Impact and Acceleration Analysis of Formula Student Vehicle

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***Abstract* - This paper is related to the analysis, simulation and designing of the Single Seater Race Car Chassis which is made according to the rules and restrictions provided in the FSAE Rulebook 2018. Chassis for any vehicle is the most important part as it becomes a structural backbone for support of different systems attached to it and carry out the load of all the different component as well as passenger and goods. The designing task is so complicated for the design of a good chassis and we have to consider the various parameters and factors while designing of this chassis and also loads experienced by the chassis due to various systems is also an important aspect. Making a lightweight chassis without any compromise for safety of the driver, and considering various rules and regulations given in the SAE rulebook while designing of the chassis, and also understanding various specific cross-section for the chassis fabrication is very important. In this various software like ANSYS and SOLIDWORKS have been used for the process of doing modeling and Analysis of the car frame.**

***keywords* - Ansys, Solid-works, ,Finite Element Analysis, Space Frame Chassis, Chassis, Beam Element 189, FSAE (Formula Student Society OF Automotive Engineers), AISI (American Iron and steel institute, Mpa (Mega Pascals), 4G (39.2266 m/s2).**

1.Introduction

SAE Supra is the national level event which is held under the banner of SAE International All the under graduate students from all round the nation takes participation in making the aesthetic, ergonomic and safe chassis, for the aim of the competition. For this competition, the teams thrive to create the foremost well-designed car frame with all parameters considered. Designing of the chassis is that the most vital part for any team, thanks to the actual fact that it supports all the assorted department of the full vehicle. Cockpit design is very important, because it should accommodate 95th percentile male, and also the look should be made in such the simplest way that it should not compromise the motive force safety at any condition. the look mustn't fail at any cost, and it should have the minimum required stiffness, strength and torsional rigidity, and it should be highly reliable and safe. At the top after the analysis and fabrication of the chassis, during its presentation the judging is completed by the officials by considering results from technical inspection, static event and dynamic event, and by summary all the given points during this all events the ultimate decision is taken.

2.Methodology

The subsequent model of the only seater motorcar chassis is formed on ANSYS Design Modeler by using ANSYS Beam 189. The BEAM189 element is suitable for analysing slender to moderately stubby/thick beam structures. The element is predicated on Timoshenko beam theory which has shear-deformation effects. The element provides options for unrestrained warping and restrained warping of cross-sections. The element could be a quadratic three-node beam element in 3-D. With default settings, six degrees of freedom occur at each node; these include translations within the x, y, and z directions and rotations about the x, y, and z directions. An optional seventh degree of freedom (warping magnitude) is offered. The element is well-suited for linear, large rotation, and/or large-strain nonlinear application. First the specified coordinates were found and inputted within the design modeler, so the corresponding points were generated by mirroring it along the axis. at that time the remaining thing was use to join the point with lines, along with various cross members joined from node to node. Here are some different cross section chosen for different parts of the chassis from the FSAE rulebook.

Table 1 : Cross Section to be taken as per the FSAE rulebook.

Item or Application	Outside dimension x wall thickness
Main & Front Hoops, Shoulder harness Mounting Bar	Round 1.0 inch (25.4mm) x 0.095 inch (2.4mm) or Round 25.0mm x 2.50 mm Metric
Side impact Structure, Front Bulkhead, Roll Hoop Bracing, Driver's Restraint Harness Attachment (Except as noted above) EV : Accumulator Protection Structure	Round 1.0 inch (25.4mm) x 0.065 inch (1.65 mm) or Round 25.0 mm x 1.75 mm metric or Round 25.4 mm x 1.60 mm metric or Square 1.00 inch x 1.00 inch x 0.047 inch or Square 25.0 mm x 25.0 mm x 1.20 mm metric
Front Bulkhead Support, Main hoop Bracing Supports. EV : Tractive System Components Protection	Round 1.0 inch (25.4mm) x 0.047 inch (1.20mm) or Round 25.0 mm x1.5 mm metric or Round 26.0 mmx 1.2 mm metric
Bent upper Side-impact member (T3.24.3a)	Round 1.375 inch (35.0 mm) x 0.047 inch (1.20 mm)

