Analysis of Formula Student Race Car

B. Subramanyam
M.Tech, MISTE, Asst. Professor
Department of Mechanical Engineering
MLR Institute of Technology, Hyderabad
JNTU University, Hyderabad, India

Vishal
B.Tech. Student
Department of Mechanical Engineering
MLR Institute of Technology, Hyderabad
JNTU University, Hyderabad, India

Mahesh Kollati
B.Tech. Student
Department of Mechanical Engineering
MLR Institute of Technology, Hyderabad
JNTU University, Hyderabad, India

K. Praveen Kumar
B.Tech. Student
Department of Mechanical Engineering
MLR Institute of Technology, Hyderabad
JNTU University, Hyderabad, India

***Abstract*—In the Automotive industry, safety of the driver has always been a matter of concern, in which there is a lot of scopes to work in. And if it's about making a race car, then the issue takes its own importance as the risk of a driver getting injured is too high .This paper is an introduction to the various types of analysis which can be performed on the formula student race car in order to ensure the safety of the driver and the various ways by which the results obtained after the analysis can be optimized for the safety of the driver has been discussed based on the experience of the team XTREMERIDERS.From this paper, one can easily get an idea about how to perform different types of analysis by applying what amount of loads on a student formula race car.**

Keywords—SUPRA, impact, analysis, G forces.

I. INTRODUCTION

SAE (society of automotive engineers) is a society which conducts different events for engineering students in order to give them the opportunity to explore their knowledge and learn things practically. One of the events which are conducted by SAE is "SUPRA SAE" in which teams are asked to manufacture a student formula race car. Throughout the process, teams are supposed to design, manufacture and test the race car so that they can compete with other teams which are participating in the competition. Also, there is a lot kept for the students to learn in it, such as team work, decision making, marketing skills and much more.

Generally this event is divided into two different levels in which the first one is called as the virtual round in which all the participating teams are asked to give a presentation of 10-15 minutes on their design of the car followed by question and answer session for 10-15 minutes by the judges and accordingly, they will be awarded the points. All the teams who make their way after clearing the first round are asked to build their car and to participate in the second round, which is generally of 4-5 days in which teams are asked to present their design reports and give business presentations to the judges. After that, all the student formula cars are inspected by the judges whether it abided by all the rules which are mentioned in the rule book or not. And if they clear technical inspection, then they are allowed to participate in different static and dynamic events like tilt test, noise test, egress test, autocross, skid pad, endurance, etc. But throughout the whole process, the major area of concern which is always to be kept in mind by the participants is the safety of the driver, and that can be achieved by performing a good number of iterations in the design as per the results obtained after the analysis of the formula student race car. So, this paper is all about what and all are the necessary tests which are to be performed on the race car and how to optimize the results in order to ensure the safety of the driver.

II. DESIGNING THE RACE CAR

Before getting started with the analysis, first of all, it is necessary to know the basic steps which are being involved in designing the formula student race car. It is always advised to go through the SUPRA SAE rule book thoroughly in order to know all the rules and constraints by keeping which in mind, formula student race car has to be built. After designing the basic structure of the race car, in any of the designing software e.g. SOLIDWORKS, CATIA, etc., the next challenging task for a team is to select an appropriate material for making the chassis of the car as high strength in chassis can ensure better safety for the driver.

