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FINITE ELEMENT ANALYSIS OF SAE ROLL CAGE

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ABSTRACT
The objective of this thesis is to analyze the design of the Formula SAE roll cage. This work describes how a common model of the roll cage is developed using solid works Finite Element Analysis to be performed by Ansys 16 software. In this paper Front impact, back impact or side impact of roll cage is performed. This paper's sole focus is the design and analysis for a chassis which has to sustain the racing environment. As chassis plays a vital role in a race car but can be called as the back bone of a good race car.

KEYWORDS: Roll cage, Ansys16, Solidworks 15, Finite element analysis.

INTRODUCTION
The most important aspect of the vehicle design is the frame. The frame contains the operator, engine, brake system, fuel system, and steering mechanism, and must be of adequate strength to protect the operator in the event of a rollover or impact. The roll cage must be constructed of steel tubing, with minimum dimensional and strength requirements dictated by SAE.

MODEL GENERATION AND BOUNDARY CONDITION OF ROLL CAGE
Model is created in Solid works 2015 and imported in Ansys workbench as stp file (Fig.1). The meshing of Geometry was performed in Ansys Workbench (Fig.2). Details of Meshing are given below in Table.1

Figure.1 Geometry

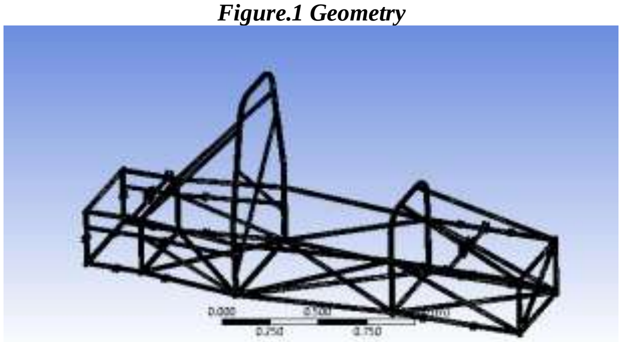


Figure.2 Meshing

Meshing Sizing	
Use Advanced Size Function	Off
Relevance Center	Coarse
Element Size	Default
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	5.8405e-006 m

Table 1: Meshing

Material Properties	
Young's Modulus	2e+11
Poisson's Ratio	0.3
Bulk Modulus	1.6667E+11
Shear Modulus	7.6923E+10
Tensile Yield Strength	2.5E+08
Transition	Fast
Span Angle Center	Coarse

Table 2: Properties of Structure Steel

LOAD ANALYSIS

Case 1: Front Impact: - In this Case Back side of Roll Cage Provide Fixed Support and load is applied front of the roll cage as shown in Figure 3 and Figure 4

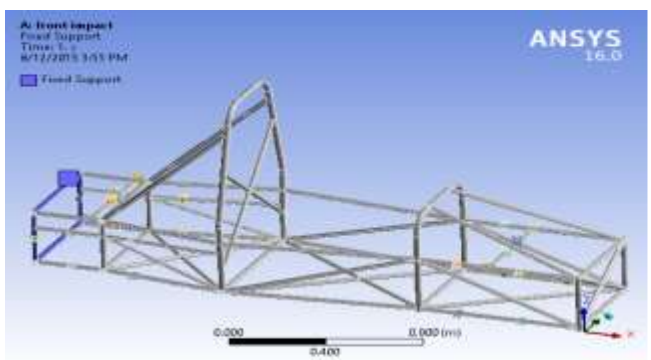


Figure: 3 Support

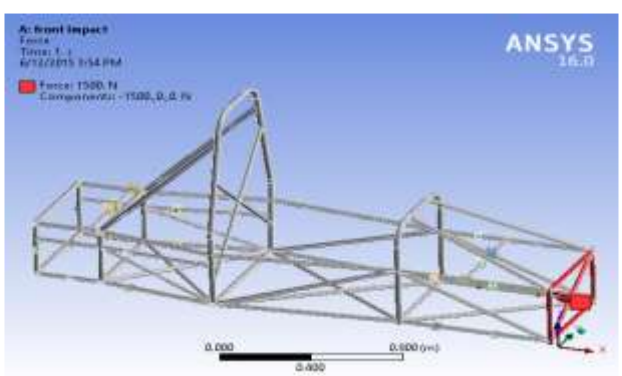


Figure:4 Load Condition

Case 2: Front Impact: - In this Case Front side of Roll Cage Provide Fixed Support and load is applied back of the roll cage as shown in Figure 5 and Figure 6

