Design And Analysis of Roll Cage of Supra Vehicle

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ABSTRACT

SUPRA SAE states that the goal of the competition is to design and manufacture a prototype of a small-scale production vehicle. Manufactured vehicle will take part in an event which is governed by the international student body named “SAE”, and the event named “SAE SUPRA” is held every year and is a national level competition which is also called “FSAE India”. This competition deals with Events divided into two categories, .1 Statics; .2 Dynamics. The static events consist of Cost report, Design report and Business plan and the Dynamics are of Acceleration, Breaking, Steering and Endurance. Before which the vehicle should pass the technical inspection, in which the Judges “Race Certify” the vehicle.

In the present research paper the Design and Analysis of SAE vehicle is done and Tabular Space ,Frame model is being used in the design of the vehicle, and the entire vehicle deals with the rules and boundaries of the competition as mentioned in the SAE SUPRA Rulebook 2018. The method of designing the vehicle starts off with the help of CAD software called SOLIDWORKS 2018 and the analysis is carried out using ANSYS 18.0 .The design is validated with the rules of SUPRA and the results are compared with the previous design.

Key Words : Supra ,Roll Cage, Design ,Analysis

1.INTRODUCTION

SAEINDIA is a strategic alliance partner of SAE International registered in India as an Indian nonprofit engineering and scientific society dedicated to the advancement of mobility industry in India.

The main tasks to set a benchmark for the following generations to compete and make a better vehicle. The team did good research on Formula SAE vehicles to get an idea about what they were going to enter into.

The main aim is to make the vehicle as economical as possible, high on driver comfort, and as compatible with engine as possible and avoid manufacturing of parts or sub-assemblies. Another important aspect was the compliance with the rule book. Keeping these factors in mind and considering the interests and hold of the team members in each department, the team was divided into 5 parts. These were sub-departments which took care of various sub systems of the vehicle as well as the managerial and documentation part. The teams were initially divided into

1. Frame/Roll cage& Body
2. Engine & Drive train
3. Suspension
4. Steering
5. Brakes

The reports and the market surveying was also done by the departmental members for their respective sub-teams. Hence the work load was equally divided and no resources and time wasted.

2. METHODOLOGY

2.1Design Approach

The designing process was initiated by choosing the drivers with a small selection at a go-kart place nearby. The drivers with the best lap time were selected and taking their dimensions and weight into account a cockpit was designed which was suitable for both the drivers. The dimensions and free play required for various sub-assemblies that would later come into the cockpit were considered and finally a cockpit was fixed. This was rather an inside out approach considered keeping in mind the team's philosophy of driver comfort and safety. Single cylinder KTM 390 engine was selected to be used in the car by the team. The team initially went with the original specifications of the car including its standard parts research, track width and wheelbase lengths, upright geometry. This was done so as to stick to the philosophy of maximum compatibility of sub-assemblies and avoiding fabrication of more number of standard parts.

After a thorough research the team decided to make a PVC pipe model of the roll cage which was already designed. After facing the real-time constraints and hardships of the design, the changes were made in all the required aspects, thereby changing a number of members on the frame as well as the track width and wheelbase of the car. After the completion of the PVC model the procuring of materials fabrication work was started. The fabrication initiated with the cutting and machining of pipes and welding them together to form the roll cage of the car. Simultaneously the other departments were working on their decision matrices for the parts to be used. The team also purchased some used parts from the market so as to have an idea of how certain import subassemblies would turn out to be and also the prerequisites and problems with each part. As the work progressed from roll cage to engine mounting, various sub-assemblies were also started to be mounted on the car.

2.2Design Objectives

The student race car is designed with specific objectives in mind to provide a direction to guide the team through the design process. Some of the most important design objectives for this year‘s team included the following:

2.3Ergonomics and driver comfort

In addition to rules specified by Supra SAE, all relevant parts of the car are designed with driver comfort in mind. The seat is customized in a way to have better safety, packed to occupy least space and provide optimum comfort for the driver. The cockpit area and foot box are large enough and are designed to easily accommodate the participating drivers of the team. Keeping the spirit of the competition in mind, the car should be designed for the weekend racer and needs to be comfortable for the driver for an entire day of racing. As per the rule book, the cockpit is designed in such a way that a driver can exit the vehicle safely within 5 seconds. The pedal assembly and steering rack is adjusted to provide easy manoeuvring, braking and access for tuning and replacement.

