Design and Fabrication of Roll Cage of a Car

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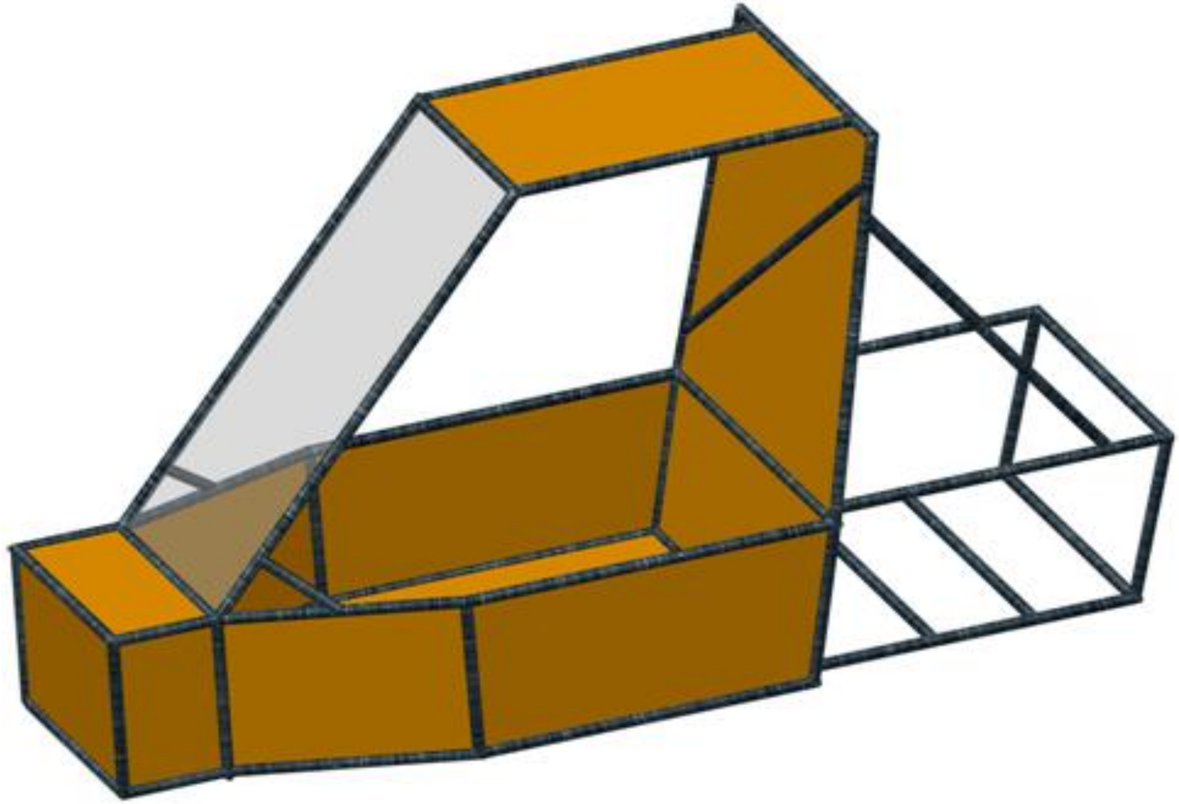
List of Content

Abstract

Abstract

- Our study aims to design, develop and fabricate a roll cage, in accordance with the SAE. A roll cage is a skeleton of an All-Terrain Vehicle (ATV). The roll cage is the Structural base which protects the occupant in case of impact and roll over incidents. Here we are going to deal with design of roll cage for an ATV considering various loading tests like Front Impact, Side Impact and Rear Impact. We have focused on every point of roll cage to improve the performance of vehicle without failure of roll cage. Finally the roll cage will be fabricated as per the tools and techniques available in our workshop.

Introduction



- Roll Cage can be called as skeleton of a vehicle, besides its purpose being seating the driver, providing safety[8].

Introduction

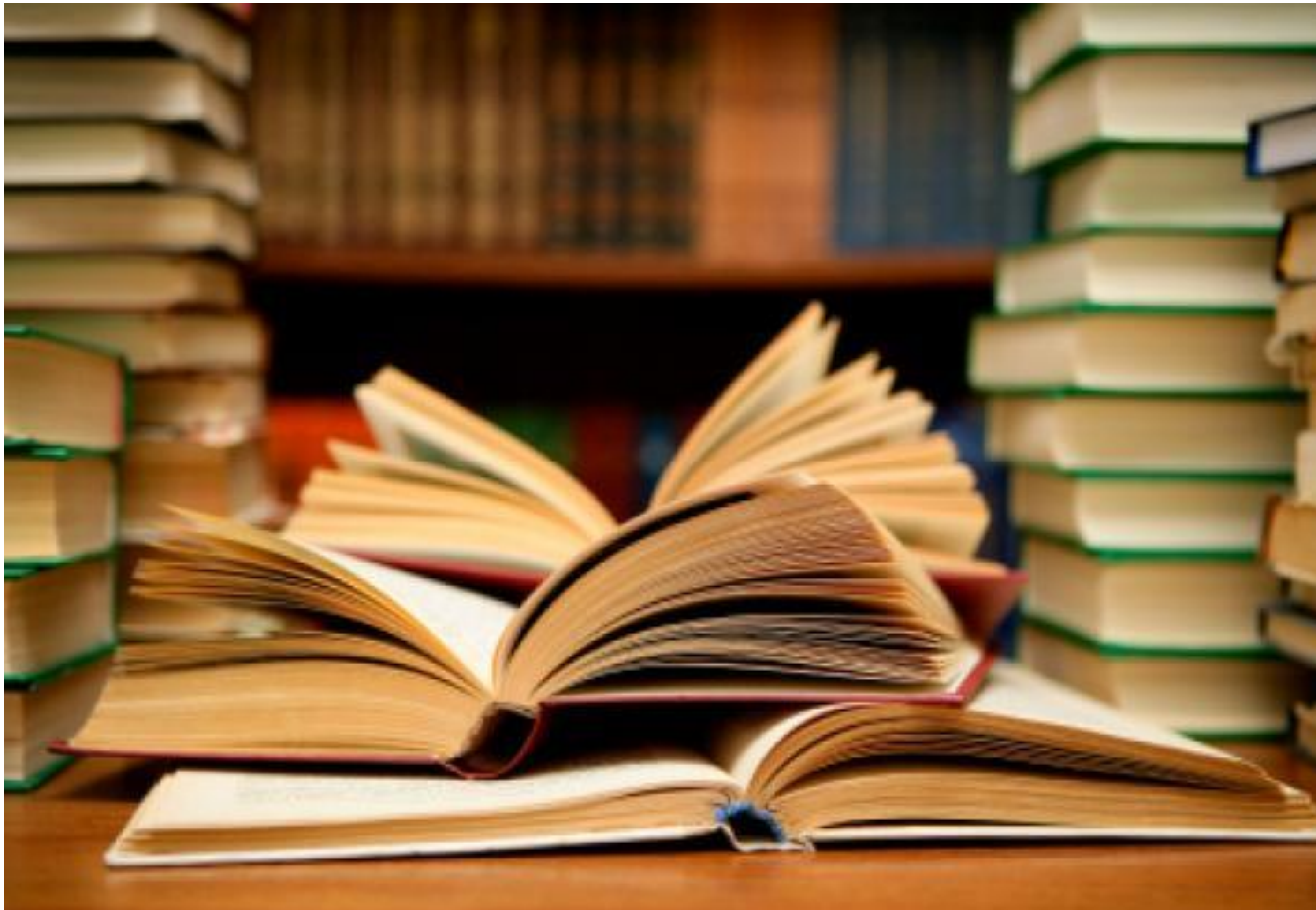
- ATV means a all terrain vehicle which is specially designed for a off roads driving.
- ATV is designed for very rough terrain, jumps, endurance.
- The design process of this single-person vehicle is iterative and based on several engineering and reverse engineering processes.
- Following are the major points which were considered for designing the off road vehicle:
    - Endurance
    - Safety and Ergonomics.
    - Market availability.
    - Cost of the components.
    - Standardization
    - Safe engineering practices.