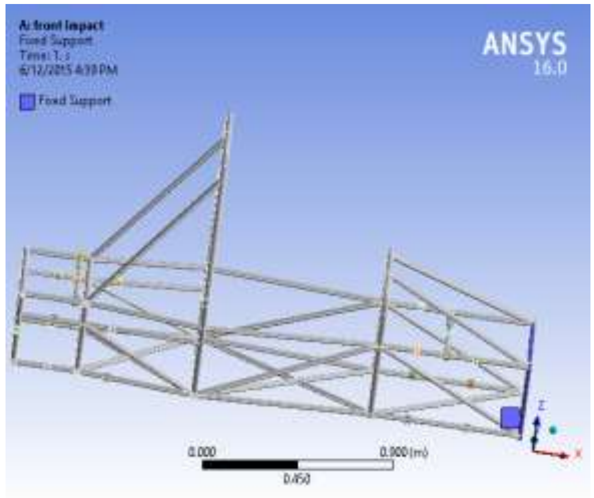


Figure: 5 Support

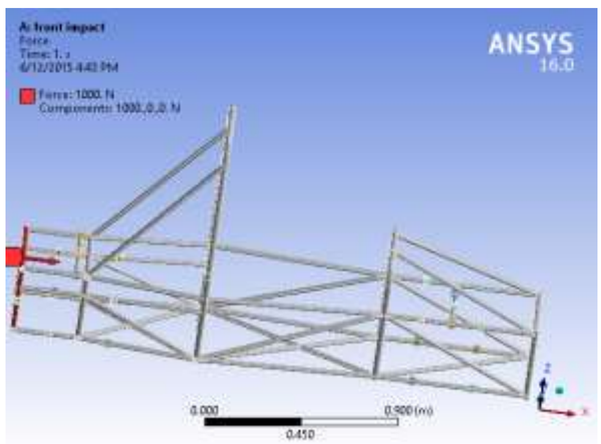


Figure: 6 Load Condition

Case 3: Side Impact: - In this right side of Roll Cage Provide Fixed Support and load is applied left of the roll cage as shown in Figure 7 and Figure 8

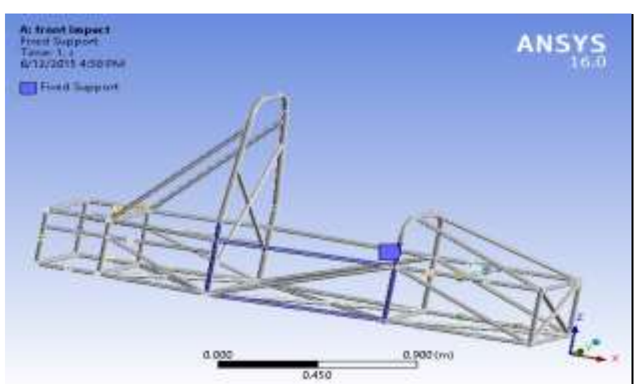


Figure: 7 Support

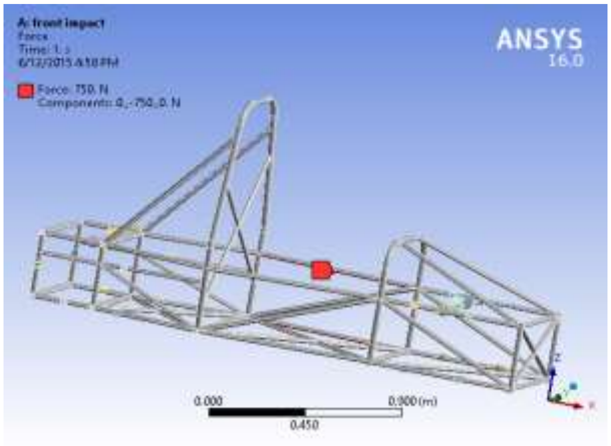


Figure: 8 Load Condition

RESULTS

After solving the above mentioned load in Ansys 16 Workbench following Results obtained in Static Structure.

Maximum principal stress theory

According to this, if one of the principal stresses σ1 (maximum principal stress), σ2 (minimum principal stress) or σ3 exceeds the yield stress, yielding would occur. In a two dimensional loading situation for a ductile material where tensile and compressive yield stress are nearly of same magnitude

$\sigma 1 = \pm \sigma y$, $\sigma 2 = \pm \sigma y$

Using this, a yield surface may be drawn, as shown in figure-9

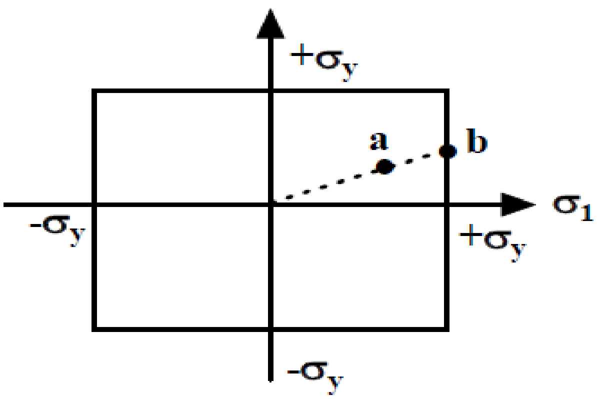


Figure: 9 Yield surface corresponding to maximum principal stress theory

Maximum principal strain theory

According to this theory, yielding will occur when the maximum principal strain just exceeds the strain at the tensile yield point in either simple tension or compression. If ε1 and ε2 are maximum and minimum principal strains corresponding to σ1 and σ2, in the limiting case.