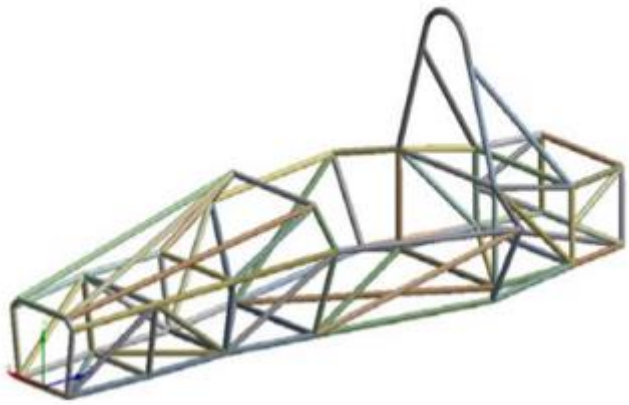

Figure 1 : Geometry of chassis

3.Material Selection

There are various loads and forces which act during the motion of the chassis, therefore proper selection of the material is an important aspect. Stiff and lightweight chassis is very important, and this is directly affected by the stiffness of the chassis. The material of chassis should withstand loading forces and diverse environmental factors. After checking all mechanical properties, availability, cost and other important factors, following material was selected for the fabrication of the chassis and the material is AISI 4130. Every material having different parameters and properties as follows, from them AISI 4130 is selected due to its advantages over other materials in ultimate strength and the low in weight mentioned in following table.

Table 2 : Different Properties for AISI Material.

Property	AISI 4130	AISI 4140	AISI 440 C	AISI 304
Density (Ib/n$^{3)}$	0.284	0.284	0.275	0.29
Ultimate tensile strength	81.2	95.0	110-286	85
0.2 % Yield Strength (ksi)	66.7	60.2	65-280	35
Elongation (%)	21.50	25.70	14	55
Hardness (Brinell)	217	197	97	123
Shear Modulus (ksi)	11600	11600	11603	12500
Poisson's Ratio	0.27-0.30	0.27-0.30	0.29	0.29

4.Meshing

The mesh consists of 9082 quadratic beam elements with six degrees of freedom (UX, UY, UZ, ROTX, ROTY, ROTZ) at each node, these elements are based on Timoshenko beam theory and it's computationally efficient and has good convergence properties with respect to mesh refinement.

5.Finite Element Analysis

Linear Static structural analysis is performed on four different cases which are resulting into four different results.
Case 1: Side Impact Test,
Case 2: Front Impact Test,
Case 3: Rear Impact Test ,
Case 4: Acceleration Test,
In this the Side Impact, the Front Impact and the Rear Impact are further divided into 2 more cases on which the analysis is done. The reason for doing these cases is to make sure that the chassis is safe in both condition during the impact and the deformation is minimal as possible.

Case 1 : Side Impact Test

Side impact are caused when the vehicle crashes the side of one or more vehicles when impacted. The common cause for side impact is during an unattended crossing at an intersection. Side impact test are done to know how much the driver, or any other passenger are safe during an accident. In FSAE also the side impact structures are important to make sure safety of driver.

Deformation: -

Case 1.1 - Side Impact test at a cockpit node

As discussed above about the side impact in this case the side impact is considered at a node of the cockpit as shown in the figure below. The load experienced at that point is far more and crucial.

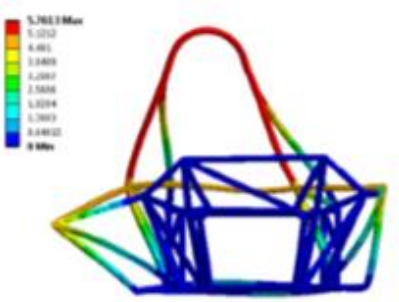

Figure 2 (a): Front View

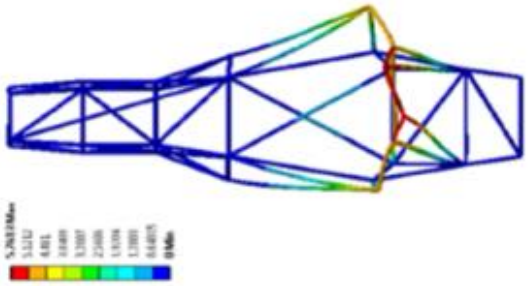

Figure 2 (b): Top View

Figure 2 (c): Side View

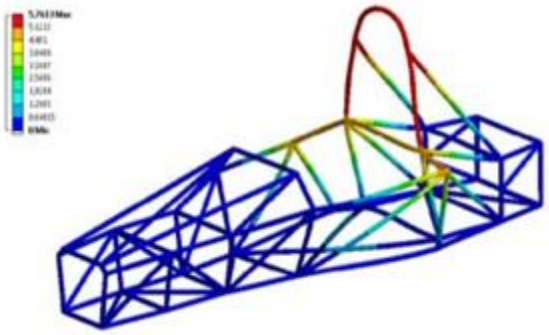

Figure 2 (d): Isometric View

Case 1.2 - When Side impact is at whole plane of structure

In this case it is assumed that the whole side impact structure takes the load during an accident. So, the whole force of the impact is taken by the whole area and it is divided to the others adjoining members.

