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Stress Optimization of F1 Car Chassis Using FEA Technique

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Abstract: Chassis is the primary structural component of an automobile. It is the main supporting structure of a vehicle to which all other systems like braking, suspension and differential are attached. In this project, a methodology for F1 Car chassis design and structural stability analysis is presented. A literature study is carried out to review various existing designs of vehicle chassis, latest innovations and advanced materials used to manufacture the same. The various types of forces and stresses commonly acting on chassis structures are analyzed and their effects on the vehicle are understood. After completing literature study, several findings are listed in a systematic manner, by providing ample arguments to justify each of them. The pro-con analysis is conducted to evaluate merits and demerits of each alternative type of chassis and the material to manufacture it. In this research work, the material are Aluminum Alloy and AISI1144 Carbon steel. Analysis both material in different parameters which are essential for any ideal chasiss such as various types of forces and stresses commonly acting on chassis structures are analyzed and their effects on the vehicle. The most essential design criteria are derived by selecting different materials which then acts as important guidelines during the actual design process. Structural chassis frame is designed as per the design criteria, using the CAD software CATIAV5R19 and the structural stability of the same is tested and analyzed using ANSYS Workbench 19.0 software. From the results of these analysis tests the static structural stability of the design is confirmed.
Keywords: Ansys Workbench, Design for Material, Chassis and Carbon Steel.

I. INTRODUCTION

The word chassis was derived from the Middle French Chaciz, from chasse in the year 1864. A chassis is a physical frame or structure of an automobile, an airplane, a desktop computer, or any other multi-component device. In simple words, something leftover when body is removed from a vehicle is called "chassis" [1]. It is the main supporting structure of a vehicle to which all other components are attached, and it can be comparable to the skeleton of a living organism. The components of the vehicle like transmission system, axles, wheels, tyres, suspension, controlling system like braking, steering, etc., and even electrical systems are mounted on the chassis frame. Chassis is the main mounting for all the components including the body. So, it is also called as the 'Carrying unit' and the Backbone of a vehicle. Until 1930's, virtually every vehicle had a structural frame, separate from the cars body. This construction design is known as "body- on- frame". Since then, nearly all passenger cars have received Uni-body construction, meaning their chassis and bodywork has been integrated into one another. The last United Kingdom mass-produced car with separate chassis was Triumph Herald, which was discontinued in 1971. However, nearly all trucks, busses, and pickups, continue to use a separate frame as their chassis. The objective of this project is to design and construct a chassis for an F1 car. This new conceptual car aims to revolutionize the way cars are made, as cars of today are outdated as they have been made in the same way from decades. To design a chassis for F1 car, we have carried out a detailed study about the various materials used of chassis. We have listed the various types of load conditions, types of stresses acting on a vehicle frame, the different type of requirements a chassis design must meet. In addition, we also studied about the different types of chassis existing in the car industry. The chassis is designed by the CAD/CAM software CATIA V5R19 which is a 3D CAD, CAM, and CAE platform for product development. It combines the industrial and mechanical design, simulation, collaboration, and machining in a single package. The tools in this software enable fast and easy exploration of ideas with an integrated concept-to production toolset [2].

A. F1 Car Design Consideration

The design process of the chassis consists of many steps, from the initial assignment to the task of chassis design to the start of construction. These steps are; to identify the restriction, determine the required performance criteria, research design techniques and methodology, use of CAD software to design chassis and lastly start construction. Throughout these steps, choices must be made based on the targets that are to be achieved to meet the performance requirement. The designer of the chassis must have an idea as to how all components of the car are going to function in relation to each other. As a result, the designer must know how all parts must interact and take this interaction into account when designing the frame.

The design of a racing car chassis, or any racing chassis for that matter, is going to be based on suspension points, power train layout, driver position controls, safety, etc [3]. These important points must come together to form an effective package for the car to perform as intended.

B. Good Quality Chassis

Be structurally sound in every way over the expected life of the car and beyond. This means that nothing will ever break under normal conditions. Maintain the suspension mounting locations so that handling is safe and consistent under high cornering and bump loads.

This means that there is no flexing of the body, or at least to reduce flexing on lowest possible value. Support the body panels and other components so that everything feels solid and has a reliable life span. Protect the driver from external intrusion. Structural stiffness is the basis of what you feel at the seat of your back bottom [4]. It defines how a car handles, body integrity, and the overall feel of the car.