$$\varepsilon_1 = \frac{1}{E}(\sigma_1 - \nu\sigma_2) \qquad |\sigma_1| \geq |\sigma_2|$$

$$\varepsilon_2 = \frac{1}{E}(\sigma_2 - \nu\sigma_1) \qquad |\sigma_2| \geq |\sigma_1|$$

This gives, $E\varepsilon_1 = \sigma_1 - \nu\sigma_2 = \pm\sigma_0$

$$E\varepsilon_2 = \sigma_2 - \nu\sigma_1 = \pm\sigma_0$$

The boundary of a yield surface in this case is thus given as shown in figure-10

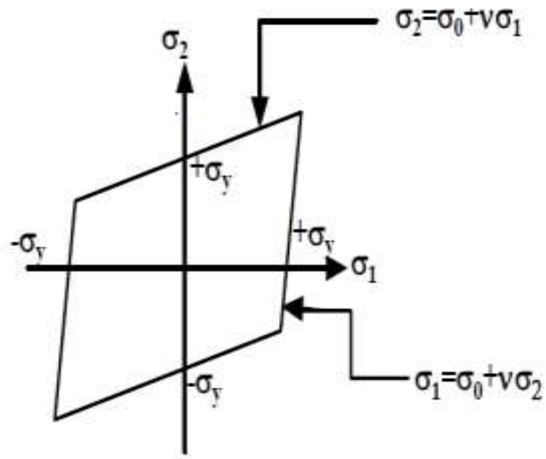
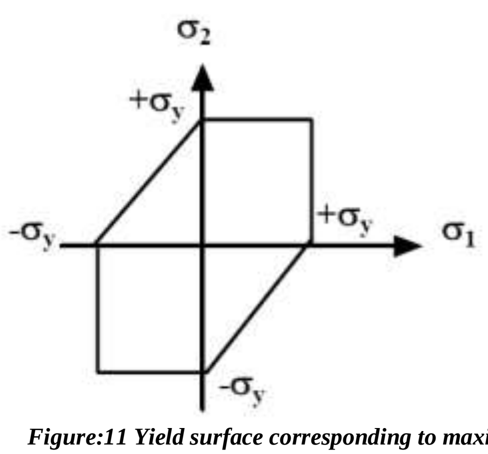


Figure: 10 Yield surface corresponding to maximum principal strain theory.

Maximum shear stress theory

According to this theory, yielding would occur when the maximum shear stress just exceeds the shear stress at the tensile yield point. At the tensile yield point $\sigma 2 = \sigma 3 = 0$ and thus maximum shear stress is $\sigma y/2$. This gives us six conditions for a three-dimensional stress situation:



$$\sigma_1 - \sigma_2 = \pm\sigma_y$$

$$\sigma_2 - \sigma_3 = \pm\sigma_y$$

$$\sigma_3 - \sigma_1 = \pm\sigma_y$$

Figure:11 Yield surface corresponding to maximum shear stress theory

Case 1: Front Impact Result

The following results obtained in Front Impact

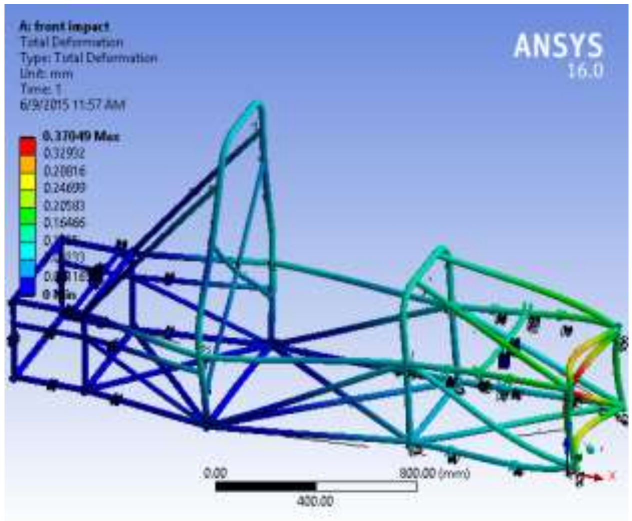


Figure: 12 Total Deformation

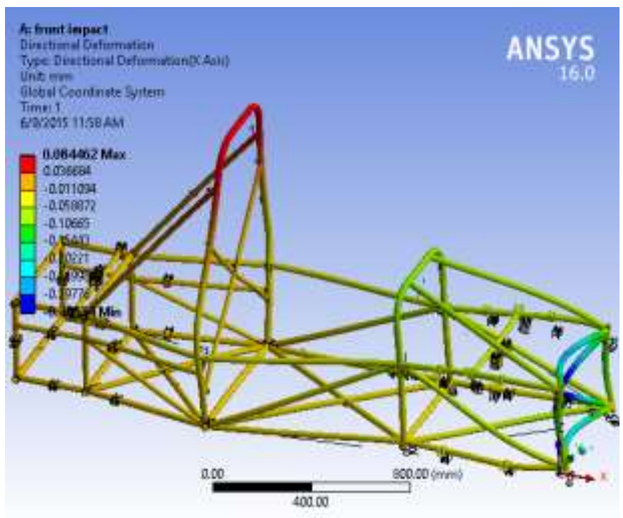


Figure: 13 Directional Deformation

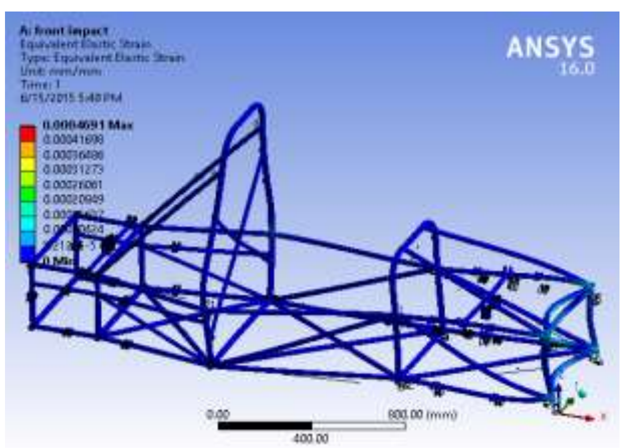


Figure: 14 Equivalent Elastic Strain

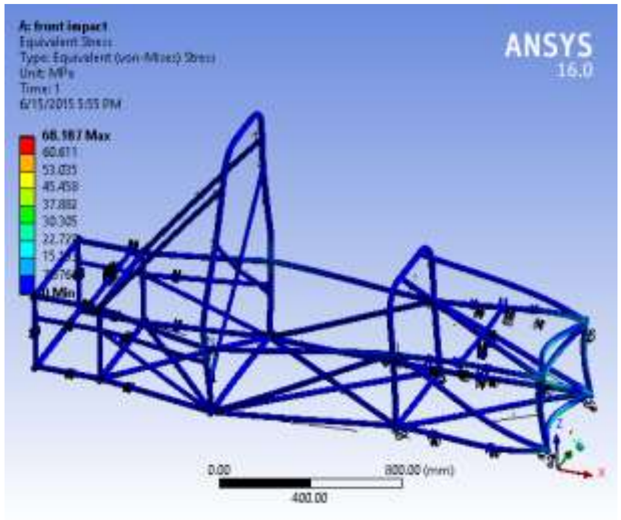


Figure: 15 Equivalent Stress

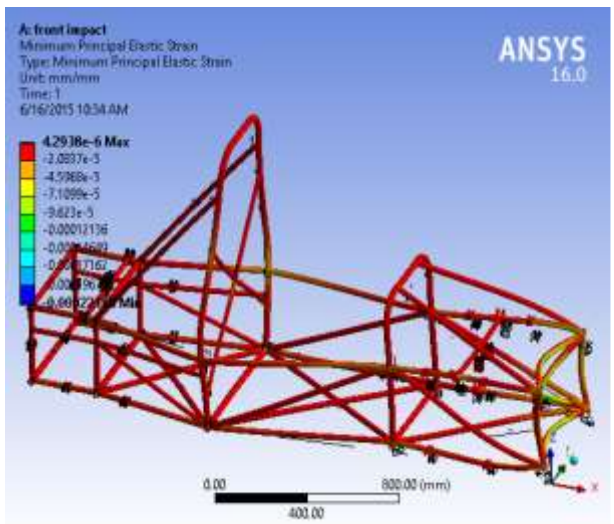


