19107_SAMANVAYA RACING_CAD/CAE Report

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1. INTRODUCTION

The objective of this report is to present the CAD design & analysis of our vehicle for ADVANCE EFFICYCLE 2019 SEASON.

Our aim is to design a vehicle with good built quality and better strength by using a high strength material for roll cage. We have also considered various measures for compactness, better ergonomics, safety etc. For this we have designed the roll cage in SOLIDWORKS 2016 x64 SR15.0. The analysis is done for different materials to finalize the material for roll cage

2. FRAME MATERIAL OPTIONS

The material is used with different cross-sections and its separate combinations are written below:

i. Steel (AISI 1018)
Cross-Section Type; 1in x 0.84in x 2mm

ii. Steel (AISI 1018)
Cross-Section Type; 1.25in x 1.13in x 1.5mm

iii. Steel (AISI 4130)
Cross-section type; 1.25in x 1.13in x 1.5mm

iv. Steel (AISI 4130)
Cross-section type; 1.25in x 1.11in x 1.65mm

PROPERTIES/MATERIAL	SAE 1018	SAE 4130
Density (gm/cm^3)	7.87	7.85
Elongation (%)	16-27	17-28
Elastic Modulus (GPa)	205	205
Yield Strength (MPa)	365	460
Ultimate Tensile Strength (MPa)	440	560
Poisson Ratio	0.29	0.29
Shear Modulus (GPa)	80	80
Cost (per m)	Rs.375	Rs.525
Roll Cage Weight (kg)	29.14	28.83
Lead time for delivery (days)	7	7

3. CALCULATION OF BENDING STRENGTH AND BENDING STIFFNESS

We know that,

Bending strength is given by: **M= (S_y*I)/C**
Where: S_y = Yield strength
C = Distance from neutral axis to extreme fiber

Also, Bending Stiffness is considered to be proportional to the product EI.

i.e. **Bending Stiffness ∝ E.I**
Where: *E*= Modulus of elasticity

I= Second moment of area for the structural cross section

Dimension	Grade	I (mm^4)	S_Y (MPa)	E (GPa)	M= S_YI/C (N/m_2)	S ∝ E.I (Nm^2)
1.25inx1.5mm	AISI 1018	1.61x 10^4	365	205	371.99	3.381 x10^3
1inx2 mm (Ref.)	AISI 1018	1.01x 10^4	365	205	291.31	2.128× 10^3
1.25inx1.5mm	AISI 4130	1.61x 10^4	460	205	468.82	3.381 x10^3
1.25inx1.65mm	AISI 4130	1.01 x10^4	460	205	354.46	3.014 x10^3

4. CAE ANALYSIS OF VEHICLE/FRAME

Impact force = 2G
Meshing Conditions- Relevance Centre= Fine
Relevance=100
Element Size= 10mm

A. FRONTAL IMPACT ANALYSIS

Material-1 (Steel AISI 1018,1inx0.84inx2mm)

a) Assumption & Considerations:

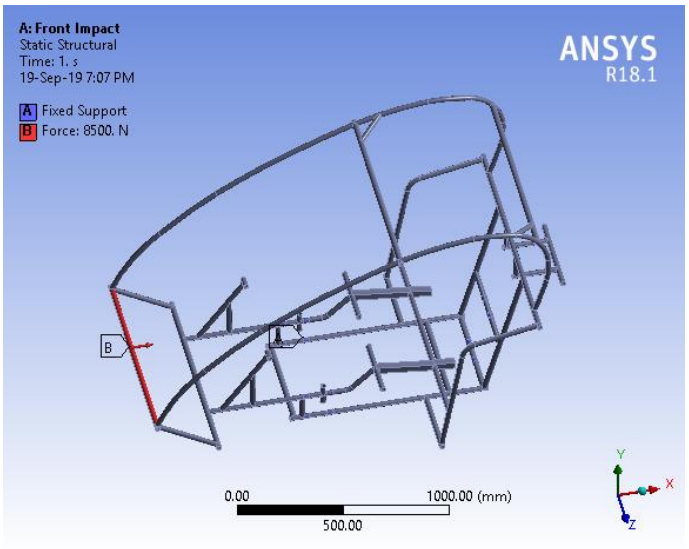
Following assumptions & consideration were made for performing the analysis for frontal impact on frame/vehicle.
Impact force was applied on the foremost part of the roll cage.

Mounting points of suspension arms were fixed.

Initial Speed=9.11m/s

Final Speed=0m/s

Reaction time=0.13s



b) Calculation of Impact Forces:

Work Done= $(0.5*M*V_{final}^2 - 0.5*M*V_{initial}^{2)}$

$|W|=|-0.5*M*V_{initial}^2|$

$=|-0.5*240*9.114^2|$

=9967.8 Nm

Work Done=Force * Displacement

=(F*S)

S=Impact Time*V_{max}

=0.13*9.114

=1.184m

So,

F=W/S

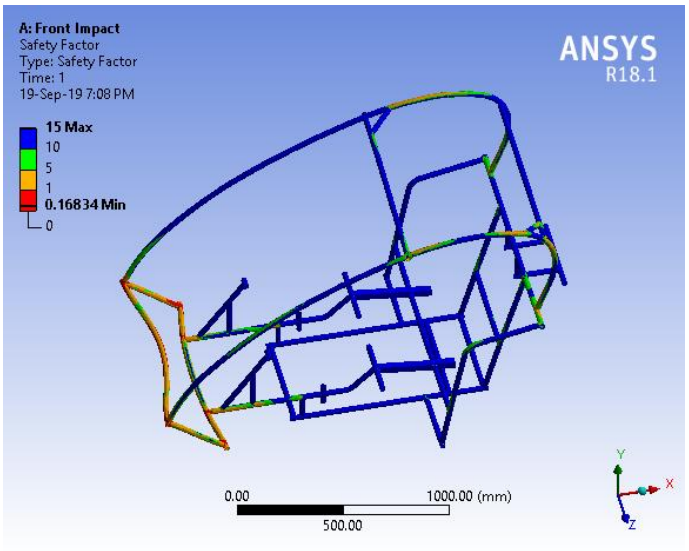
=9967.8/1.184

=8418.75N

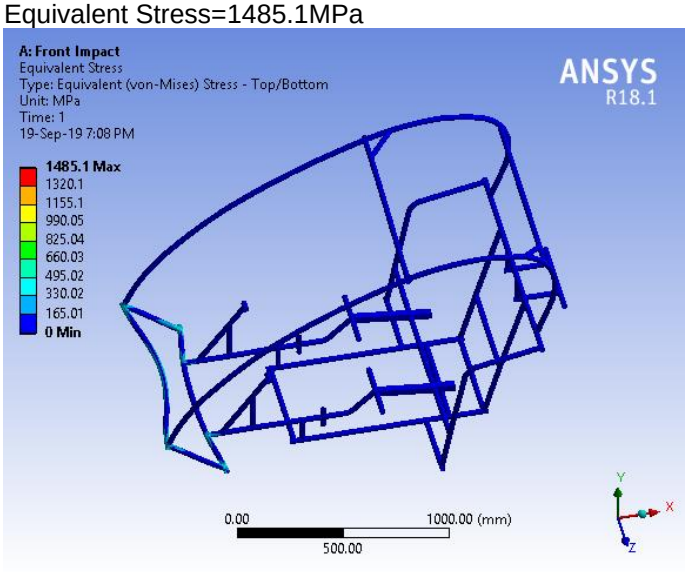
≈8500N

c) Analysis Results:

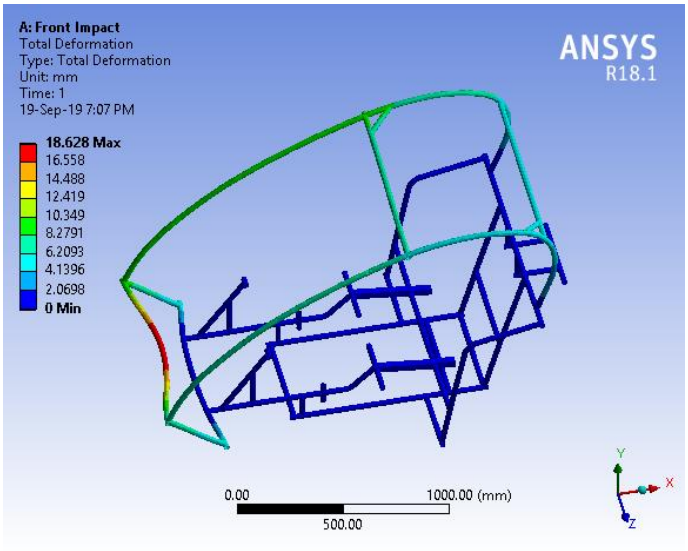
Safety Factor=0.16834



Equivalent Stress=1485.1MPa



Total Deformation = 18.628 mm



d) Optimizations:

* Unnecessary members are removed

* T joints are preferred instead of corner joints

Material-2 (Steel AISI 1018,1.25inx1.13inx1.5mm)

a) Assumption & Considerations:

Following assumptions & consideration were made for performing the analysis for frontal impact on frame/vehicle.
Impact force was applied on the foremost part of the roll cage.

Mounting points of suspension arms were fixed.

Initial Speed=9.11m/s

Final Speed=0m/s

Reaction time=0.13s

b) Calculation of Impact Forces:

Work Done= $(0.5*M*V_{final}^2 - 0.5*M*V_{initial}^{2)}$

$|W|=|-0.5*M*V_{initial}^2|$

$=|-0.5*240*9.114^2|$

=9967.8 Nm

Work Done=Force * Displacement

=(F*S)

S=Impact Time*V_{max}

=0.13*9.114

=1.184m

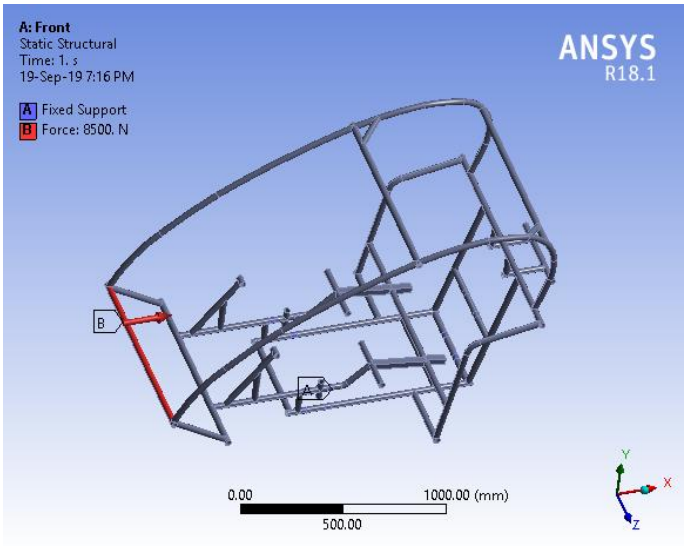
So,

F=W/S

=9967.8/1.184

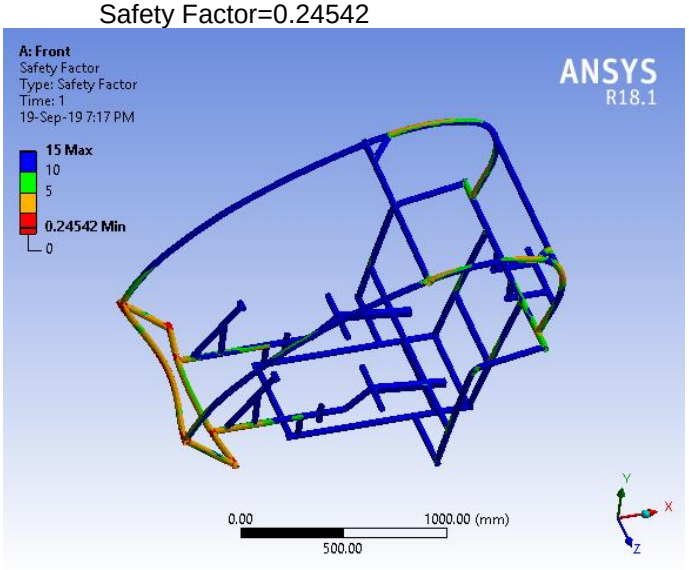
=8418.75N

≈8500N

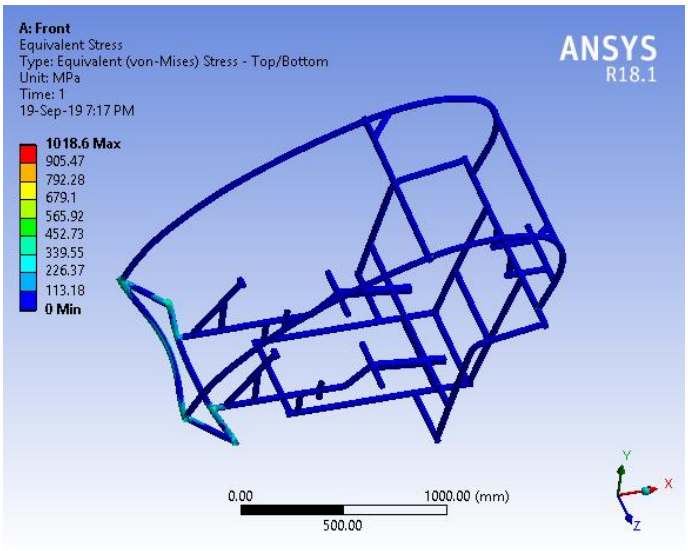


c) Analysis Results:

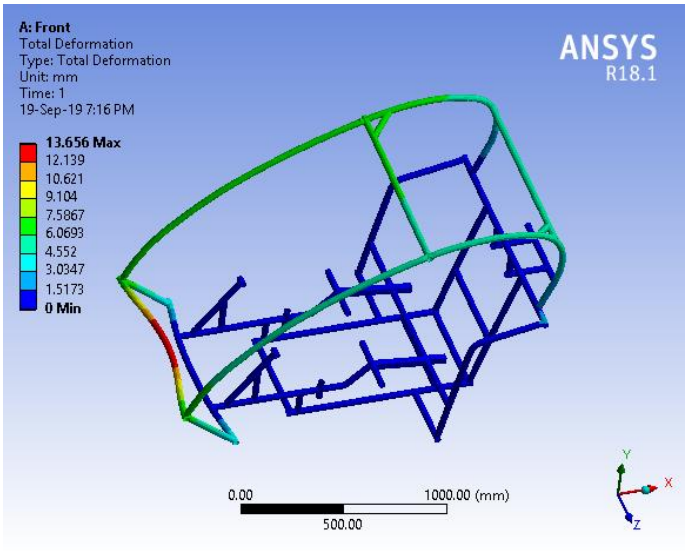
Safety Factor=0.24542



Equivalent Stress=1018.6MPa



Total Deformation = 13.656 mm



d) Optimizations:

* Unnecessary members are removed

* T joints are preferred instead of corner joints

Material-3 (Steel AISI 4130,1.25inx1.13inx1.5mm)

a) Assumption & Considerations:

Following assumptions & consideration were made for performing the analysis for frontal impact on frame/vehicle.
Impact force was applied on the foremost part of the roll cage.

Mounting points of suspension arms were fixed.

Initial Speed=9.11m/s

Final Speed=0m/s

Reaction time=0.13s

d) Calculation of Impact Forces:

Work Done= $(0.5*M*V_{final}^2 - 0.5*M*V_{initial}^{2)}$

$|W|=|-0.5*M*V_{initial}^2|$

$=|-0.5*240*9.114^2|$

=9967.8 Nm

Work Done=Force * Displacement

=(F*S)

$S=\text{Impact Time}*V_{max}$

=0.13*9.114

=1.184m

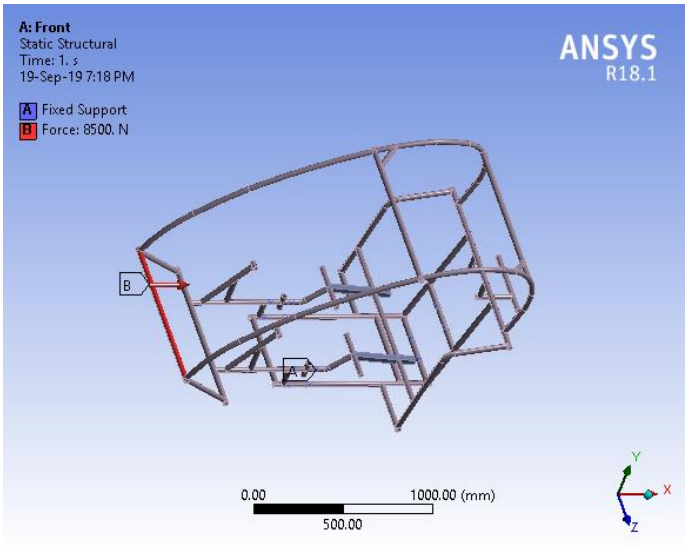
So,

F=W/S

=9967.8/1.184

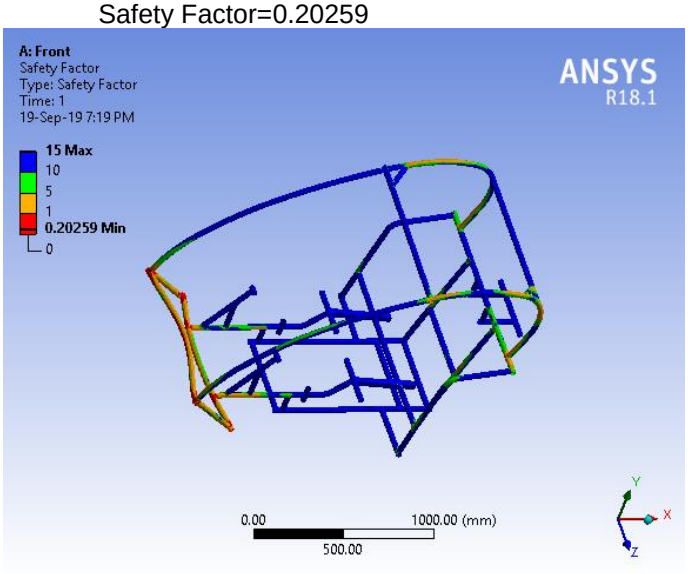
=8418.75N

≈8500N

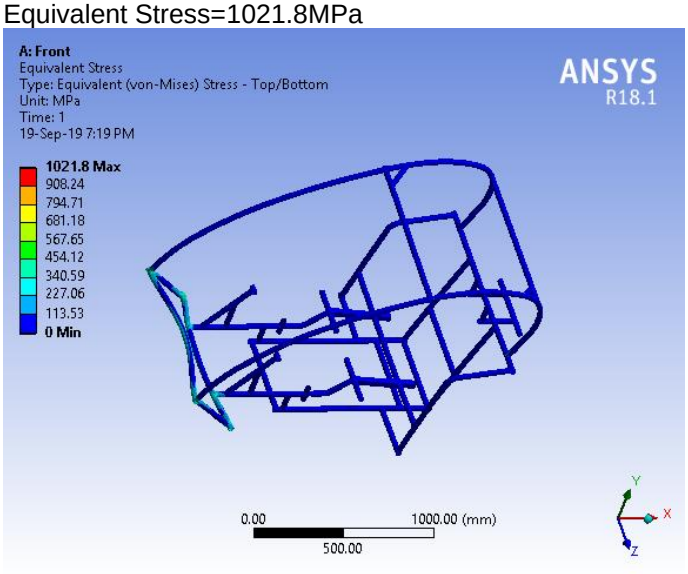


b) Analysis Results:

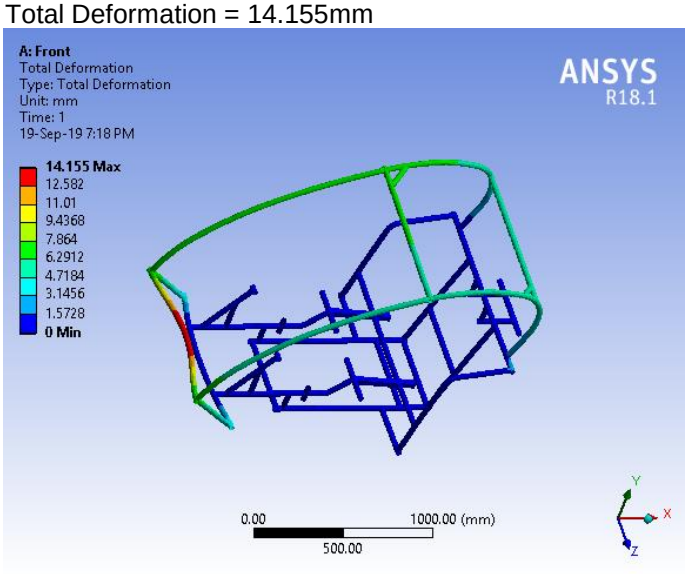
Safety Factor=0.20259



Equivalent Stress=1021.8MPa



Total Deformation = 14.155mm



d) Optimizations

* Unnecessary members are removed

* T joints are preferred instead of corner joints

Material-4 (Steel AISI 4130,1inx1.11inx1.65mm)

a) Assumption & Considerations:

Following assumptions & consideration were made for performing the analysis for frontal impact on frame/vehicle.
Impact force was applied on the foremost part of the roll cage.

