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DESIGN, SIMULATION AND FABRICATION OF ROLL CAGE FOR ALL TERRAIN VEHICLE

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Abstract-*The study aims to design, analyze and fabricate a roll cage for an ATV in accordance with the rulebook of SAE BAJA 2018. SAE BAJA is an all-terrain vehicle competition which gives under graduate student a practical experience in engineering sciences. It deals with modelling of roll cage of an automobile (SAE BAJA) and analyzing it to give an optimum design. The roll cage must be constructed of steel tubing, with minimum dimensional and strength requirement dictated by Society of Automotive Engineers (SAE). The main objective of this research work is to perform a structural analysis on an ATV frame considering the safety features including total safety of driver during any collision or accident, to have a compact structure with less weight and with good aesthetic as well. The structural model is prepared in CREO software and the numerical analysis of the frame is accomplished in ANSYS software. The manufacturing objective is to design a vehicle which is safety ergonomic, aerodynamic, highly engineered which can make it highly efficient.*

Keywords - *Roll cage, ANSYS, ATV, FEA, SAE BAJA, Driver Safety, Weight, strength*

I. INTRODUCTION

ATV means all terrain vehicle which is specially designed for 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.

A frame of a vehicle plays the most important role in safety of the passenger. 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 passenger cabin must have the capacity to resist all the forces exerted upon it.

This can be achieved either by using high strength material or better cross sections against the applied load. But the most feasible way to balance the dry mass of roll-cage with the optimum number of members is done by triangulation method. The roll cage must be constructed of steel tubing, with minimum dimensional and strength requirements dictated by SAE. The SAE BAJA vehicle development manual also restricts us about the vehicle weight, shape and size, and dimensions. Circular cross-section is employed for the roll cage development as it helps to overcome difficulties like increment in dimension, rise in the overall weight and decrease in fuel efficiency. It's always a perfect one to resist the twisting and the rolling effects, therefore is preferred for torsional rigidity. Material for the roll cage is selected based on strength, cost and availability. The roll cage is designed to incorporate all the automotive sub-systems. Based on the result obtained from these tests the design is modified accordingly. The purpose of the roll cage is to maintain a minimum space surrounding the driver and to support all subsystems. The cage is designed and fabricated to prevent any failure of the cage's integrity. Designing of roll cage is done with ergonomic and safety conditions as specified in SAE rule book. The structural model is prepared in CREO 3.0 software and the numerical analysis of the frame is accomplished in ANSYS workbench 15.0 software. The manufacturing objective is to design a vehicle which is safety ergonomic, aerodynamic, highly engineered which can make it highly efficient.[4]

II. PROBLEM STATEMENT

Roll cage weight plays vital role in vehicle performance. Due to the overweight of the roll cage, the ATV may lag in performance.Nowadays, racing car use tubular or space frame roll cage system built from steel pipes. Therefore, it is necessary to reduce the problem of Overweight occurred and make the Improvement of design. Steel grade AISI 4130 will used to solve the Overweight problem.

The intricacy of design and the arrangement of the tubular members cast a waste space which not makes the car more compact Roll cage weight plays vital role in vehicle performance. Due to the overweight of the roll cage, the ATV lagged in performance. To justify the design of roll cage considering driver's safety and ergonomics. To analyze the roll cage in different modes of failure and to avoid the breakage in extreme conditions of collision. To increase the material utilization with minimum wastage for the optimum cost of the roll cage.

III. OBJECTIVES

i. To design the roll cage structure considering the driver's safety.
ii. To design roll cage in accordance with the rulebook of SAE- BAJA.
iii. To reduce weight of roll cage and maintain a desired centre of gravity.
iv. To design a vehicle for driver's ergonomics which considers driver's comfort, optimal placement of steering wheel, pedal positions, spacious cockpit.
v. To avoid the failure in the front collision, rear collision, side collision, rolling and torsion.