Figure: 16 Maximum Principal Elastic Strain

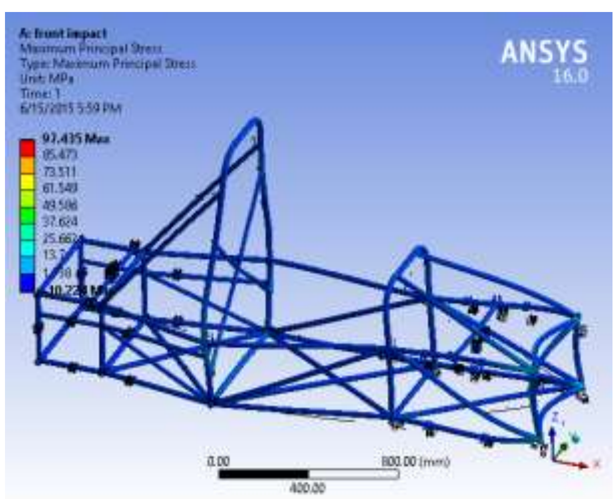


Figure: 17 Maximum Principal Stress

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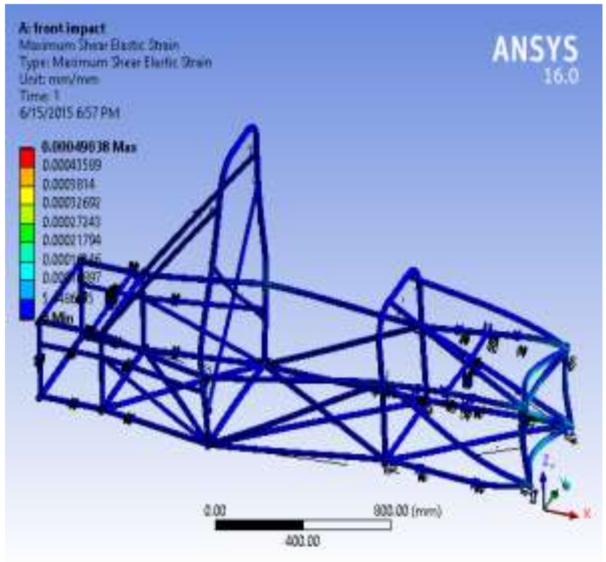

Figure: 18 Maximum Shear Elastic Strain

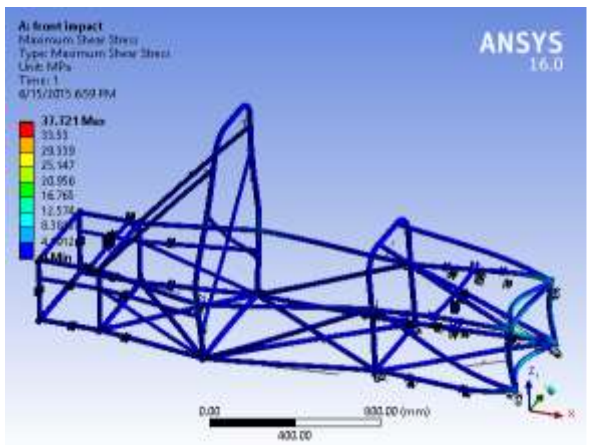

Figure: 19 Maximum Shear Stress

Case 2: Back Impact Result
The following results obtained in back Impact

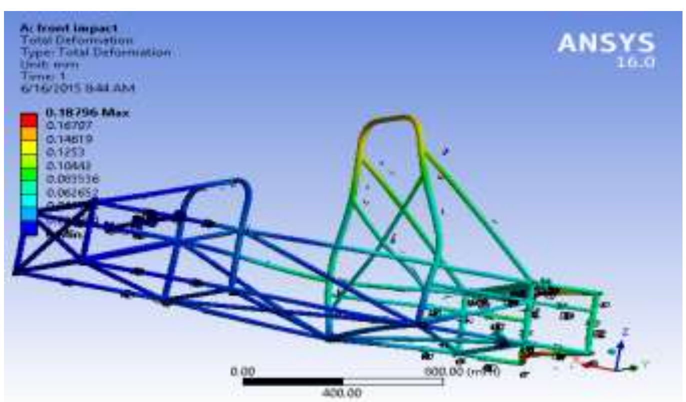

Figure: 20 Total Deformation

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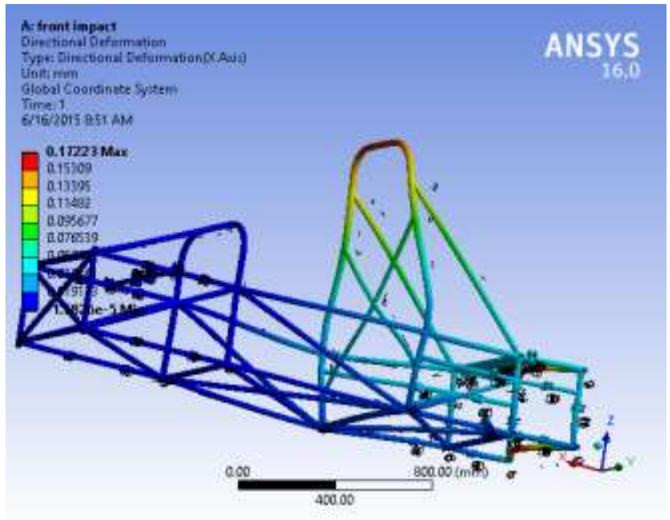

