Design and Analysis of Structure of Roll Cage for SUPRA SAE

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Abstract— This 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. A roll cage is a specially engineered and constructed frame built in the passenger compartment of a vehicle to protect its occupants from being injured in an accident, particularly in the event of a rollover. The main objective of the project to generate the CAD model of roll cage structure, to perform design and analysis of roll cage structure using FEA and to increase the product quality. Nowadays, most of the components of vehicle are in the stage of replacing with Steel and aluminium materials. This is due to the properties of material that can be designed freely to hold the load from any direction. Its light-weight property makes it possible to enlarge the performance of the car while maintaining low weight. On the basis of objective, data accumulated and design calculations the CAD model of the roll cage was design using Solidworks. After CAD modelling the Finite Element Modelling and Finite Element Analysis was carried out by using HYPERMESH and Nastran to validate the Designed CAD model. The linear static analysis results shows that the stresses are well within the safe limit, hence the design is safe.

Key words: Roll Cage, SUPRA SAE

I. INTRODUCTION

In this work, we presented in detail the literature study on roll cage structure. The type of structure used generally are reviewed. The method for structure design is elucidated. This work emphasizes the study of method for designing and analyzing the roll cage structure for SUPRA SAE in various aspects.

The STUDENT FORMULA competitions challenge teams of university undergraduate and graduate students to conceive, design, fabricate, develop and compete with small, formula style, vehicles. The vehicle should have very high performance in terms of acceleration, braking and handling and be sufficiently durable to successfully complete all the events described in the STUDENT FORMULA Rules and held at the STUDENT FORMULA competitions. a complete design and analysis report of roll cage structure is must for the competition.

A Formula student race car is a simplified version of Formula One race car designed and built by the university students for competitions like FSAE, Supra SAE, and Formula Student etc. body structure plays a major role during race car racing. usually, in race a car, roll cage structure with minimum 3.5mm thickness is used owing to ease of design and lighter in weight. However, various combinations of material and thickness used.

A roll bar is a single bar behind the driver that provides moderate rollover protection. Due to the lack of a protective top, some modern convertibles utilize a strong windscreen frame acting as a roll bar.Also, a roll hoop may be placed behind both headrests (usually one on older cars), which is essentially a roll bar spanning the width of a passenger's shoulders.

Fig. : A race car body shell with integrated roll cage

II. DATA ACCUMULATION

A. *Design requirements*

Required Documents for VEHICLE ELIGIBILITY
"Design Report"on, Front impact analysis, Side impact analysis, roll over, bottom impact and head stand.
Given data:
Weight of car = 300 kg
Speed = 7 m/sec
Time for impact = 0.12 sec
Total energy absorbed must meet or exceed = 7350 Joules

B. *Data Calculations*

During impact, time of impact will be greater for deformable bodies as compare to that of rigid bodies
From work done energy principal
Work done = change in Kinetic energy

$$w = (0.5 \times m \times V^2)$$

$$w = 0.5 \times 300 \times 7^2 = 7350 \text{ N.m}$$

Now, work done = Force x Displacement
work done = F x S
where, S = impact time x velocity

