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# Design and Analysis of Student Formula Car Roll Cage

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## Abstract

**Objective**: To design and analyze the student formula car roll cage by using analytical method. **Method/Analysis:** In this method the analysis is based on the dynamic loads applied on the roll cage through the conditions of normal driving, along with torsion rigidity of the roll cage. Roll cage can absorb high energy impacts at the same time as controlling the rate of deceleration. **Finding**: The effect of analytical calculations are used in designing student formula SAE car roll cage, with the recommendations made that the mild steel and carbon-fiber skins on a tabular space frame. **Application/ Improvements**: The proposed analysis paves a path of reference for design and analysis of student formula car roll cage.

**Keywords:** Dynamic Loads, Roll Cage, SAE (Societyof Automotive Engineers)

## 1. Introduction

Designing of an engineering component involves three consistent problems[1]. Selecting a material, Shape specification and Manufacturing process. As per requirement depending on the properties and based on the rule book[2] of event the material AISI 4130 has been selected.

### 1.1 IRules for Material to be used According to Supra SAE 2016

As per supra SAE 2016 rule minimum material requirements be the main structure of the car be capable of constructed moreover square or round bar. For the mate-

Table 1. Constraints of roll cage tubes according to rule book

| Sl. no. | Roll cage piece | Outside dimension and thickness of wall |
|---|---|---|
| 1 | Shoulder harness mounting bar, Main and front hoops. | Round25.4 X 2.413 mm |
| 2 | Side impact structure, Front bulkhead, Driver's restraint, Harness attachment and Roll hoop bracing. | Round25.4 X 1.651mm or<br>Square 25.4 X 25.4 X1.2446 mm |
| 3 | Front bulkhead support, Main hoop bracing supports. | Round 25.4 X 1.2446 mm |

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rial of Mild or Alloy steel tubing (minimum 0.1% carbon) of minimum dimensions are specified in Table 1.

### 1.2 Material Properties Designed for Bending and Buckling Strength Calculations[3]

Young's modulus=200 GPa
Yield strength=305 MPa
Ultimate strength=365 MPa

### 1.3 Welded Tube Joint Calculations[4]

Yield strength=180 MPa
Ultimate strength=300 MPa

### 1.4 Material Selection based on Properties of Metal[5]

An objective of material selection has been laid down on basis of application:

To design a light weight chassis with the ease of manufacturability, durability during service hours, cost effectiveness, availability and strength of material[6].

### 1.5 Material and its Mechanical Properties

The following table gives the mechanical properties of various materials.

From Table 2, material AISI 4130 has been selected because of its high strength to weight ratio.

AISI 4130 has good durability in service hours, material has easy machining ability, it can withstand heavy loads and it can easily weld.

## 2. Design and Analysis of Formula Supra SAE 2016 Car Roll Cage

To start the preliminary design of the frame several of the design guidelines are required to be set. They include intended transmission, steering, mounting of steering, suspension system and seat. Chassis design has been divided into four major cross sections i.e., front roll hoop, main roll hoop, front bulkhead and the rear bulkhead being fixed.

The main roll hoop was fixed by considering the engine mounting points and the drive shaft positions that has been fixed earlier. A naked minimum space was utilized for the engine. The maximum space should be provided in the driver cockpit area for more comfort. Ergonomics consideration is in use into account for design of the driver cockpit in the race car according rules of SUPRA SAE INDIA. Template was considered to verify the final model of cockpit.

**Table 2.** Materials and its Mechanical properties

| Sl.no. | Properties | AISI 1018 | AISI 1020 | AISI 4130 | ASTM 106(Grade B) |
|---|---|---|---|---|---|
| 1 | Tensile strength(MPa) | 400 | 394 | 560 | 450 |
| 2 | Yield strength(MPa) | 370 | 294 | 460 | 240 |
| 3 | Density(Kg/m$^3$) | 7.87*106 | 7.87*106 | 7.89*106 | 7.87*106 |
| 4 | Strength to weight ratio(KN-m/Kg) | 51 | 50.06 | 70.97 | 57.179 |
| 5 | Cost per meter length(Rupees) | 300 | 300 | 350 | 450 |

## 2.1 Ergonomic and Safety

For evaluation of ergonomics and safety issues of the driver, made different drivers to sit on the provided template by the event organizer and record the data values of each driver needed for providing ergonomics and safety to the driver. From the recorded values average of data was taken to best suit of 95$^{th}$ percentile of male drivers. The Table 3 shows the recorded data of various drivers for ergonomic conditions.

Before finalizing the lengths of chassis the prototype was prepared by using of PVC pipes to get the clear idea on the model of race car roll cage based on the ergonomic conditions data. The Figure 1 gives the dimensions of cockpit as per requirements.