2.4Manufacturability

SUPRA SAE states that the goal of the competition is to design and manufacture a prototype of a small-scale production vehicle. In the interest of completing the car for testing, all parts of the vehicle were designed with manufacturability and affordability in mind. Parts are positioned both for packaging and performance and easy access for tuning and replacement. A strong emphasis was placed on integrating a number of stock parts from the KTM 390 engine, transmission, Drive shafts, upright, discs and Brake calliper for better compatibility of different sub-assemblies.

2.5Simplicity

In the interest of reliability, affordability and weight reduction, the number of parts and systems on the car were kept to a minimum. This idea was most prevalent in the fabrication of roll cage where members were kept as minimum as possible and bending of pipes instead of joining to increase the strength of the roll cage. Using readily available parts also contributed to the team‘s achievement of a simple design.

2.6 Material Selection

Table 1: Material Selection.

MATERIAL	Density (Kg/m^3)	Modulus of elasticity (KN/mm^2)	Yield Strength (MPa)	Cost per meter (INR)
Carbon Steel	7850	0.2	200	1200
Aluminium Alloys	2700	0.07	240	468
Stainless steel	8000	0.19	290	1670

4130 Alloy steel	7850	0.20	460	500

The team decided to use a tubular space frame due to cost, ease of construction, and facilities available. Additionally, no extra analysis is required for Structural Equivalency Forms, which affords the team extra time for further analysis and testing. Because the chassis is a tubular space frame design, the materials used in its construction were limited to readily available, easily weld-able materials. In the interest of simplicity, it was decided that all tube members would be made from the same type of material for maintaining uniformity in fabrication process. The following materials were considered:

2.7 Front Bulk Head

The front bulkhead, as defined by the SAE SUPRA rules, is "a planar structure that defines the forward plane of the Major Structure of the Frame and functions to provide protection for the driver's feet". The front bulkhead is to be made from 25.4mm diameter 2.6mm wall thickness mild steel. On the
Car, the front bulkhead is simply a rectangular structure which is 12 inches (304.8mm) tall by 10 inches (254mm) wide, measured at the tubing centreline. A bend of 90 degrees is made at both the top ends of the bulkhead. The size and shape of the front bulkhead are determined by ease of construction and in order to give the driver ample foot room, as well as the ability to easily accommodate the template, for the front of the chassis.
This template must be passed through the driver's foot and leg compartment to a point 4 inches rearward of the rear most pedals adjusted to its forward most position.

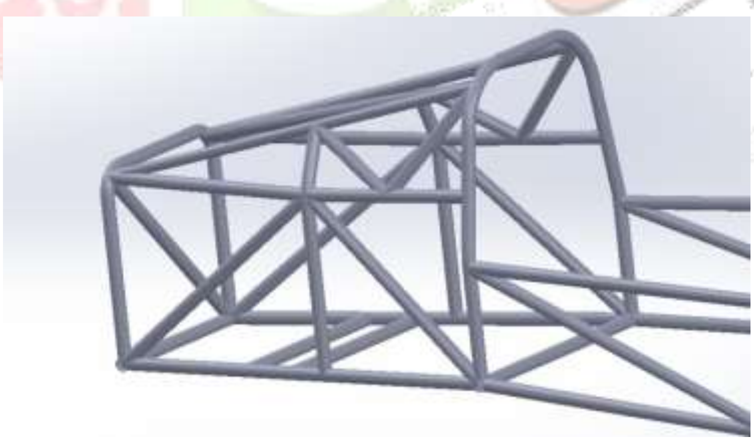

Figure 1: Front Bulk Head.

