Design and Analysis of Formula Car Chassis And Bodywork

Karan Jawale [1], Harshad Mhatre[2], Prathmesh Pedamkar[3], Devashish Jahagirdar[4], Prof. V. N. Patil [5]
Department of Mechanical Engineering
[1,2,3,4] Student, Bharati Vidyapeeth College of Engineering, Navi Mumbai
[5]Professor, Bharati Vidyapeeth College of Engineering, Navi Mumbai

Abstract- *The purpose of this project is to design and build a space-frame chassis for a race car to compete in the FSAE competition as part of the TRIUMPHANT RACERS team. Every year an FSAE competition is organised in which students from various universities compete to design, build and race their own open wheeled race cars. A unique chassis design is required as the car will be powered by internal combustion engine mounted within the frame.*

Keywords- FSAE, Chassis Frame, bodywork, solidworks, torsional rigidity.

I. INTRODUCTION

The Formula SAE competition attracts students from different universities and from different countries. The competition is divided into two main parts. The first one is static part and other one is dynamic part. Static event consist of technical inspection, Brake test, Tilt test, design event along with two presentation cost report and business presentation. Dynamic event consist of acceleration test, skid pad, autocross, fuel economy and endurance test. The ideal car should be of high performance, good fuel economy and should satisfy all the design safety rules mentioned in rulebook of FSAE international [1].

A space frame chassis is used to manufacture FSAE car. It lies somewhere between the ladder chassis and the monocoque, it is constructed from an arrangement of small, simple members which make up a larger frame.. By adding up small members in triangular pattern a truss bridge can be formed. These patterns are always in pure tension and compression. This concept is used behind the design of the space frame. The chassis should be easy to manufacture, repair and maintain. Stiffness is also a desirable property for a race car chassis to have. The suspension for the car has been designed by another student under the assumption that the chassis acts as a rigid body so if the chassis deforms too much under load then the suspension is unlikely to work as desired.

This paper will give idea about chassis design, material selection, simulation and analysis of Chassis.

II. LITERATURE REVIEW

In the early days of the automobile where coachbuilders were used, the term "chassis" was often used to describe the frame, engine and suspension as one complete unit. Essentially it described everything in a car other than the bodywork and cabin. In some other contexts "chassis" defines only the frame of the car with the drive-train and suspension being considered entirely separate items. This latter interpretation of the word is what is used throughout this project, where the terms "chassis" and "frame" mean the same thing are interchangeable.

Before commencing any design work it is useful to see what is already being done by others in the same field. The book published by Penguin Books is entitled "The Race Car Chassis" and is written by Forbes Aird. The book discusses different types of chassis' and the history of chassis evolution. It focuses primarily on space-frames which is highly relevant to this project due to the low cost, readily available materials used and relatively simple manufacturing processes.

Another text that was analysed for this project w as "Chassis Engineering" written by Herb Adams and published by Penguin Books. Adams considers the chassis to include suspension and bodywork components so the book contains a large amount of information about suspension setup and tuning as well as tyre characteristics which is not relevant for this project as the suspension for the car has already been designed by another student.

III. DESIGN OF CHASSIS

Methodology:

A wooden frame was made to replicate main hoop and front hoops. A comfortable seating position was chosen to decide the angles for brake pedal and seat. But angle for brake pedal was not achieved, so closest achievable angle was set and according to it the seat was adjusted accordingly for comfortable seating.

A position for in-cockpit gear shifter was chosen for better handling and accessibility .

Material Selection:

Material used : AISI 1018
AISI 1018 Composition :
C - 0.14 -0.20 %
Fe – 98.81-99.26 %
Mn – 0.6-0.9%
P =< 0.040 %

After ample comparison with similar counterpart, AISI 4130 had the best properties and was set as benchmark for the comparison . However, AISI 1018 was chosen for three following reasons over AISI 4130 :

- Chromoly or AISI 4130 can be bend further without deforming and hence lower wall thickness tubes can be used. However , race cars are designed for stiffness and thin walled tubes would mean lower stiffness. So, instead of going with higher wall thickness on expensive of the two, chromoly, the team decided to go with AISI 1018 of same wall thickness.
- AISI 4130 requires TIG welding which is expensive as compared to the MIG that can be used on AISI 1018.
- Being a beginner team, if the situation arises to change the tubes because of errors, the team calculated an estimate of 3 times as much on chromoly as compared to 1018.