**Table 3.** Recorded data of various drivers for ergonomic conditions

| Sl. no. | Person | Back-rake angle (degree) | Thigh angle (degree) | Seat angle (degree) | Steering wheel height (mm) | Shoulder height (mm) | H-point to dash (mm) | Knee height (mm) |
|---|---|---|---|---|---|---|---|---|
| 1 | A | 70 | 20 | 90 | 380 | 600 | 650 | 310 |
| 2 | B | 70 | 19 | 91 | 400 | 580 | 650 | 300 |
| 3 | C | 70 | 20 | 90 | 380 | 600 | 650 | 330 |
| 4 | D | 70 | 20 | 90 | 380 | 600 | 650 | 310 |

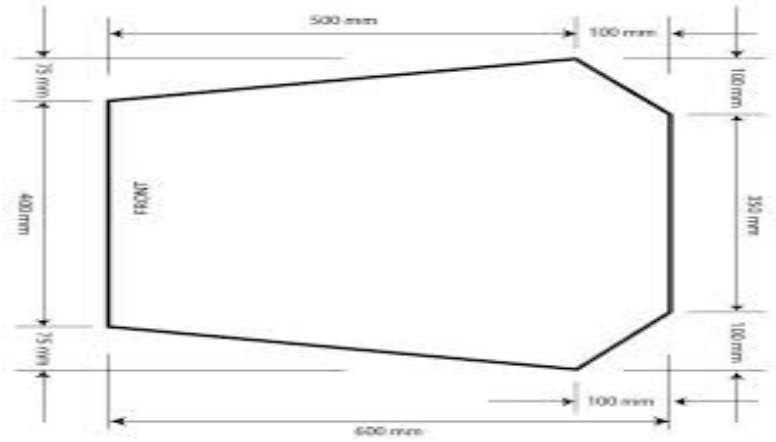


**Figure 1.** Template of cockpit.

## 3. Design of Car Roll Cage

After the ergonomic consideration and prototype modeling, the decision was made taken to race car design and 2D sketch on floor by fixing the following data. Wheel base of 1650 mm, wheel track at front of 1270 mm and wheel track at rear of 1250 mm. Figure 2 gives the dimensions of car roll cage as per requirement.

After completion of line drawing of chassis, structural members of pipe with specified dimension has been added in dimension has been added in design tool i.e., solid works and the pipes were joined perfectly.

### 3.1 Dimensions of Pipes

For main hoop, front hoop bulk head, side impact, rear bulk head: 25.4 mm * 2.5 mm

For remaining supporting members and bracing: 25.4 mm * 1.6 mm.

