STATIC STRUCTURAL ANALYSIS OF CHASSIS IN COMPLIANCE WITH INTERNATIONAL RULES OF A PROTOTYPE FORMULA STYLED VEHICLE

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Abstract **-** This research concerns on making a design and analysis of the car chassis that will fit all aspects and concepts according to the rules of a formula styled race car. The nature of a race car's performance and fatigue failure depends on the structure and material selection of the car. Therefore, it is important for a designer to grasp the topics such as metallurgy and structural design. The objective of this project to design and analyse of car chassis to avoid any prospect of failure of the structure and to provide adequate supporting member to make it stronger in terms of deformation. Finite element analysis enables to predict the region that tends to fail due to loading. Another main objective is to study the effect of load that applied in term of driver weight, the car body and the equipment.

Keywords: Impact, Analysis, Torsional Stiffness, SOLIDWORKS.

I. INTRODUCTION

In Automobile, One of the most important part of a vehicle is its skeletal edge that carries other major automobile divisions such as braking & handling, engine, suspension system etc. FSAE has constituted guidelines based on various factors including driver's safety & Ergonomics. According to the guideline the chassis should be made up of light weight and high strength metal like AISI 1018, AISI 1080 or AISI 4130. Our goal is to make the chassis that must be rigid enough to withstand vibrations, buckling, twists, shocks and many other static and dynamic stresses. In this case of formula styled vehicle the design of car involves high performance parameters to achieve better strength & stiffness. All the Analytical calculations and design process of frame is to be done in Solid works software.

The supporting chassis on which the engine and other mechanical components are fastened is the primary foundation of the FSAE chassis. Before being developed, the design must go through a series of tests. To ensure that a decent chassis is built, the design of the chassis, its ability to carry loads with minimal failure, ergonomics issues, weight, and the ability to withstand a variety of stresses must all be considered as the chassis is being built. This is essential in order to ensure the highest possible performance of the chassis with the least amount of failure due to applied load while racing. To design a chassis, the process should comply with the FSAE (Formula Society Automotive Engineering) International standards.

Many studies create their own methodologies for analyzing and testing their chassis designs. Various types of software are utilized to develop the chassis during the design process. CATIA V5 software, AutoCAD, SOLIDWORKS, and Pro-E are all used by some of the researchers. Every CAD program used to design chassis has its own set of benefits and drawbacks, although most studies prefer SOLIDWORKS since it comes preconfigured with flexible documentation options like documenting product geometries and dimensions, material specifications, bill of materials, and so on, making the entire process of documenting component designs easier. Although only in the aviation and automobile industries, it is widely used.

II. LITERATURE REVIEW

Sourabh Sirsikar, Ajay bhosale, and Akshay Kurkute [1]. A research paper:-

They have proposed the comparison of chassis types. Tubular space frame chassis is approved by FSAE students after examining numerous different forms of chassis geometry. Self-supporting chassis are ideal for mass production for businesses and manufacturers. The torsion resistance of a ladder chassis is quite low. For hand-built cars such as formula student vehicles, only monocoque and space frame chassis are practical. Monocoque chassis are lighter and more robust than traditional chassis.

However, its downsides include a complex structure and a high price. Although space frame chassis are slightly heavier than monocoque chassis, they are nevertheless considered light. In Formula Student competitions, acceleration and road handling qualities must be as high as feasible. Space frame chassis are the most suitable chassis type for Formula Student teams, based on all of these considerations.

This research paper showed us few steps involved in the analysis process and how to calculate the loads experienced by different structures and elements. The following are some of them: -

i) Front impact analysis
ii) Rear impact analysis
iii) Side impact analysis
iv) Front torsional analysis
v) Rear torsional analysis

By using "impulse-momentum equation "An impulse was equal to the net force on the object times the time period over which this force was applied. Below, derived impulse from the equation F = ma, which represents Newton's second law of motion. This equation helps for resolution of forces which will act on the chassis for Front-impact, Rear impact, Side-impact Analysis.

