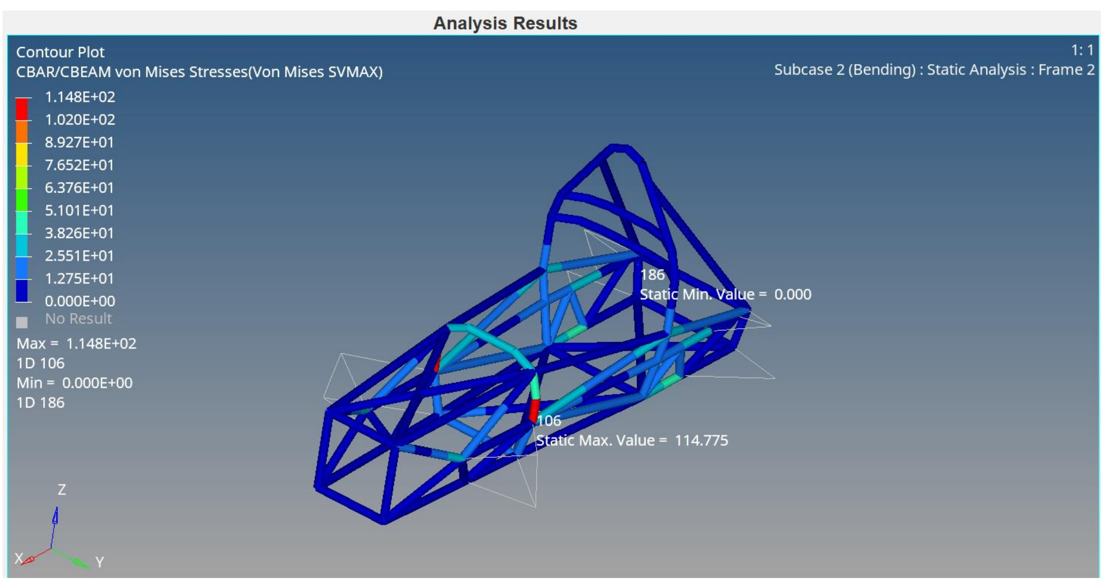

Figure-17 Max von mises stresses

Shear:

- Displacement of contour plot for the deformed frame under shear loading
- Note: the displacements are scaled by a factor of 50 as instructed