IV. DESIGN AND DEVELOPMENT

4.1 Material selection

There are various materials available for roll cage member; we consider some parameter like strength, weight cost & availability. As per the market parameters three materials were selected for roll cage materials which are AISI 1018, AISI 1020 and AISI 4130 chromoly. Every material having different parameters and properties as follows, from them AISI 4130 is selected due to its advantages over other materials mentioned in following table. [4]

Table 1.Material comparison for Roll Cage material

specification	AISI 1018	AISI 1020	AISI 4130
Carbon %	0.15-0.20	0.18-0.23	0.28-0.33
Density (kg/m^3)	7.87×10^3	7.7×10^3	7.85×10^3
Yield strength (mpa)	370	350	435
Tensile ultimate strength (mpa)	440	400	560

4.2 Design of roll cage

After selection of material next step is to draw 3-D model of roll cage with all considering set parameters of various systems and sub systems and according to rules of SAE BAJA Rulebook. For the start of the design, we have used CREO software in which we have drawn the line drawing of roll cage. The next step after the line drawing of roll cage is piping of roll cage in the CREO software of using it's one of the feature which is Framework. By using this feature, piping of roll cage can be done with the various cross sections required. [1]

Roll cage have been supported with all possible triangular structure so that forces acting on members can be distributed uniformly throughout the members. Shocker has been mounted passing through the centre line of triangle.

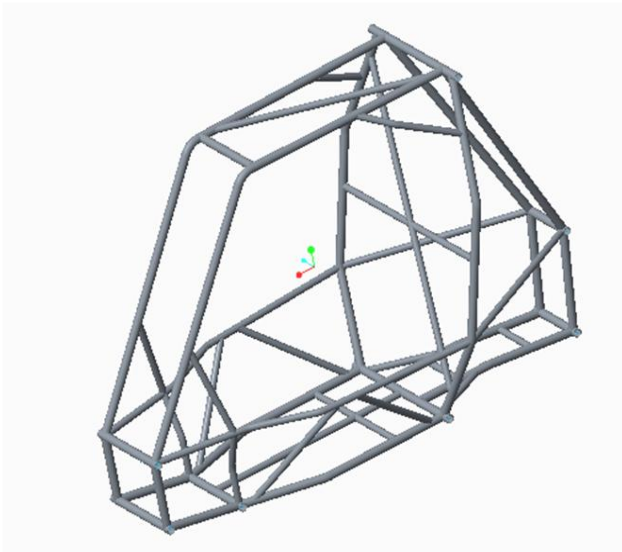
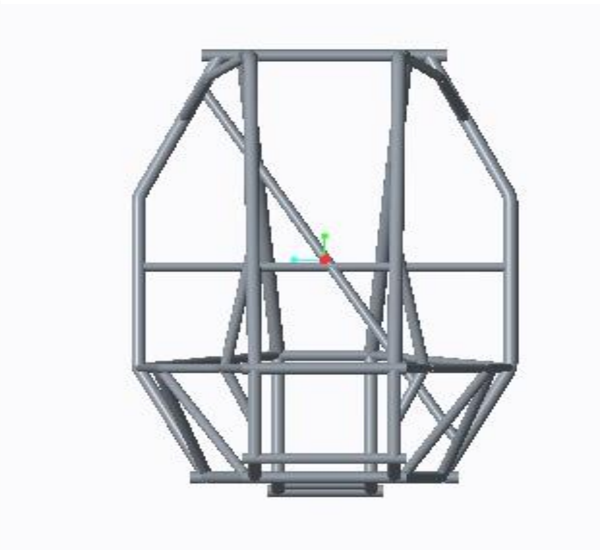

Figure 1. Isometric view of the Roll cage in CREO 3.0Figure 2. Front view of the Roll cage in CREO 3.0