Prajwal Kumar M. P, Vivek Muralidharan, and G. Madhusudan [2], A research paper:-

This article used ANSYS to demonstrate several material selection methods, design optimization techniques, and finite element analysis (FEA). The chassis' material property is an important characteristic to consider while developing and producing a car. During mobility, the chassis is subjected to a variety of forces; it must remain intact without giving, be rigid to absorb vibrations, and be resistant to high temperatures. AISI 4130 Chromium Molybdenum steel (Chromoly) and AISI 1018 are two of the most often utilized materials for space frame chassis. Despite the fact that chromoly steel 4130 has somewhat superior structural qualities than AISI 1018 Grade steel, AISI 4130 is superior to handle all types of stresses.

Design optimization is a method of engineering design that use a mathematical explanation of a solution problem to assist in the selection of the best design from several alternatives. Despite its weight, the Space frame chassis was chosen over a monocoque because its production is less expensive, requires fewer tools, and damages to the chassis are quickly repaired. There are four cross sections of chassis namely, Front bulk head, rear bulk head, front roll hoop & the main roll hoop.

K Praveen Kumar, Vishal, B Subramanyam, and Mahesh Kollati [3], A Research paper:-

In these paper they have proposed Design Analysis of Race Car Chassis. It showed us few steps that involved in the analysis process and also gave us an idea of how to carry out calculations with different loads experienced by different structures and the member of chassis.

This paper also help us to analyze the design. There are two types of analysis which are done on vehicles, they are Static and Dynamic Analysis. Static analysis is done for the vehicle which is at the rest or stationary positions and dynamic analysis is done for the vehicle which is in motion. Hence basically from this article we will discuss only static analysis, as we have an idea that formula student race car won't be going on such a drastic high speed so there is no need to carried out dynamic analysis of formula student race car and one of the important point is that, Stiffness is the resistance of the frame to torsional loads. FEA is use to analyze the torsional stiffness of the chassis of the added mass. Therefore while designing a race car chassis it is important to get a balance between the weight and stiffness of the chassis.

David Krzikalla, Ales Silva, Jakub Mesicek, and Jana Petru [4], A Research paper:-

This research article concerns on the modelling of the simulation structure for the torsional stiffness evaluation of a Formula Race car chassis. They have proposed that the carbon-fiber monocoque chassis are lighter & stiffer as compared to steel frames but their price, irreparability & manufacturability are the major drawbacks that's why the teams usually go for the steel tube Frames since they are easy to design and manufacture for a low price and with less effort. The frame of ground vehicles serves as a shell to carry all vehicle components, and protect the driver and to attach the suspension withstanding all forces from the tires. Since the suspension system is attached to the frame, the frame stiffness is crucial and vehicle handling is affected. There are also several factors affected vehicle handling including longitudinal torsional stiffness. Torsional stiffness is the resistance of the frame against torsional deformation (twisting). Torsional deformation C is usually expressed as ratio of the applied torque T and deformation angle of the frame α

$$C = \frac{T}{\alpha}$$

The need for testing the torsional stiffness or generally the frames' properties grows from the need of designers to understand the frame behavior under various circumstances while racing along the track, as they want to design as light and stiff a frame as possible.

III. METHODOLOGY

Methodology is a way of doing something based on particular principle and methods. While designing chassis or any other product several process has to be carried on chassis or product before actual result can be obtained. Proper method must be planned and considered along with following FSAE rules and regulations before and during designing of chassis to achieve better result and to solve all the problems that are arriving while designing.

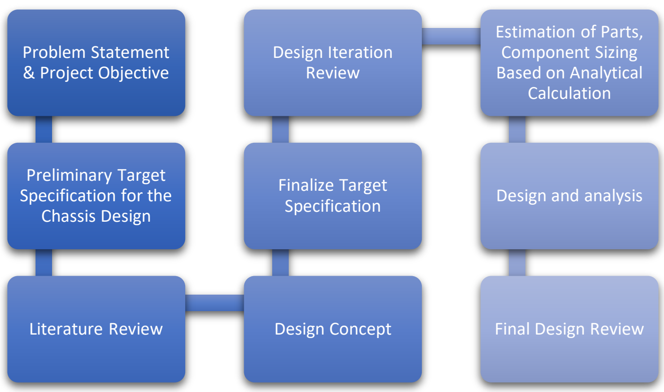

Fig. 01. Work Flow Chart

In FSAE, driver safety is very important factor, and the safety of the driver is our primary responsibility or top priority while designing chassis. Point that are to be mentioned in driver safety are seat inclination, height of the seat from the ground, pedal box position, angle of viewing etc. are taken into consideration.