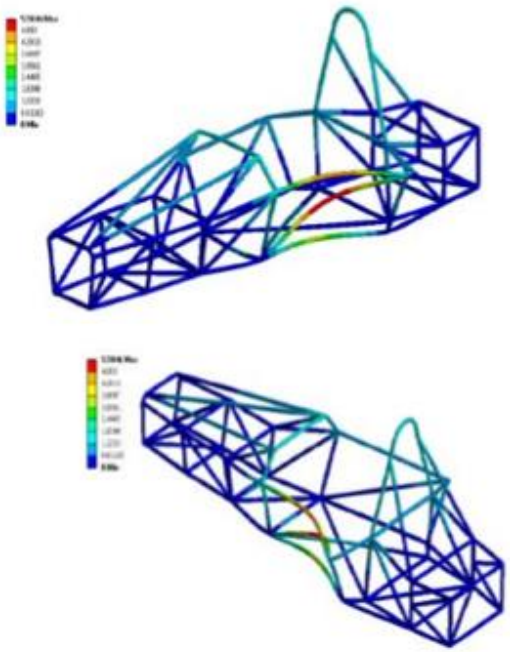

Figure 3 : Isometric View

Case 2 : Front Impact Test

Front Impact is the necessary test to be done due to utmost importance, as 46% of the total accidents are front impact and has most influence on the vehicle so test is done to check the safety of the chassis. For this purpose, a full area frontal impact test is conducted assuming a suitable ground clearance. The results presented above for front impact are for a scenario where the front wheels are not in contact with the ground and the vehicle front structure is allowed to deflect upwards due to the impact, as shown in the deformation plots. In such scenario which is the general case, the stresses are around 435 MPa which is not safe. However, if an assumption is made where during the front impact, if the front tires are on the ground and the upward deflection of the front portion of the vehicle is prevented by some control techniques, then the peak stresses are around 112 Mpa, this scenario was analyses and the direct.

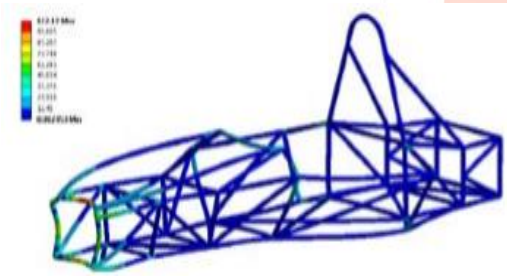

Figure 4 (a) : Bending Stress

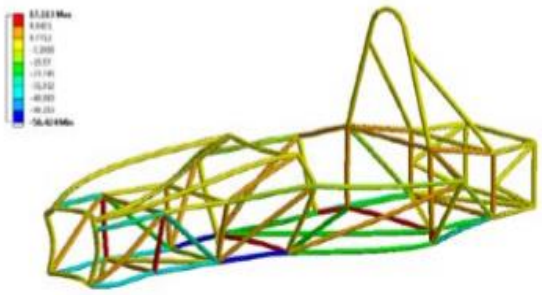

Figure 4 (b) : Direct Stress

Case 3 : Rear Impact Test

Rear impact is accident caused at when there is traffic, wherein a vehicle crashes into the vehicle in front of it. This is impact happens on rare occasions but when it does happen it may cause a lot of harm.

Case 3.1 - Nose dip

When there is hard breaking the Nose of the chassis is dip and there is a small lift at the rear.