Introduction

- **Project Objectives**

- The main objectives behind our project are as followed:
- To design a safest vehicle for the driver.
- To design in accordance with the Rulebook.
- To design for the driver's compatibility.
- For optimum stability of the vehicle.
- To reduce the weight and maintain a desired centre of gravity.
- To maintain stability in turns.
- For prevention from front collision, rear collision, side collision and rolling.

Literature review



Literature review

- **Denish S. Mevawala et al**[1] *determined the roll cage not only forms the structural base but also a 3-D shell surrounding the occupant which protects the occupant in case of impact and roll over incidents. The roll cage also adds to the aesthetics of a vehicle. This paper deals with* design of roll cage *for an ATV and* Various loading tests *like* Front Impact, Side Impact *and* rear impact *have been conducted. They have focused on every point of roll cage to improve the performance of vehicle without failure of roll cage.*
- *They concluded after the analysis that roll cage structure for its strength against the collision from front, rear, as well as side. Factor of safety is under the safe limit. The roll cage is sustained 4G force from front as well as rear & 2G force from side. But, deformation & stresses are under the limit*
- *Key Words :* design of roll cage, loading tests, Front Impact, Side Impact and rear impact

Literature review

- **Thanneru Raghu Krishna Prasad et al.[2]** *designed the frame & suspension of the Society of Automotive Engineers (SAE) Baja car which is a single-seated all-terrain vehicle and is used for off road usage and endurance on a rough terrain. In many aspects it is similar to an All-Terrain Vehicle (ATV) except that it is much smaller in size and has safer rollover capabilities. The modeling of the frame and suspension is done by using pro-e software. This design is checked by Finite Element Analysis after estimating the load and the weight of the frame.*
- *They decided that the usage of* solidworks® *was very helpful to the design and analysis of the frame and suspension for Mini Baja Car*. the finite element analysis gave a very accurate prediction of where failure would occur in this situation.
- Key Words : SAE® Baja car, design, analysis

Literature review

- **Khelan Chaudhari et al.[3]** *studied about design, development and fabrication of the roll cage for All - Terrain Vehicle accordance with the rulebook of BAJA 2013 given by SAE. Material for the roll cage was selected based on strength, cost and availability. The roll cage was designed to incorporate all the automotive sub-systems. A software model is prepared in Pro-engineer. Based on the result obtained from these tests the design was modified accordingly. After successfully designing the roll cage, it was fabricated.*
- *They concluded that the design, development and fabrication of the roll cage was carried out successfully. The roll cage was used to build an ATV by integrating all the other automotive systems like transmission, suspension, steering, brakes and other miscellaneous elements.*
- Key Words : strength, cost, availability, Pro-engineer®, fabrication

Literature review

- **GAURAV S. CHIMOTE et al.**[4] *stated that the objective of their design and analysis of an ATV was fun to drive, versatile, safe, durable and was also a high performance off road vehicle. They ensured that the vehicle spastics the limits of set rules. Their vehicle was capable of negotiating the most extreme terrain with confidence and ease. They met these objectives by dividing the vehicle into major component subsystems.*
- *They concluded that when undertaking design of any vehicle there were several factors to be considered that were common to all engineering vehicles.*
- Key Words : versatile, safe, durable, negotiating extreme terrain

Literature review

- **Puneet Malhotra et al** [5] *stated that their study was to design of an All-Terrain Vehicle (ATV) in accordance with the SAE BAJA 2014 rule book. A detailed designing of components were carried out by them like Roll cage, Suspensions & Braking mechanism. The main focus of their was on Safety of driver & Stability of vehicle. Roll cage of their vehicles was designed in such a way that in case of rolling of vehicle (mostly occurs in high speed turns & off roading that it will provide double the strength to the roll cage with also considering the Aesthetic of the cage. International standards were followed by them where ever possible and an extensive market survey was also done. Finite Element Analysis was carried out on roll cage & braking mechanism for optimum safety & reliability of the vehicle.*
- Key Words : Safety of driver, Stability of vehicle, optimum safety, reliability of the vehicle.