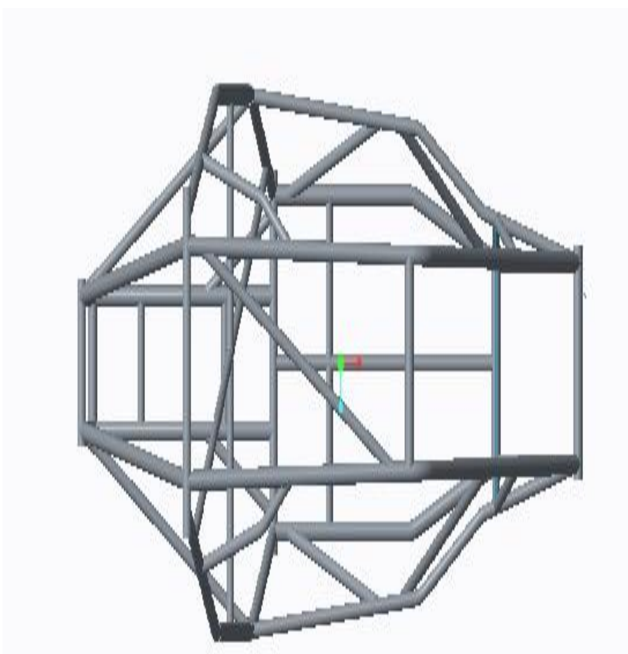
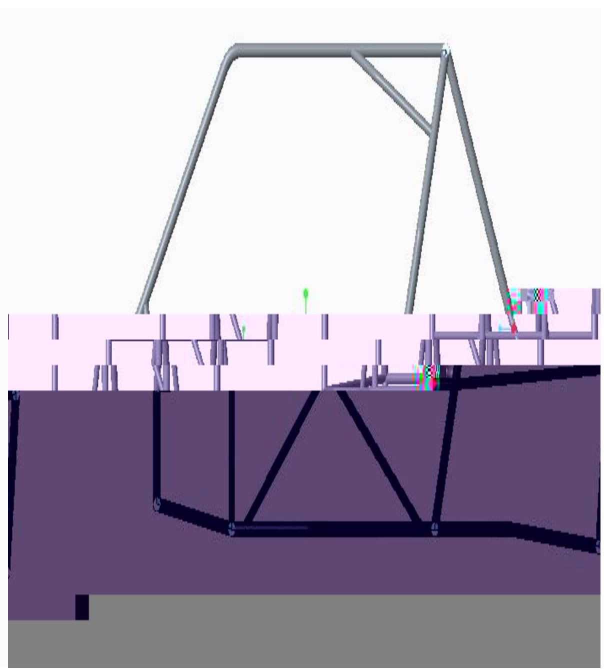

Figure 3. Top view of the Roll cage in CREO 3.0Figure 4. Side view of the Roll cage in CREO 3.0

4.3 Analysis of Roll Cage

A. Front Impact Analysis-

Front impact or the static front impact analysis, Deceleration of 10g‟s was assumed for the loading which is equivalent to a static force of 14715N load on the vehicle, assuming the weight of the vehicle is 250kg (with including 60 kg driver weight). We apply 14715N from the front for the test of front impact of the roll cage structure of the vehicle for determining strength at the time of front collision. [6]

F= m*a
 = 250*10*9.81
= 14715 N

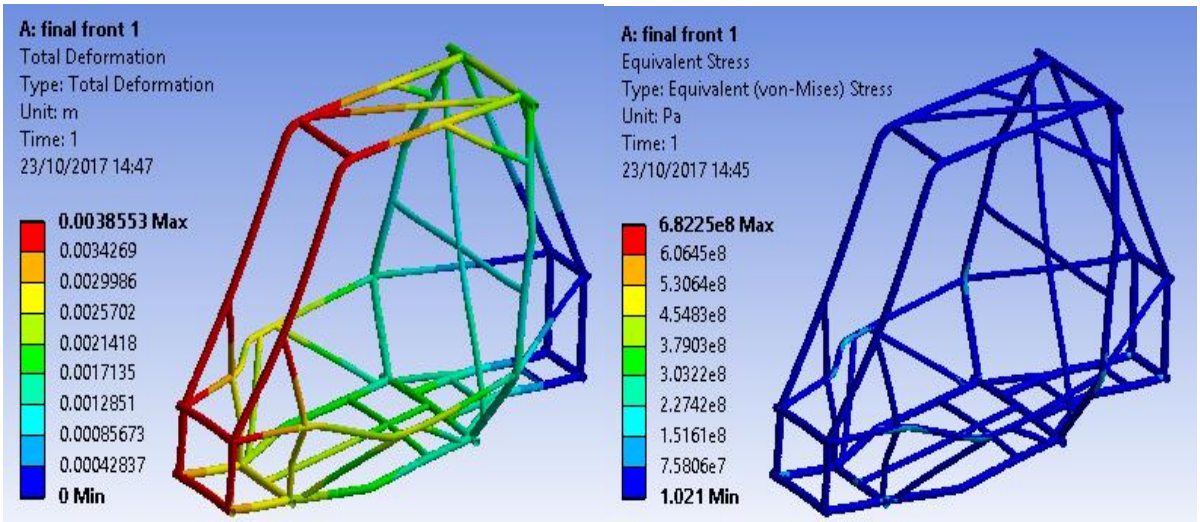

Figure 5. Static Structural Analysis with Total Deformation &von-Mises Done in ANSYS Workbench 15.0

B. Side Impact (SIM) Analysis-

Side impact or the static side impact analysis, Deceleration of 6g"s was assumed for the loading which is equivalent to a static force of 8829N load on the vehicle, assuming the weight of the vehicle is 250kg (with including 60 kg driver weight). We apply 8829N 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. [6]