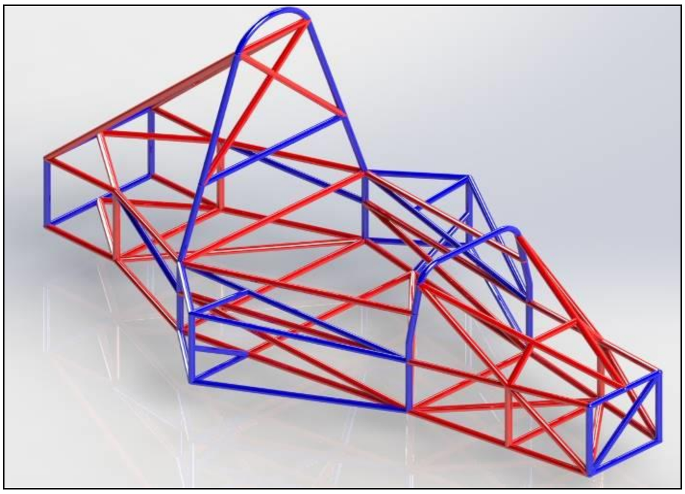


Fig.1. Isometric view Chassis design with structural pipe members

A.selecting the material for the chassis

While selecting the material for the chassis, one has to be very careful as it plays a vital role in giving strength to the body of a formula student race car. As there are a number of materials which are available for making the chassis of a race car, there is always a lot of confusion in selecting the best one for us. So, materials can be selected on the basis of different parameters such as its availability in the market, cost of the material, properties of the material and its strength to weight ratio. As per the rule given in the SUPRA rulebook , the material that is to be used for making the chassis of the race car should be having a minimum "0.3%" carbon content in it. So keeping this constraint in mind, a comparative study has to be done on the best available options in order to select the material for the chassis of the race car.

TABLE.1. Properties of various materials

Name	Ultimate strength (Mpa)	Yield strength (Mpa)	Density g/cm^3	Strength to weight ratio(KN-m/kg)	Cost per meter (□/M)
AISI 1018	410	370	7.80	55-60	300
AISI 1020	430	390	7.80	60-62	320
AISI 4130	560	460	7.80	72-75	350

After studying the comparison made in the above table, an easy decision can be made that the mild steel "AISI 4130" is a better material, as it is having an appreciable weight to strength ratio at just a cost of few more rupees in comparison to the other materials.

III. ANALYSIS OF THE FORMULA RACE CAR

After the selection of the material, the next task is to analyze the design. There are two types of analysis which are done on a vehicle. They are static and dynamic analysis. Static analysis is done for the vehicle which is in the stationary position and the dynamic analysis is done for the vehicle which is in motion. Here basically it will be discussed only on static analysis, as formula student race car won't be going on such a drastic high speeds.

A.Types of analysis

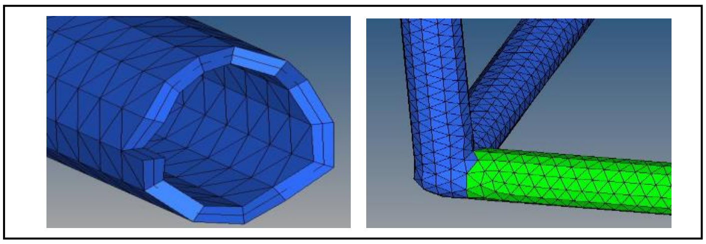
- Front impact analysis
- Rear impact analysis
- Side impact analysis
- Front torsional stiffness
- Rear torsional stiffness

B. Steps for performing analysis

There is a number of software which is available to perform analysis on the object such as Hyper Mesh, ANSYS, Solid works, etc. And here analysis has been done on the Hyper Mesh software. There are few basic and simple steps which are to be followed in order to perform all the different types of static analysis on the race car and they are given as follows:

- Import the design in the hyper mesh software
- Apply necessary properties of the material
- Mesh the structure completely
- Apply load (G forces) at the required portion of the chassis of the car.
- Fix the suspension constraints
- Note down the obtained yield strength value and calculate Factor of safety (FOS) for it.

Fig.2. Meshed images of different dimension of pipes:



C. How to calculate loads

Most of the students face the question of how much load is to be applied for performing different types of tests. The answer is simple and can be explained by using few basics laws of physics in the following ways:

- Suppose a vehicle "A" is at rest (u=0),
- And it is having a mass 300 kg (an average mass of a student formula race car)
- And vehicle "B" is coming at a speed of 105 km/s speed (maximum permissible speed of the formula student vehicle)
- Both the vehicle A and B meet with an impact collision with each other with a time of impact collision 0.4 seconds(an average time of impact for a formula student race car)

Then by using the above date, it can be written as:

V=0 (final velocity of the vehicle after collision)
U=29.16m/s (initial velocity of the vehicle)
T=0.4 sec (time of impact taken)
a=? (Acceleration to be found)

By using the formula:

$V=U+A*T$
$0=29.16 + a*(0.4)$
$a=72.9 m/s^2$

We know,

Force = mass * acceleration
Force =300 * 72.9
Force =21,870N

G Force= force/ (mass of the vehicle * 9.8)
G-Force =21,870/ (300* 9.8)
G Force=21,870/2940
G Force= 8

So here we can conclude that a normal **8 G load** is to be applied in order to analyze the chassis in different aspects.