Second most important thing is to know how much load the different parts of chassis can withstands. So, The General Formula that we used to calculate load is.

Final velocity (v) = Initial velocity (u) + Acceleration (a) *Time of impact (t).

i.e. $v = u + at$

And, Force (F) = Mass (m) * Acceleration (a)

i.e. $F = m * a$ unit [Newton (N)]

IV. DESIGNING

Before designing a FSAE race car, it is necessary to know the basic steps involved in designing. So, it is always advised to go through the FSAE rule book in order to know all the rules and regulations they have carried out to maintain a certain criteria and for the driver's safety. By keeping which in mind, the vehicle should be built. The structure of the race car can be design in any of the designing software e.g. CATIA, SOLIDWORKS, etc.

According to the rulebook the basic component of the chassis are:-

- Front Bulkhead
- Front Roll Hoop
- Front Hoop Bracing
- Main Roll Hoop
- Main Hoop Bracing

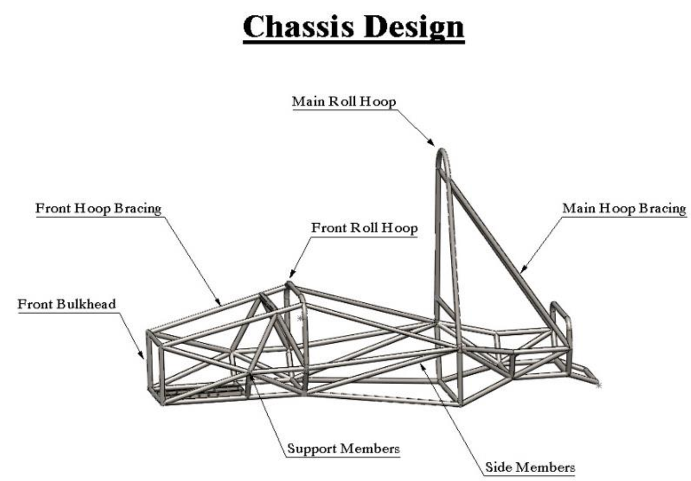

Fig. 02. Chassis Design

V. MATERIAL SELECTION

The material chosen for the chassis is important in ensuring the structure's strength. The power to weight ratio will be affected by material choices, which is directly proportional to the chassis weight. It can also help by reducing member deflection, increasing chassis strength, and determining how much reinforcement is needed. The material chosen for the chassis should be both cost-effective and possess all of the attributes required to construct a sturdy chassis while keeping the driver's safety in mind. Keeping this requirement in consideration, a comparative assessment of the best available possibilities must be conducted in order to select the material for the race car's chassis.

Difference between The properties of materials

(Table No. 01)

Properties	AISI 4130	AISI 1080	AISI 1018
Density[kg/m3]	7.8	7.8	7.8
Young's Modulus[GPA]	210	210	210
Brinell Hardness	200	174	120
Yield Strength[MPA]	460	375	360
Strength to weight ratio[KN-m/Kg]	72-75	55-60	55-60
Cost per meter	500	200	250

After reviewing the table above, it is clear that the chromoly steel "AISI 4130" is the superior material, as it has a higher weight-to-strength ratio but costs few more rupees than the other materials.

VI. ANALYSIS

Before manufacturing any part, the first and the important step is to carry out analysis. Analysis of the product is carried out in order to rectify the errors and the strength of the product to achieve the desired output. By doing analysis we get the clear view of the product before actual manufacturing. In the same way FSAE chassis also need to analyze before actual manufacturing, to achieve better outcomes in terms of strength, Driver's Safety etc. There are different type of analysis which are given below.