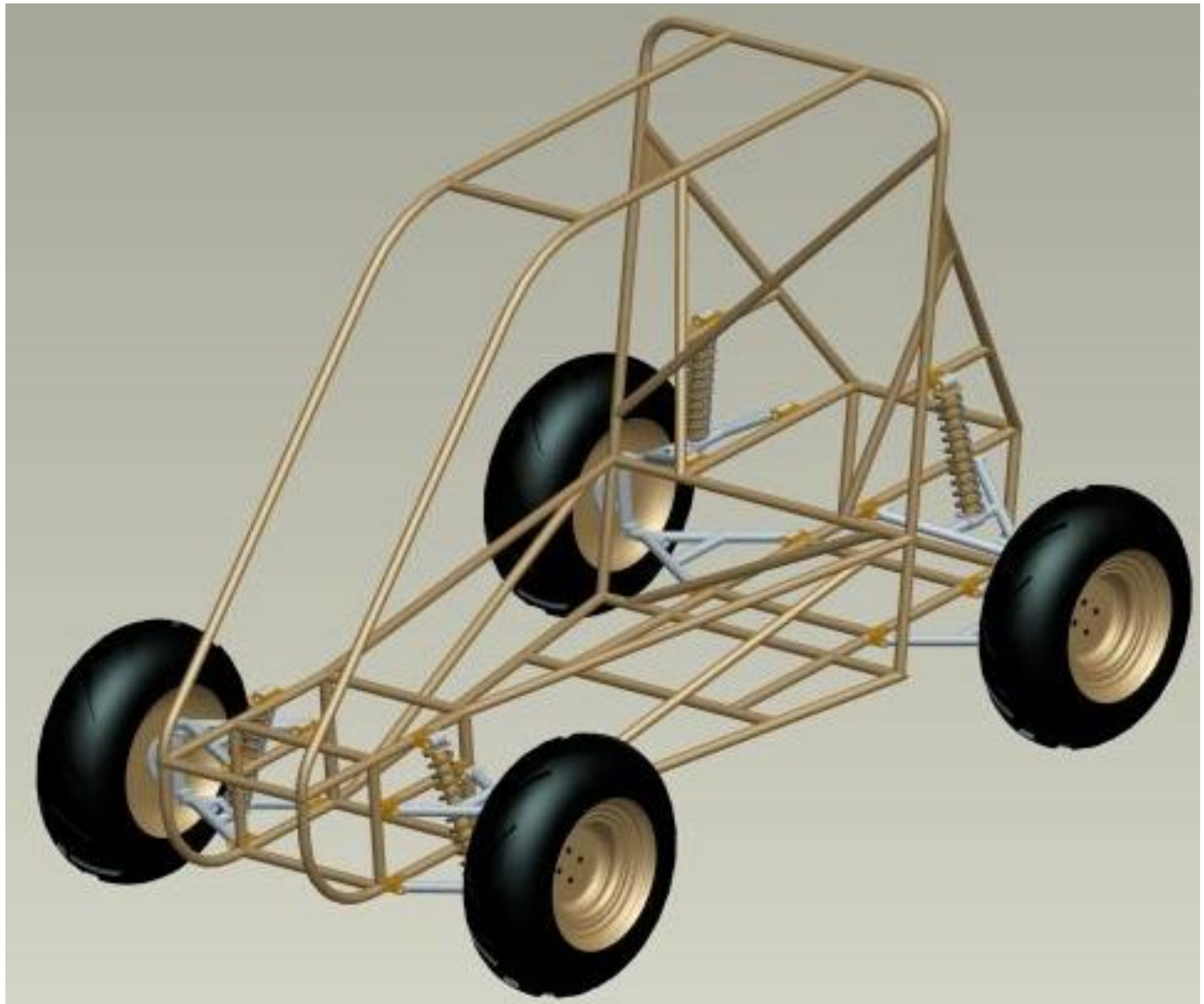
Literature review

- **Sanjay Sharma et al** [6] *stated that the main objective of their research work was to find the mode, shape, and corresponding natural frequency of a roll cage for an ATV. Finite element analysis is used to determine the mode shapes and frequencies. They have designed a roll cage which consists of both structural base and 3-D shell which protects the user in case of impact and roll over incidents. CATIA V5 was been used for modelling the roll cage and ANSYS 14.5 for FEA analysis. The body shape of the roll cage was fixed from the front end. The frame of the roll cage consists of three main parts known as boot space, driver cabin and engine chamber.*
- Key Words : Finite Element Analysis, Ansys®