2.8 FRONT ROLL HOOP

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According to the SAE SUPRA Rules, the front roll hoop is "a roll bar located above the driver's legs, in proximity to the steering wheel." The front roll hoop is to be made from 1inch (25.4mm) diameter 0.0394inch

(2.6mm) wall thickness steel. The front roll hoop is a complex tube on the car, as it has four bends, the difficulty in making bends which are not coplanar stems from the necessity to not only position the bend correctly and bend to the correct angle, but to measure and position the tube so that the bend will be oriented correctly. In addition, it must be tall enough to allow drivers to fit into the chassis while passing the “2-inch rule,” which states that a line drawn from the top of the main hoop to the top of the front hoop must be at least 2 inches from the top of any seated driver’s helmet. In our case it has 3-inch clearance from the driver’s helmet.

Figure 2: Front Hoop.

2.9 Front Bulkhead, Support System and Front Hoop Supports

This is the structure which connects the front hoop and front bulkhead. The front bulkhead support system must be made from 1 inch diameter and a minimum of 1.65mm wall thickness steel tubing properly triangulated node-to-node. Additionally, the front hoop must be supported by front hoop supports, integrated securely into the rest of the structure, these tubing members must also support the front suspension attachment points, as well as shock attachments. They must also be placed to accommodate the foot well template.

There were several choices for the front hoop supports. However, it would have been possible that the driver’s legs or feet would have not been fully contained within the primary structure of the frame, unless the front bulkhead is made larger. Additionally, under braking and cornering, some of the loads of the front suspension upper control arms would be transferred into tubes which would be loaded purely in bending, as there would be nothing to stop the frontbulkhead bending

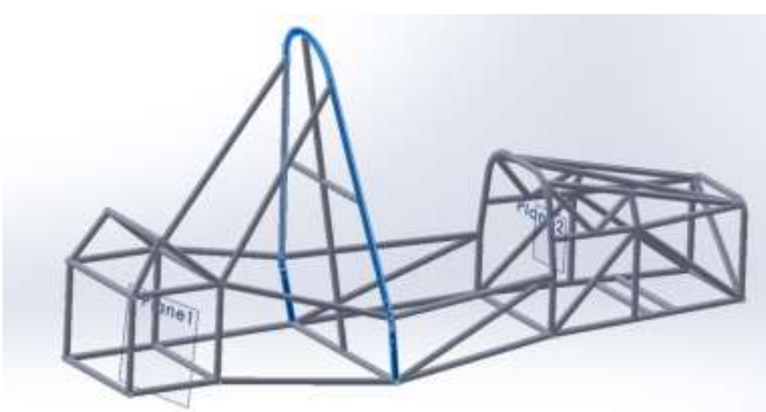

Figure 3: Main Hoop.

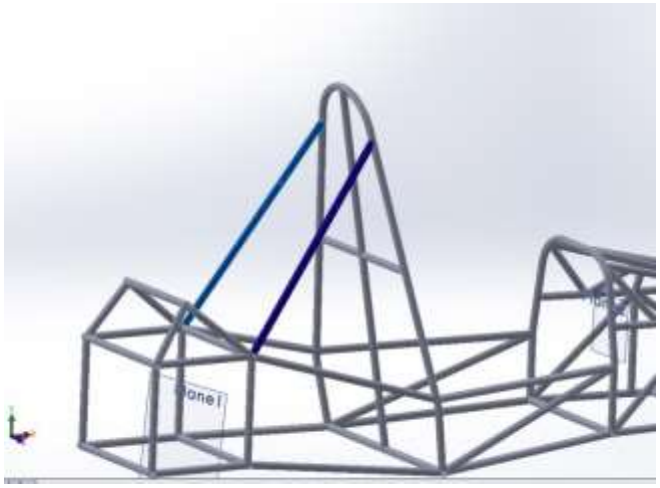

Figure 4: Main Hoop bracing members

3.Calculations

To maintain stability at high speeds, a longer wheel base was decided upon. The track width was measured in proportion with the wheel base, thereby providing good lateral load transfer and corner entry. The wheel base was set at 1829 mm (72"). A front track of 1372 mm (54") and a rear track of 1372mm (54") were chosen.