- Front impact analysis
- Rear Impact Analysis
- Side Impact Analysis
- Front Torsional Analysis
- Rear Torsional Analysis

1. Front Impact Analysis

In this analysis we applied the force to the front bulkhead at the approximate locations of the impact attenuators, Lets predict a situation, where a car running at a speed of 110 km/hr collide with the stationary formula student race car from front. In front impact analysis, rear end of the chassis is kept completely fixed and force is applied on the front bulkhead member of chassis. The force applied is 2.5 KN.

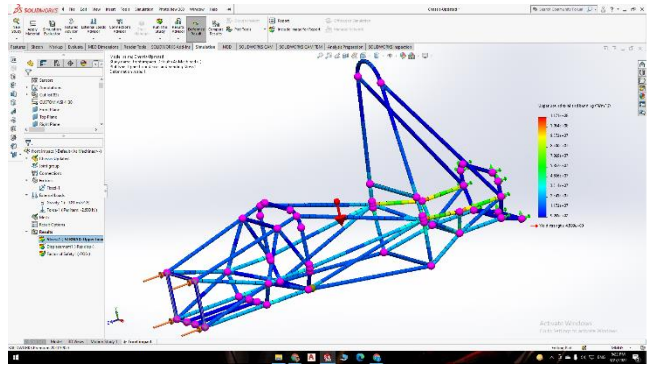

Fig. 03. Front Impact Analysis Stress Plot

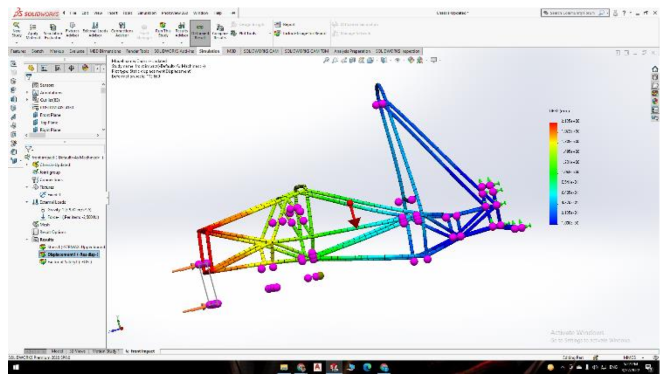

Fig. 04. Front Impact Analysis Displacement Plot

2. Rear Impact Analysis

This test is conducted if the vehicle gets hit at the rear section. These types of accidents are rare, but when it happens, it could be harsh. In this type of analysis, let's predict a situation, where a car running at a speed of 110 km/hr collide with the stationary formula student race car from the rear side. The fixed portion for this analysis is the front portion and force is applied on the rear bulkhead member of chassis. The force applied to the rear section is 2.5 KN.