Mounting points of suspension arms were fixed.

Initial Speed=9.11m/s

Final Speed=0m/s

Reaction time=0.13s

b) Calculation of Impact Forces:

Work Done= $(0.5*M*V_{final}^2 - 0.5*M*V_{initial}^{2)}$

$|W|=|-0.5*M*V_{initial}^2|$

$=|-0.5*240*9.114^2|$

=9967.8 Nm

Work Done=Force * Displacement

=(F*S)

S=Impact Time*V_{max}

=0.13*9.114

=1.184m

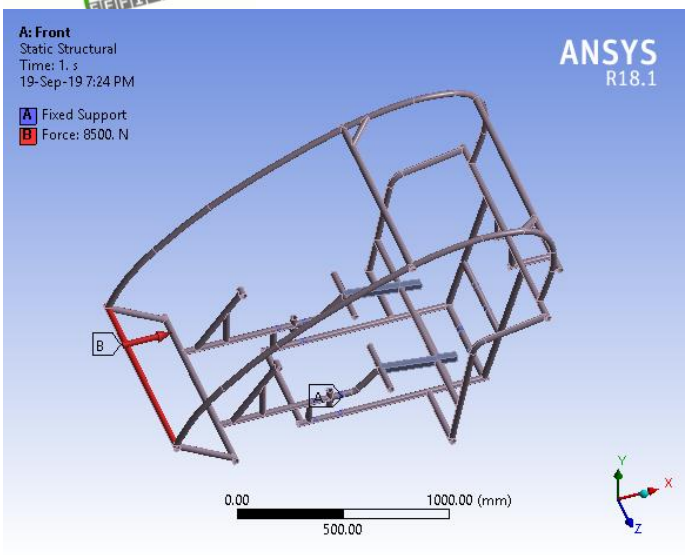
So,

F=W/S

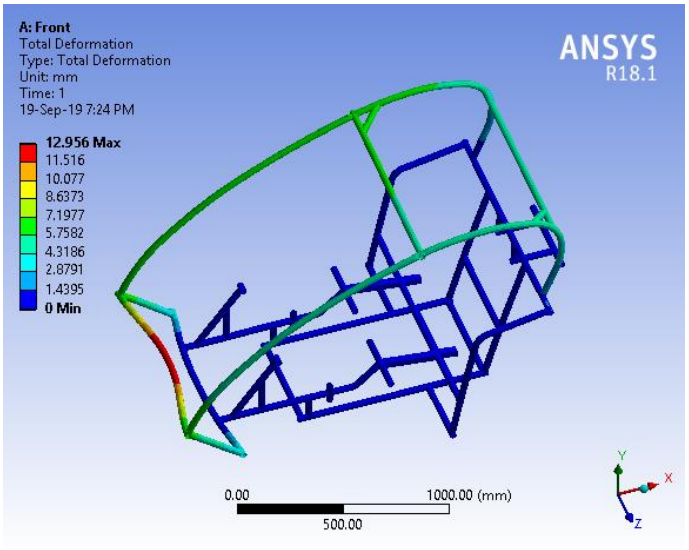
=9967.8/1.184

=8418.75N

≈8500N

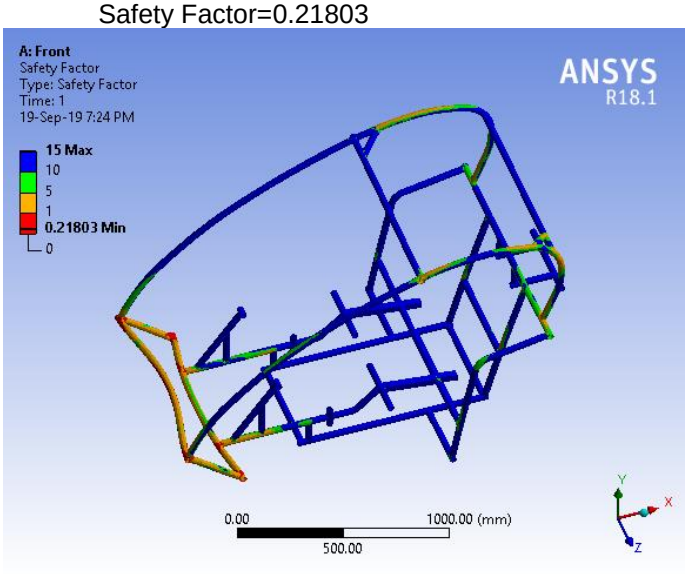


Total Deformation 12.956 mm

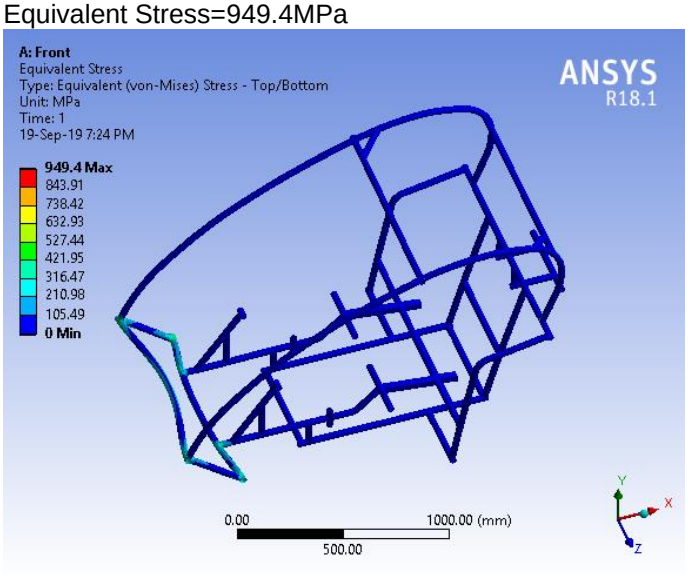


c) Analysis Results:

Safety Factor=0.21803



Equivalent Stress=949.4MPa



d) Optimizations:

* Unnecessary members are removed

* T joints are preferred instead of corner joints

B. SIDE IMPACT ANALYSIS

Material-1 (Steel AISI 1018, 1inx0.84inx2mm)

a) Assumption& Considerations:

Following assumptions & consideration were made for performing the analysis for frontal impact on frame/vehicle.
Impact force was applied on the foremost part of the roll cage.

Mounting points of suspension arms were fixed.

Initial Speed=9.114m/s

Final Speed=0m/s

Reaction time=0.30s

b) Calculation of Impact Forces:

Work Done= $(0.5*M*V_{final}^2 - 0.5*M*V_{initial}^{2)}$

$|W|=|-0.5*M*V_{initial}^2|$

$=|-0.5*240*9.114^2|$

=9967.8 Nm

Work Done=Force * Displacement

=(F*S)

S=Impact Time*V_{max}

=0.30*9.114

=2.73m

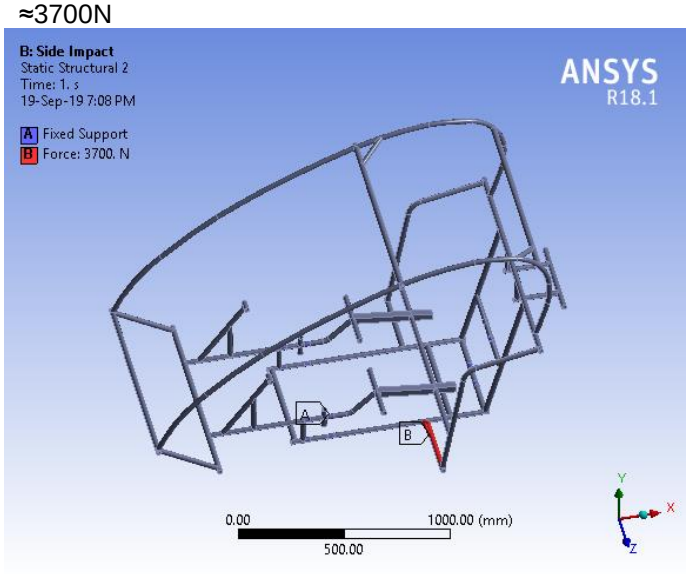
So,

F=W/S

=9967.8/2.73

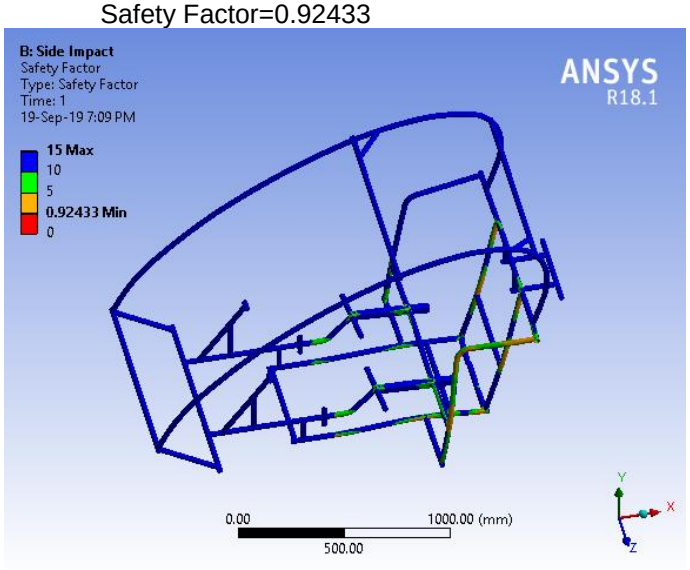
=3645.6N

≈3700N

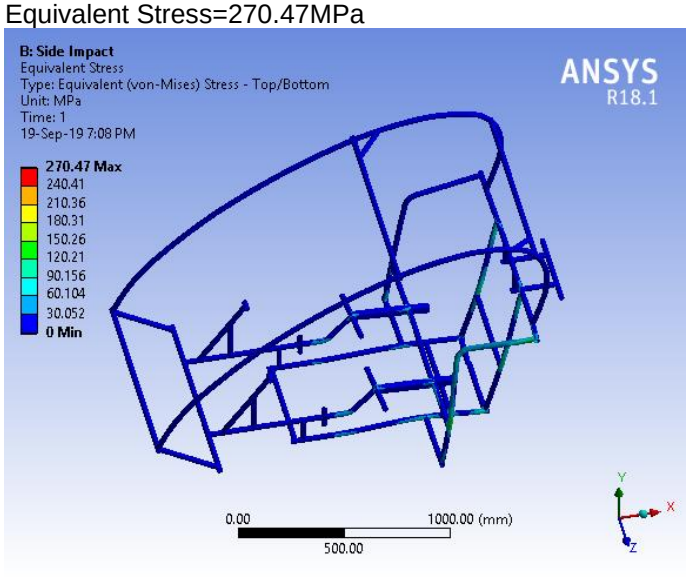


c) Analysis Results:

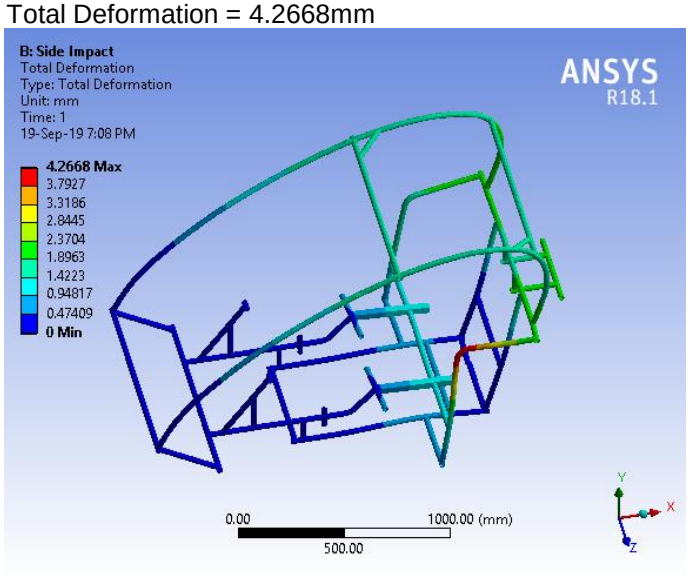
Safety Factor=0.92433



Equivalent Stress=270.47MPa



Total Deformation = 4.2668mm



d) Optimizations:

* Unnecessary members are removed

* T joints are preferred instead of corner joints

Material-2 (Steel AISI 1018, 1.25inx1.13inx1.5mm)

a) Assumption & Considerations:

Following assumptions & consideration were made for performing the analysis for frontal impact on frame/vehicle.
Impact force was applied on the foremost part of the roll cage.

Mounting points of suspension arms were fixed.

Initial Speed=9.114m/s

Final Speed=0m/s

Reaction time=0.30s

b) Calculation of Impact Forces:

Work Done= $(0.5*M*V_{final}^2 - 0.5*M*V_{initial}^{2)}$

$|W|=|-0.5*M*V_{initial}^2|$

$=|-0.5*240*9.114^2|$

=9967.8 Nm

Work Done=Force * Displacement

=(F*S)

S=Impact Time*V_{max}

=0.30*9.114

=2.73m

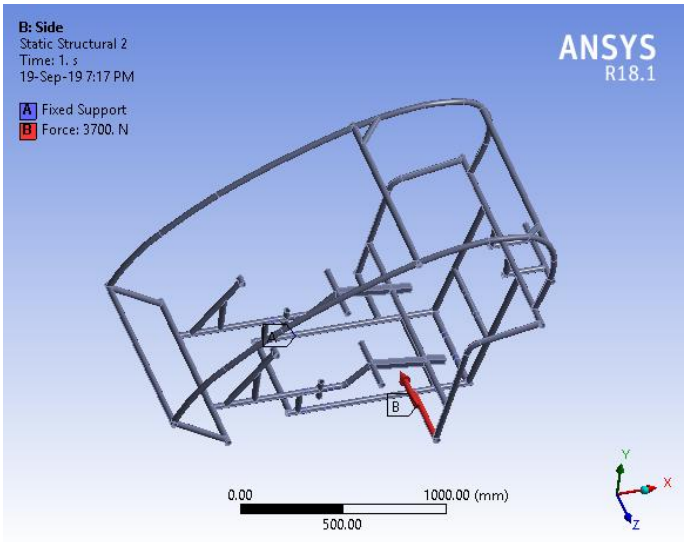
So,

F=W/S

=9967.8/2.73

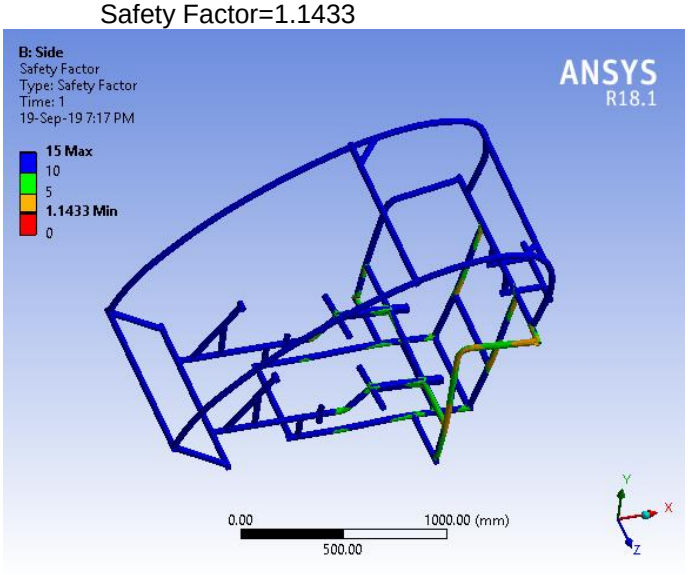
=3645.6N

≈3700N

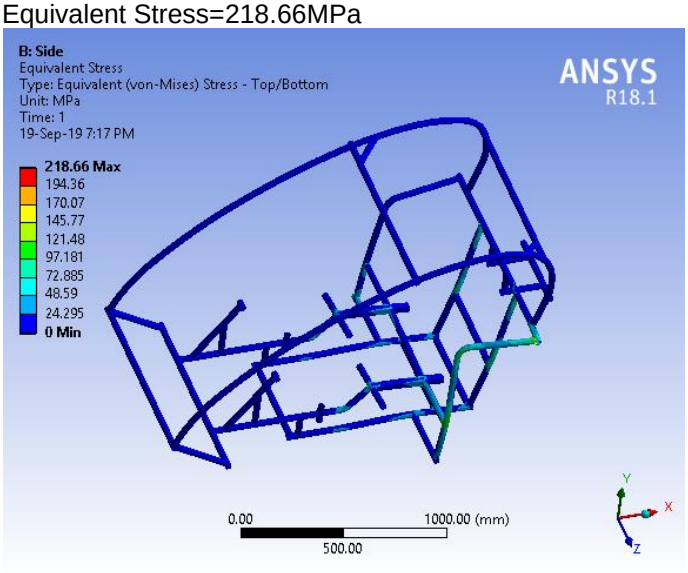


c) Analysis Results

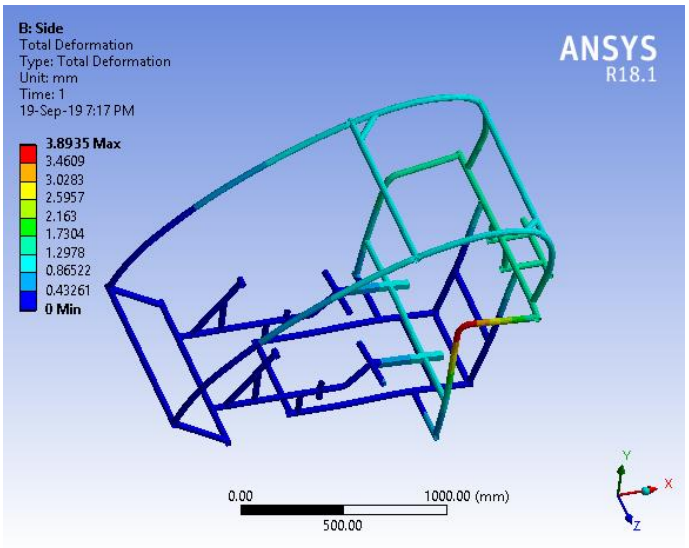
Safety Factor=1.1433



Equivalent Stress=218.66MPa



Total Deformation = 3.8935mm



d) Optimizations:

* Unnecessary members are removed

* T joints are preferred instead of corner joints

Material-3 (Steel AISI 1018, 1.25inx1.13inx1.5mm)

a) Assumption & Considerations:

Following assumptions & consideration were made for performing the analysis for frontal impact on frame/vehicle.
Impact force was applied on the foremost part of the roll cage.