$$S = 0.12 \times 7 = 0.84 \text{ m}$$

$$F = \frac{w}{S} = \frac{7350}{0.84} = 8750 \cong 9000 \text{ N}$$

C. *CAD Modeling*

Cad Model of the Roll cage of supra SAE as per the design calculations

1) *Existing CAD Model:*

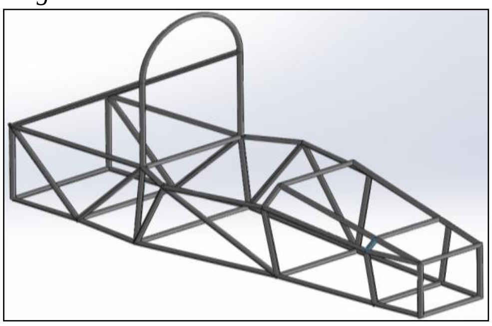


Fig. : Isometric View of roll cage

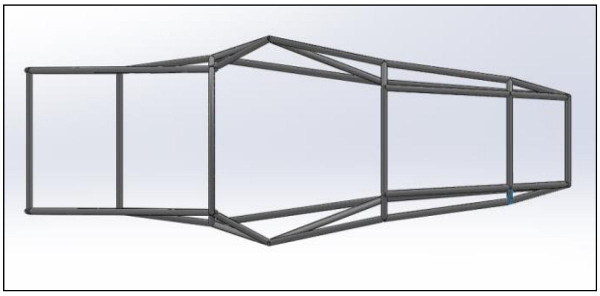


Fig. : Front view and Top view of Roll cage

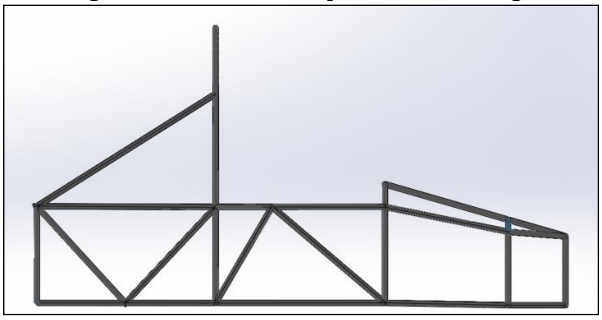


Fig. : Side view of roll cage

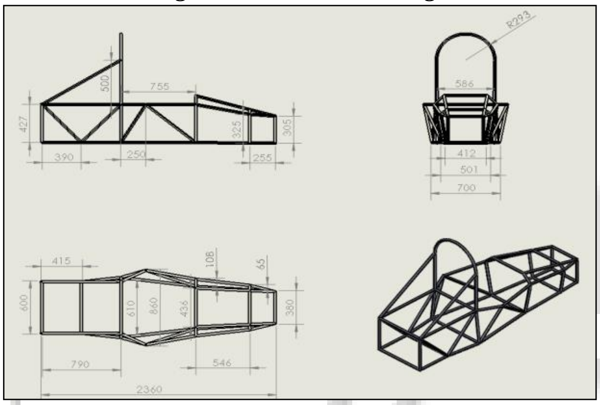
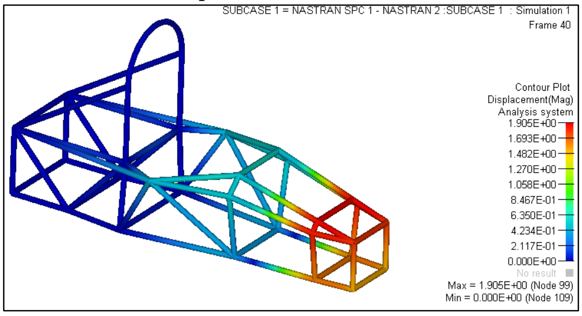


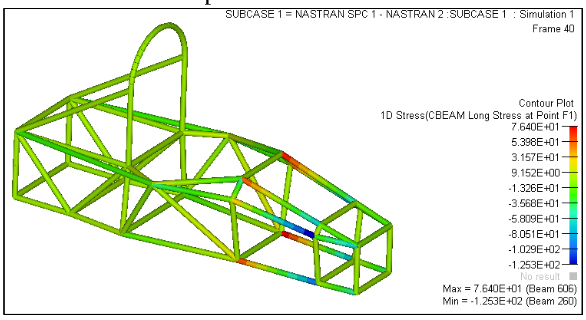
Fig. : Detail view of roll cage

D. Finite Element Analysis

1) CASE 1- Front impact:

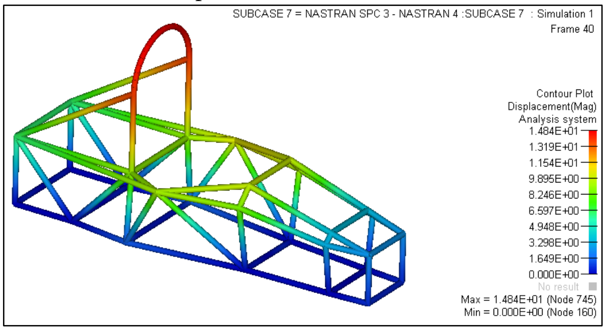


Displacement= 1.9 mm

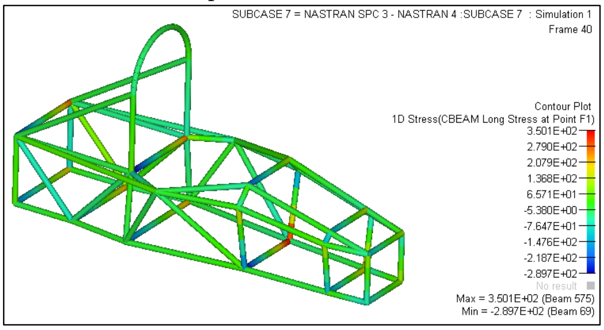


Stresses = 76.4 MPa

2) CASE 2- Side impact:

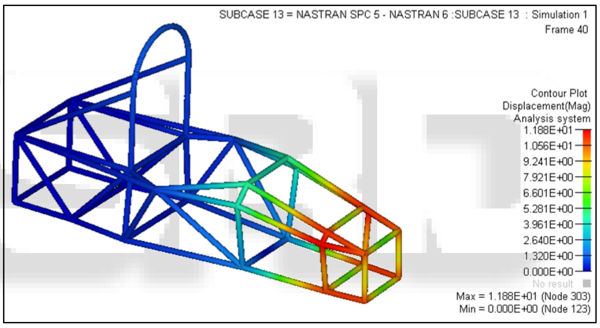


Displacement= 14.8 mm

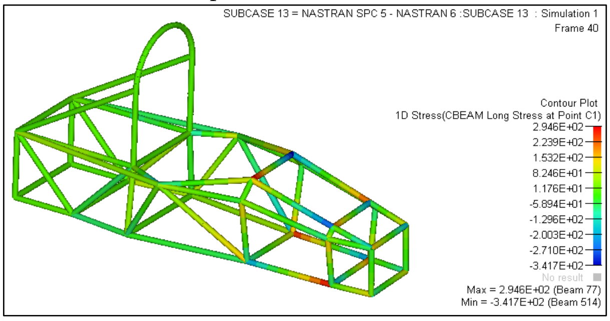


Stresses = 350 MPa

3) CASE 3- Roll over:

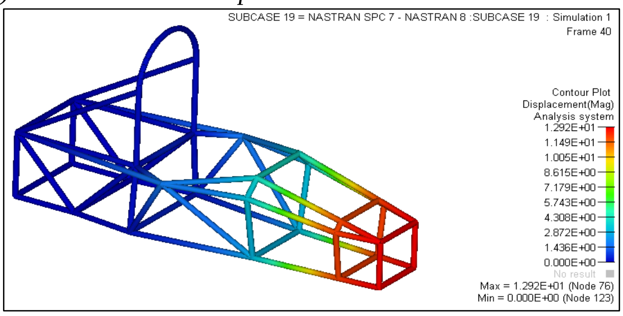


Displacement= 11.8 mm

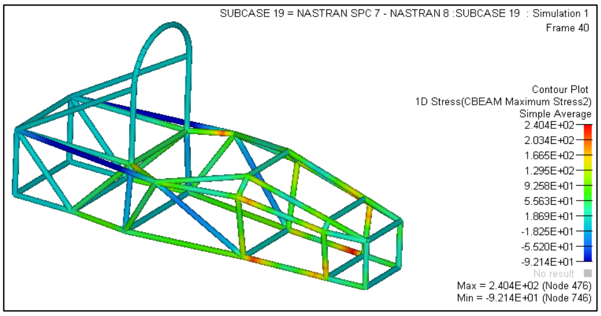


Stresses = 294.6 MPa

4) CASE 4- Bottom impact:

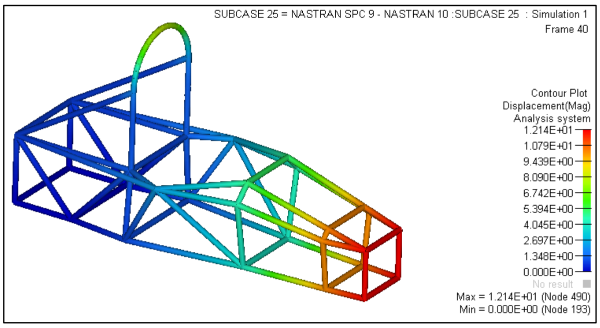


Displacement= 12.9 mm

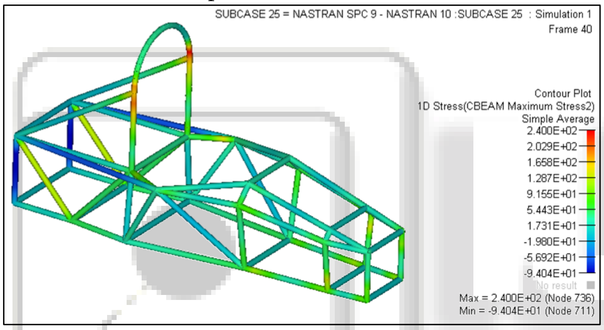


Stresses = 240 MPa

5) *CASE 5- Head stand:*



Displacement= 12.1 mm



Stresses = 240 MPa

III. RESULT DISCUSSION

1) As per the criteria of rule book provided by Supra SAE roll cage structure is analyzed using Finite Element Analysis techniques. To validate the roll cage structure for 5 different loading conditions as per Supra SAE, five different analyses are performed.
2) From Finite Element Analysis for Front impact loading maximum displacement 1.9 mm observed and Maximum stress 76.4 Mpa.
3) From the Finite Element Analysis for Side impact loading maximum displacement 14.8 mm and maximum stress 350 MPa observed.
4) With roll over boundary conditions maximum displacement 11.8 mm and maximum stress 294.6 Mpa.
5) In Bottom impact conditions maximum displacement 12.9mm and maximum stress 240Mpa obtained.
6) Maximum displacement 12.1mm and maximum stress 240 Mpa obtained in the Head stand boundary conditions.
7) Properties of Chromium-molybdenum steel (AISI 4130) is used for roll cage analysis. Yield stress of roll cage structure material is 360.6 Mpa.
8) From the Finite Element analysis results it is seen that all the stresses developed in five different boundary conditions are less than the material yield stress.

IV. CONCLUSION

As per Supra Sae rules and guidelines a roll cage structure for student formula car is designed. A cad model of roll cage is modeled using Solidworks. To validate the structure for five different loading conditions (front impact, side impact, roll over, bottom impact and head stand) A Finite Element Analysis is carried out using Hypermesh for preprocessing and Nastran for processing the analysis. For the safe design developed stresses must be less than the material yield stress.

Maximum stress 350 MPa observed in side impact loading among all load cases. Where yield stress of Material is 360.6 MPa. As it is seen from the result that stresses developed in roll cage with all boundary conditions is less than the material yield stress. Hence design is safe for all boundary conditions.

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