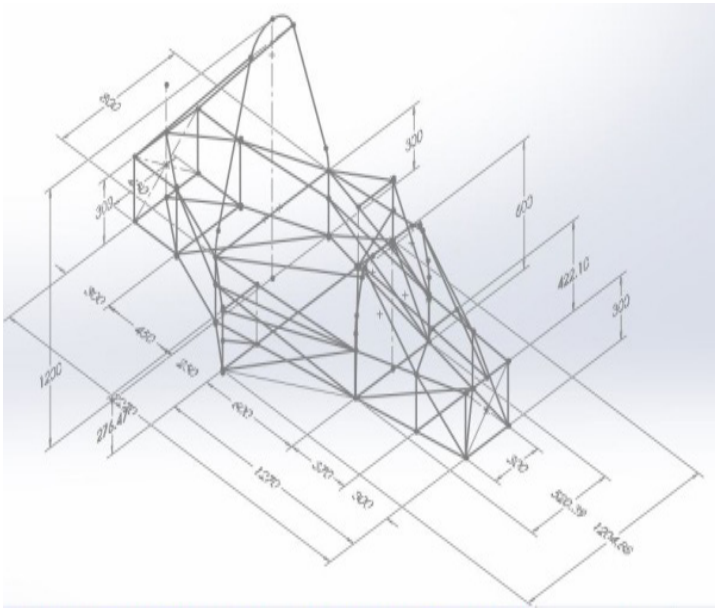

**Figure 2.** Dimensional sketch of car roll cage.

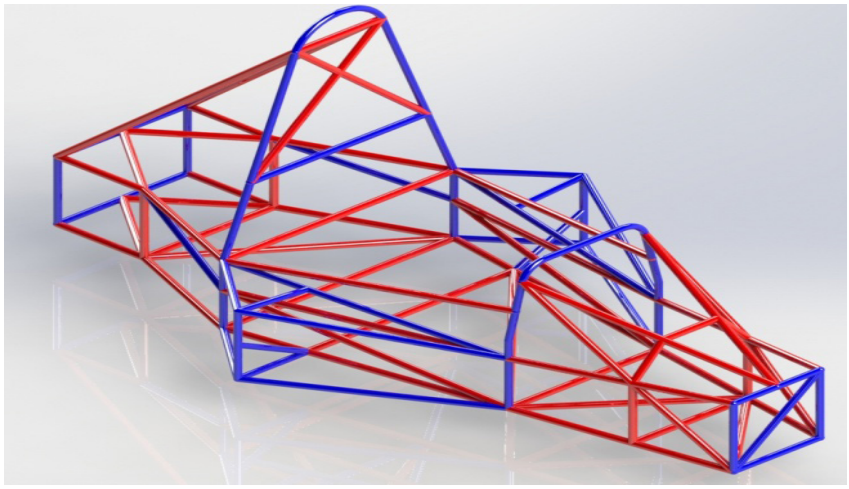

**Figure 3.** Dimensional model of car roll cage.

Figure 3 shows the 3D model of car roll cage. In Figure 3 the blue color pipes indicate 2.5 mm thickness and red colour pipes indicate 1.6 mm thickness.

## 4. Analysis of car roll cage

Different types of flexure analysis have been carried out like front impact, rear impact, and side impact. The torsion analysis was also carried to maintain required amount of torsion rigidity for the vehicle because rigidity plays a major role during cornering of race car. Here 'G' is considered as the weight of vehicle[6].

### 4.1 Front Impact Structural Analysis

Constraints applied at rear suspension points, applied load is 10 G and force applied at front part of the bulk head. From Figure 4 the factor of safety achieved 1.43 and displacement 1.194 mm.

### 4.2 Rear Impact Structural Analysis

Constraints applied at front suspension points, applied load is 10 G and force applied at rear part of the chassis. After analyzing rear impact structural system the factor of safety achieved 1.43 and displacement 1.194 mm.

### 4.3 Side Impact Structural Analysis

Constraints applied at front and rear suspension points, applied load is 7 G and force applied at the outer most member of the left or right side of the chassis. After analyzing rear impact structural system the factor of safety achieved 1.80 and displacement 1.190 mm.

### 4.4 Front Torsion Analysis

Constraints applied at rear suspension points, applied load is 7 G and force applied is two couple forces in front suspension points. After analyzing front torsion analysis

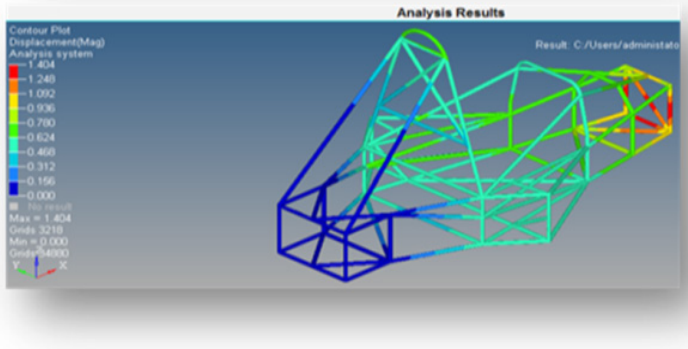


**Figure 4.** Analysis of car roll cage for front impact.

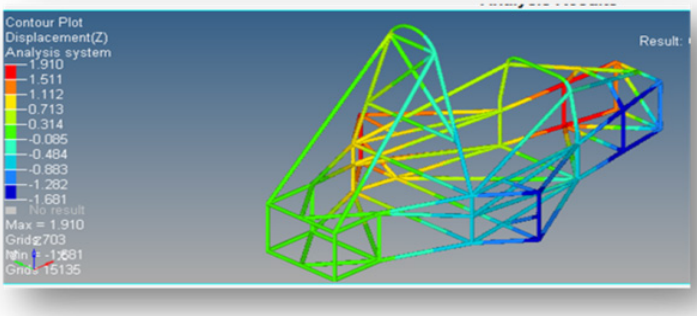


**Figure 5.** Front torsion analysis of car roll cage.

from Figure 5 the torque developed is 2,450 N-m and stiffness is 1256.41 N-m/degree.

### 4.5 Rear Torsion Analysis

Constraints applied on front suspension points, applied load is 7 G and force applied is two couple forces in rear suspension points. After analyzing front torsion analysis the torque developed is 2,817.5 N-m and stiffness is 1476.41 N-m/degree.

## 5. Conclusion

For formula SAE car roll cage the design and analysis has been carried out by considering the ergonomic conditions. The results are satisfied for required Factor of safety, displacement and stiffness. The design parameters are recommended to manufacture of formula SAE car roll cage.

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