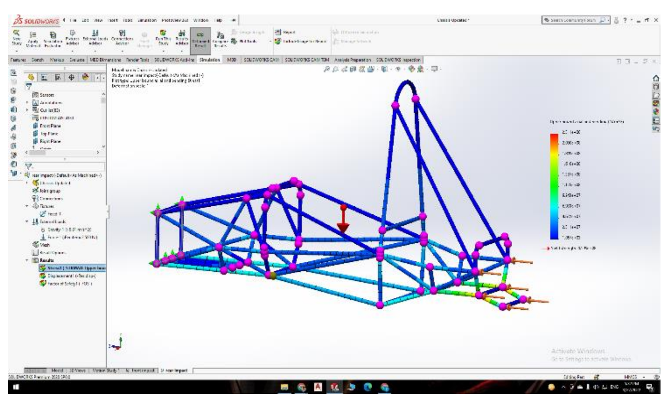

Fig. 05. Rear Impact Analysis Stress Plot

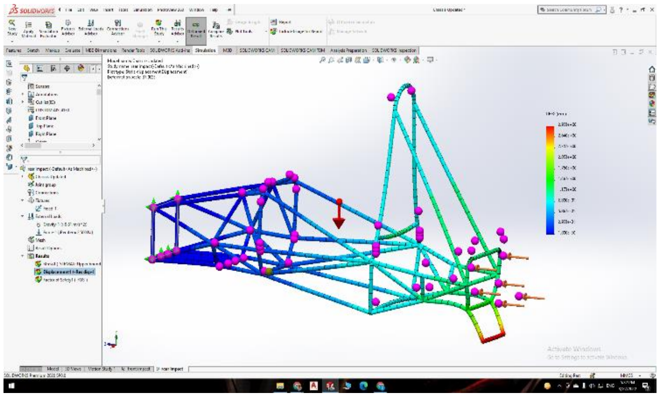

Fig. 06. Rear Impact Analysis Displacement Plot

3. Side Impact Analysis

In this type of test, predict a situation, where a car running at a speed of 90 km/hrs collide with the side member of chassis of stationary formula student race car. In side impact analysis both the front and rear end suspension tabs of chassis are fixed and force is applied on the left or right side of chassis.

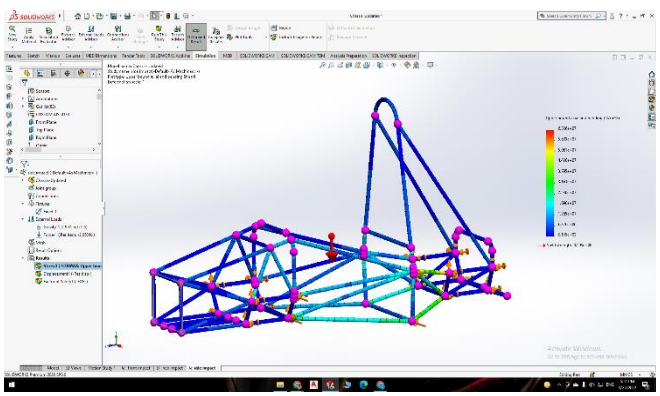

Fig. 07. Side Impact Analysis Stress Plot

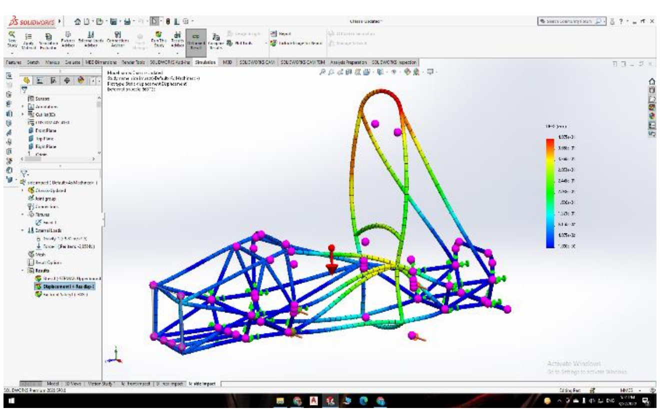

Fig. 08. Side Impact Analysis Displacement Plot

4. Front Torsional Analysis

Torsional analysis is used to find torsional stiffness. Torsional stiffness is an important characteristic while designing a chassis with an impact on the ride and comfort as well as the performance characteristics of the car. Let's assume a situation where a formula student race car will take turn around the corners with a speed of 110 Km/Hr. In the front torsional analysis the loads are applied at the approximate location of the front suspension mounting points and they are equal in magnitude but opposite in direction & the rear suspension mountings are fixed.