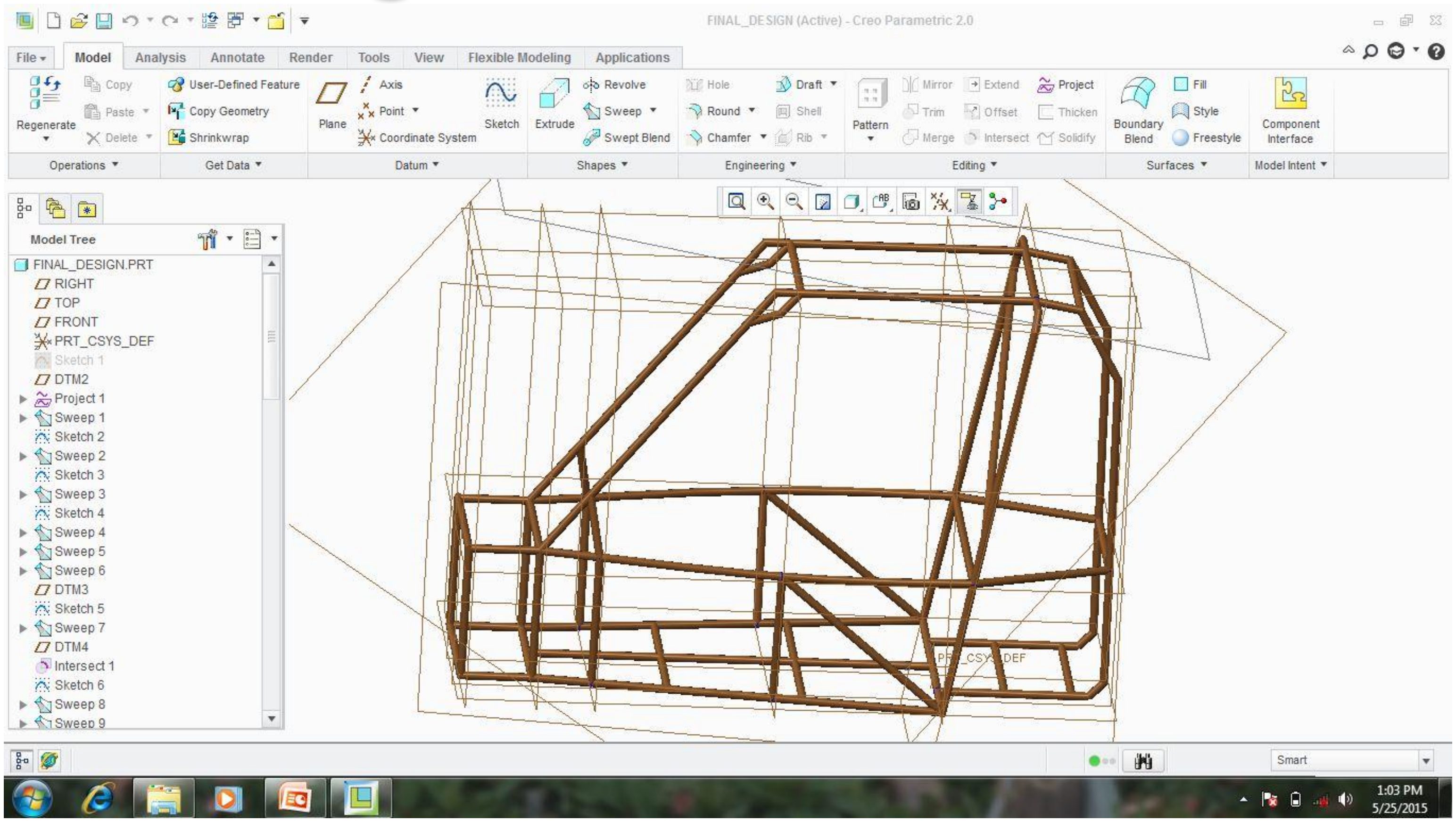
Project Methodology

1. Define the Project
2. Study about SAE BAJA Vehicle
3. Select the design methodology
4. Select Material of the ‘ROLL CAGE’ structure
5. Design of ‘ROLL CAGE’
6. Analysis of ‘ROLL CAGE’
7. Based on Result, Implementation in ‘ROLL CAGE’ Design
8. Analysis of Final Design
9. Fabrication of ‘ROLL CAGE’

Design of ‘ROLL CAGE’



Roll Cage Structure



- We have designed all Roll Cage designs in software ‘Creo parametric 2.0’

Elements of Roll Cage[8]

- **Primary Members**
  - Rear Roll Hoop (RRH)
  - Roll Hoop Overhead Members (RHO)
  - Front Bracing Members (FBM)
  - Lateral Cross Member (LC)
  - Front Lateral Cross Member (FLC)

- **Secondary Members**
  - Lateral Diagonal Bracing (LDB)
  - Lower Frame Side (LFS)
  - Side Impact Member (SIM)
  - Fore/Aft Bracing (FAB)
  - Under Seat Member (USM)
  - All Other Required Cross Members

Elements of Roll Cage[8]

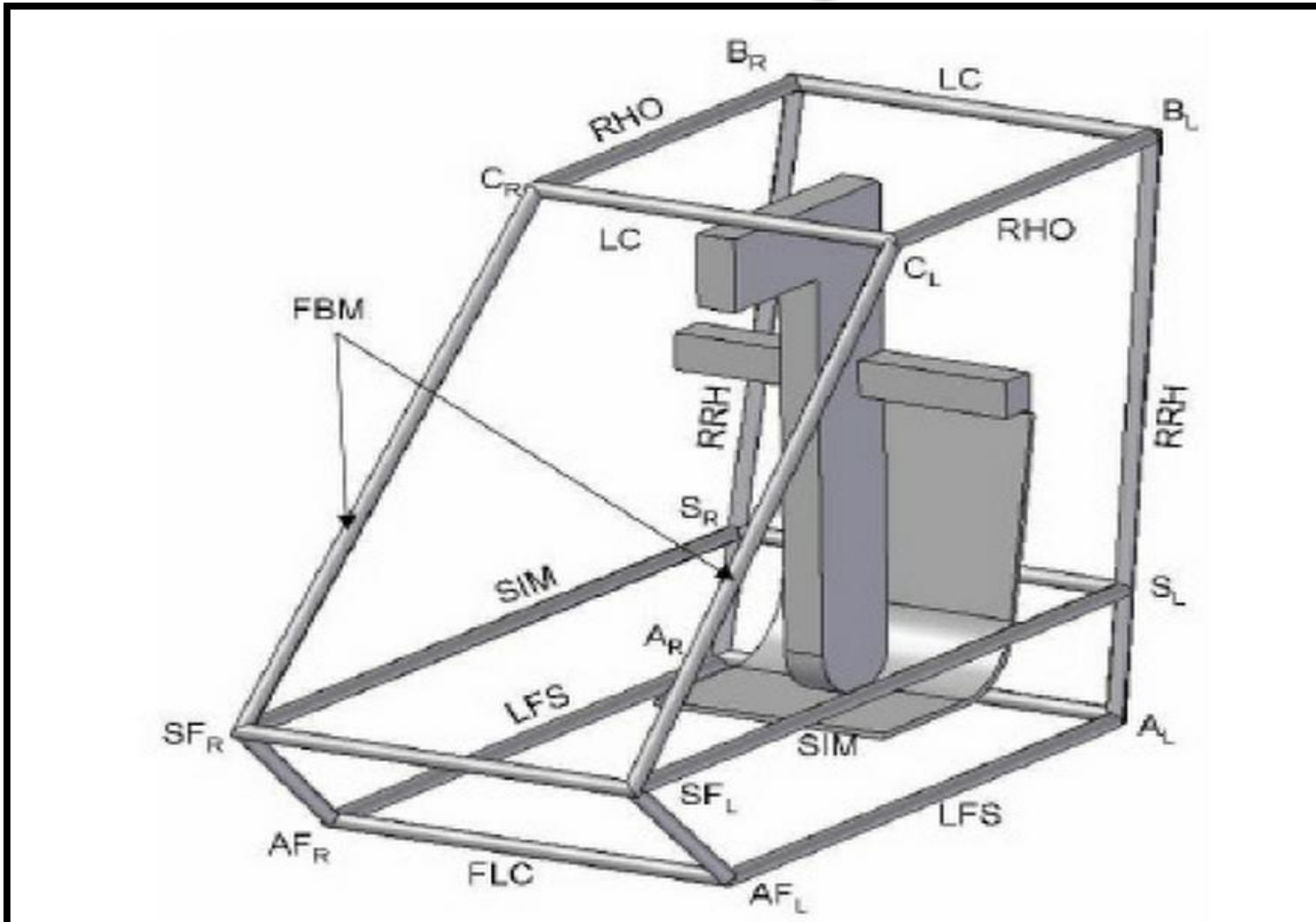
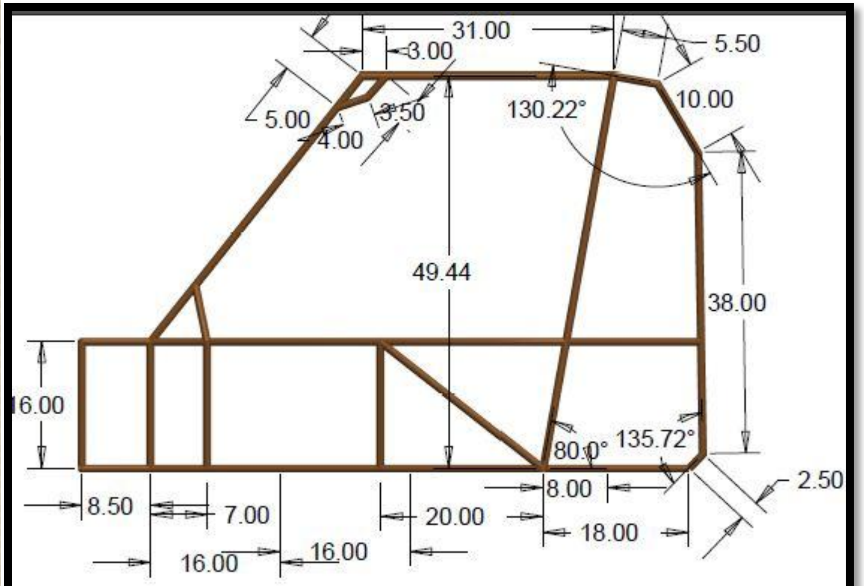