F = m*a
= 250*6*9.81*
= 8829 N

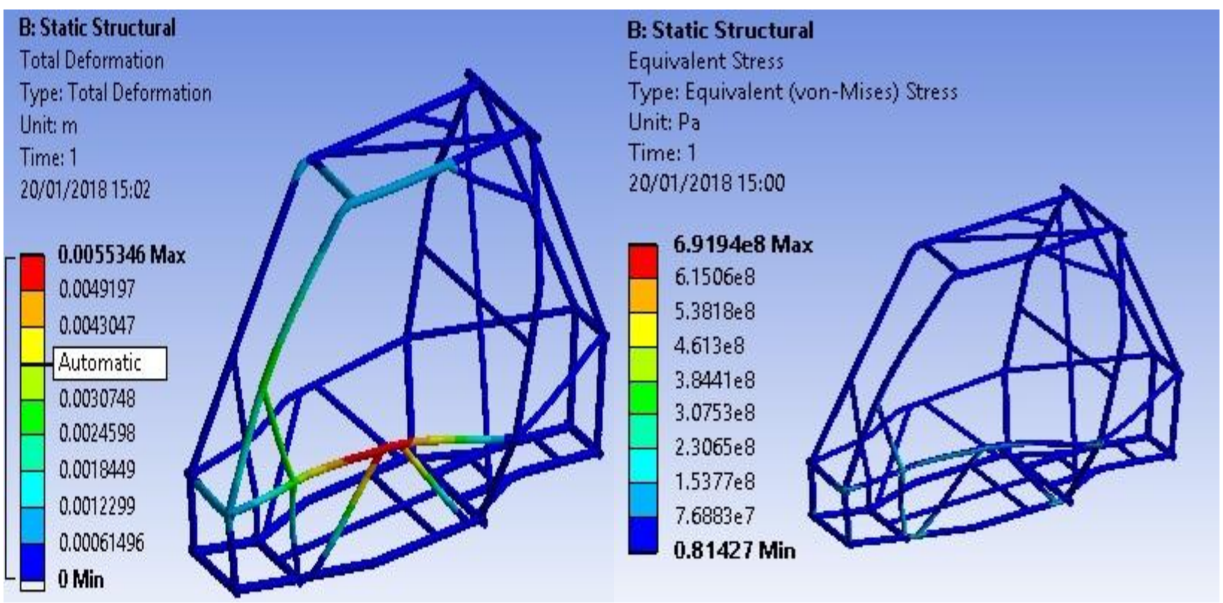

Figure 6. Static Structural Analysis with Total Deformation &von-Mises Done in ANSYS Workbench 15.0

C. Roll Over Analysis-

Roll over impact or the static roll over impact analysis, Deceleration of 4g"s was assumed for the loading which is equivalent to a static force of 5886N load on the vehicle, assuming the weight of the vehicle is 250kg (with including 60 kg driver weight).

We apply 5886N from the top for the test of roll over impact of the roll cage structure of the vehicle for determining strength at the time of roll over collision. [6]