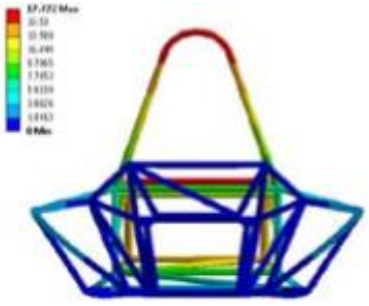

Figure 5 (a) : Front View

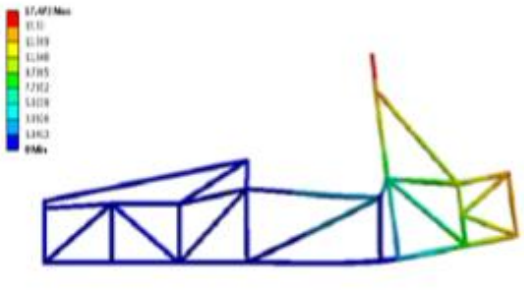

Figure 5 (b) : Side View

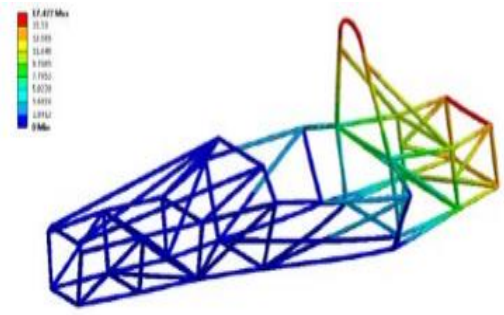

Figure 5 (c) : Isometric View

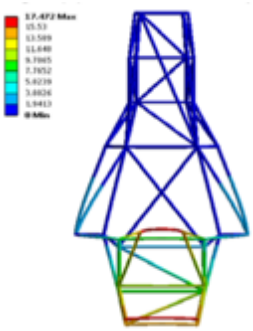

Figure 5 (d) : Top View

Case 3.2 - No Nose Dip

In this condition there is some things provided which avoid the chances of nose dip during the sudden braking.

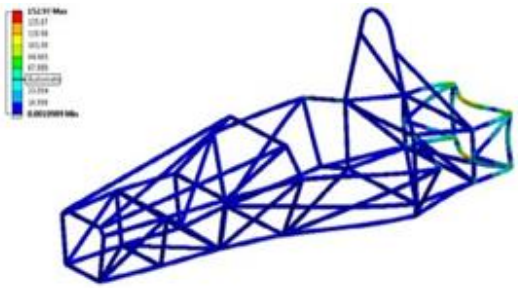

Figure 6 (a) : Bending Stress

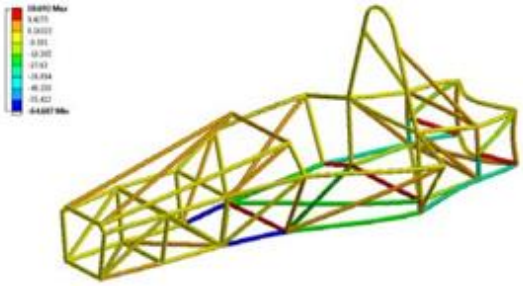

Figure 6 (b) : Direct Stress

Case 4 : Acceleration Test

This test is done at the force of 4G and the results are shown below.

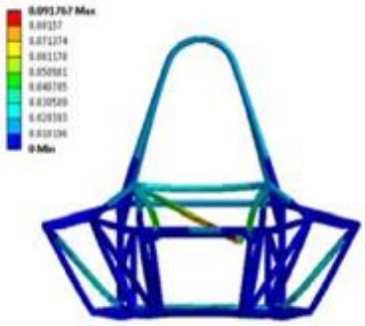

Figure 7 (a) : Front View

Figure 7 (b) : Side View

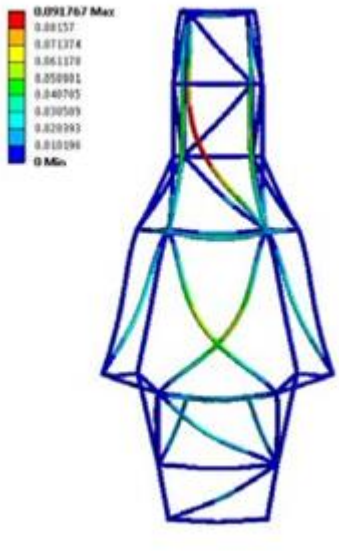

Figure 7 (c) : Top View

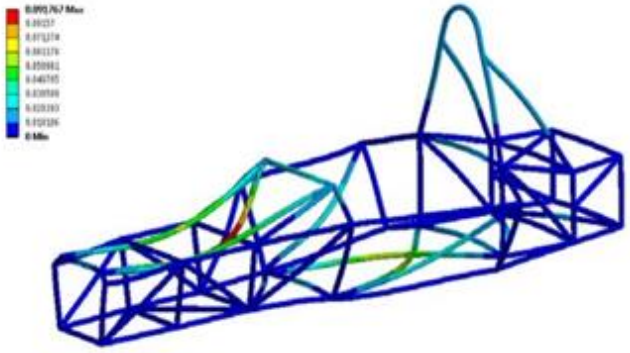

Figure 7 (d) : Isometric View

6.Conclusion

A chassis consists of an internal vehicle frame that supports an artificial object in its construction and use, can also provide protection for some internal parts. In this work Structural frame of chassis is first designed on solid works software and also structural Analysis are used. After designing this structural chassis, it is tested and analysed for different fatigue, static and dynamic loads which is done on ANSYS Software to obtain proper chassis design with minimum deflection for failure. For fabrication of chassis selection of material is also an important criterion due to fact of sustaining loads and forces and resist any deformation. Any deflection or deformation may be averted using structural support which may provide rigidity and stiffness to the chassis and also may help in terms of reliability and endurance strength. The overall need is to create a light, stiff, rigid and safe chassis to fulfil its given purpose.

7.References

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