Fig. 1 Elements of the Roll Cage

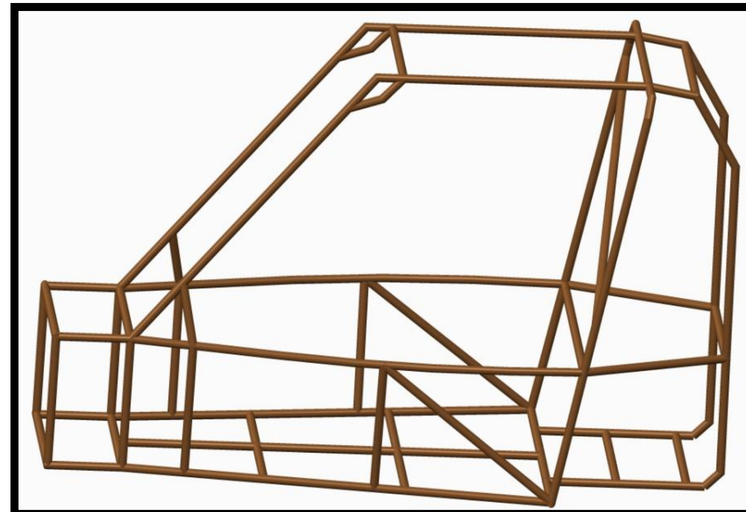
Table -1: Frame Constraints[8]

No	Constraint	Range
1	Vehicle Length	≤ 108"
2	Vehicle Width	≤ 64"
3	Helmet/Frame Clearance	≥ 6"
4	Driver/Frame Clearance	≥ 3"
5	Hip Clearance	≥ 5"
6	Frame Tubing Diameter	≥ 1"
7	Wall Thickness of Rear Roll Hoop, Lateral Diagonal Bracing, Roll Hoop, Overhead Members, and Front Bracing Members	≥ 0.062"
8	Lower Frame Side, Side Impact Member, Fore/Aft Bracing, Front Lateral Cross Member, Lateral Diagonal Bracing	≥ 0.035"
9	Rear Roll Hoop width @ 27" above Driver Seat	≥ 29"
10	Side Impact Member above seat bottom (vertically)	8"-14"
11	Rear Hoop Overhead Members above Driver Seat	≥ 41"
12	Front Bracing Member Angle from vertical	≤ 45°
13	Steel Carbon Content	≥ 0.18%

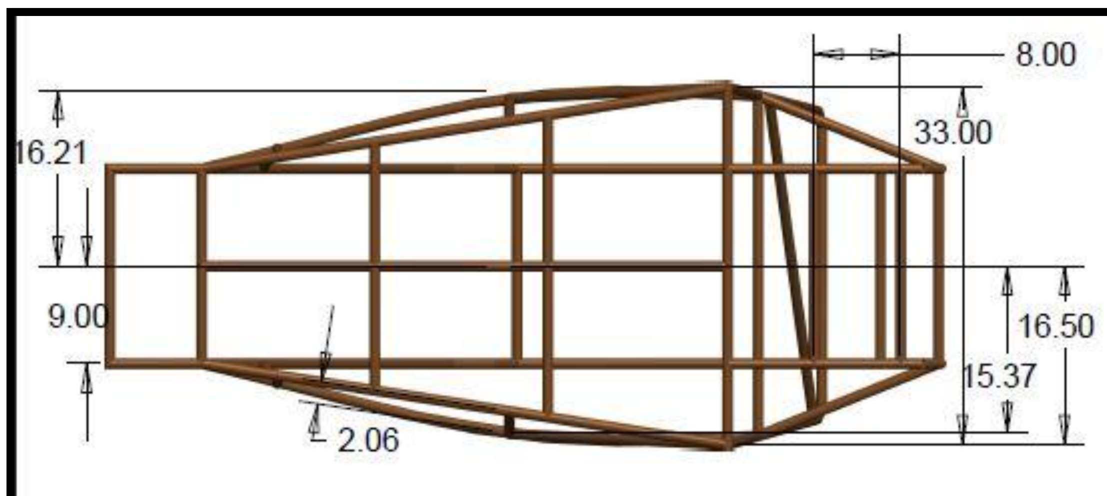
Design :



Side view



Default view



Top view

All dimensions are in INCH

Tube Specification

- Tube sizes: Outer Diameter: 25.4 mm (1.00”)

  Wall Thickness: 2 mm (0.078”)
- Then design of the roll cage considering AISI 1018 Mild Steel pipes of shown dimensions was done and we might get the factor of safety more than 2, which could justified the selection.