Chassis stiffness is what separates a great car to drive from what is merely OK. Contrary to some explanations, there is no such thing as a chassis that doesn't flex, but some are much stiffer than others. Even highly sophisticated Formula 1 chassis (actually, Formula 1 has monologue structure) flex, and sometime some limited and controlled flexing is built in the car. The range of chassis stiffness has varied greatly over the years.

Basic chassis designs each have their own strengths and weaknesses. Every chassis is a compromise between weight, component size, complexity, vehicle intent, and ultimately, the cost. And even within a basic design method, strength and stiffness can vary significantly, depending on the details.

C. Types of F1 Chassis

Space Frame And Monocoque Chassis

1) *Ladder Chassis:* This is the earliest kind of chassis. From the earliest cars until the early 60s, nearly all cars in the world used it as standard. Even in today, most SUVs still employ it. Its construction, indicated by its name, looks like a ladder - two longitudinal rails interconnected by several lateral and cross braces. The longitude members are the main stress member.

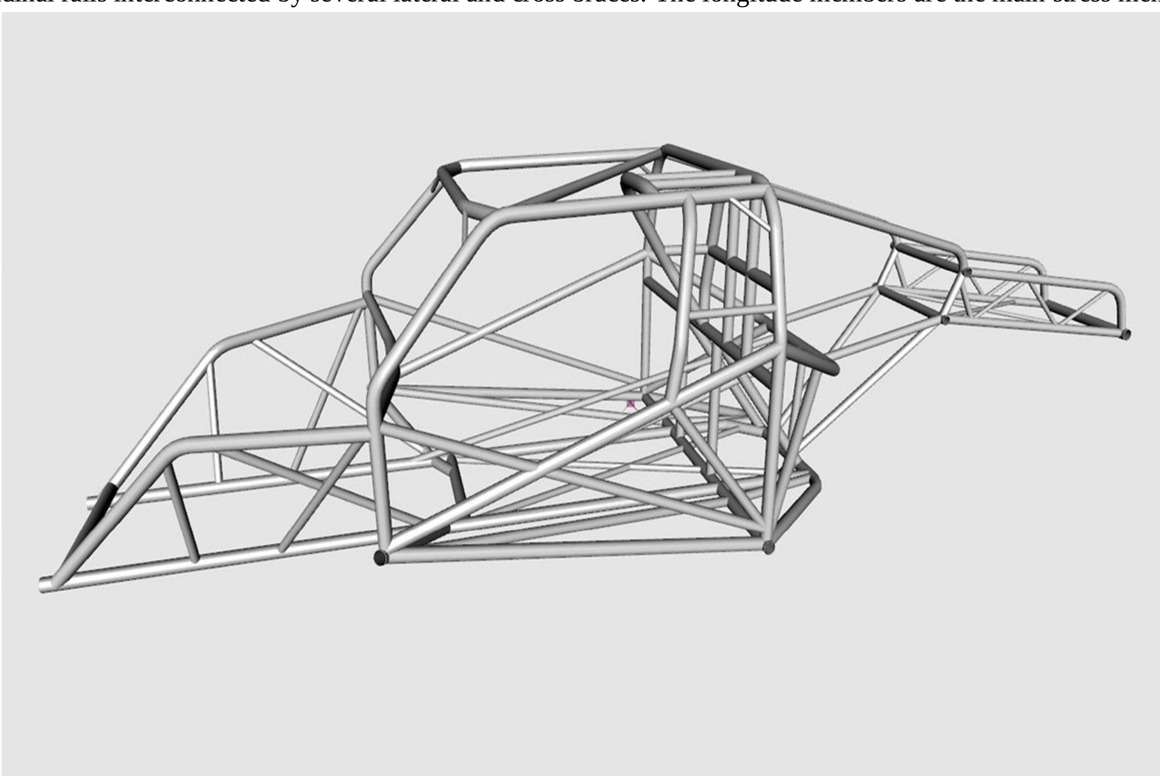

Fig.1 Ladder Chassis

2) *Backbone Chassis:* Backbone chassis is a type of a car construction chassis that is similar to the ladder design. Instead of a two-dimensional ladder type structure, it consists of a strong tubular backbone (usually but not always rectangular in cross section) that connects the front and rear suspension attachment areas [5]. The tunnel or backbone becomes a primary load bearing member. Backbone chassis is very simple: a strong tubular backbone connects the front and rear axle and provides nearly all the mechanical strength.

Fig-2 Backbone chassis

3) *Space Frame:* The two most important goals in the design of a race car chassis are that it be lightweight and rigid. Lightweight is important to achieve the greatest acceleration for a given engine power. Rigidity is important to maintain precise control over the suspension geometry, that is, to keep the wheels firmly in contact with the race course surface.