IV. SAMPLE CALCULATION

Here are some sample calculations which are calculated for all kinds of analysis and even images has been shared in order to explain how loads and constraints are to be fixed in order to perform analysis on the chassis.

1. Front impact:

For this test, a situation is assumed, where a car running at a speed of 105 Km/h will collide from the front with the stationary student formula race car.

CONSTRAINTS: Rear suspension points
LOAD: 8 G
FORCE: At the front part of the bulkhead
FOS: 440/307.6=1.43
DISPLACEMENT: 1.194 mm

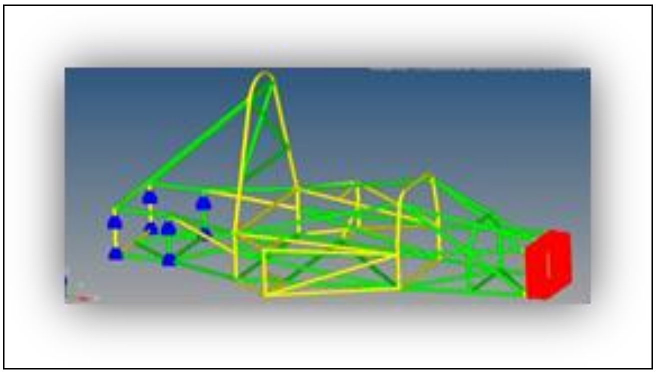


Fig.3. Front impact analysis setup

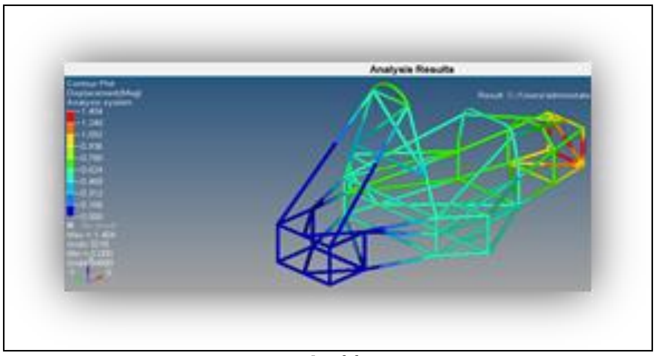


Fig.4. Result of front impact

2. Rear impact:

For this test, a situation is assumed, where a car running at a speed of 105 Km/h will collide from the rear with the stationary student formula race car.

CONSTRAINTS: Front suspension points
LOAD: 8 G
FORCE: At the rear most part of the chassis
FOS:440/274.63=1.60
DISPLACEMENT: 2.49 mm

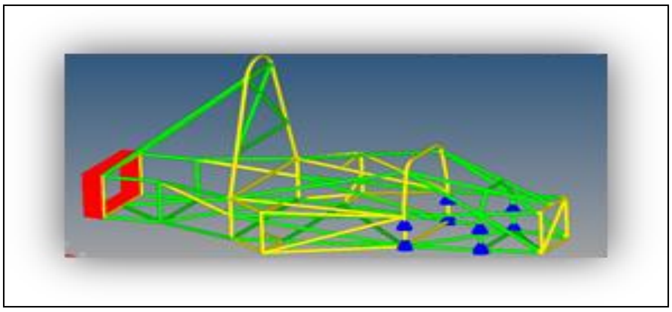


Fig.5. Rear impact analysis setup

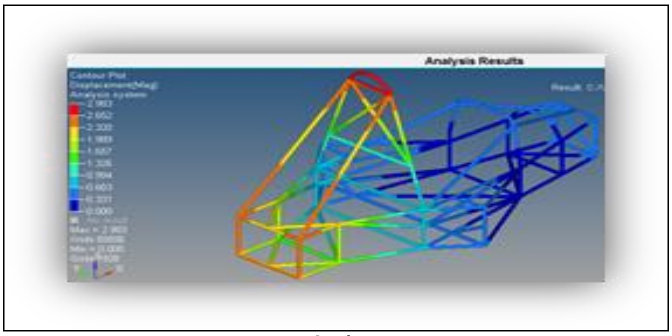


Fig.6. Result of rear impact

3. Side impact:

For this test, a situation is assumed, where a car running at a speed of 105 Km/h will collide from the side with the stationary student formula race car.