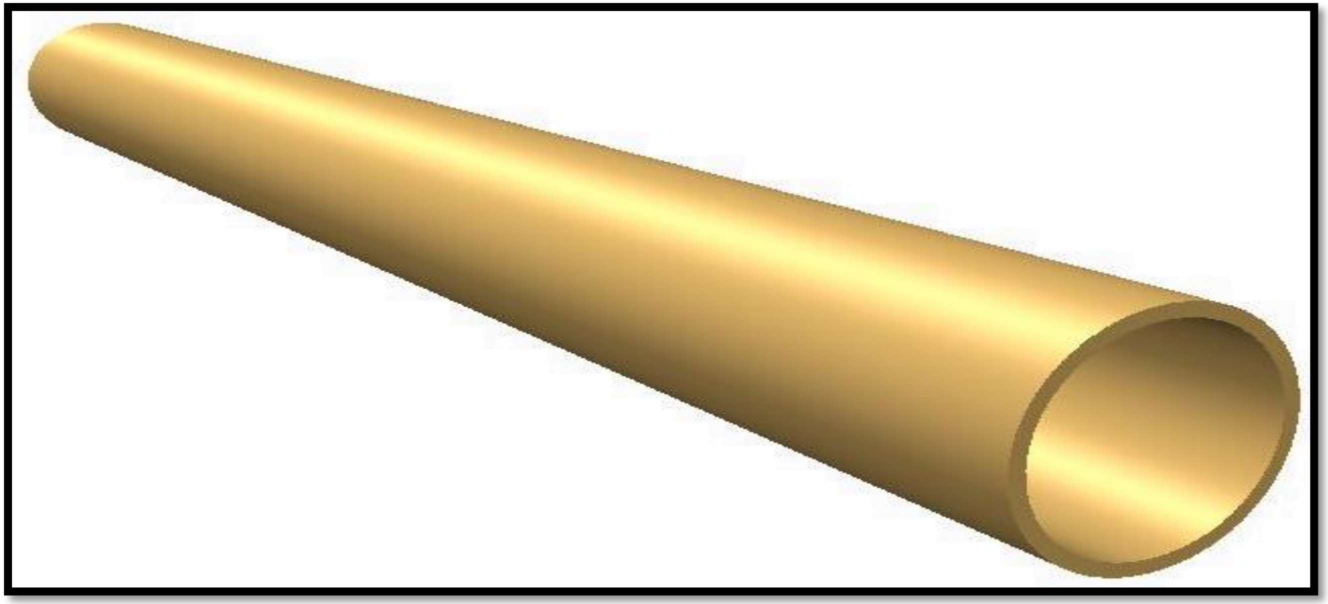


Fig. 2 Designed model of tube in Creo 2.0®

Material Specification

- We have selected AISI 1018 mild low carbon steel for the fabrication of the roll cage.

Chemical Composition[10]

Table-2: Chemical Composition of AISI 1018 mild low carbon steel

Element	Content
Carbon, C	0.14 – 0.20 %
Iron, Fe	98.81 – 99.26 %
Manganese, Mg	0.60 – 0.90%
Phosphorous, P	≤ 0.040 %
Sulfur, S	≤ 0.050 %

Material Specification

Physical Properties[10]

Table-3: Physical Properties of AISI 1018 mild low carbon steel

Mechanical	Unit value
Tensile Strength, Ultimate	440 MPa
Tensile Strength, Yield	365 MPa
Elongation	15.0%
Modulus of Elasticity	205 GPa
Machinability	70 %

Analysis of 'ROLL CAGE'

Impact load calculation

- After finalizing the frame along with its material and cross section, it is very essential to test the rigidity and strength of the frame under severe conditions. The frame should be able to withstand the impact, torsion, roll over conditions and provide almost safety to the driver without undergoing much deformation. Following tests were performed on the roll cage.

  - (i) Front impact
  - (ii) Rear impact
  - (iii) Side impact
  - (iv) Longitudinal Torsion

(i) Front & Rear Impact Calculation[1] :

- Front and rear impact or the static front and rear impact analysis, Deceleration of 4G's was assumed for the loading which is equivalent to a static force of 11772 N (equivalent to 12000 N) load on the vehicle, assuming the weight of the vehicle is 300 kg (with including 130 kg driver weight). We apply 12000 N from the front for the test of front impact and rear for the test of rear impact of the roll cage structure of the vehicle for determining strength at the time of front and rear collision.

$$F = m*a$$

$$= 300*(4*9.81)$$

$$= 11772\ N\ (\text{equivalent to } 12000\ N)$$

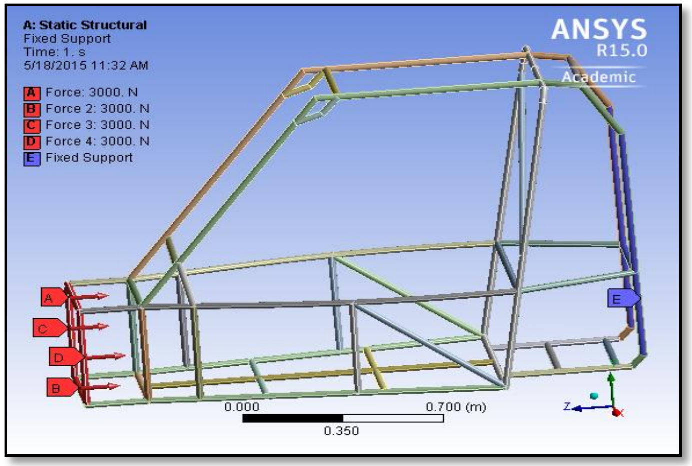


Fig. 3 Constraint for front impact analysis

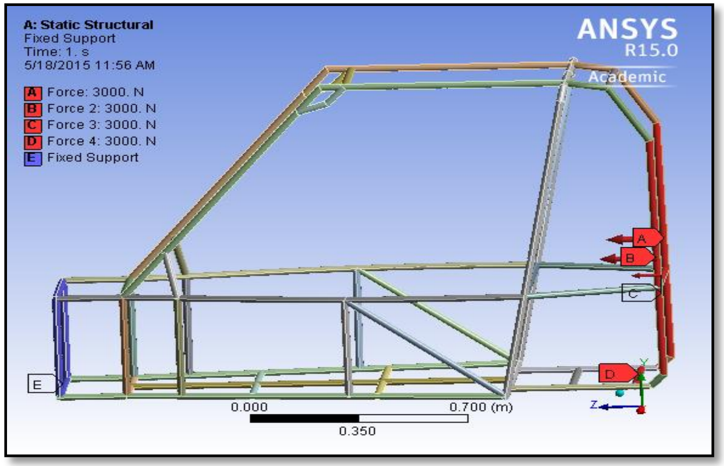


Fig. 4 Constraint for rear impact analysis

(i) Front & Rear Impact Analysis :