Mounting points of suspension arms were fixed.

Initial Speed=9.114m/s

Final Speed=0m/s

Reaction time=0.30s

b) Calculation of Impact Forces:

Work Done= $(0.5*M*V_{final}^2 - 0.5*M*V_{initial}^{2)}$

$|W|=|-0.5*M*V_{initial}^2|$

$=|-0.5*240*9.114^2|$

=9967.8 Nm

Work Done=Force * Displacement

=(F*S)

S=Impact Time*V_{max}

=0.30*9.114

=2.73m

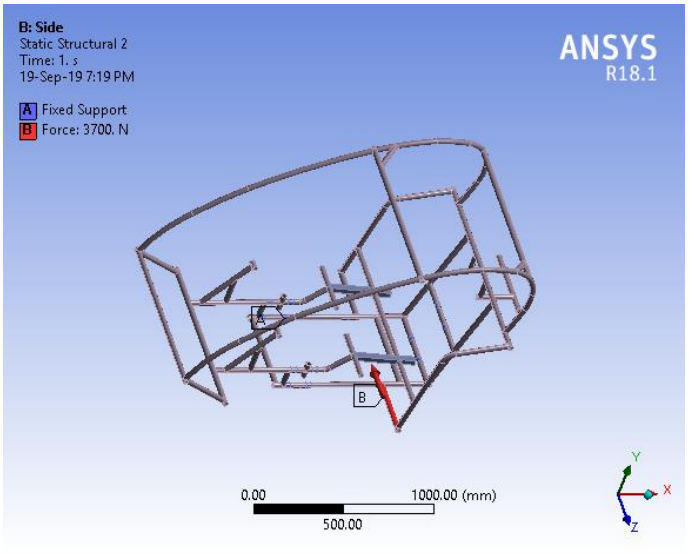
So,

F=W/S

=9967.8/2.73

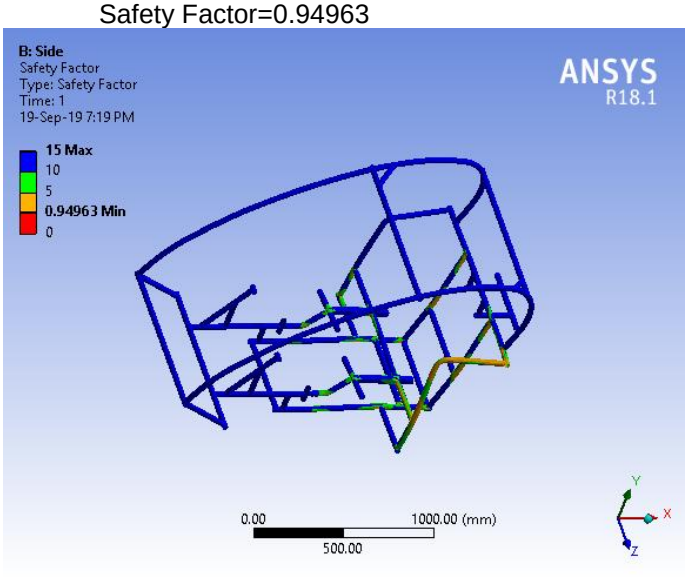
=3645.6N

≈3700N

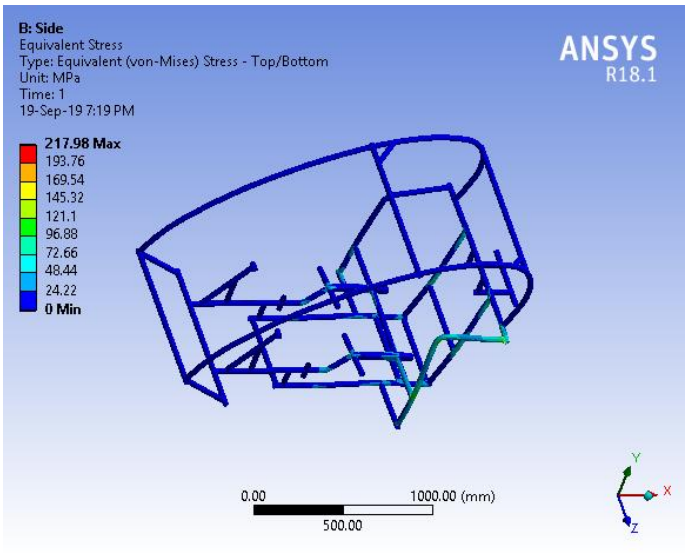


c) Analysis Results

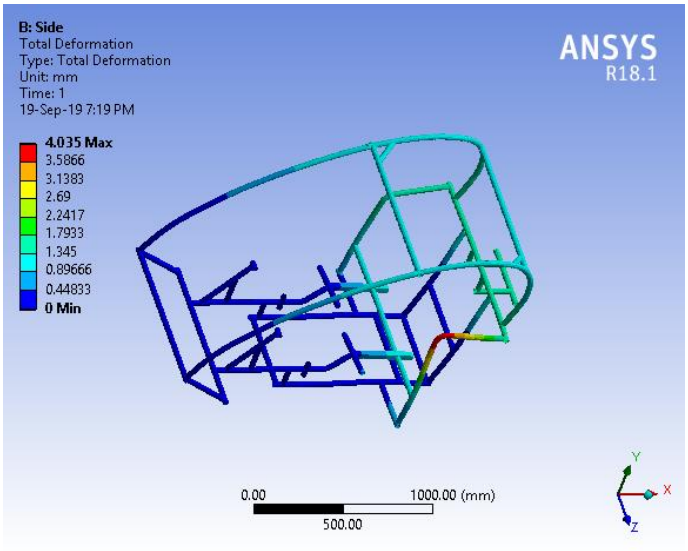
Safety Factor=0.94963



Equivalent Stress=217.98MPa



Total Deformation = 4.035mm



=(F*S)

S=Impact Time*V_{max}

=0.30*9.114

=2.73m

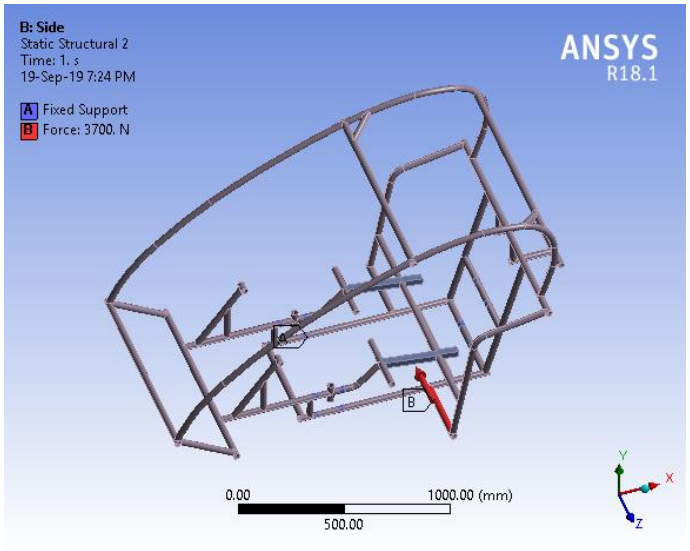
So,

F=W/S

=9967.8/2.73

=3645.6N

≈3700N



d) Optimizations:

* Unnecessary members are removed

* T joints are preferred instead of corner joints

Material-4 (Steel AISI 4130, 1inx1.11inx1.65mm)

a) Assumption & Considerations:

Following assumptions & consideration were made for performing the analysis for frontal impact on frame/vehicle.
Impact force was applied on the foremost part of the roll cage.

Mounting points of suspension arms were fixed.

Initial Speed=9.114m/s

Final Speed=0m/s

Reaction time=0.30s

b) Calculation of Impact Forces:

Work Done= $(0.5*M*V_{final}^2 - 0.5*M*V_{initial}^{2)}$

$|W|=|-0.5*M*V_{initial}^2|$

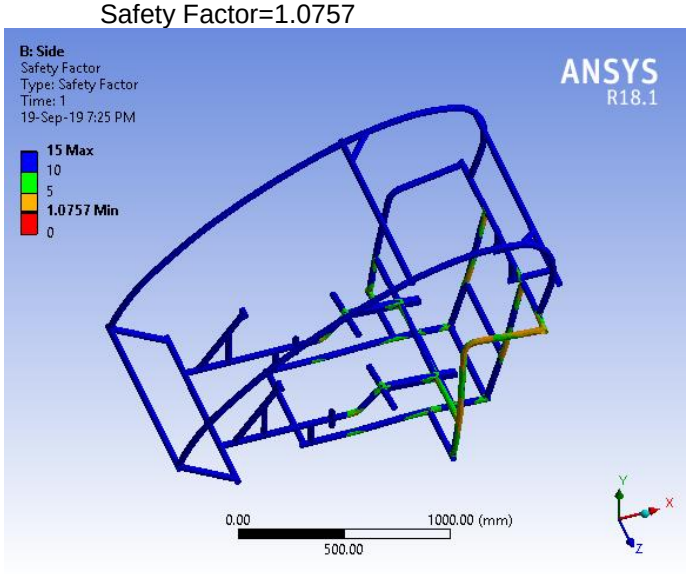
$=|-0.5*240*9.114^2|$

=9967.8 Nm

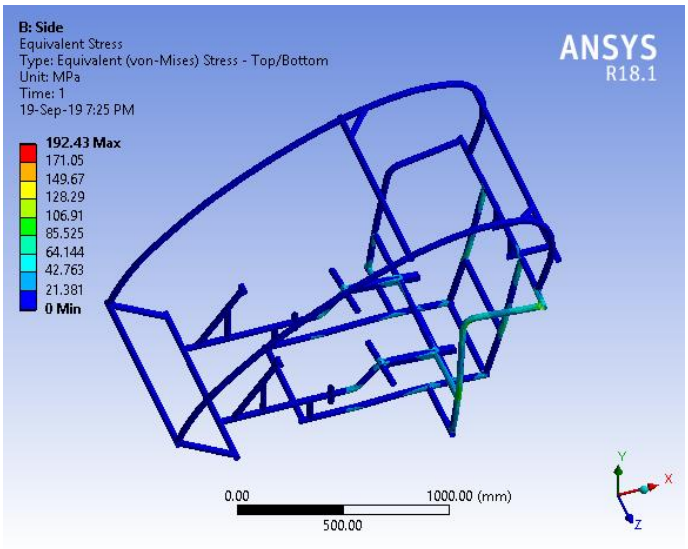
Work Done=Force * Displacement

c) Analysis Results

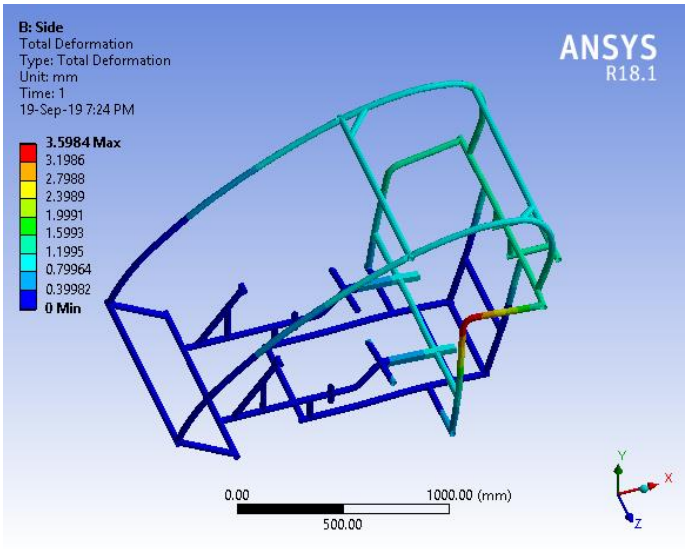
Safety Factor=1.0757



Equivalent Stress=192.43MPa



Total Deformation = 3.5984mm



d) Optimizations:

* Unnecessary members are removed

* T joints are preferred instead of corner joints

C. ROLLOVER ANALYSIS

Material-1 (Steel AISI 1018, 1inx0.84inx2mm)

a) Assumption & Considerations:

Following assumptions & consideration were made for
Lower most members were fixed
performing the analysis for rollover on frame/vehicle.
Mounting points of suspension arms were fixed.

Impact force = G

Meshing Conditions- Relevance Centre = Fine
Relevance = 100
Element Size = 10mm

Reaction Time=0.13 sec

b) Calculation of Impact Forces:

$M * g * h = 0.5 * M * v^2$

$v=\sqrt{2 * 9.81 * 2}$

$=6.2641 m/s$

(Now from work energy principal)

Work Done=Change in Kinetic Energy

$|W|=|-0.5*M*v_{initial}^2|$

$=|0.5*240*6.2641^2|$

$=4708.70N$

$S=\text{Impact time} * v_{max}$

$=0.13*6.2641$

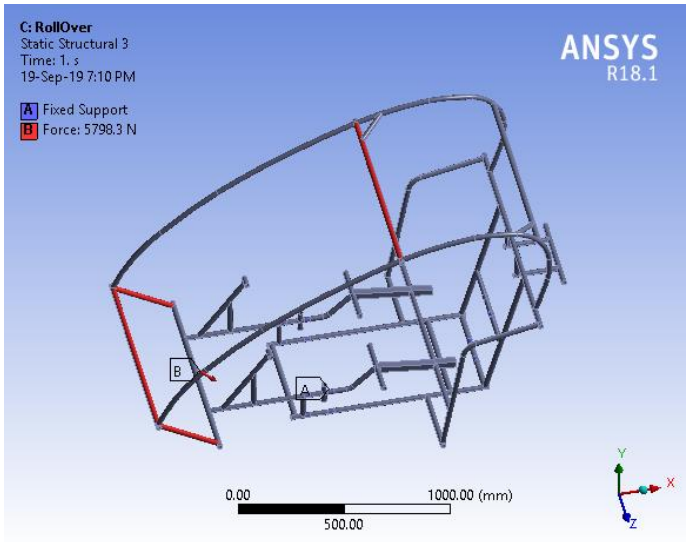
$=0.814333m$

$F=W/S$

$=4708.70/0.81433$

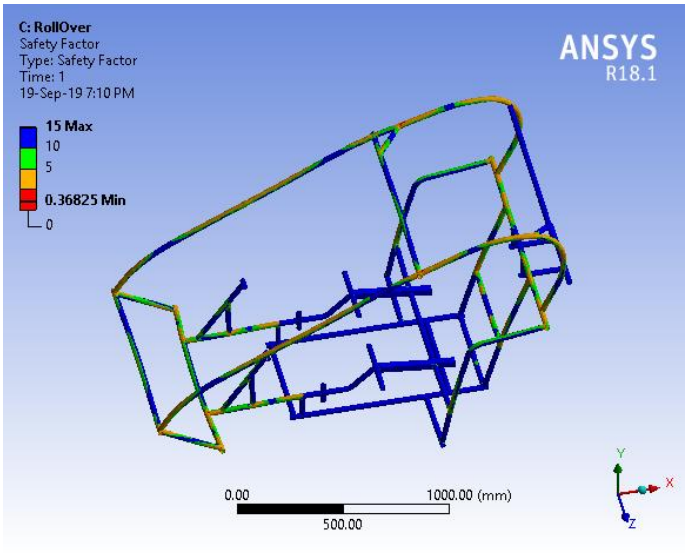
$=5782.30N$

$\approx 5800N$

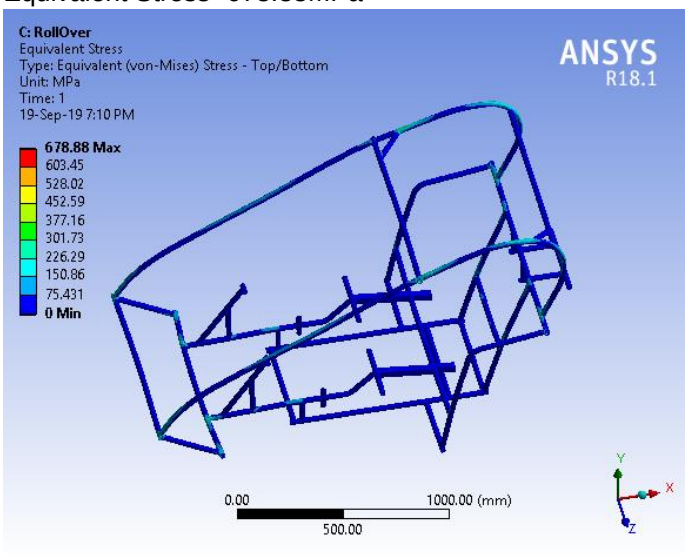


c) Analysis Results:

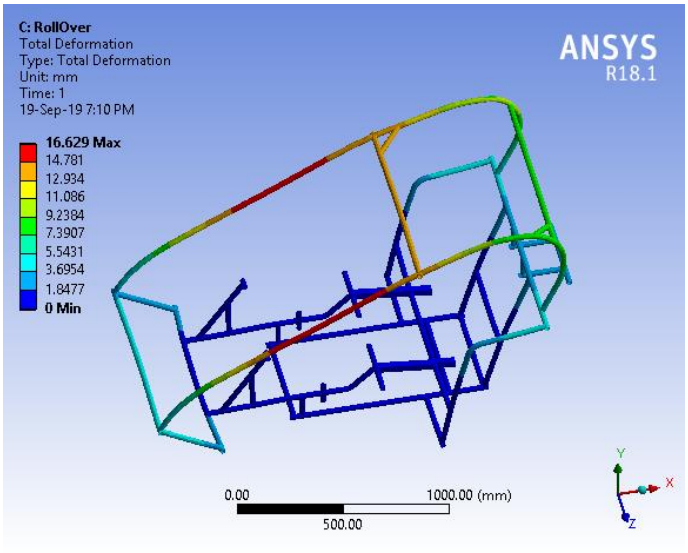
Safety Factor=0.36825



Equivalent Stress=678.88MPa



Total Deformation = 16.629mm



d) Optimizations:

* Unnecessary members are removed
* T joints are preferred instead of corner joints

Material-2 (Steel AISI 4130, 1inx0.84inx2mm)

a) Assumption & Considerations:

Following assumptions & consideration were made for
Lower most members were fixed performing the analysis for rollover on frame/vehicle.
Mounting points of suspension arms were fixed.