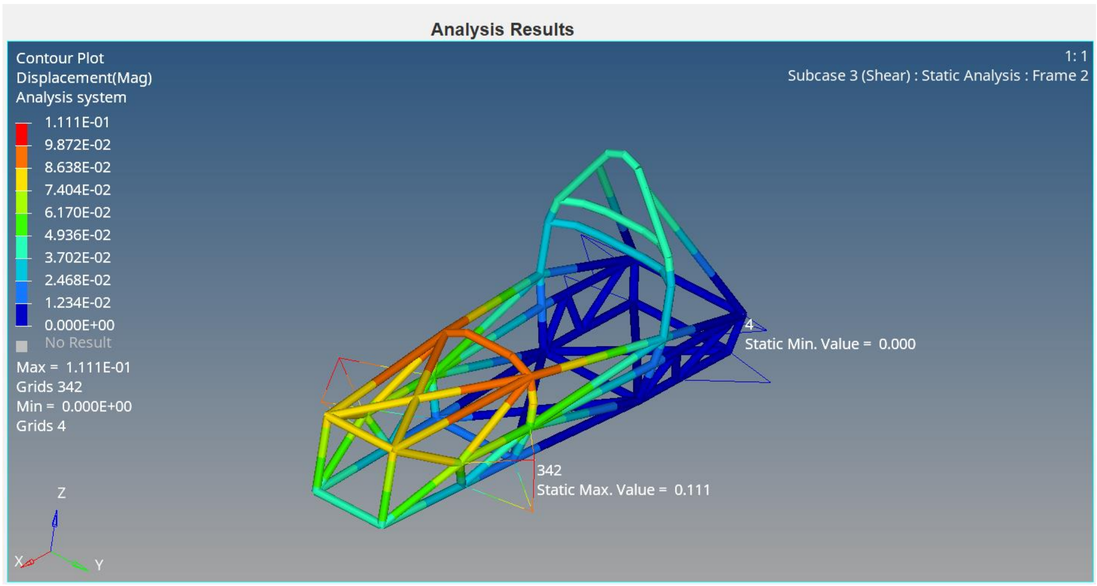

Figure-18 Max displacement contour plot for shear loading

- Max element von mises of the contour plot

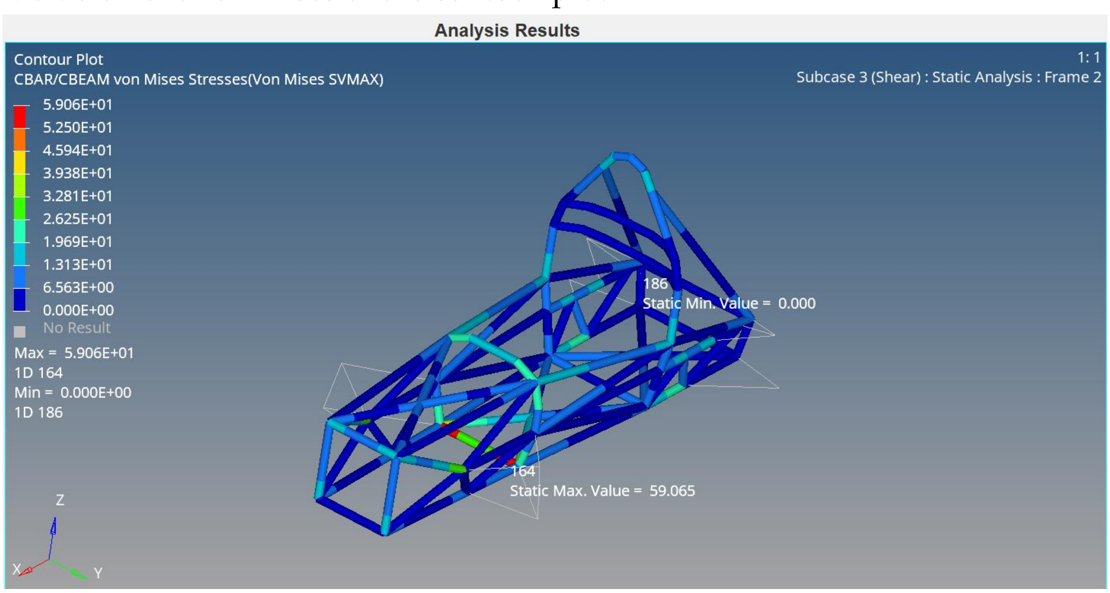

Figure-19 Von mises stress for shear loading.

PART-2

Size Optimization

Non-Discrete Size optimization:

The goal of this part of the project is to apply HyperWorks size optimization capabilities to optimize the inner and outer diameters of the tubular space frame to reduce the mass.

Size optimization setup:

The maximum displacement obtained by the linear static analysis was as shown in the following table:

Load case	Max Displacement (mm)	Node
Torsion	0.3130	342
Bending	0.1417	336
Shear	0.111	342

Design variable definition:

By defining Size Desvars variables for the outer and inner radii with the following lower and upper bound, the cross-sectional properties of the tube's cross-section may be optimized in terms of size.

	Lower bound (mm)	Upper bound (mm)	Initial Value (mm)
Inner Radius	1	14	10.5
Outer Radius	5	15	12.5

Constraints:

For each load step, three optimization responses of type static displacement (total disp) were produced (shear, bending, and torsion). For each of these three responses, design constraints were established with an appropriate load step, no lower bound, and an upper bound equal to the maximum static displacement corresponding to that load situation.

Analysis:

The user profile is set to OptiStruct, and then under the analysis tab, OptiStruct is selected to perform the optimization. The export options in the OptiStruct analysis tab are toggled to all, and the run options are toggled to Optimization.