- After the analysis of front impact the maximum deformation found to be 0.829mm as shown in fig.1 and Von-Mises Stress is 128.23 MPa as shown in fig.2.

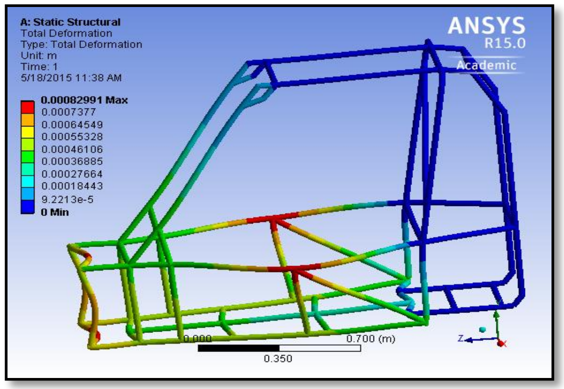


Fig. 5 Total Deformation analysis

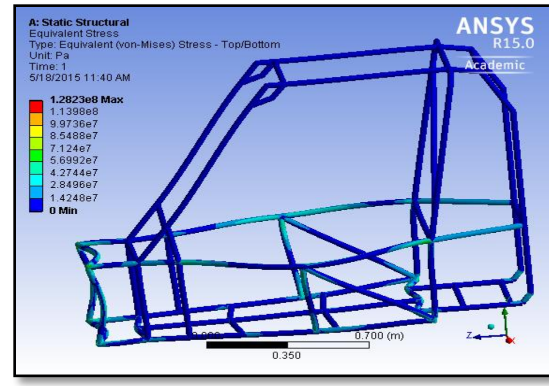


Fig. 6 Stress analysis

- After the analysis of rear impact the maximum deformation found to be 2.514mm as shown in fig.3 Von-Mises Stress is 165.58 MPa as shown in fig.4.

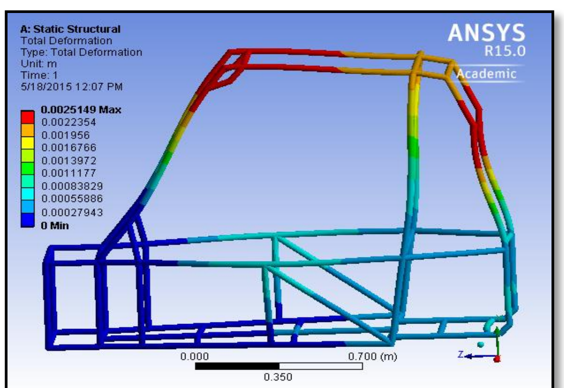


Fig. 7 Total Deformation analysis

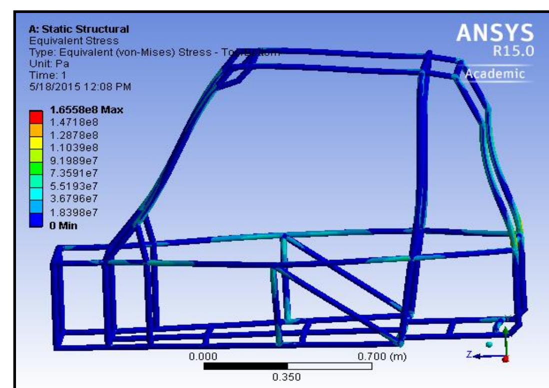


Fig. 8 Stress analysis

(ii) Side impact and Longitudinal calculation[1]:

1) Side Impact Analysis

Using the projected vehicle-driver mass of 300 kg, the impact force was calculated base on a G-load of **2**.We apply 6000 N from the side for the test of side impact of the roll cage structure of the vehicle for determining strength at the time of side collision as shown in fig. 5.

2) Longitudinal Torsion Analysis

The torsion analysis is done by constraining base and applying loads in opposite directions on front and rear ends. Loading F=6000N on opposite directions on front and rear ends applied as shown in fig.6.

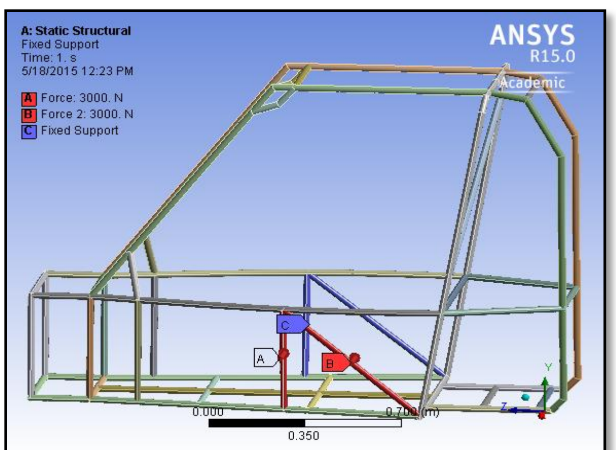


Fig. 9 Constraint for side impact analysis

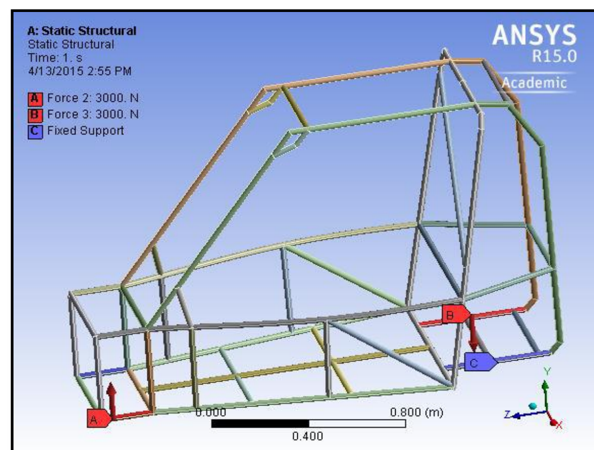


Fig. 10 Constraint for longitudinal torsion

(ii) Side impact and Longitudinal Analysis :

- After the analysis of side impact the maximum deformation found to be 3.022mm as shown in fig. 7 and Von-Mises Stress is 188.06 MPa as shown in fig.8.