Impact force = G

Meshing Conditions- Relevance Centre = Fine
Relevance = 100
Element Size = 10mm

Reaction Time=0.13 sec

b) Calculation of Impact Forces:

$M * g * h = 0.5 * M * v^2$

$v = \sqrt{2 * 9.81 * 2}$

$= 6.2641 m/s$

(Now from work energy principal)

Work Done=Change in Kinetic Energy

$|W| = |-0.5*M*v_{initial}^2|$

$= |0.5*240*6.2641^2|$

$= 4708.70N$

$S = \text{Impact time} * v_{max}$

$= 0.13*6.2641$

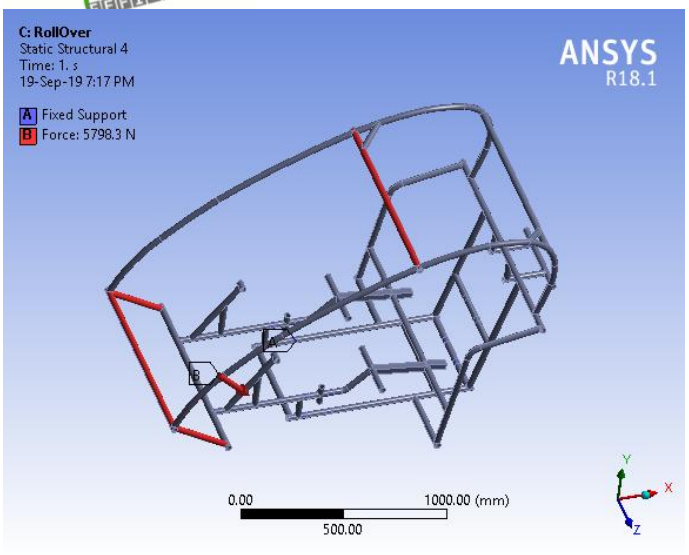
$= 0.814333m$

$F = W/S$

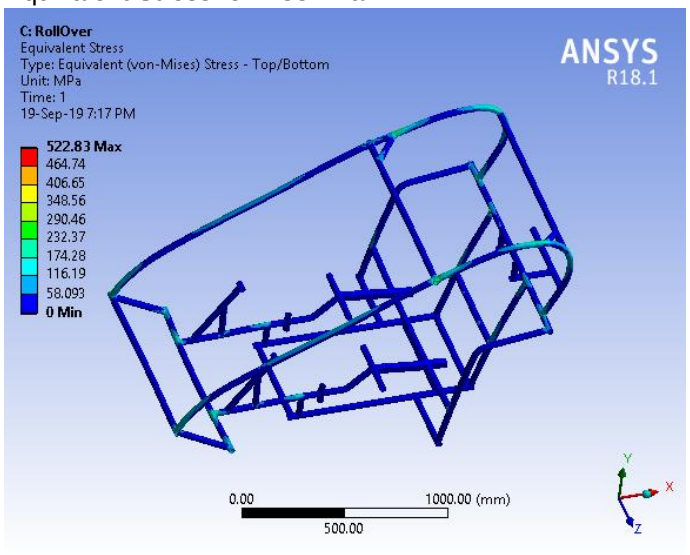
$= 4708.70/0.81433$

$= 5782.30N$

$\approx 5800N$



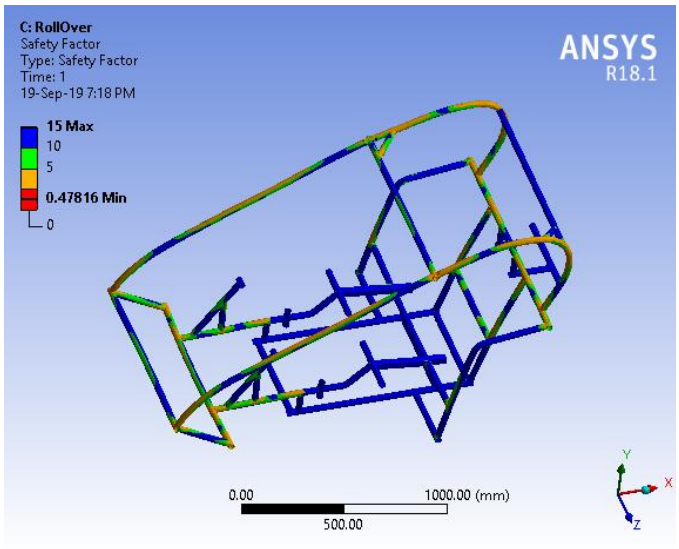
Equivalent Stress=522.83MPa

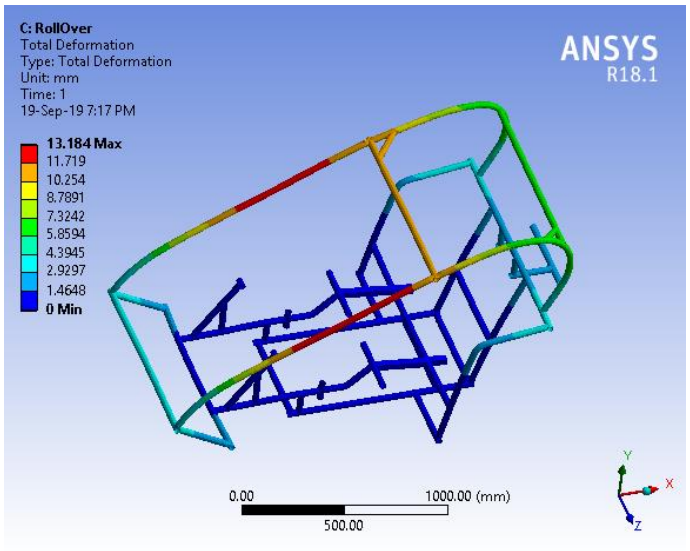


Total Deformation = 13.184mm

c) Analysis Results:

Safety Factor=0.47816





d) Optimizations:

* Unnecessary members are removed

* T joints are preferred instead of corner joints

Material-3 (Steel AISI 1018, 1.25inx1.13inx1.5mm)

a) Assumption & Considerations:

Following assumptions & consideration were made for
Lower most members were fixed
performing the analysis for rollover on frame/vehicle.
Mounting points of suspension arms were fixed.

Impact force = G

Meshing Conditions- Relevance Centre = Fine
Relevance = 100
Element Size = 10mm

Reaction Time=0.13 sec

b) Calculation of Impact Forces:

$M * g * h = 0.5 * M * v^2$

$v = \sqrt{2 * 9.81 * 2}$

$= 6.2641 m/s$

(Now from work energy principal)

Work Done=Change in Kinetic Energy

$|W| = |-0.5*M*v_{initial}^2|$

$= |0.5*240*6.2641^2|$

$= 4708.70N$

$S = \text{Impact time} * v_{max}$

$= 0.13*6.2641$

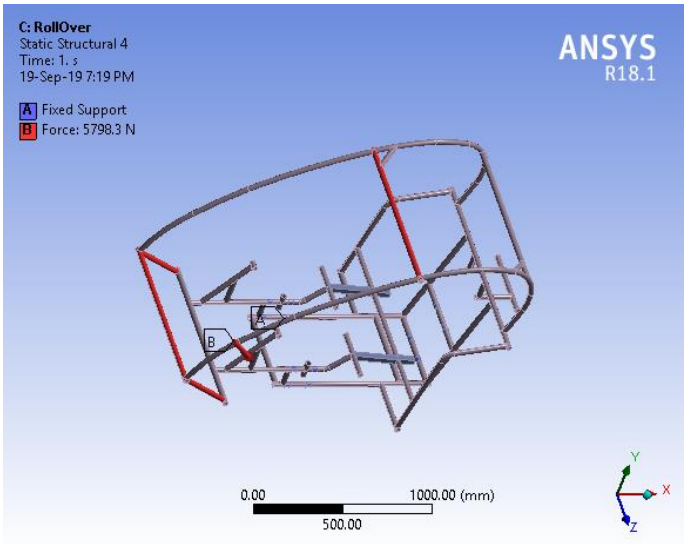
$= 0.814333m$

$F = W/S$

$= 4708.70/0.81433$

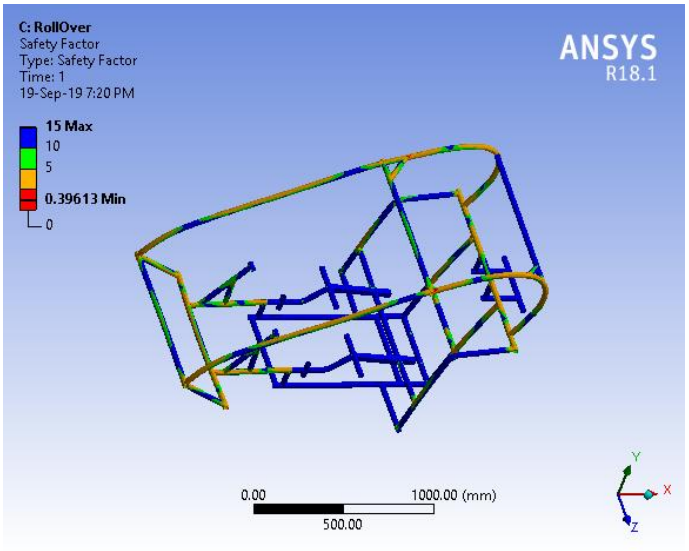
$= 5782.30N$

$\approx 5800N$

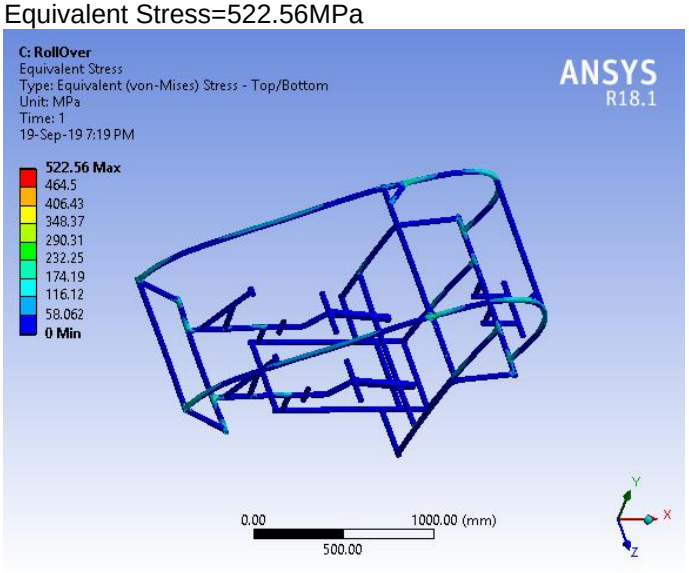


c) Analysis Results:

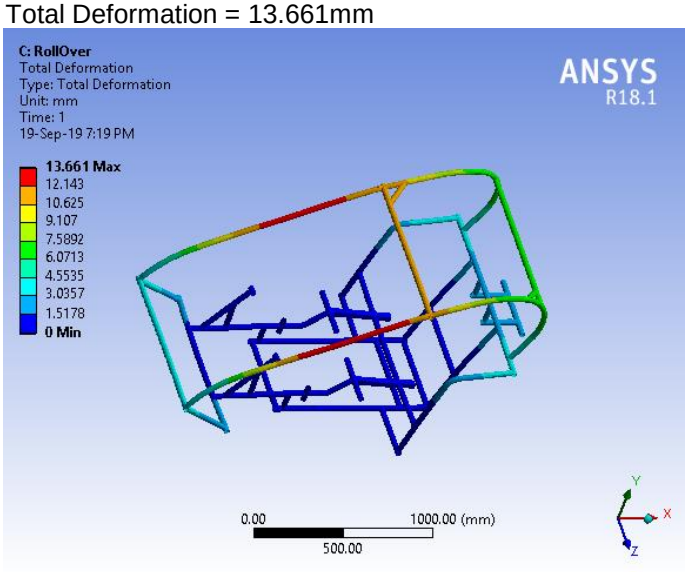
Safety Factor=0.39613



Equivalent Stress=522.56MPa



Total Deformation = 13.661mm



d) Optimizations:

* Unnecessary members are removed

* T joints are preferred instead of corner joints

Material-4 (Steel AISI 4130, 1.25inx1.11inx1.65mm)

a) Assumption & Considerations:

Following assumptions & consideration were made for
Lower most members were fixed performing the analysis for rollover on frame/vehicle.
Mounting points of suspension arms were fixed.

Impact force = G

Meshing Conditions- Relevance Centre = Fine
Relevance = 100
Element Size = 10mm

Reaction Time=0.13 sec

b) Calculation of Impact Forces:

$M * g * h = 0.5 * M * v^2$

$v = \sqrt{2 * 9.81 * 2}$

$= 6.2641 m/s$

(Now from work energy principal)

Work Done=Change in Kinetic Energy

$|W| = |-0.5 * M * v_{initial}^2|$

$= |0.5 * 240 * 6.2641^2|$

$= 4708.70N$

$S = \text{Impact time} * v_{max}$

$= 0.13 * 6.2641$

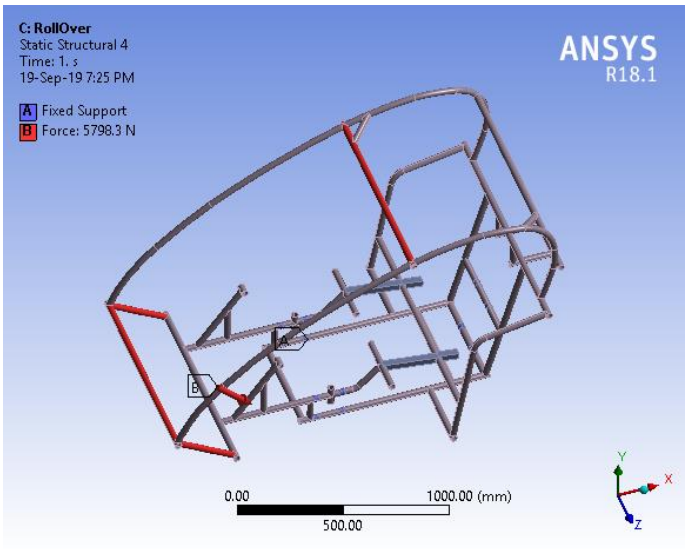
$= 0.814333m$

$F = W/S$

$= 4708.70/0.81433$

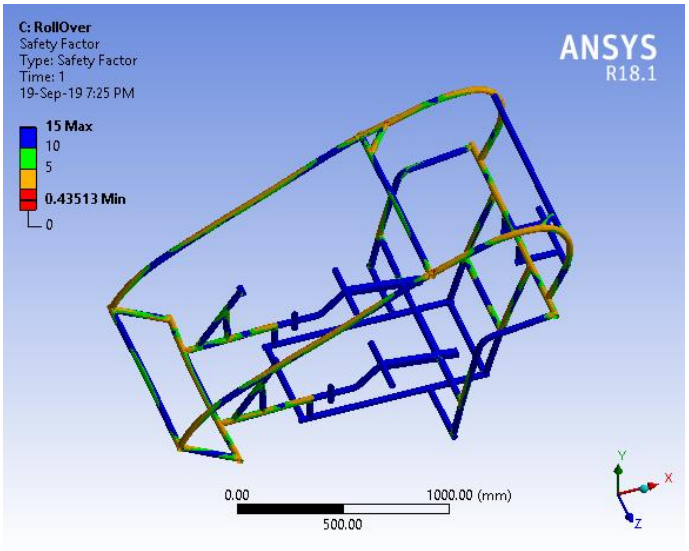
$= 5782.30N$

$\approx 5800N$

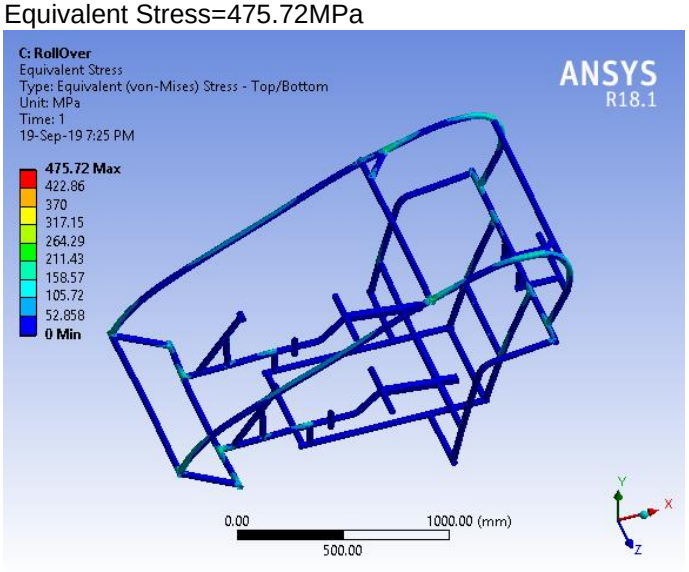


c) Analysis Results:

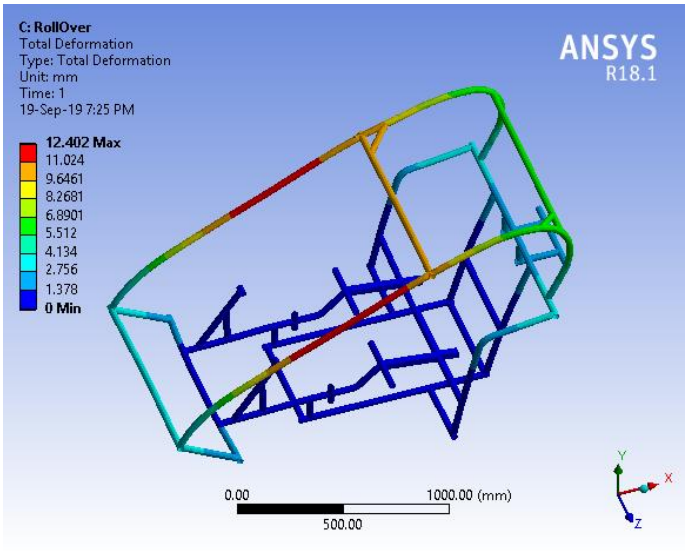
Safety Factor=0.43513

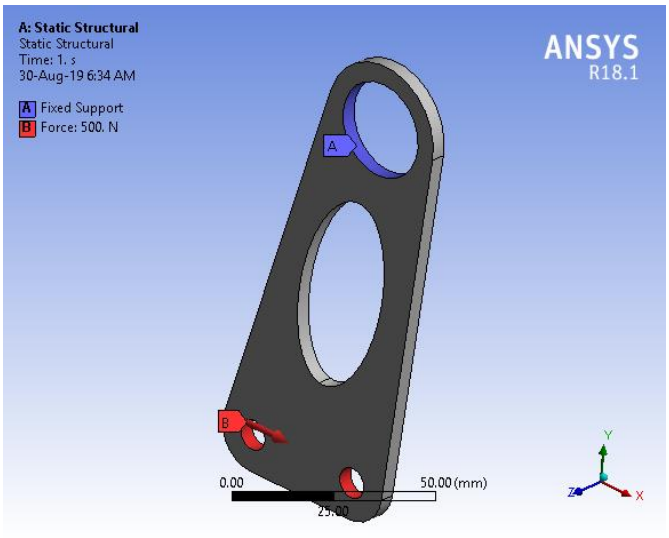


Equivalent Stress=475.72MPa



Total Deformation = 12.402mm

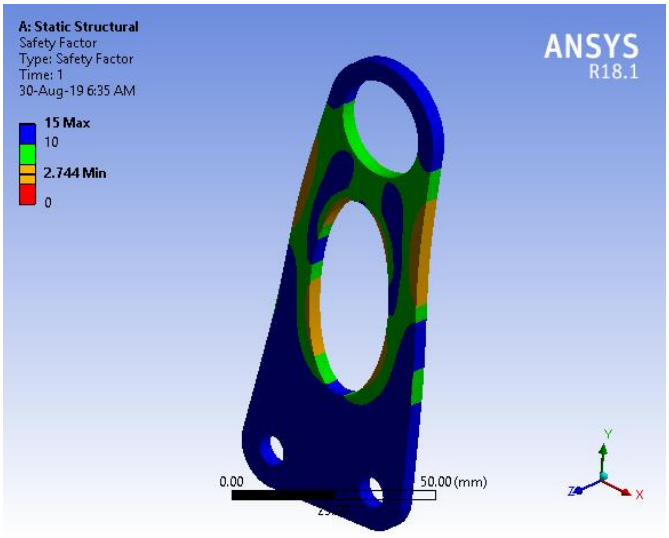




d) Optimizations:

* Unnecessary members are removed
* T joints are preferred instead of corner joints

Safety Factor=2.74



C) FINAL MATERIAL SELECTION

Comparison based on CAE results:

MATERIAL	AISI 1018						AISI 4130					
DIMENSION	1in x 0.84in x 2mm			1.25in x 1.13in x 1.5mm			1.25in x 1.13in x 1.5mm			1.25in x 1.11in x 1.65mm		
IMPACT	Front	Side	Roll	Front	Side	Roll	Front	Side	Roll	Front	Side	Roll
SAFETY FACTOR	0.16834	0.92433	0.36285	0.24542	1.1433	0.478146	0.20259	0.94963	0.39613	0.21803	1.0757	0.43513
TOTAL DEFORMATION(IN mm)	18.628	4.2668	16.629	13.656	3.8935	13.184	14.155	4.035	13.681	12.956	3.5984	12.402
EQUIVALENT STRESS(IN Mpa)	1485.1	270.47	678.88	1018.6	218.66	522.83	1021.8	217.98	522.56	949.4	192.43	475.72
WEIGHT OF ROLLCAGE(kg)		39.57			29.68			29.6			32.57	

Manufactuability:

Material	AISI 1018	AISI 4130
Weight	3	4
Strength	2	5
Machinability	4	4
Availability	4	4
Cost	4	2
Weldability	4	4
TOTAL	21	23

Materials Selected for frame:

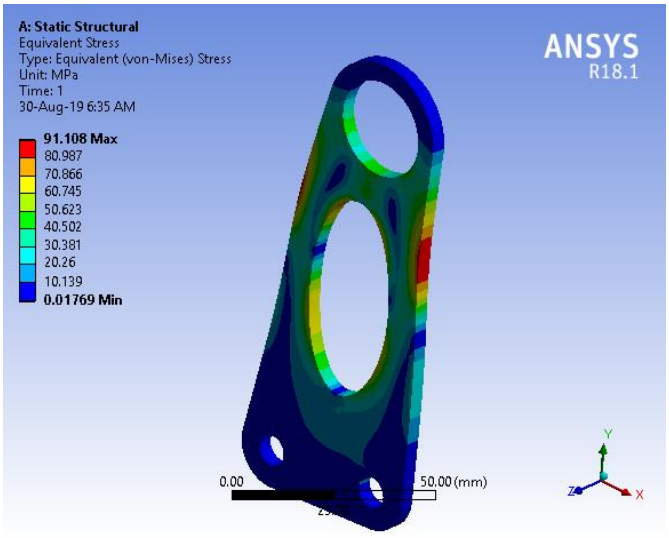
1) Material 1: STEEL AISI 4130,1.25inx1.11inx1.65mm

D) CAE ANALYSIS OF OTHER PARTS

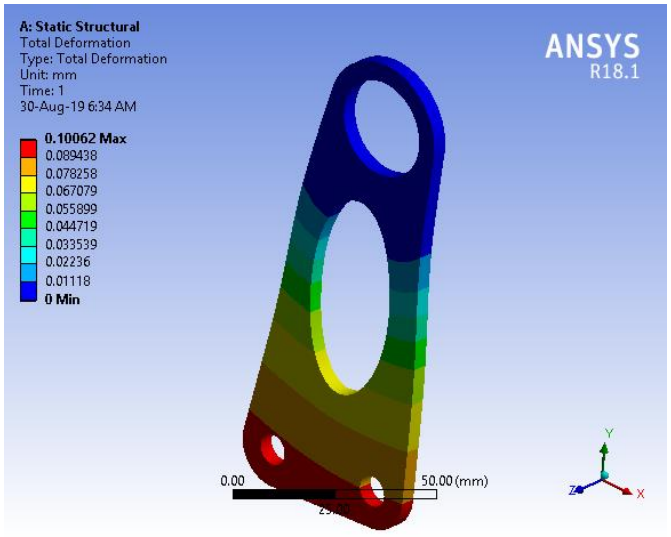
a) CAE analysis : Steering Crank

Force applied by tie rod = 500 N

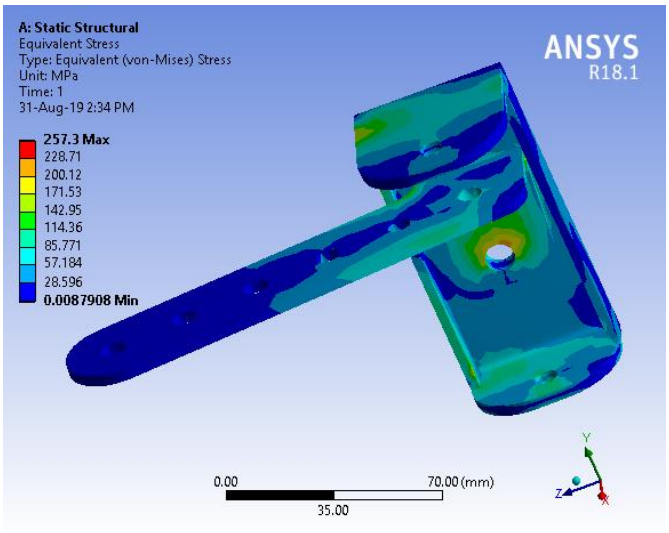
Equivalent Stress=91.11 MPa



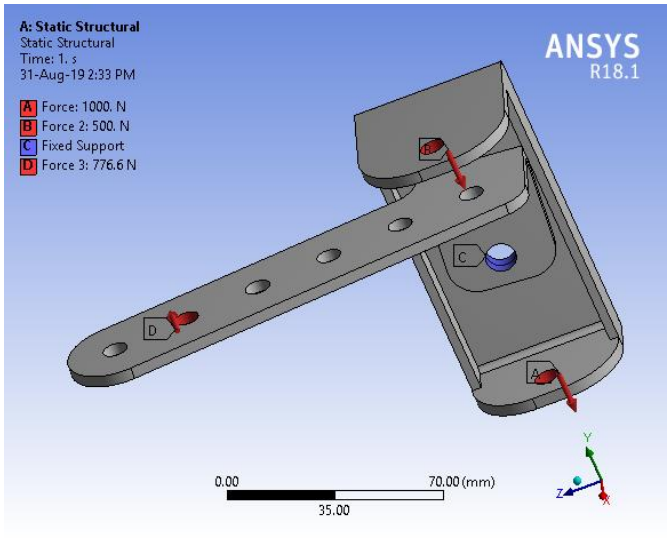
Total Deformation = 0.101 mm



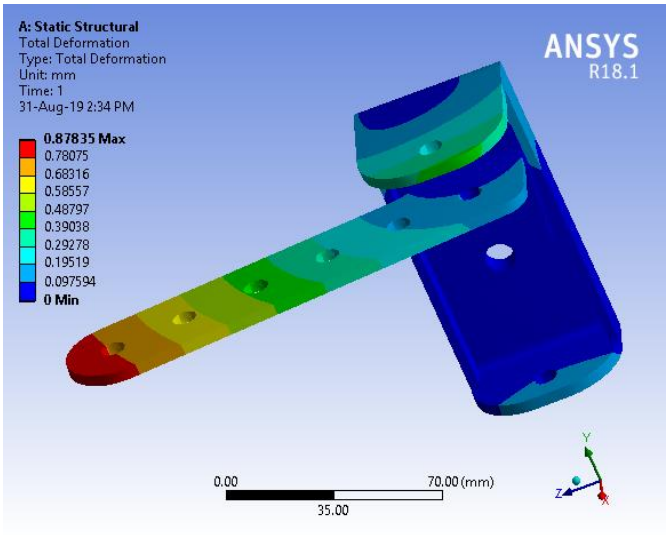
Equivalent Stress=257.3 MPa



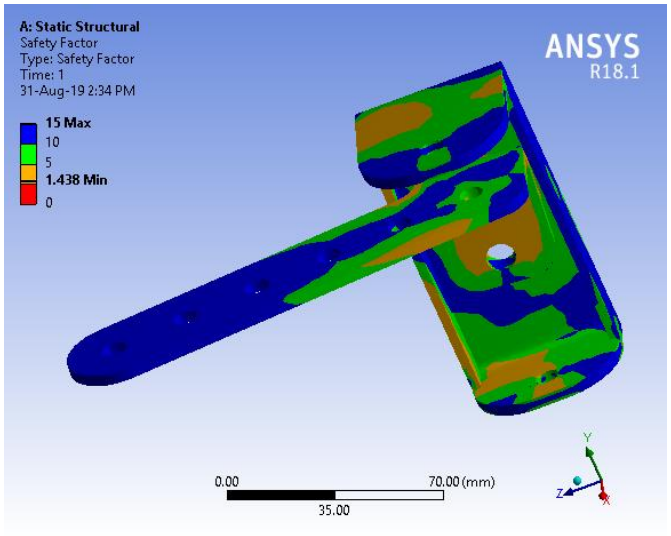
b) CAE analysis : Knuckle + Steering arm



Total Deformation = 0.878 mm

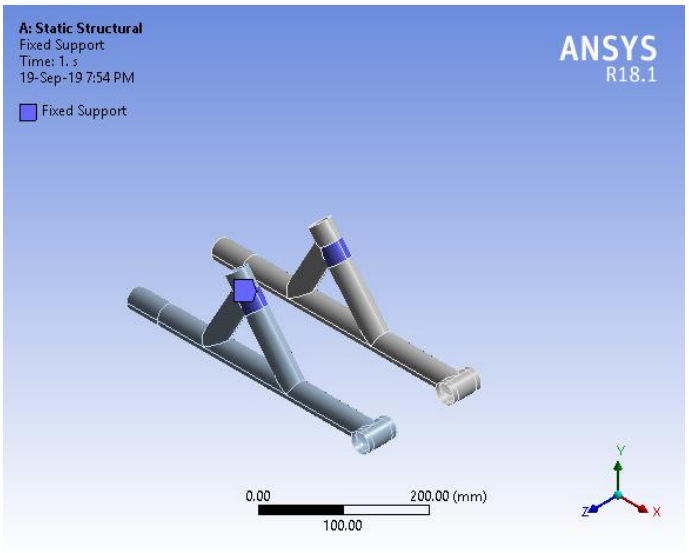


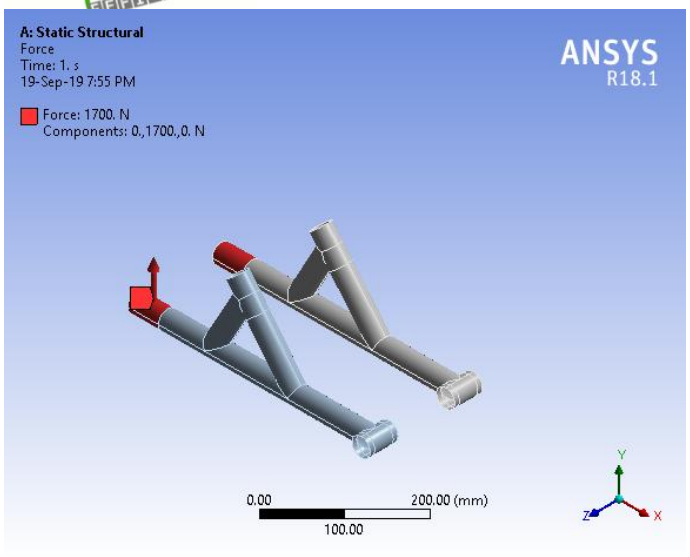
Safety Factor=1.43



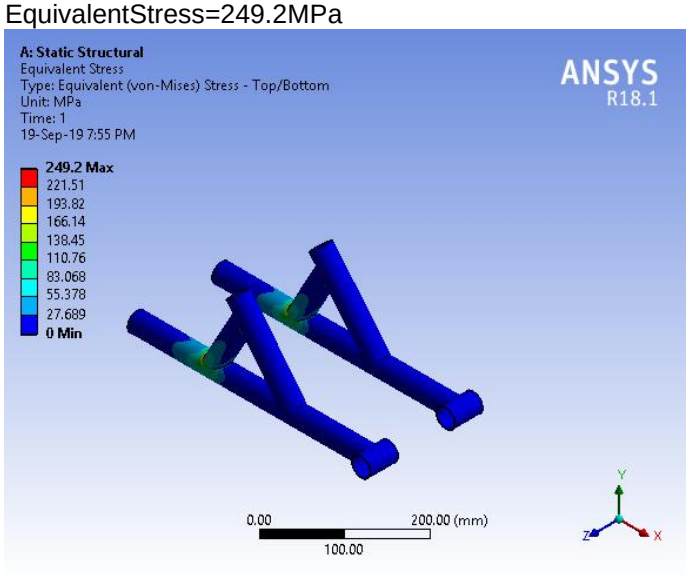
c) CAE analysis: Trailing arm

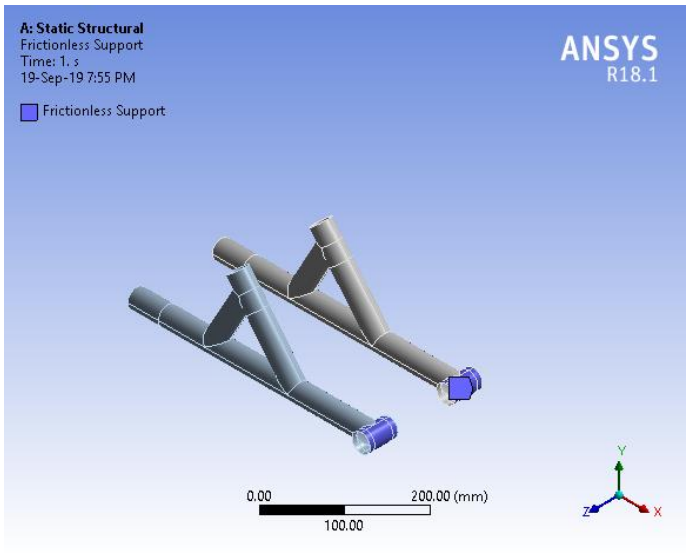
Trailing arm is subjected to a Maximum Force of 1500 N