Fig- 3 Space Frame

II. LITERATURE REVIEW

Marco Cavazzuti et al (2011), the requirement to comply with environmental regulations without compromising vehicle safety, explained weight reduction is a crucial concern for carmakers. In the automotive sector, the traditional trial-and-error methodology is no longer sufficient, and new methods are required to improve the design process.[6].

Nan Zhou et al (2012) Because the reaction of metal welded joints to fatigue characteristics is significantly non-linear, establishing an appropriate theoretical model to forecast its fatigue life using standard methods is challenging. In order to produce sufficient models for metal welded joints behaviour on fatigue characteristics, it is important to incorporate modelling approaches established in other domains [7]. Patel Vijay Kumar and Patel (2012)

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The researched automotive chassis is a critical component of any vehicle. The chassis acts as a framework for the body and other components of the vehicle. It should also be stiff enough to endure shock, twisting, vibration, and other stressors. An automobile chassis, according to Washington (2012), is an integral element of the vehicle. Maximum stress, maximum equilateral stress, and deflection are all essential considerations in chassis design. This study details the work done to optimize the vehicle chassis under maximum load with maximum shear stress, equivalent stress, and chassis deflection limitations. Shaohua Li et al (2012) the three-dimensional heavy vehicle pavement-foundation linked system is described as a seven DOF vehicle travelling through a simply supported double-layer rectangular thin plate on a linear visco elastic foundation. The dynamic responses of the coupled system with stochastic road surface roughness are numerically determined using the Galerkin technique and a rapid direct integral approach. Haval Kamal Asker et al (2012). The structure of a normal dump truck supports all sorts of difficult loads from the road and freight being loaded, as previously stated. As a result, the truck's design is heavily influenced by the intensity and strength of the structure. Hengji et al. (2012) introduced a fatigue life analysis approach that integrates multi body dynamic analysis and finite element method to explain the fatigue life for the frame of the 220t mining dump truck. Awlad Hossain et al (2012) It is illustrated how to use cantilever beams to characterize the rheological characteristics of viscous materials [8].

III. METHODOLOGY

A. Finite Element Method

Ansys is a computer aided engineering tool, which is used for the structural analysis tool and is based on Finite Element Method, Finite Element Method (FEM), firstly breaks the domain, which is object here into several smaller element, which is called Discretization and then equations for all the smaller element are done and get it calculated, it is done for the accurate result.

1) Preprocess

a) Selection of Structure: The very first step what need to be done is selection of the structure to analysis for, here in this research work it static as chassis is a static structure.

b) Material Selection: In Ansys workbench 16.0 normally structural steel shown in the material section but here for the Material of choice of the designer has to be created by feeding the properties equivalent to that material, so there is a section called Engineering Data, where all those required properties are fed to create the material need to analysis for in Ansys.

c) Material Properties: To get the same material on which the analysis suppose to be done , the same properties like density, ultimate tensile strength, yield strength, Poisson ratio Young's modulus and few other need to be added to get that material activated in the Ansys material library.

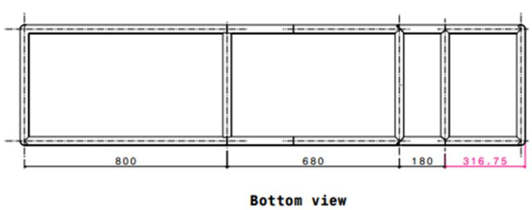
d) Geometry Creation: The model or the geometry on which work to be done can be created in the Ansys itself under the Geometry section but here the model is imported from the external source, which is a CATIA cad model, only analysis was performed here in Ansys Workbench 16.0.

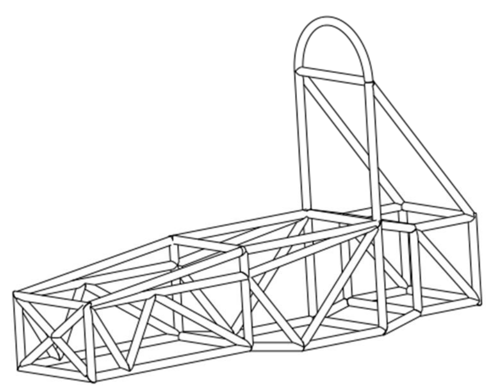
e) Model: Once the model is imported into the Ansys workbench and generated the meshing has to be performed in order to break the whole part (domain) into smaller element which is called Discretization. The smaller section is called element and the point where these entire edged meet are known as nodes.