Figure: 21 Directional Deformation

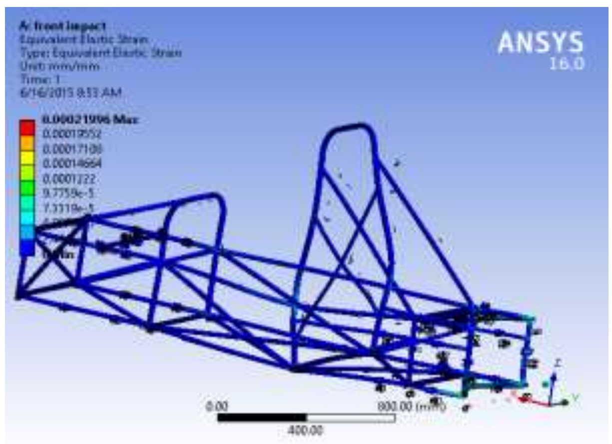

FIGURE: 22 EQUIVALENT ELASTIC STRAIN

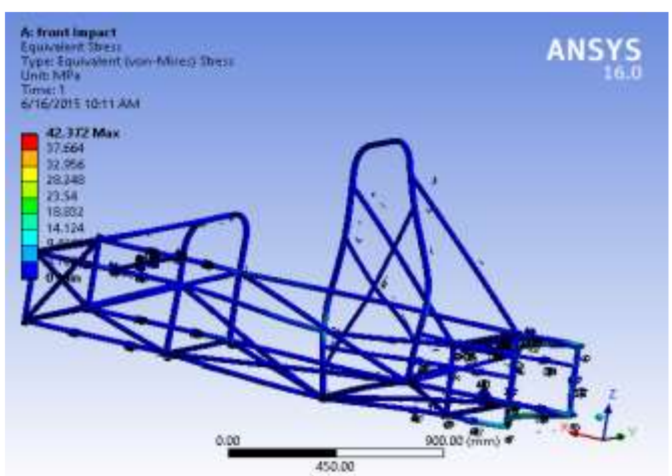

FIGURE:23 EQUIVALENT STRESS

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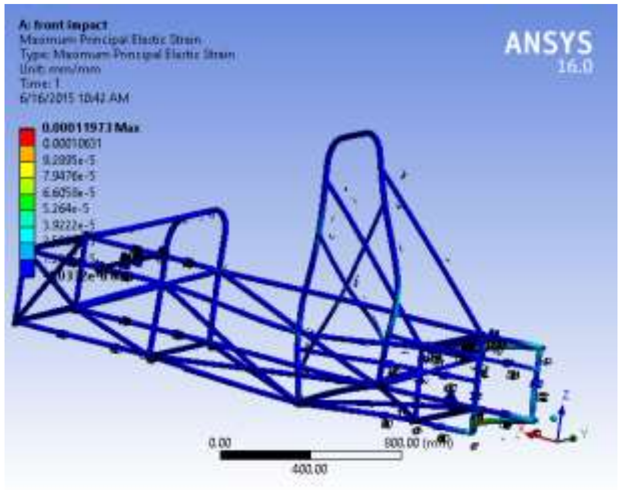