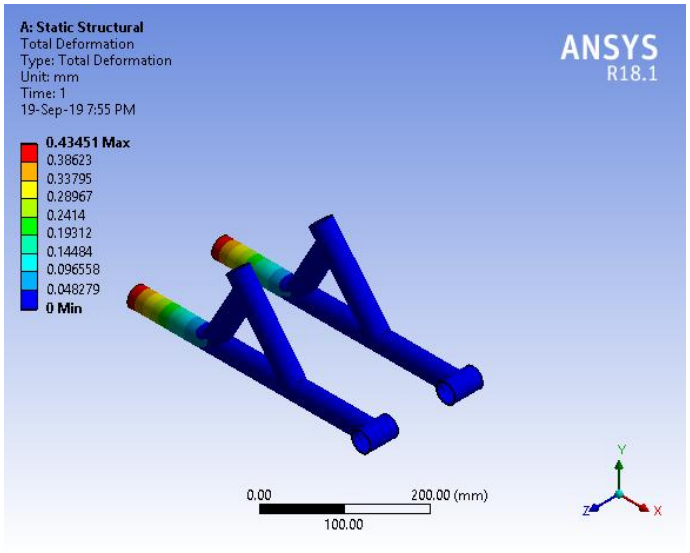


EquivalentStress=249.2MPa



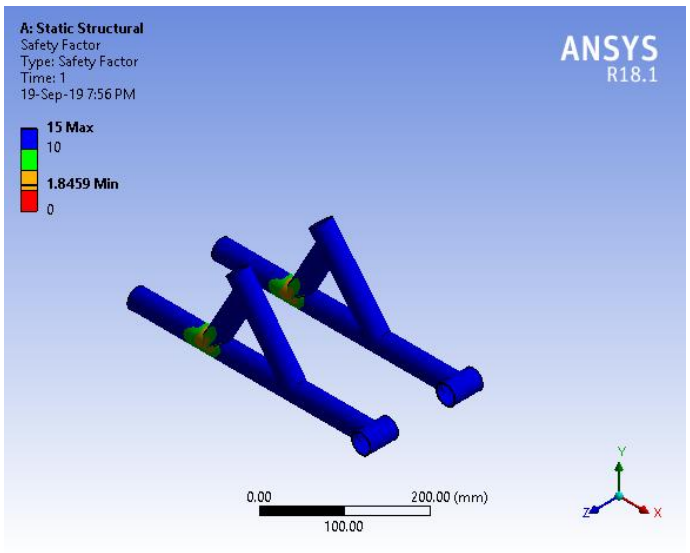


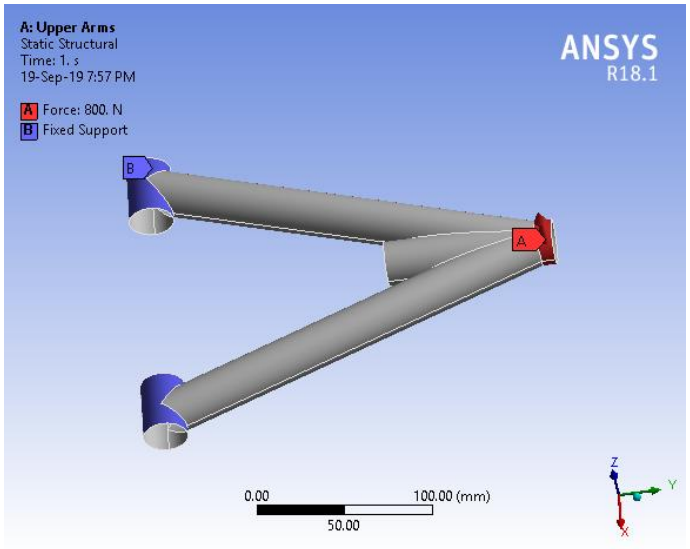
Total Deformation = 0.43451 mm



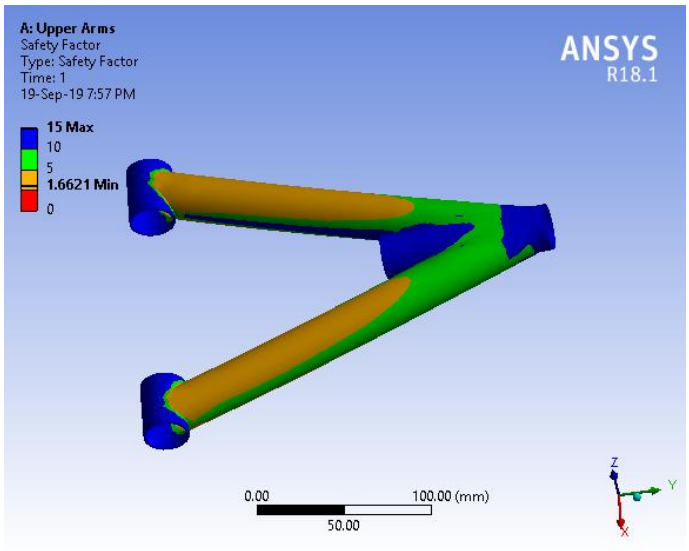
d) CAE analysis: Upper A - arm

Safety Factor=1.8459

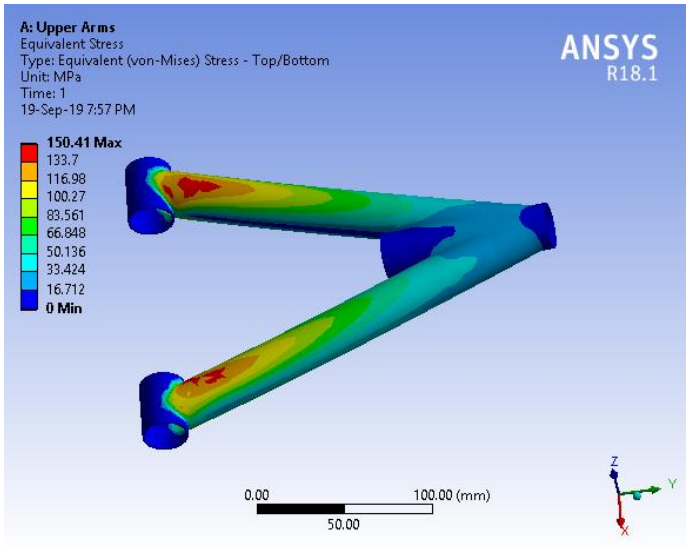




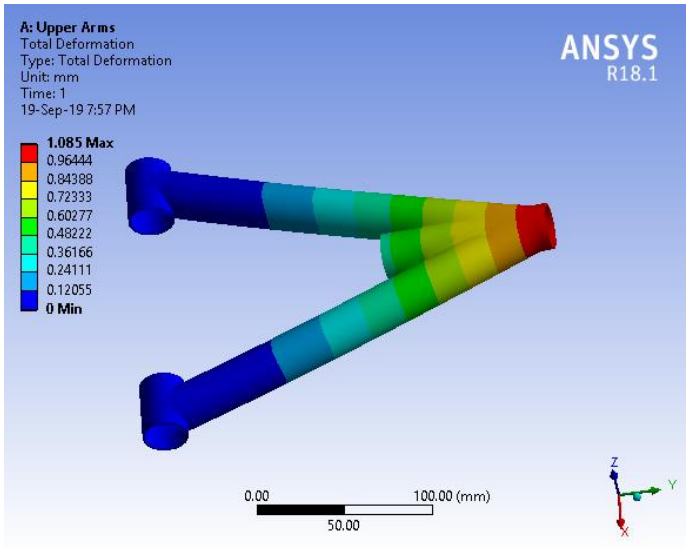
Safety Factor=1.6621



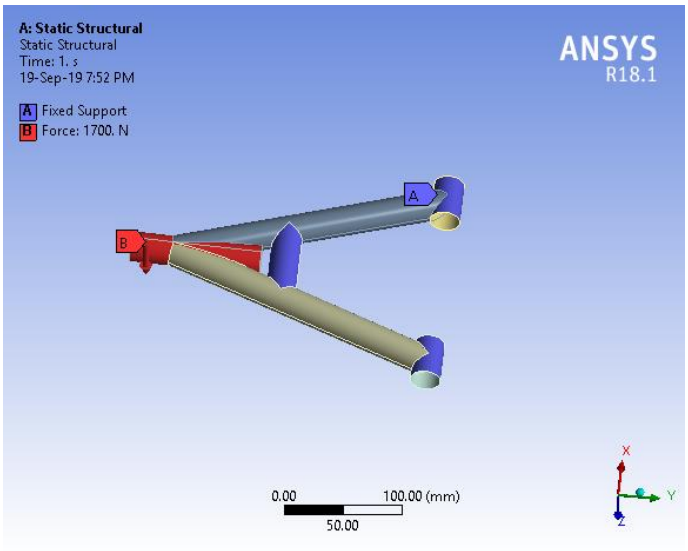
Equivalent Stress=150.41 MPa



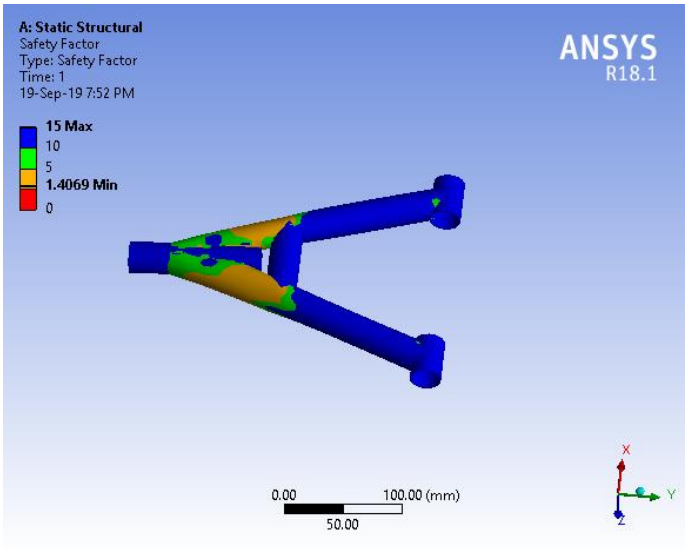
Total Deformation = 1.085 mm



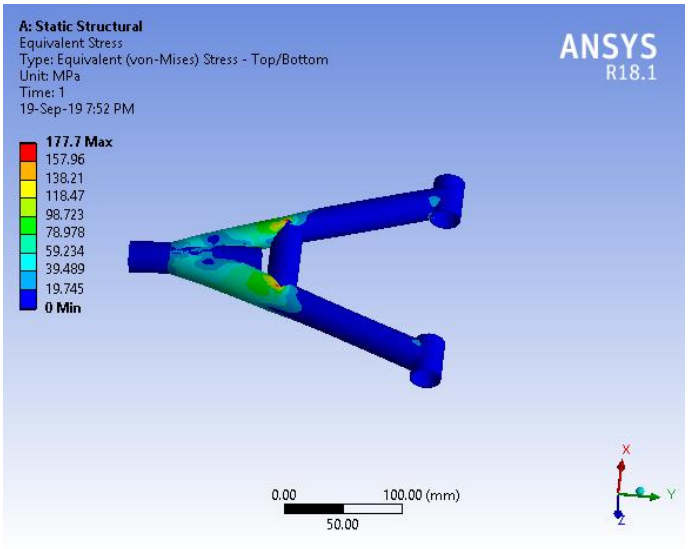
e) CAE analysis: Lower A- arm



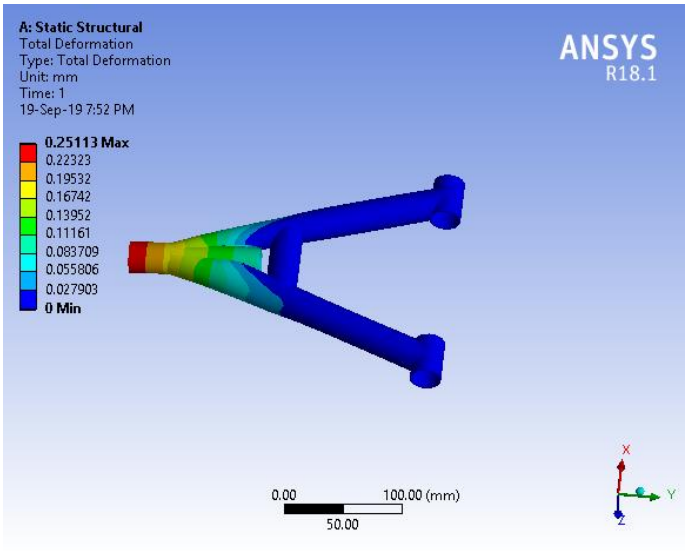
Safety Factor=1.4069

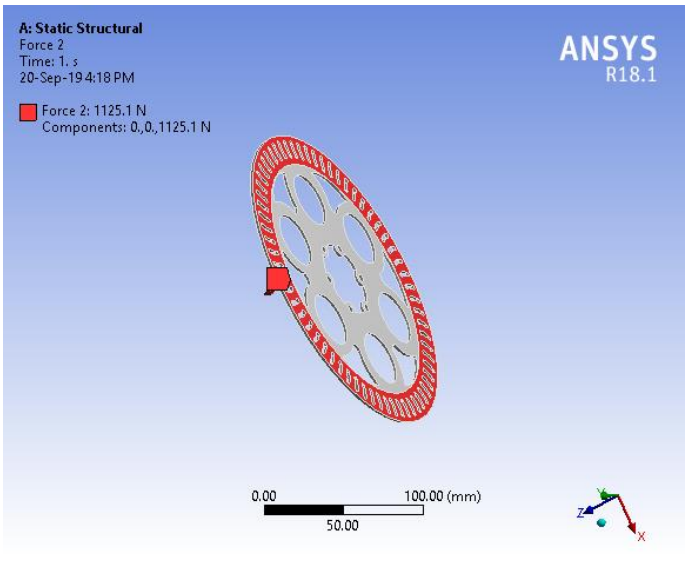


Equivalent Stress=177.7 MPa



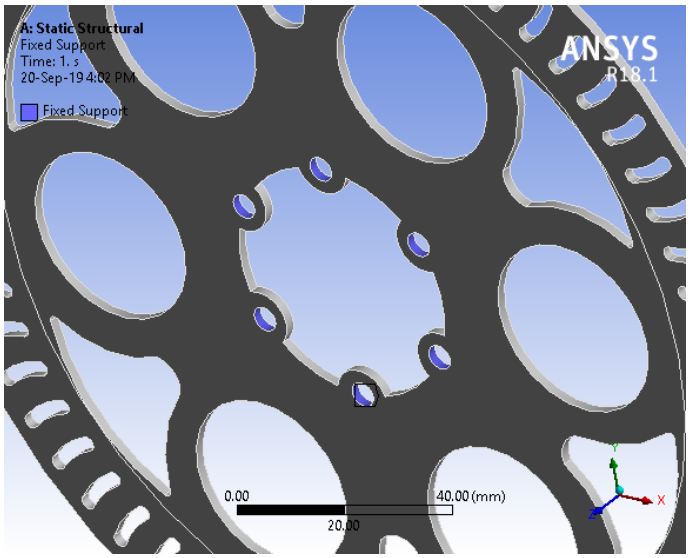
Total Deformation = 0.25113 mm

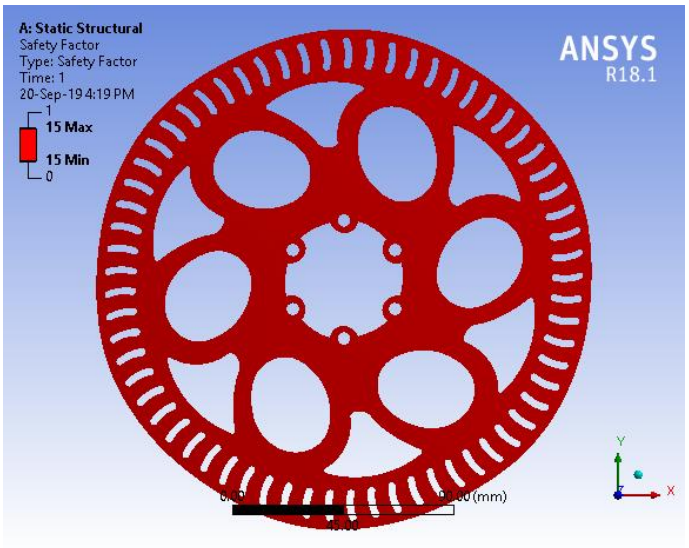




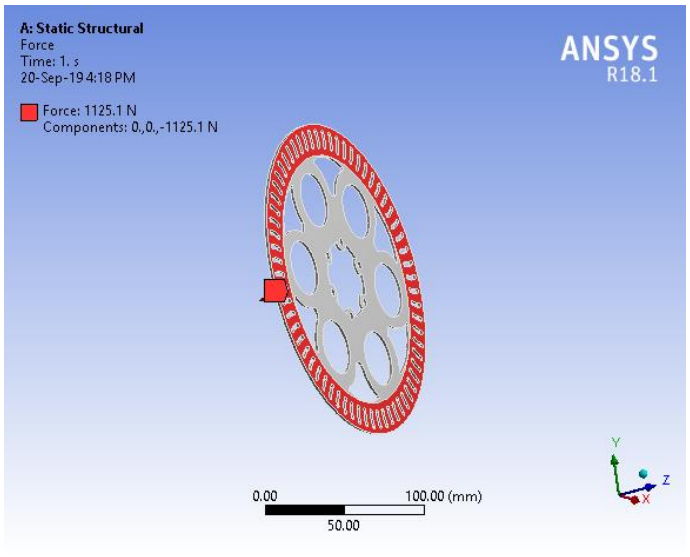
Safety Factor=15

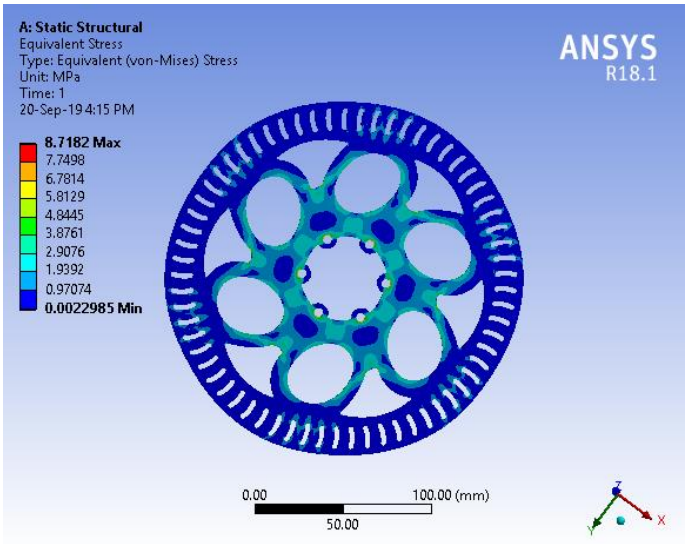
f) CAE analysis: Brake disc



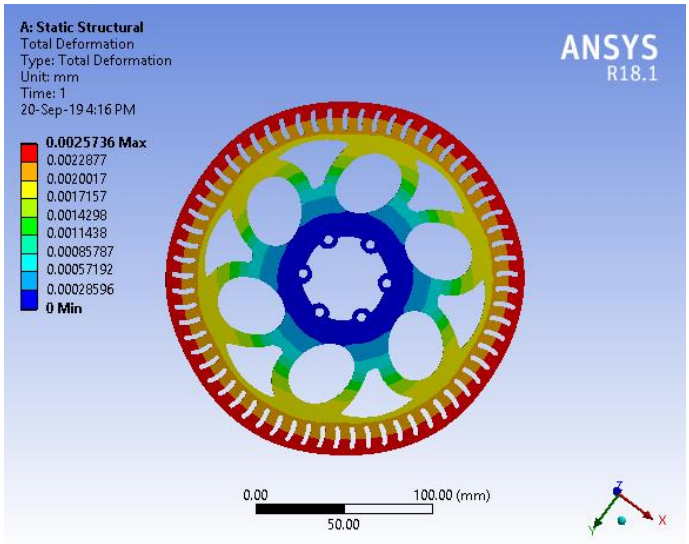


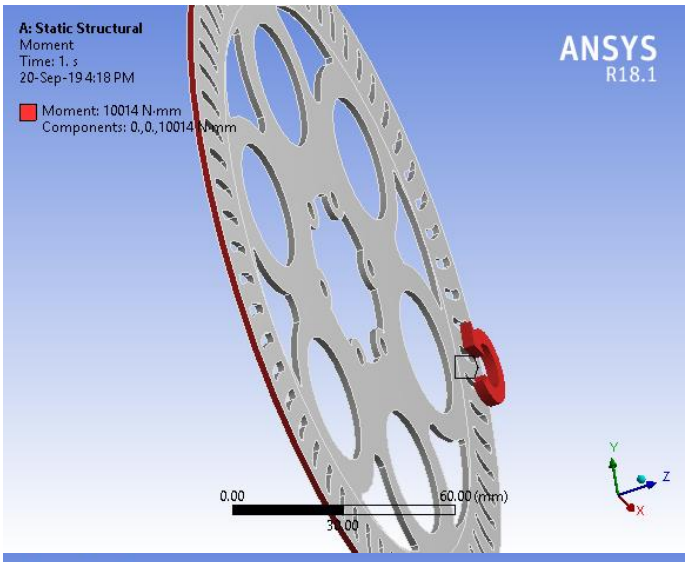