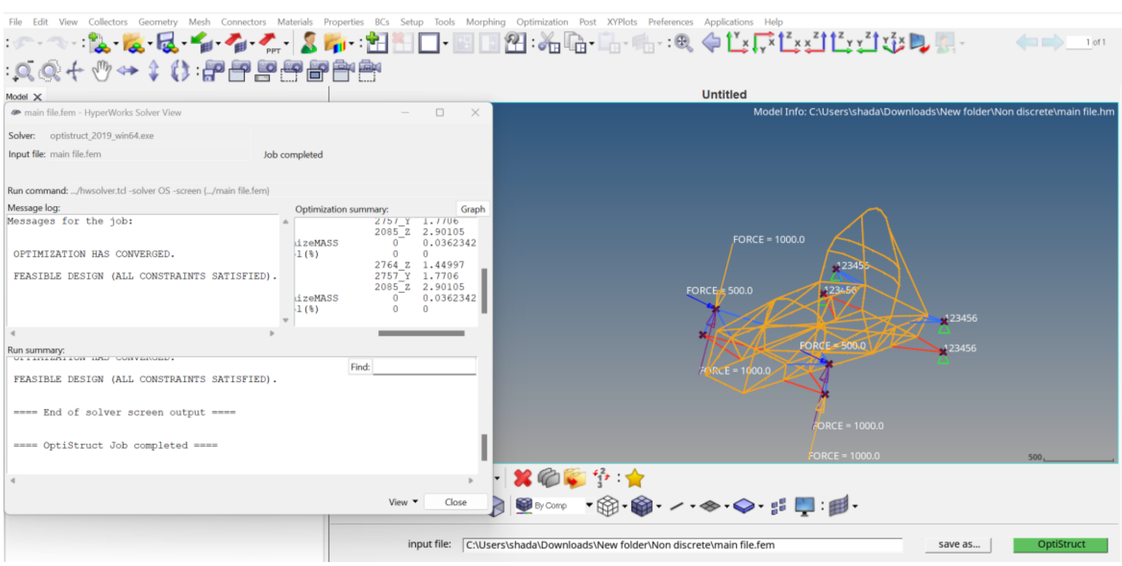

Figure-20 non-discrete size optimization analysis

Post-processing:

The table below shows the mass of the race frame in the various iterations carried out in the non-discrete size optimization.

Iteration	Tubular space frame mass
0	42.1200 kg
1	36.234 kg
2	36.234 kg

Final Optimized results:

The table below shows the final optimized dimensions of the tube and the mass of the tubular space frame chassis, and the percentage of mass reduced due to optimization.

Outer diameter	15 mm
Inner diameter	13.617 mm
Tubular space frame chassis mass	36.234 Kg
Mass savings	13.974%

Discrete Size optimization:

Size optimization setup:

The size optimization setup is entirely the same as the non-discrete size optimization. But here, in the discrete size optimization setup, we gave discrete values for the design variables, i.e., the inner radius and the outer radius of the tube section.

Inner radius discrete design variable:

- From 1 mm
- To: 14 mm
- Increment: 0.1 mm

Outer radius discrete design variable:

- From 5 mm
- To: 15 mm
- Increment: 0.1 mm

Analysis:

The user profile is set to OptiStruct, and then under the analysis tab, OptiStruct is selected to perform the optimization. The export options in the OptiStruct analysis tab are toggled to all, and the run options are toggled to Optimization.

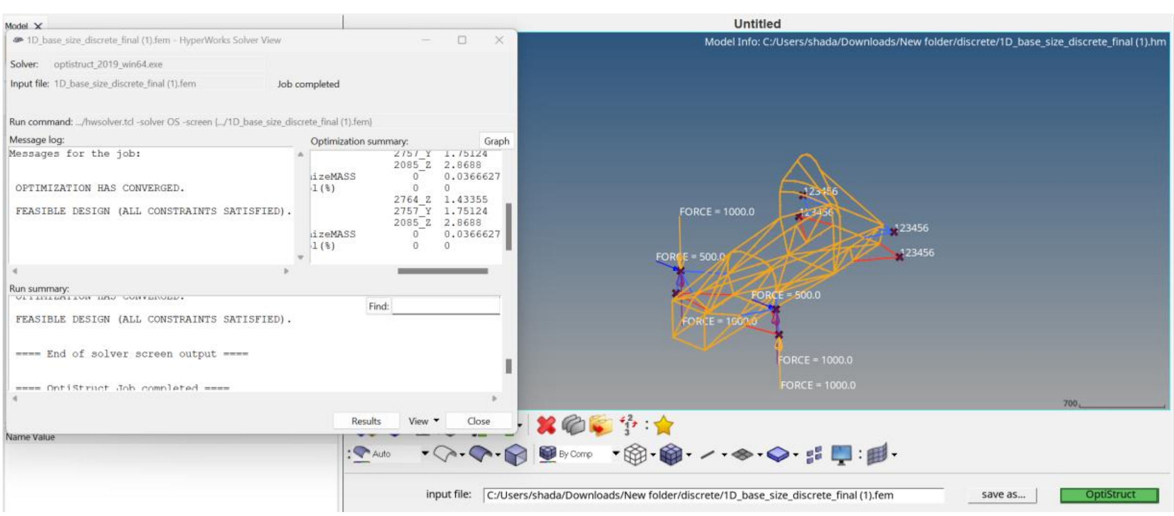

Figure-21 Discrete size optimization analysis

Post-processing:

The table below shows the mass of the race frame in the various iterations carried out in the discrete size optimization.

Iteration	Tubular space frame mass
0	42.21 kg
1	36.662
2	36.662 kg

Final Optimized results:

The table below shows the final optimized dimensions of the tube and the mass of the tubular space frame chassis, and the percentage of mass reduced due to optimization.

Outer diameter	15 mm
Inner diameter	13.6 mm
Tubular space frame chassis mass	36.662 Kg
Mass savings	13.17%

Here, in this case, we get the value of radii as a standard radius of the tube section, and there is no need to round off the answer.