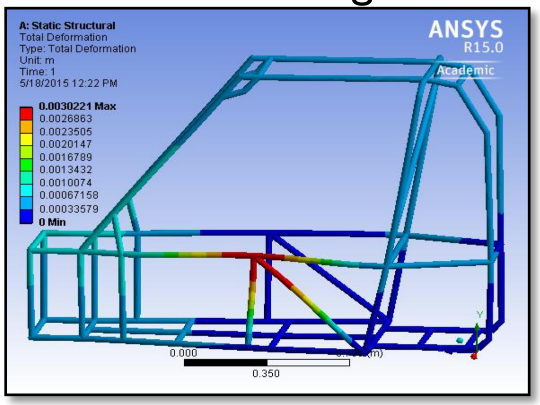


Fig.11 Total Deformation analysis

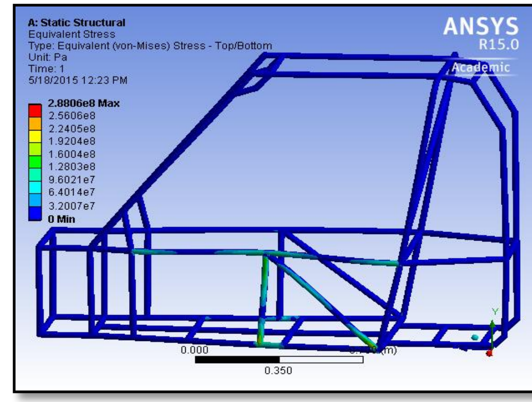


Fig.12 Stress analysis

- After the analysis of longitudinal torsional loading the maximum deformation found to be 1.41mm as shown in fig.9 and Von-Mises Stress is 148.75 MPa as shown in fig.10.

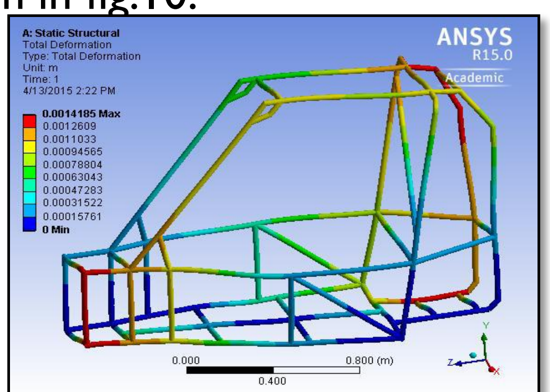


Fig.13 Total Deformation analysis

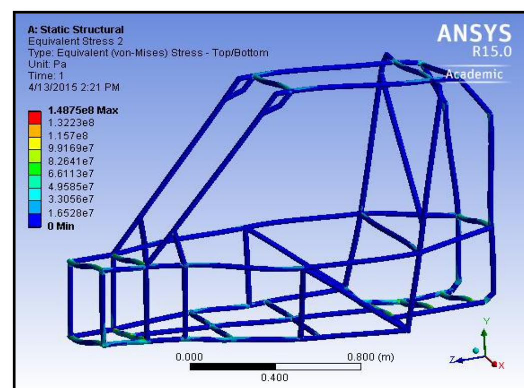


Fig.14 Stress analysis

Results

- After the calculating maximum Von-Mises Stress define the Factor of Safety (F.O.S) by using equation:

  Incorporated Factor of Safety = σ_{yt}/σ_{max} [1]

- Factor of safety as well as deformation of the roll cage at different applied load condition is as shown in table-4. Since FOS are under the limit, hence design is safe against specified Forces.

Table -4: Finite Element Analysis Results

SR. NO.	1.	2.	3.	4.
TEST	Front Impact	Rear Impact	Side Impact	Longitudinal Torsion
FORCE APPLIED (N)	12,000	12,000	6,000	6,000
YIELD STRENGTH-σ_{yt} (MPA)	365	365	365	365
VON -MISSES STRESS-σ_{max} (MPA)	128.23	165.58	188.06	148.75
FACTOR OF SAFETY	2.84	2.20	1.94	2.45
TOTAL DEFORMATION (mm)	0.829	2.514	3.022	1.41
RESULT	No Yielding	No Yielding	No Yielding	No Yielding

Fabrication of ‘ROLL CAGE’

Fabrication of ‘ROLL CAGE’

- From the results of the above tests it is concluded that the roll cage is safe under severe conditions. After the static analysis of the roll cage, material procurement was done.
- Total 7 tubes of 6m length each were procured at a cost of Rs. 5000. The cost per kg was Rs. 70.
- The material was cut and machined to required dimensions.
- Rail cutter available in the workshop was used to serve the purpose.

Fabrication of 'ROLL CAGE'

- After analyzing the material joining techniques available in the college workshop, metal arc welding was selected. All the members of the roll cage can be joined by this technique. The advantages of this welding technique are as follows:

- It is the simplest of all arc welding processes.
- The equipment is portable and the cost is fairly low.
- A big range of metals and their alloys can be welded.

Fabrication of 'ROLL CAGE'

Fig. 15 Model of Fabricated Roll cage

Conclusion

- After having lots of study, efforts and observations we came to the conclusion that our project results into light weight compared to other roll cages, reduced space requirements, reduction in material wastage, reduction in cost, multiple usage, easy for implementation, survival in un-ground surfaces and gives safety to the driver for smooth driving.
- Finally we have completed Fabrication of the Roll Cage of a Car as per design in this semester.

Application

- Roll cage can be used to reduce weight as well as for safety purpose of Driver[9].

Application

- Such roll cage can also been used in SAE-BAJA or SAE-Supra racing events.

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Thank You