F =m*a
=250*4*9.81
=5886 N

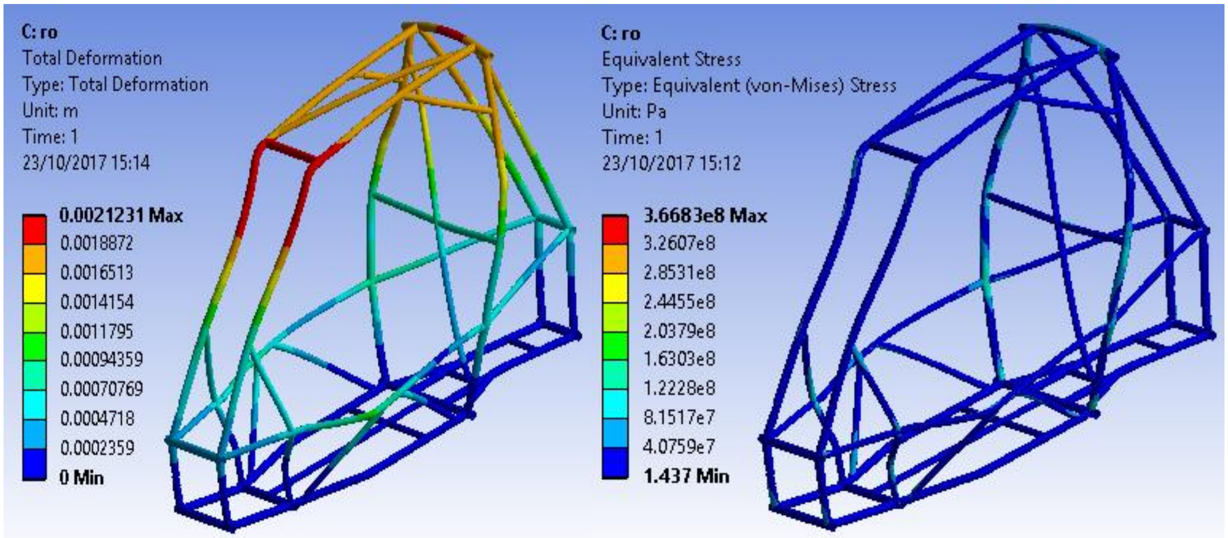

Figure 7. Static Structural Analysis with Total Deformation &von-Mises Done in ANSYS Workbench 15.0

D. Rear Impact Analysis-

Rear impact or the static rear impact analysis, Deceleration of 10g‟s was assumed for the loading which is equivalent to a static force of 14715N load on the vehicle, assuming the weight of the vehicle is 250kg (with including 60 kg driver weight).

We apply 14715N from the rear for the test of rear impact of the roll cage structure of the vehicle for determining strength at the time of rear collision. [6]

F=m*a

= 250*10*9.81

= 14715 N

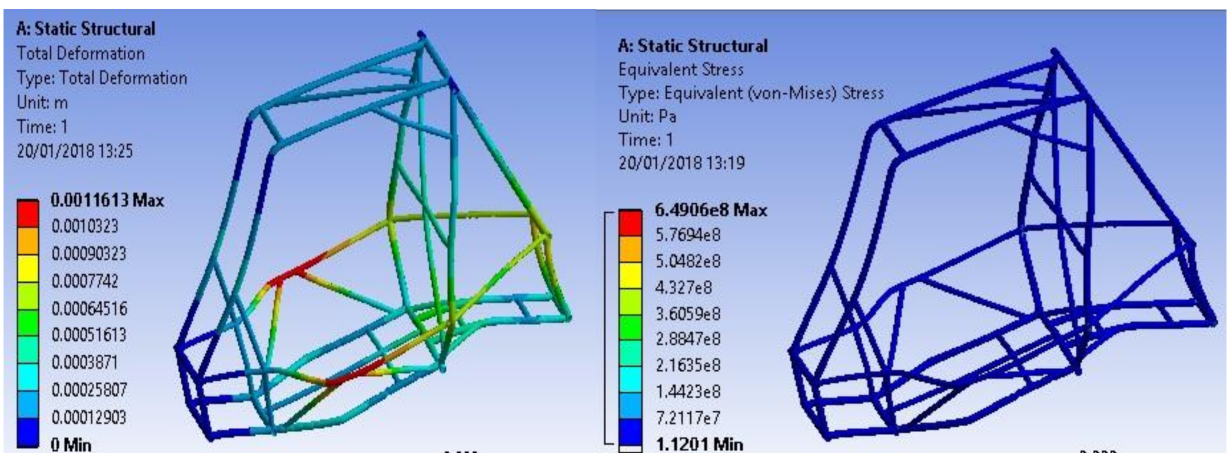

Figure 8. Static Structural Analysis with Total Deformation &von-Mises Done in ANSYS Workbench 15.0

E. Torsional Analysis-

Torsional impact or the static torsion impact analysis, Deceleration of 2g‟s was assumed for the loading which is equivalent to a static force of 2943N load on the vehicle, assuming the weight of the vehicle is 250kg (with including 60 kg driver weight).

We apply 2943N from the front left side for the test of torsion impact of the roll cage structure of the vehicle for determining strength at the time of torsional collision. [6]