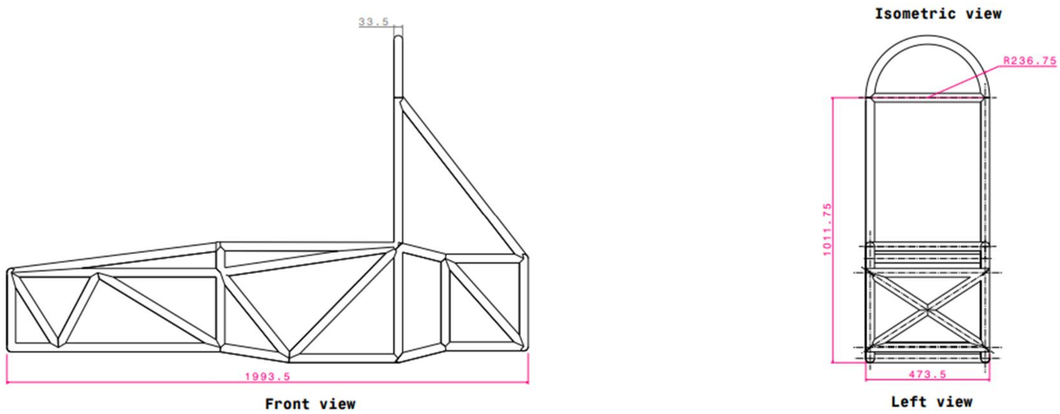
IV. RESULD AND DISCUSSION

A. Chassis (3D)

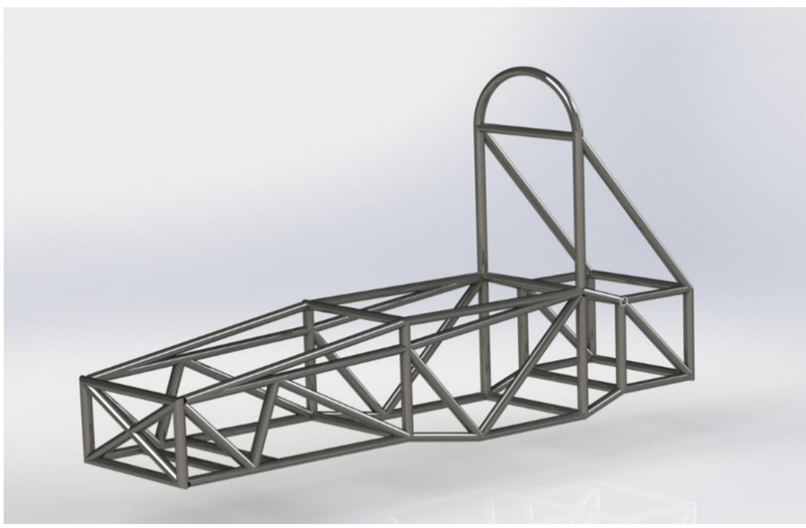
Given: Dimensions of Chassis





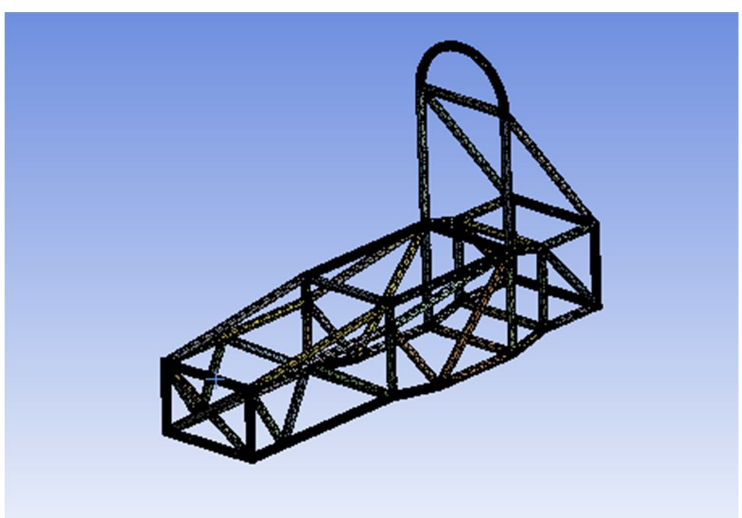


1) *Step 1- Geometry*



2) *Step 2- Meshing*

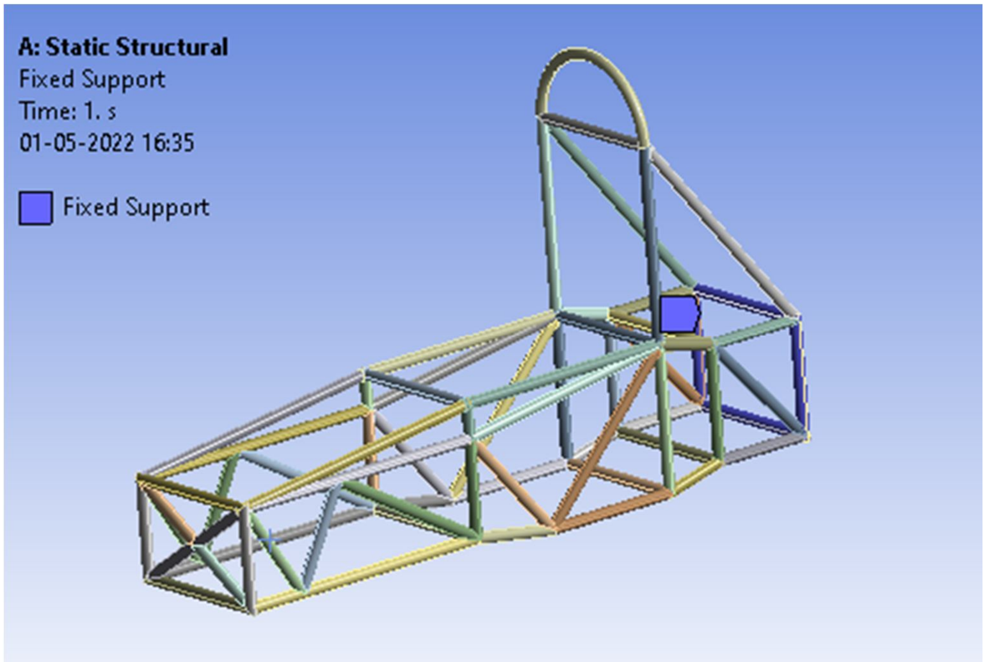
a) Element size is Default meshing (Fine & High Quality)