Welding parameters:

Welding type	MIG
Diameter of wire	0.9mm
Voltage (V)	22-25 V
Amperage (A)	100-140 A
Shielding Gas	100% CO_2

Roll Case Design:

Roll Cage or the chassis is the most important part of a vehicle and may also be described as a huge bracket since it is provides various mounting. The design of formula race car must have following parameters under consideration.

- Safety of driver.
- Strength of chassis.
- Manufacturability.

The chassis was designed in Solidworks student edition.

All the triangulated structures have been created such that the forces can be reacted well into space frame. The chassis was tested for front collision, sideways collision, rollover safety and torsional rigidity. The displacement and stress induced were within the desired limits.

Ergonomics:

- The basic goal of ergonomics is to design a make a car that is driveable by 95^{th} percentile of the country's population.

The ergonomic design started with following steps:

- A wooden frame was made to depict the main roll hoop, front roll hoop, pedals and seat.
- Driver was sited in frame and angle for pedals were decided which are easy to press without any efforts, so initially 85^0 was used and accordingly knee angle was set and location of front roll hoop was set in order to aid the degrees.
- The seat was the set for a comfortable seating and it was then adjusted for the driver to press the pedals properly. So eventually the seat angle was set to 36^0 and the pedal angle was set to 85°.
- The height of front roll hoop was determined ensuring that driver has a clear vision of front end of the car.
- The front roll hoop and main roll hoop height was determined in order to ensure the safety of the driver in condition of roll over.
- Accordingly, a suitable width of main roll hoop and front roll hoop was determined in order to ensure proper control of driver over the gear shifter and steering wheel.

Determining The Forces Acting On Chassis:

Front impact Calculations:

Mass of the car = 370 kg

Acceleration due to gravity = 9.81 m/s^2

We know, F = ma

Where, F = Applied force in N

a = Acceleration in m/s^2

m = mass in kg

The front impact force was taken to be 4gs

ie, 4 x mass of car x Acc. due to gravity
= 4 x 370 x 10

= 14800 N

The force is divided into 4 nodes of the front bulk head

ie, force on each node

= 14800/4 = 3700 N

IV. ANALYSIS & OPTIMISATION OF CHASSIS

The analysis was done on Solidworks.
Following are results below.