Figure: 24 Maximum Principal Elastic Strain

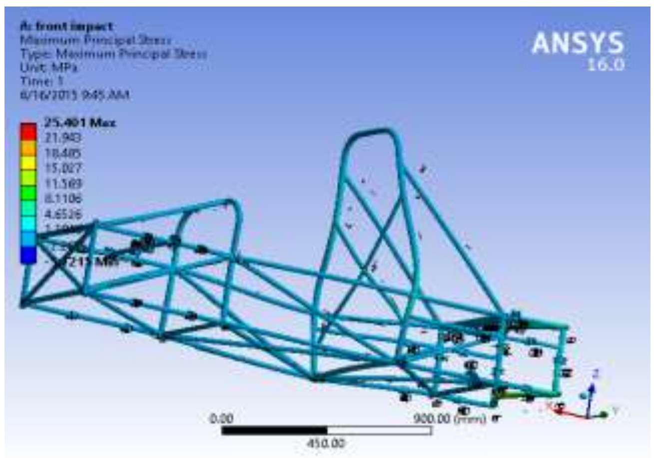

Figure: 25 Maximum Principal Stress

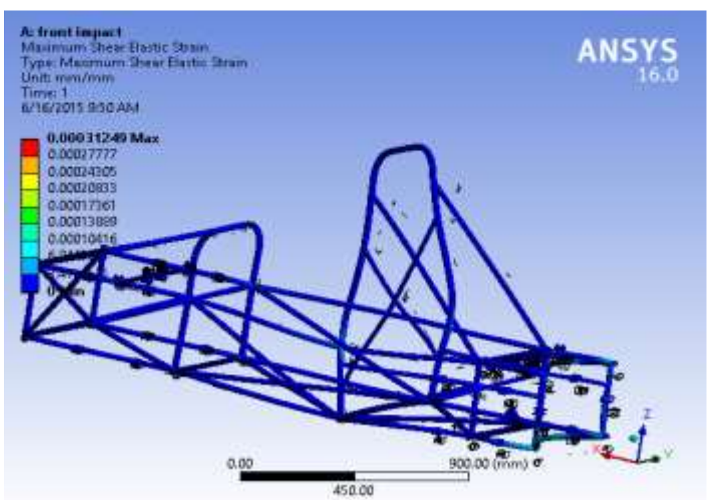

Figure: 26 Maximum Shear Elastic Strain

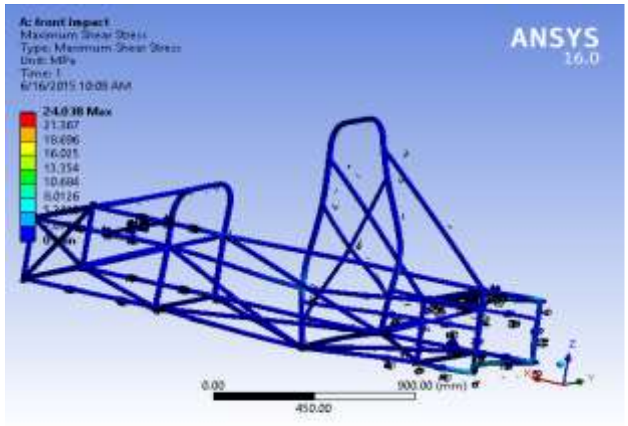

Figure: 27 Maximum Shear Stress

Case 3: Side Impact Result
The following results obtained in Side Impact

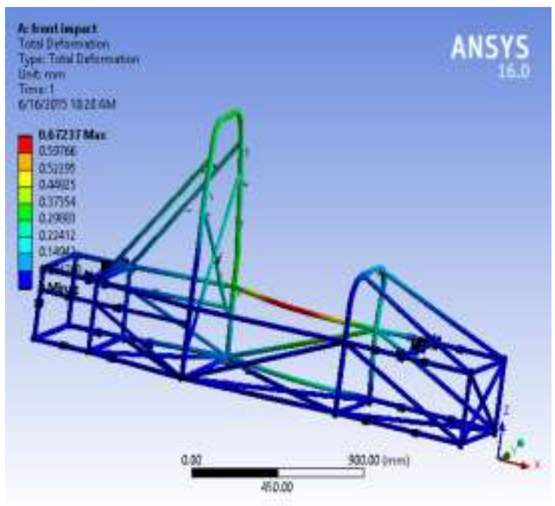

Figure: 28 Total Deformation

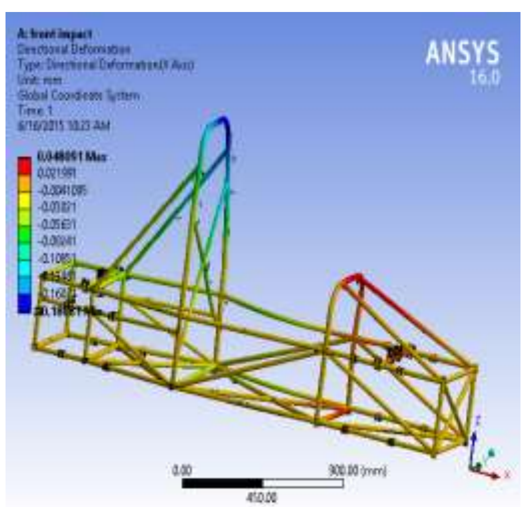

Figure: 29 Directional Deformation

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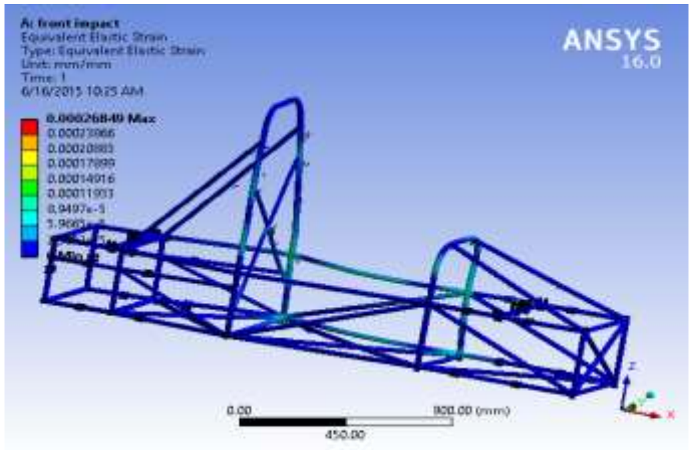