F=m*a

= 250*2*9.81

= 2943 N

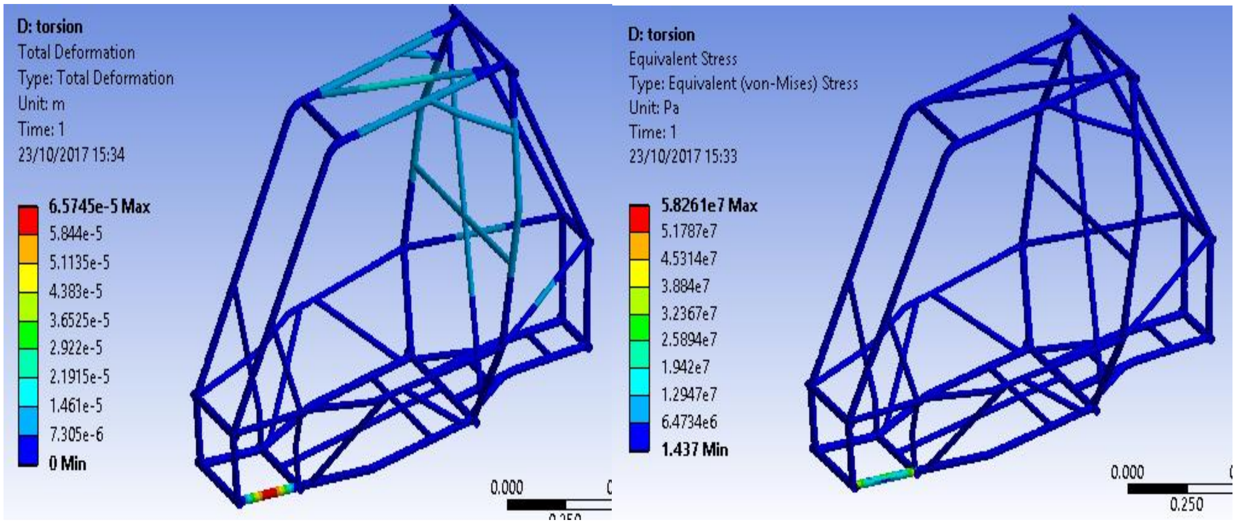

Figure 9. Static Structural Analysis with Total Deformation &von-Mises Done in ANSYS Workbench 15.0

V. CALCULATIONS

Calculations of material strength
Definitions-
E =Modulus of elasticity
I = second moment of inertia

5.1 Designed for Primary member
Diameter - 1.25” (31.75 mm)
Wall Thickness - 0.06299” (1.6 mm)
Material - AISI 4130 Steel

From tubing geometry
Modulus of elasticity E= 205 Gpa
Outer diameter D_o = 31.75 mm
Thickness t = 1.6 mm
Inner diameter D_i = 28.55 mm
Second moment of inertia
$I = (\pi/64)*(D^4_O - D^4_i)$
$= 17.268*e3\ mm^4$
Yield strength S_y = 562.53 Mpa
Distance from the Neutral axis
to extreme fibre
C = 15.875 mm

5.1.1 Bending strength –
$= (Sy*I)/C = (562.53*17.268e3)/15.875$
= 611.92 N-m[1]

5.1.2 Bending Stiffness –
$= E*I = (205*17.2688)$
= 3540.104 N-m2[1]

5.1.3 Torsional stiffness per unit degree –
= (T/α) = (G*J)/L
= ((8.0*E10)*(3.4537*E-8)/1
= 2762.96 N-m/degree [3]

5.2 Designed for Secondary member
Diameter - 1” (25.4mm)
Wall Thickness - 0.06496” (1.65 mm)
Material - AISI 4130 Steel

From tubing geometry
Modulus of elasticity E= 205 Gpa
Outer diameter D_o = 25.4mm
Thickness t = 1.65 mm
Inner diameter D_i = 22.1 mm
Second moment of inertia
$I = (\pi/64)*(D^4_O-D^4_i) = 8.722e3\ mm^4$
Yield strength S_y = 543.24 Mpa
Distance from the Neutral axis to
Extreme fibre C = 12.7 mm

5.2.1 Bending strength –
$= (Sy*I)/C$
= (543.24∗8.722e3)/ 12.7
= 373.09N-m[1]

5.2.2Bending Stiffness –
$= E*I$
= (205∗8.722)
= 1788.05 $N\text{-}m^2$[1]

5.2.3Torsional stiffness per unit degree–
= (T/α) = (G*J)/L
= ((8.0*E10)*(1.744*E-8)/1
= 1029.305 N-m/degree [3]

CONCLUSION

The designed roll cage is found to be reliable and the factor of safety is above the safe limit. Hence, deformation & stresses are under the limit and the designed is safe. From the theoretical Calculations and ANSYS results, it is seen that the stresses obtained are within the material properties of AISI 4130 Chromoly. The design, development of the FRAME are carried out successfullyFinally after lots of iterations, efforts and observations we came to know that our projects results into light weight compared to other iterative roll cages, reduced space consumption, reduction in material wastage, reduction in cost, multiple usage, easy for implementation, survival in un-ground surfaces and gives safety to the driver for uneven conditions.

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