Equivalent Stress=8.7182 MPa

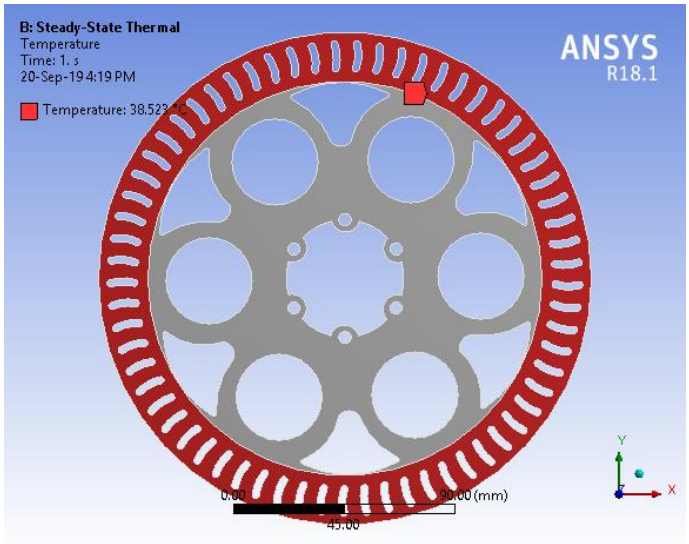


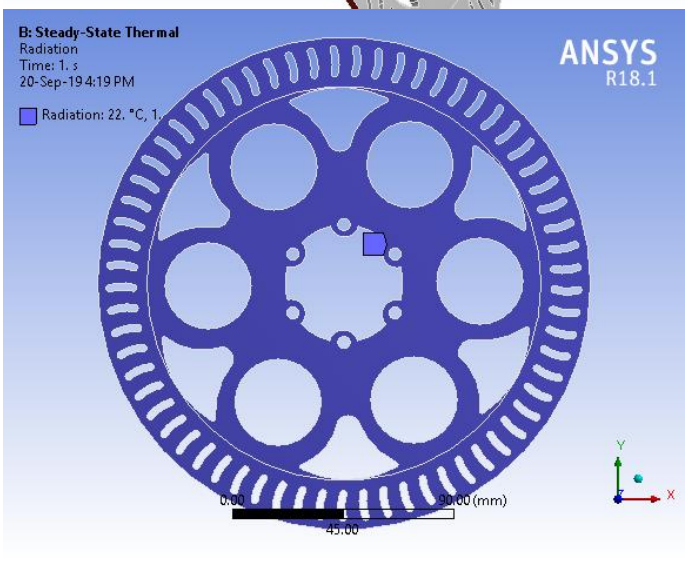


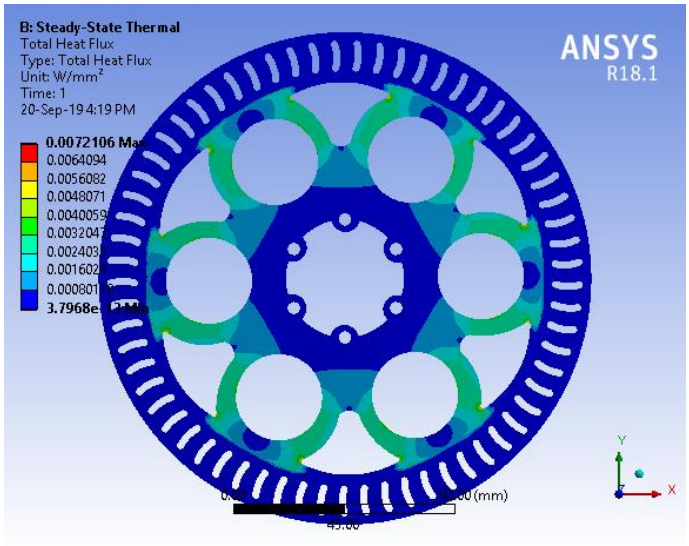
Total Deformation = 0.0025 mm

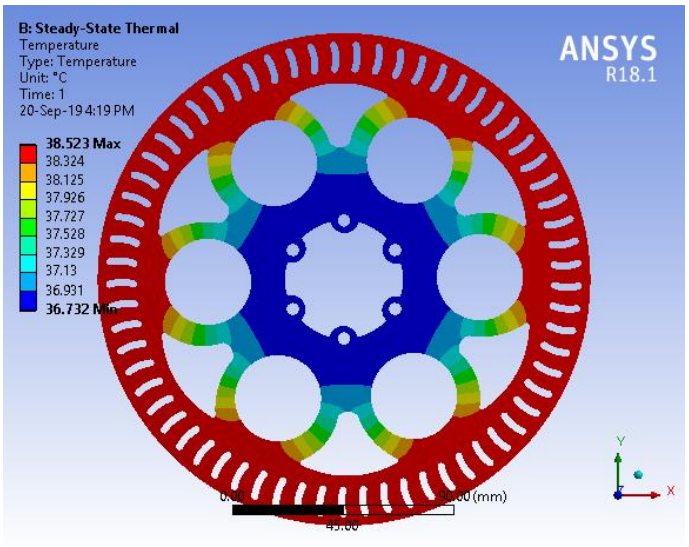






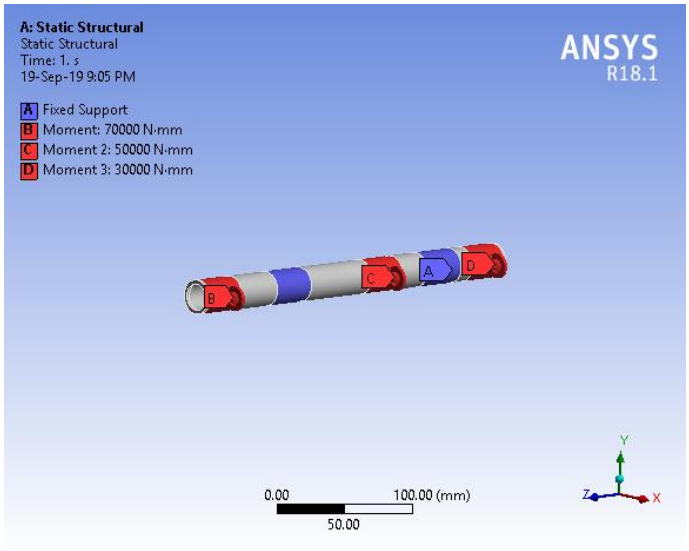




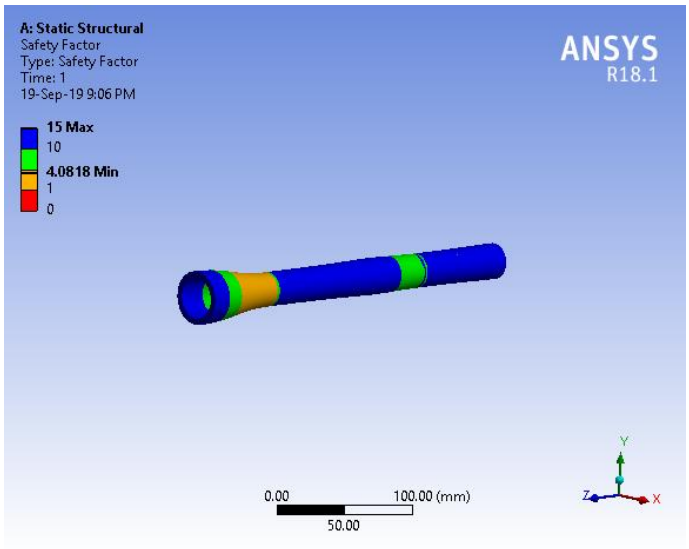


g) CAE analysis: Shaft 1

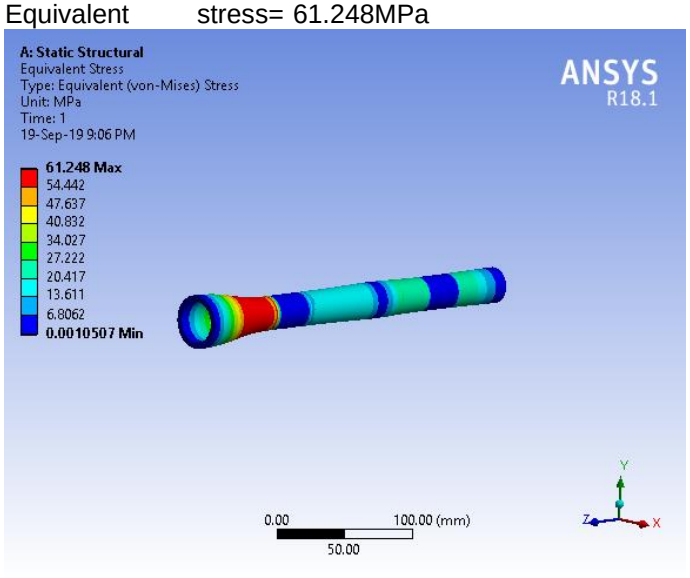
Maximum Moment= 70000 N-mm



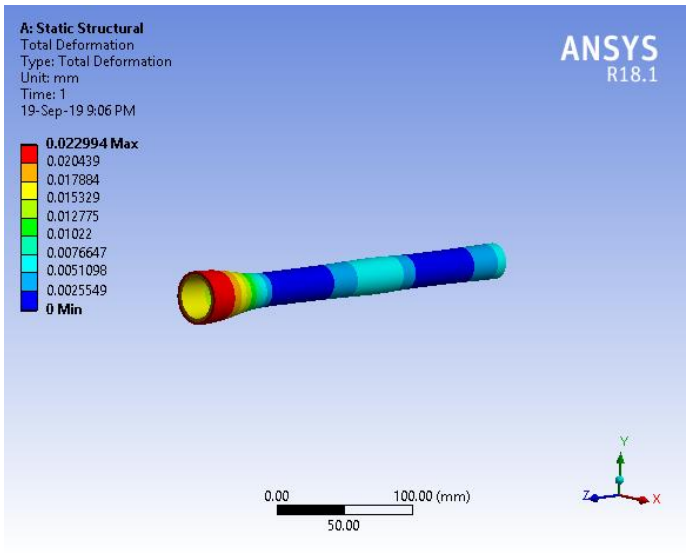
Factor of safety =4.0818



Equivalent stress= 61.248MPa

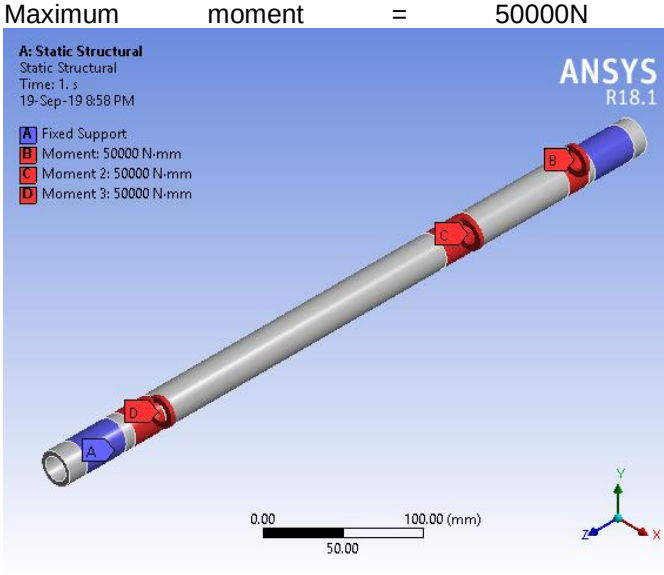


Total deformation=0.022994mm

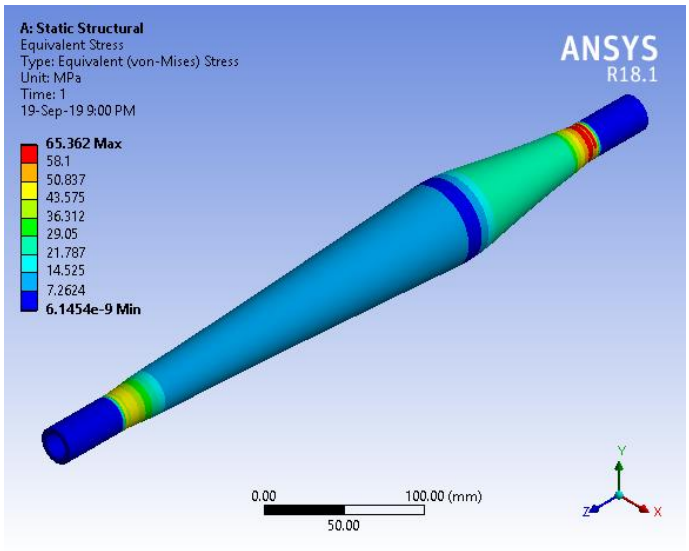


h) CAE analysis: Shaft 2

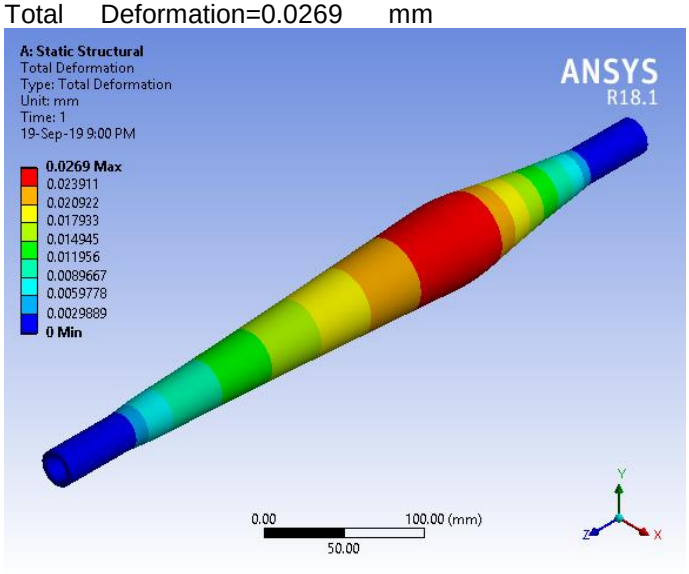
Maximum moment = 50000N



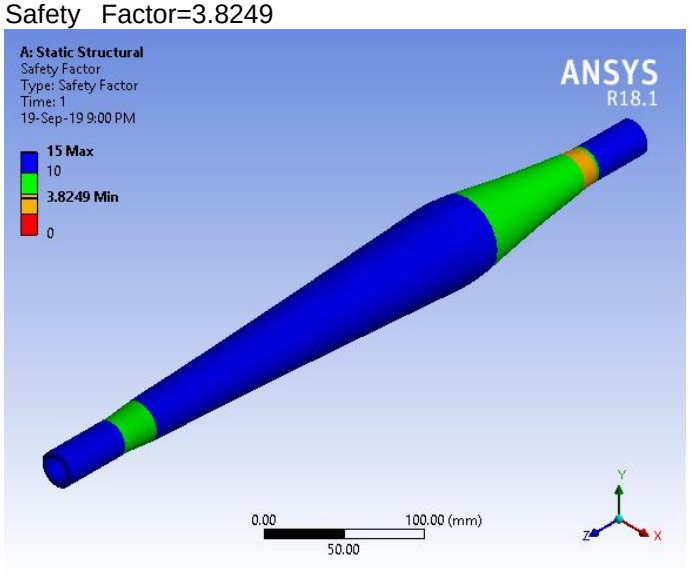
Equivalent stress = 65.362 MPa



Total Deformation=0.0269 mm



Safety Factor=3.8249



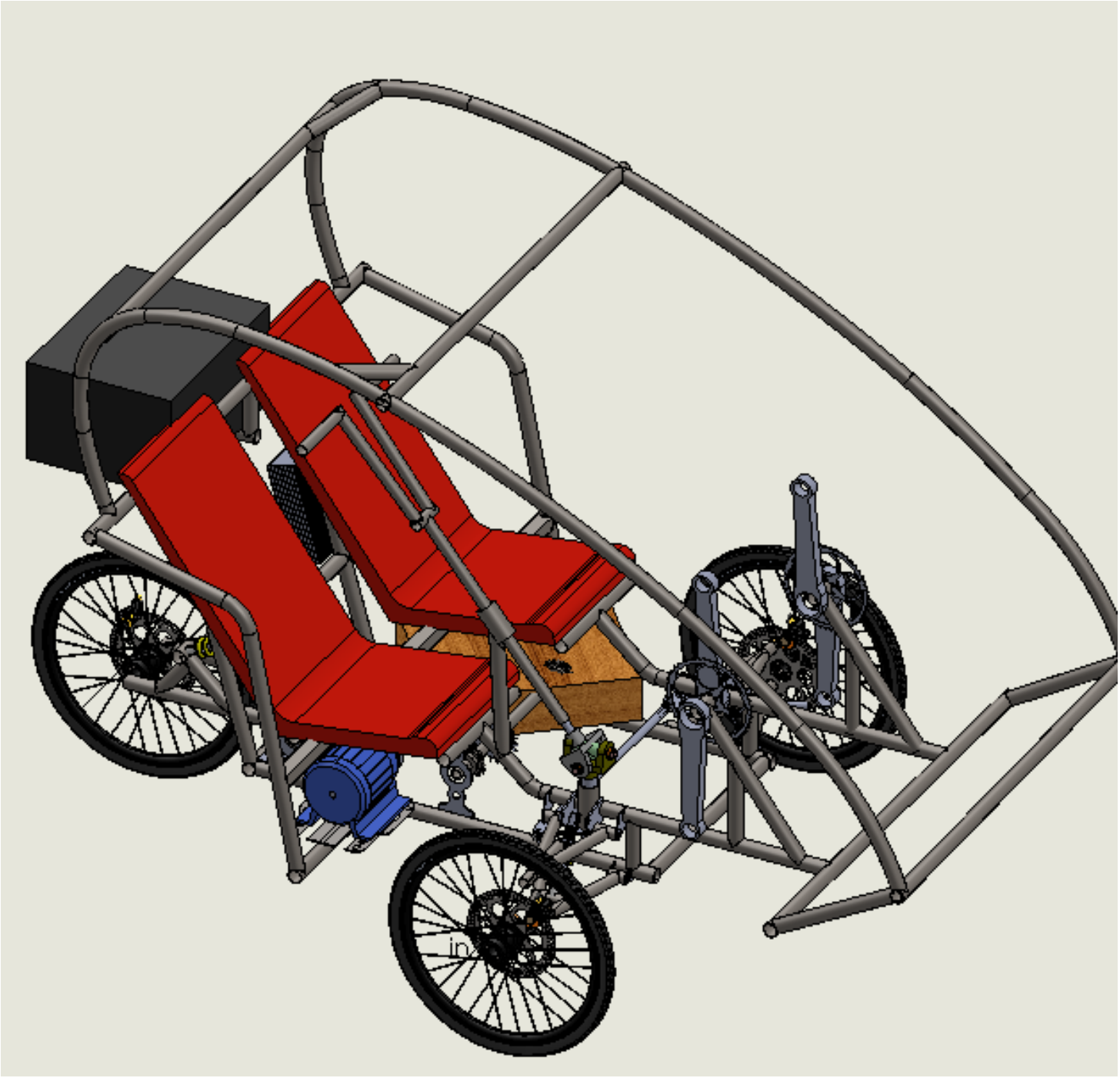
E) VEHICLE VIEWS

Vehicle views are included at the **Appendix-1** with all dimensions as asked (all views given at Appendix-1 are mandatory). Complete CAD model with the placement of all components are shown.