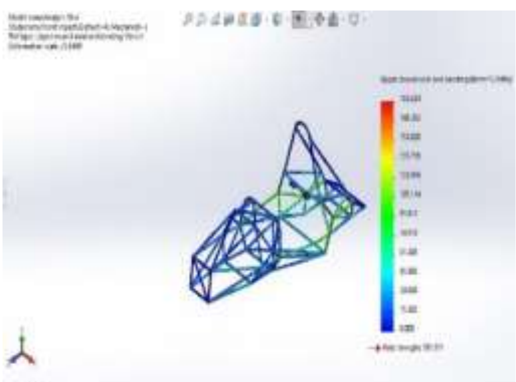

Fig 1. Front impact Stress

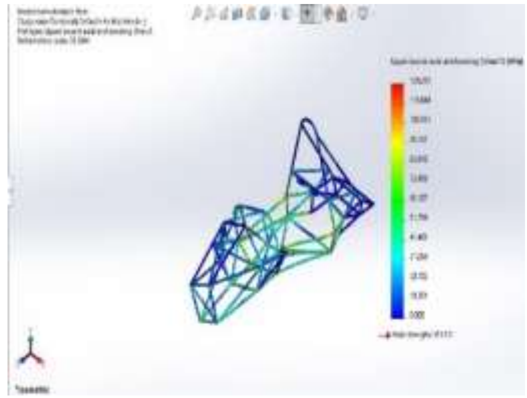

Fig 2. Torsional Stress

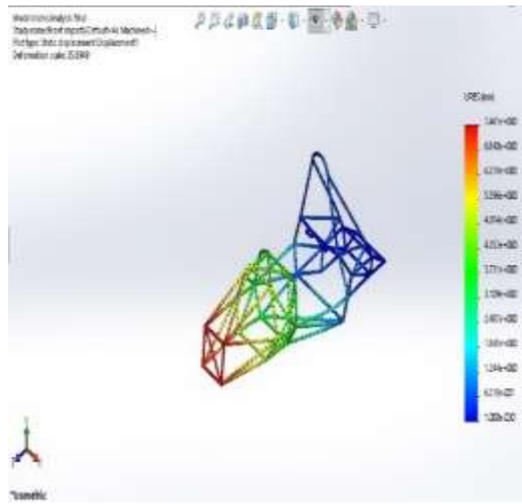

Fig 3. Static Displacement

V. DESIGN OF BODYWORK

Design Parameters:

The design parameters of the bodywork are focused around safety and accessibility of the system components and driver.

❖ Safety:
- Have no sharp forward facing edge.
- Close out the drivers cockpit.
- Protect the radiators from FOD.

❖ Accessibility:
- Be removable without modification of other parts of the car.
- Not restrict airflow to the radiators.
- Easily interface and mount to the car.
- Easily interface and mount to the undertray.

With these design parameters satisfied, the remaining design choices were made with aesthetics in mind.

Aerodynamic considerations beyond basic visual streamlining were ignored.

Design:

The bodywork was designed in SolidWorks.

There are three lofted surfaces on one half of the car, each mirrored about the centreline plane.

The primary surface from the nose cone to the front hoop is referenced as the main bodywork, while the sidepods and side impact panels form the additional two surfaces.

Fig 4. Bodywork Design

Main Bodywork:

The main bodywork is a single lofted surface with surface trims around the opening for front suspension. This surface was formed from a series of cross sectional curves contoured to the frame. The upper guide curve forms the upper contour of the bodywork at the centre plane. The lower guide curve was sketched offset to the ground plane in order to interface with the unknown ride height of the undertray. The ground-facing surface of the bodywork was left open, as this area would be closed out by the undertray.

Sidepods:

While traditionally a tool for improved cooling, the sidepods only serve as a protective cover for the radiators to protect from damage. All cooling needs are met by the radiator fans and thus the sidepods are simply streamlined within reason so as to not detract from the flow to the radiators.

Material Selection:

In order to manufacture the bodywork, two materials can e used viz. carbon fibre, fibre glass.

The bodywork is composed of the fibre glass. The reason behind the selection of fibre glass is it's way cheaper than carbon fibre and easy to manufacture and provides good strength.

Fasteners Used :

- The bodywork will be mounted on the chassis using zip ties and nut-bolts.
- There will be a total of 20 taps mounted on the chassis for bodywork.
- 6 taps on one side and 6 on the other for mounting the sidepods.
- The rest are mounted on the front of the chassis for the firm support to the bodywork.
- For mounting on the taps , M4 type of bolt are used.

Fig 4. Top view of bodywork

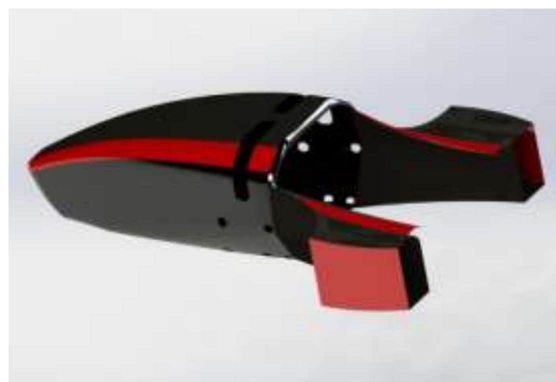

Fig 4. Side view of bodywork

VI. CONCLUSION

1. This paper consists of design and analysis of Formula car chassis and bodywork. The chassis of the car made according to rules mentioned in SAE INTERNATIONAL rulebook and we tried to overcome all the flaws and fulfilled our objectives.
2. A simple mathematical model was developed for comparing the structural stiffness to the suspension stiffness to gain insight into proper design targets for the vehicle structure.
3. All the manufacturing processes employed are safe and will not undergo failure.

4. The material AISI 1018 was selected for the chassis and fibreglass for the bodywork.

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