We know that the Ackermann angles can be calculated by using the formula

$$\frac{1}{\tan\theta_o} - \frac{1}{tan\theta_i} = \frac{B}{L}$$

B= wheel base

L= track width

$$\frac{1}{\tan\theta_0} = \frac{1}{\tan 16.71} + \frac{1829}{1372}$$

$\theta_0 = 21.19°$

$$R_1 = \frac{B}{\tan\theta_i} + \frac{L}{2} = 6.7m$$

$$R = \sqrt{{R_1}^2 + B^2} = 6.82m$$

4.RESULTS

4.1Analysis is done using ANSYS 18.0

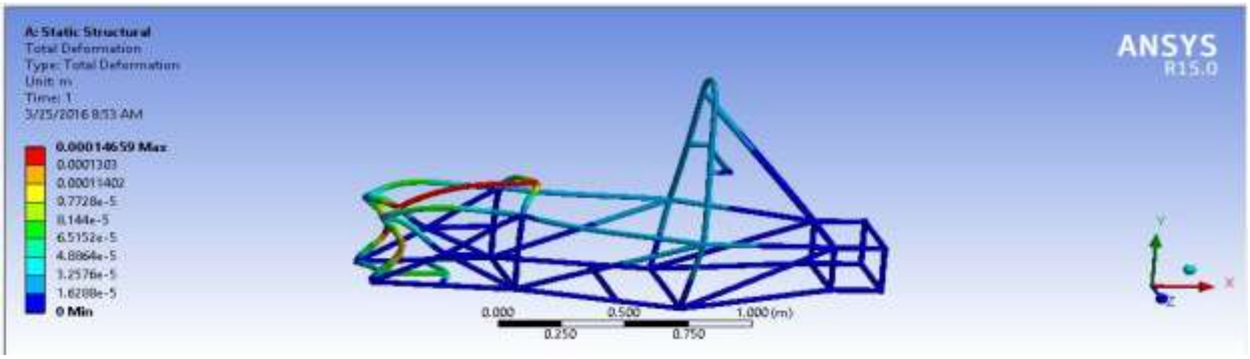

Fig : Front impact analysis

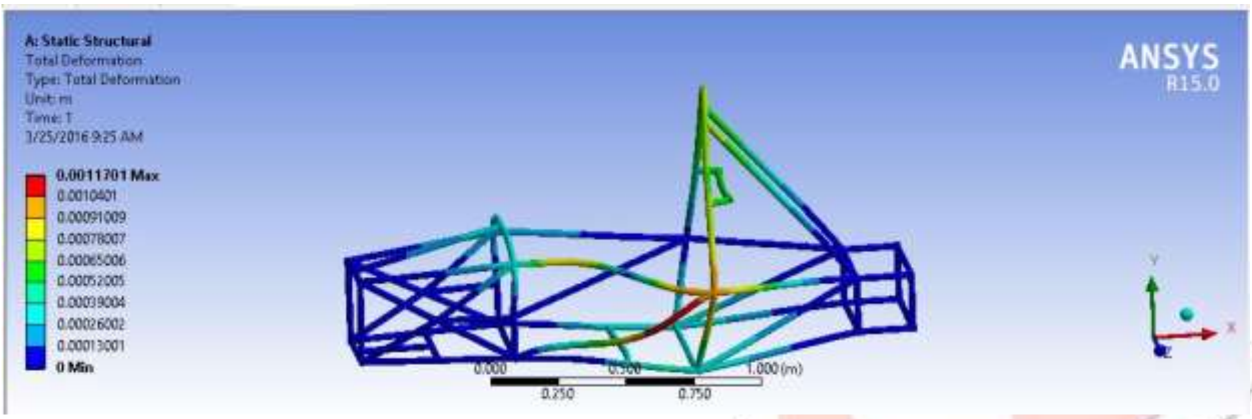

Fig Side impact analysis

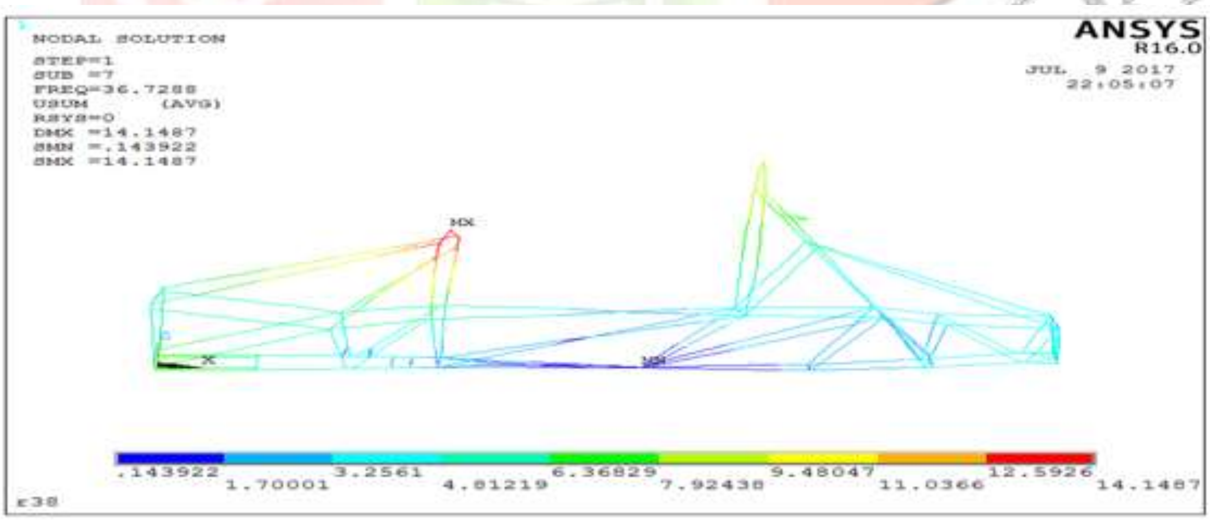

Fig: Nodal Solution

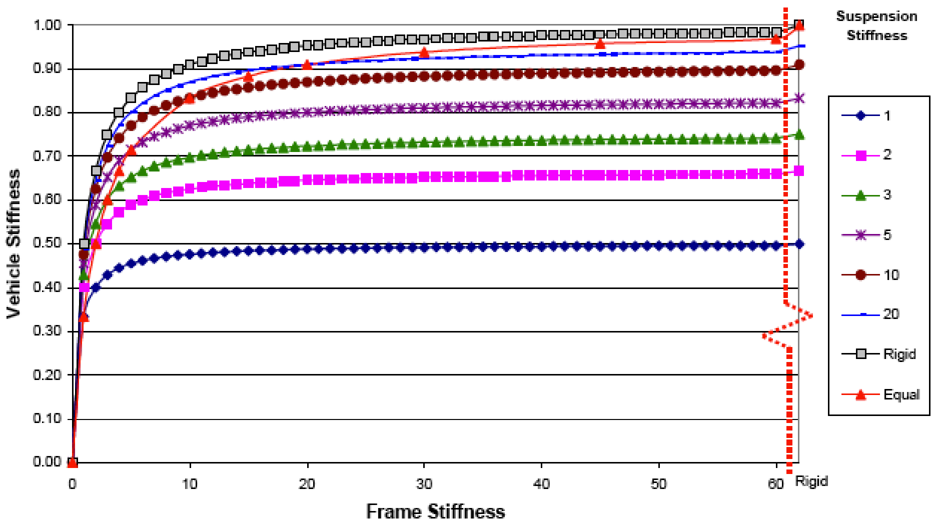

Fig : Suspension Stifness test.

5. CONCLUSIONS

The overall weight of the vehicle was 281 kgs

- The material of the cassis is 4130 Alloy steel.
- The power output of the engine is 42 BHP.
- Cost per unit machined product is found to be Rs 3,81,000/-
- The comparison of cost analysis of machining and investment casting hence the mass
- The vehicle was manufactured according to the proposed design and calculations. Precautions were taken to reduce the errors as much as possible by the means of jigs, fixtures, actual dimensions chart and other methods. The vehicle was tested on a professional race track and was found to be safe and robust.

6. REFERENCES

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