All hand sketches, 2D drawings, prototype images may be included in Appendix-2.

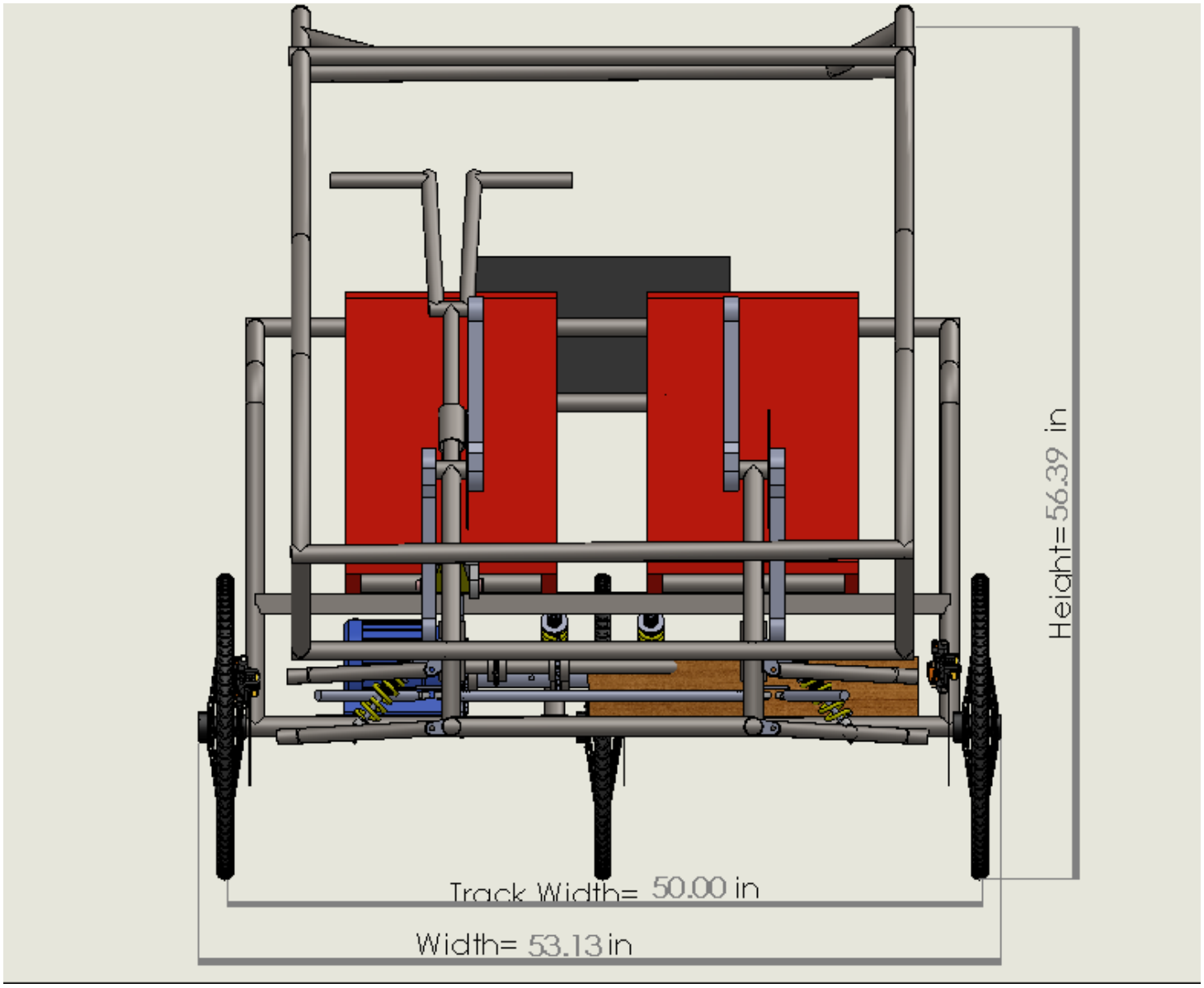
APPENDIX-1: Vehicle Views

Figure-1 (Isometric View of Vehicle)



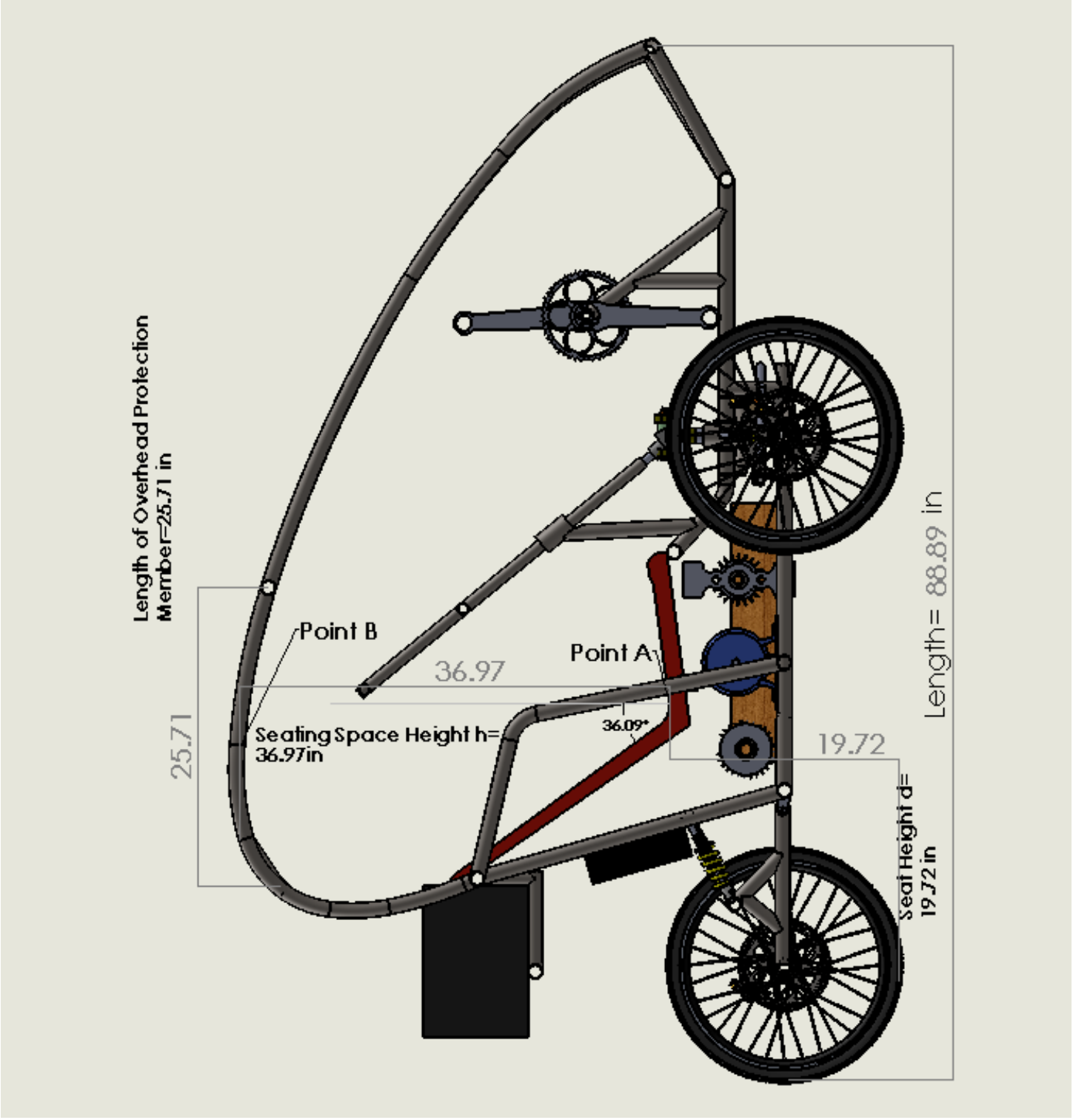
APPENDIX-1: Vehicle Views (contd.)

Figure-2 (Front View of Vehicle)



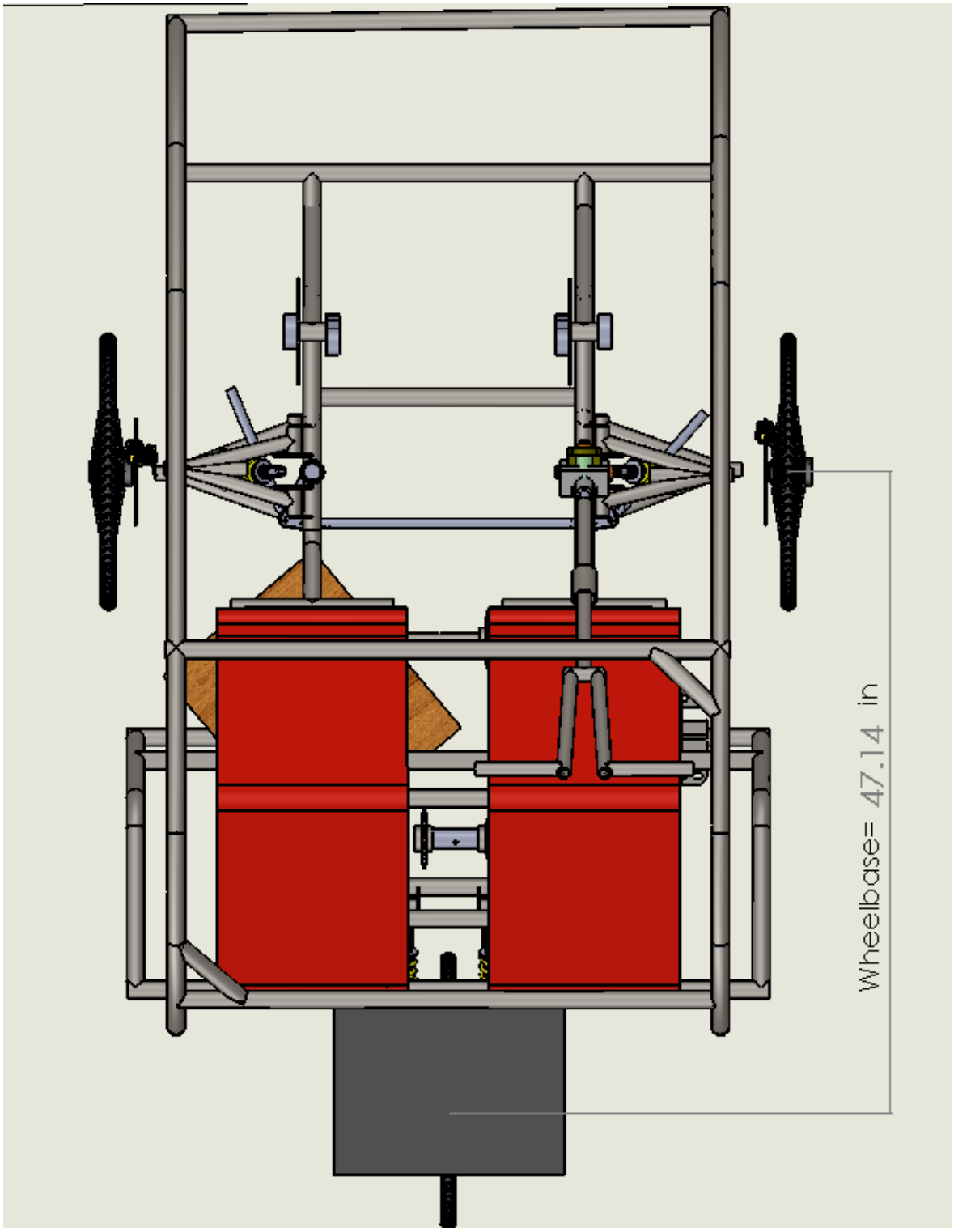
APPENDIX-1: Vehicle Views (contd.)

Figure-3 (Side View of Vehicle)



APPENDIX-1: Vehicle Views (contd.)

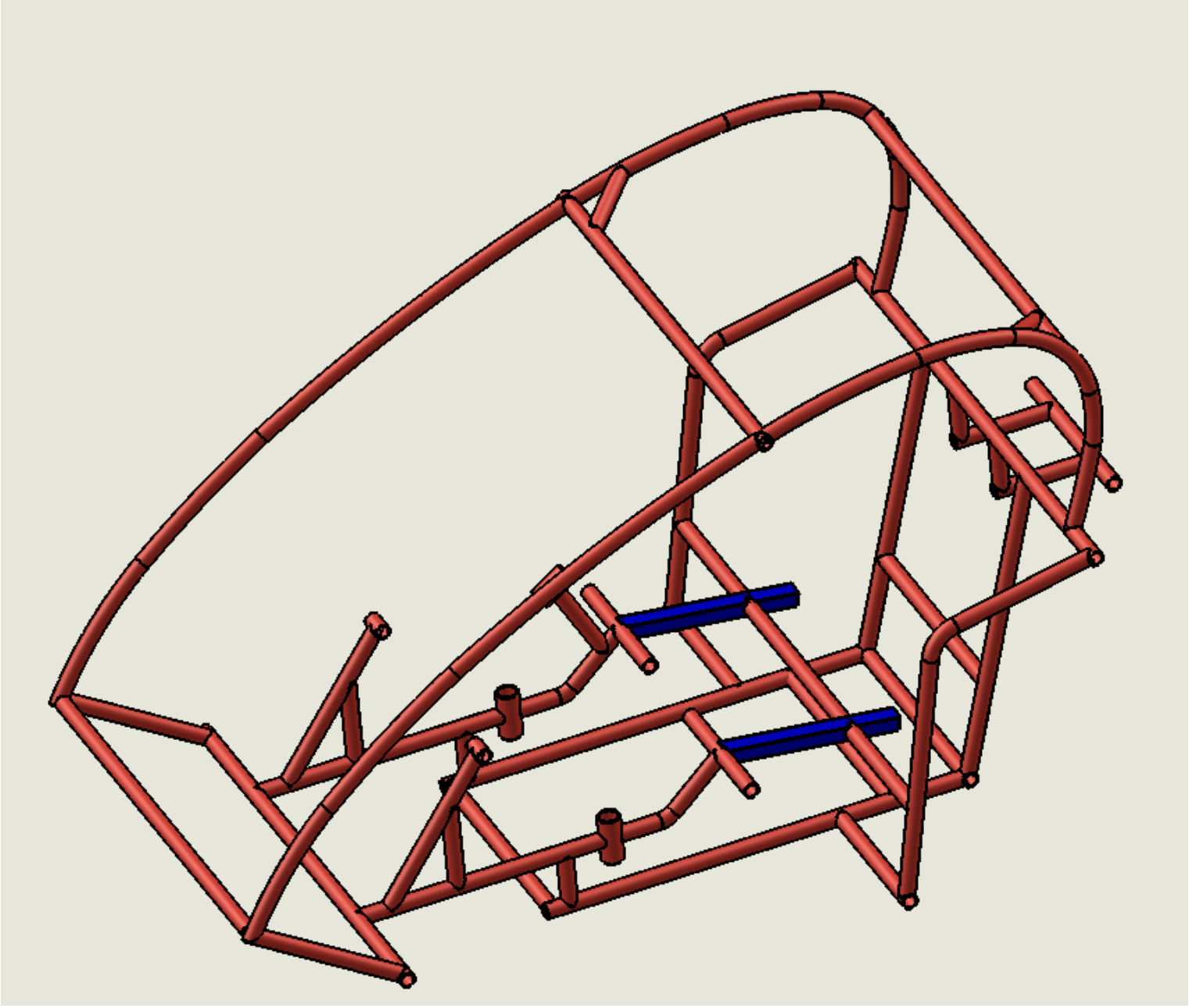
Figure-4 (Top View of Vehicle)



APPENDIX-1: Vehicle Views (contd.)

{Different Materials/Cross-section should be shown with different colors.}

Figure-5 (CAD Model of Frame)



GUIDELINES

1. The CAD model must be complete for the presentation in CAD/CAE Report.
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5. The file must be submitted as a part of documentation package before the submission deadlines as mentioned in current season rulebook.
6. The font must be "Helvetica", black, 10 size.

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