CONSTRAINTS: Front and rear suspension points
LOAD: 7G
FORCE: At the outermost member of the left/right side
FOS:440/244.83=1.80
DISPLACEMENT: 1.190 mm

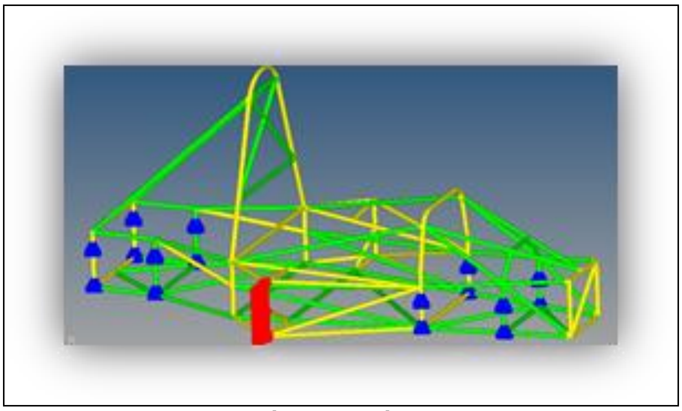


Fig.7. Side impact analysis setup

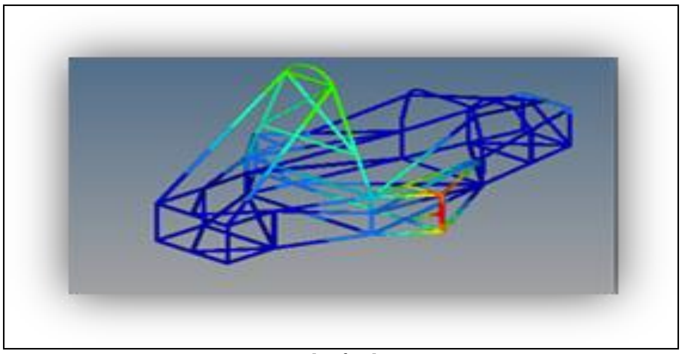


Fig.8.Result of side impact

4. Torsional analysis:

❖ *Front torsional:*

For this test, a situation is assumed when student formula race car will take turns around the corners at a speed of 105 Km/h.

Torsional stiffness is the resistance of the chassis to torsional loads [1]. These loads are formed by undulating road surface or cornering forces [2]. It is desired that torsional stiffness should be high for a race car design because it allows the

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 10, October-2016

handling of the vehicle to be precisely controlled by adjusting the suspension parameters of it. [3]
CONSTRAINTS: Rear suspension points
LOAD: 7G
FORCE: Two couple forces in front suspension points
Torque= (350*70*200)/2=2,450 N-m
Stiffness (K)
=Torque/deflection=2450/1.95
=1256.41N-m/degree