Figure: 30 Equivalent Elastic Strain

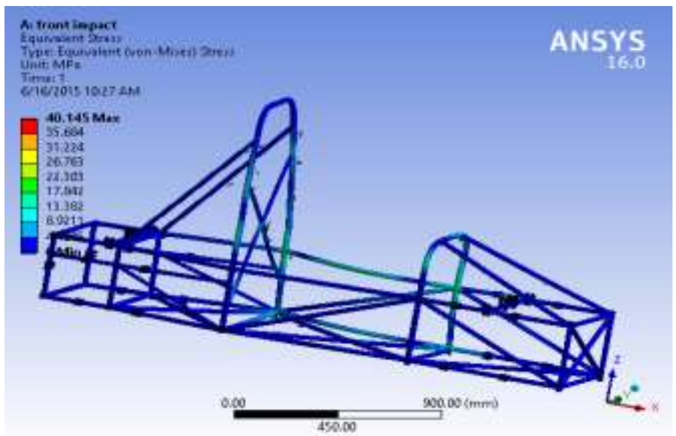

Figure: 31 Equivalent Stress

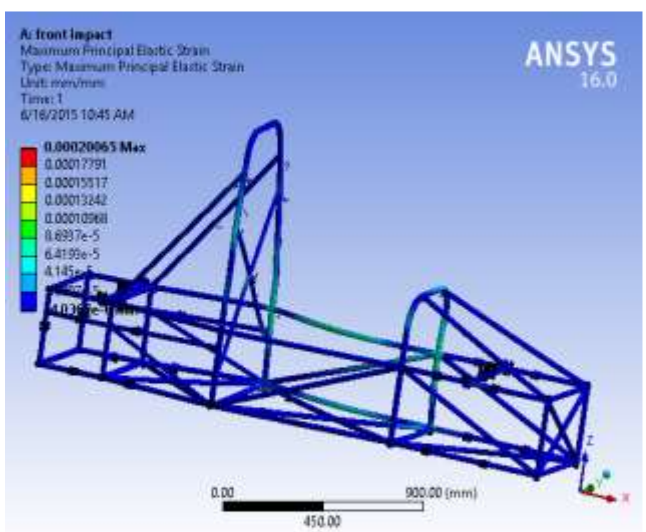

Figure: 32 Maximum Principal Elastic Strain

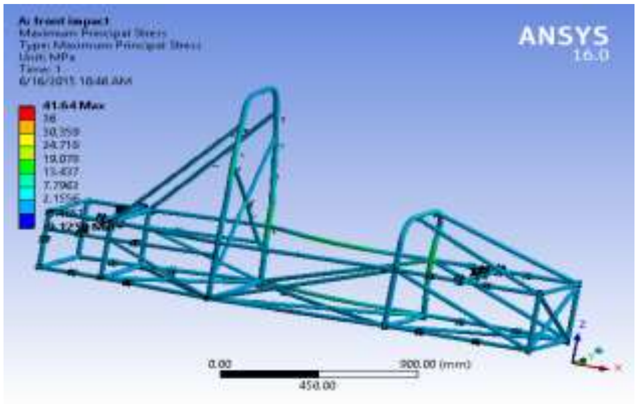

Figure: 33 Maximum Principal Stress

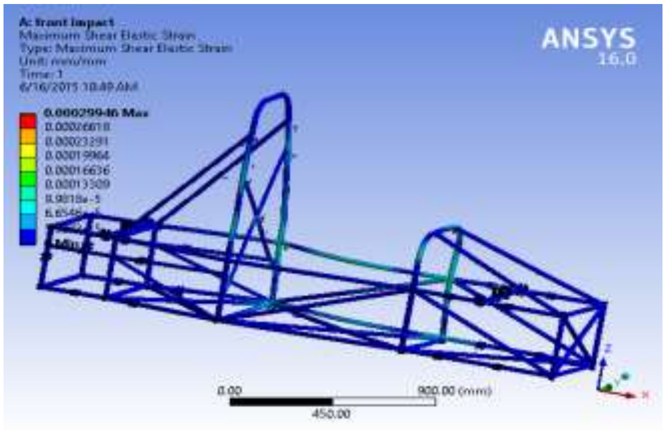

Figure: 34 Maximum Shear Elastic Strain

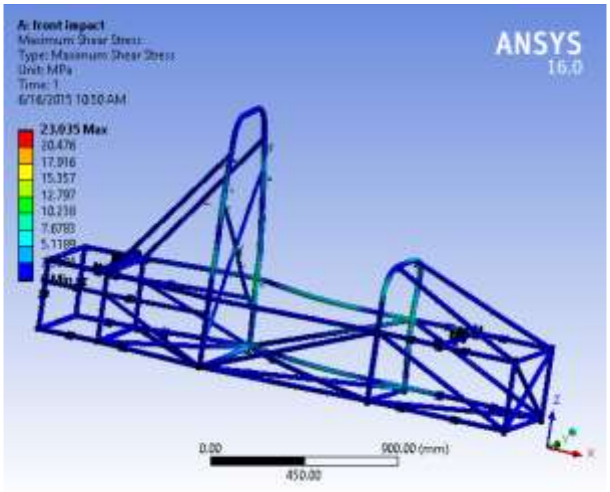

Figure: 35 Maximum Shear Stress

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CONCLUSION

The completion of the chassis is a major annual milestone for every FSAE team. A completed chassis provides motivation to complete other parts of the car because the team members can now visualize what has been in the design phase for months. Every team sets a goal to complete their frame early, giving them a chance to test the car for two or three months before each competition, but frequently there are delays. These delays can range from financial difficulties, materials procurement problems, workshop limitations, and team member skill development.

The chassis design and construction process is a cornerstone of the FSAE project. The many details that must be considered during this procedure provides great practice to aspiring engineers and gives them a leg up on their competition.

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