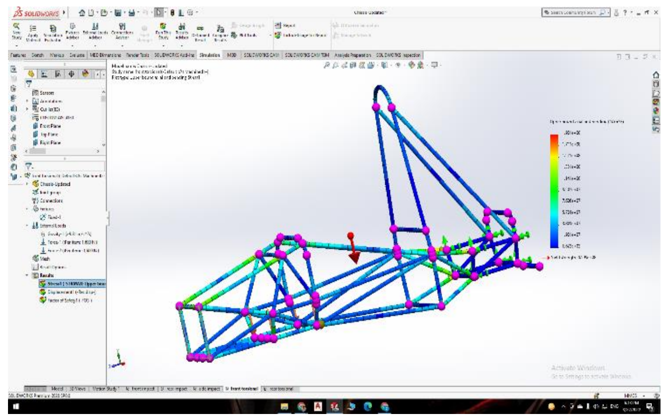

Fig. 09. Front Torsional Analysis Stress Plot

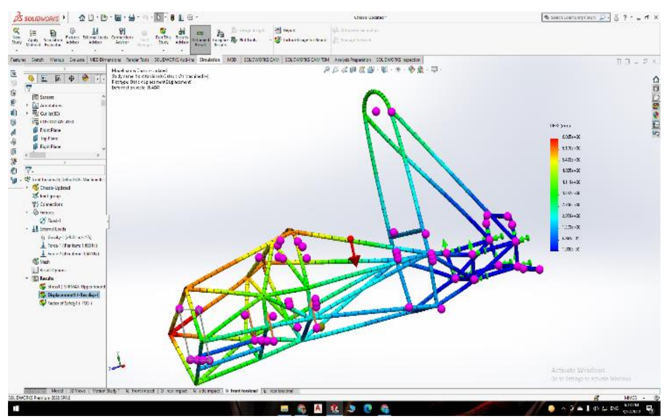

Fig. 10. Front Torsional Analysis Displacement Plot

5. Rear Torsional Analysis

Unlike front torsional analysis, the loads are applied at the approximate location of the rear suspension mounting points and they are equal in magnitude but opposite in direction & the front suspension mountings are fixed.

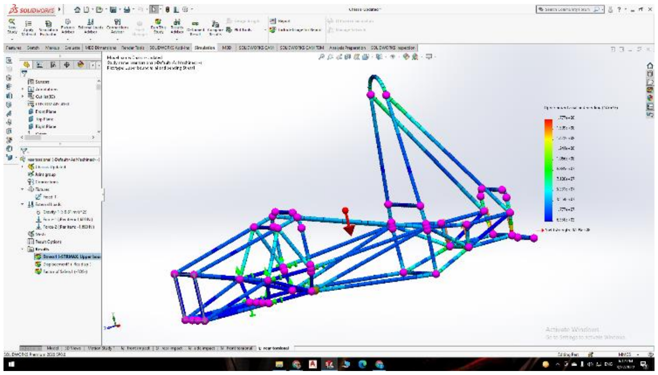

Fig. 11. Rear Torsional Analysis Stress Plot

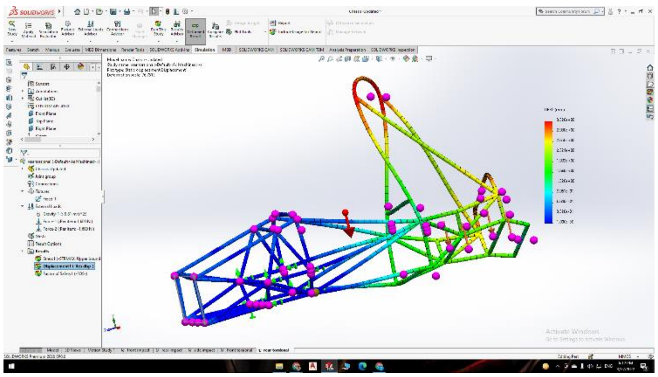

Fig. 12. Rear Torsional Analysis Displacement Plot

VII. CONCLUSION

In conclusion, we developed the chassis using SOLIDWORKS software and assessed it using various types of forces. The effect of load on the structure of the FSAE vehicle was investigated. We've figured out how to choose the ideal Chassis material to improve the overall performance and quality of the product, as well as provide strength to the vehicle. The entire design and analysis meets and exceeds the requirements of the Formula One race vehicle rule book. The possibility of the structure failing has been considered, as well as the provision of suitable supporting members to make it stronger in terms of deformation. This article also indicates that the construction and material selection of a race car affects its performance and fatigue failure.

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