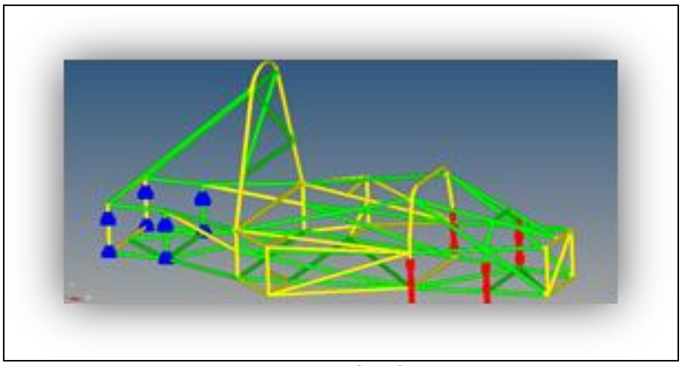


Fig.9. Front torsional analysis setup

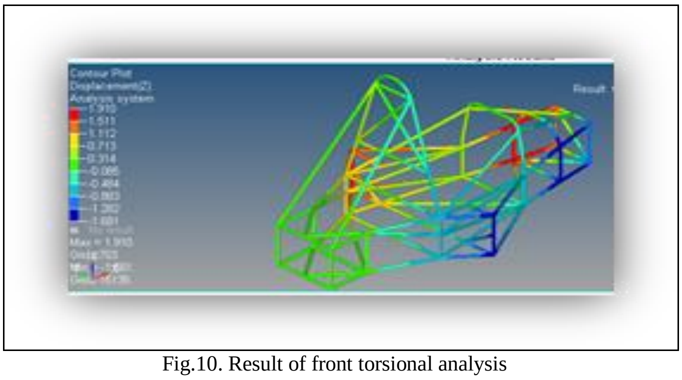


Fig.10. Result of front torsional analysis

❖ *Rear torsional:*
CONSTRAINTS: Front suspension points
LOAD: 7G
FORCE: Two couple forces in rear
Suspension points
Torque= (350*70*230)/2=2,817.5 N-m
Stiffness (K) =Torque/deflection
=2817.5/1.95
=1476.41 N-m/degree

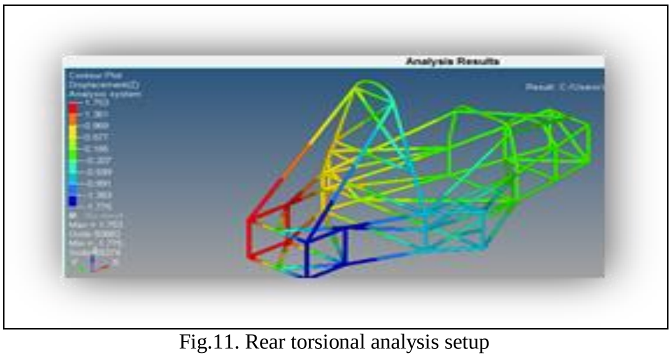


Fig.11. Rear torsional analysis setup

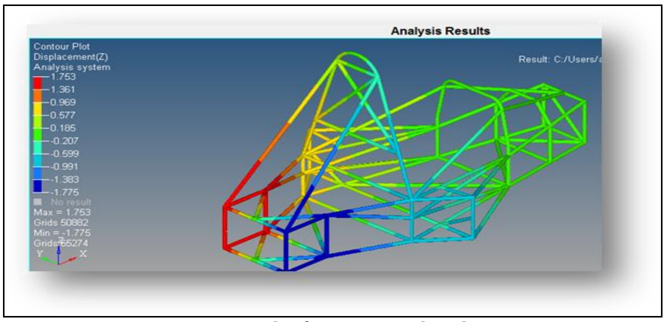


Fig.12. Result of rear torsional analysis

TABLE.2. Overall view of all the analysis

Analysis	Load	Stress (N/mm^2)	Displacement (mm)	FOS
Front impact	8G	373.7	1.194	1.43
Rear impact	8G	274.63	2.49	1.60
Side impact	7G	244.83	1.190	1.8
Roll over	2G	258.63	1.69	1.9

V. ACKNOWLEDGMENT

We would like to thank our Institute for providing such a tremendous support and encouragement to participate in SUPRA SAE 2016 event. We also appreciate the help provided by our secretary Mr. Rajasekhar Reddy and Faculty advisors Dr.S.Madhu and Mr. Bridjesh for the completion of the project. Our Sincere gratitude to our fellow mates Mr. Shiva, Mr. Ankit Kumar Singh, Mr. Varnath Reddy, Mr. Pavan Kumar and Mr. Deepak Reddy for their valuable guidance and suggestion in the project and also to keep us always motivated throughout the project. Last but not the least we thank our entire team (XTREME RIDERS) for their magnanimous contribution towards the project.

VI.CONCLUSION

After applying different types of static analysis and by giving different loads while performing the analysis of a formula student race car, it is concluded that the formula student car is safe for the driver. It is also concluded that the factor of safety obtained after the analysis should lay 1.5 to 2.5, as it is considered as an appreciable factor of safety for any formula student race car. Not only that ,here it was understood how to select the appropriate material for making the chassis of the formula student race car as it also plays a vital role in providing strength to the race car body.

VII. REFERENCES

[1] Abrams, Ryan, “Formula SAE race car analysis-simulation & testing of the engine as a structural member”, F2008-SC-005
[2] Aerodynamics – by L.J. Clancy
[3] Brendan J Waterman, university of Western Australia, Master thesis “Design and construction of a space frame chassis”.