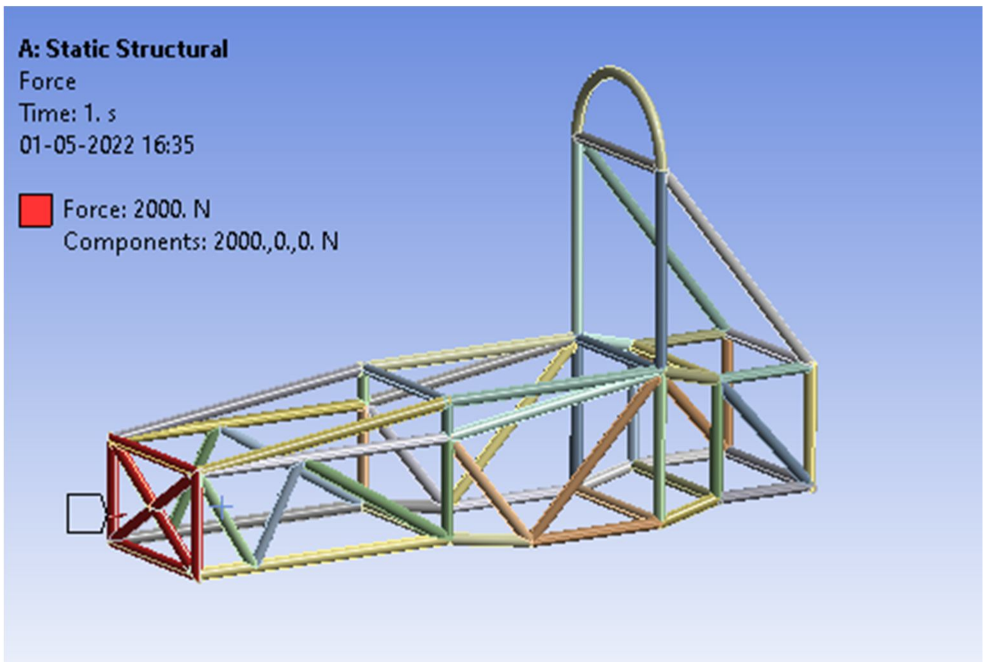
3) Step 3 – Setup

Boundary condition

a) Back side Fixed



b) Front Impact Force: 2000N



c) Material is taken as AISI 1144 Carbon Steel

Density = 7850 kg m^-3

Young's Modulus = 2.1E+11 Pa

Poison's ratio = 0.3

Bulk Modulus = 1. 75E+11 Pa

Shear Modulus = 8.07E+10 Pa

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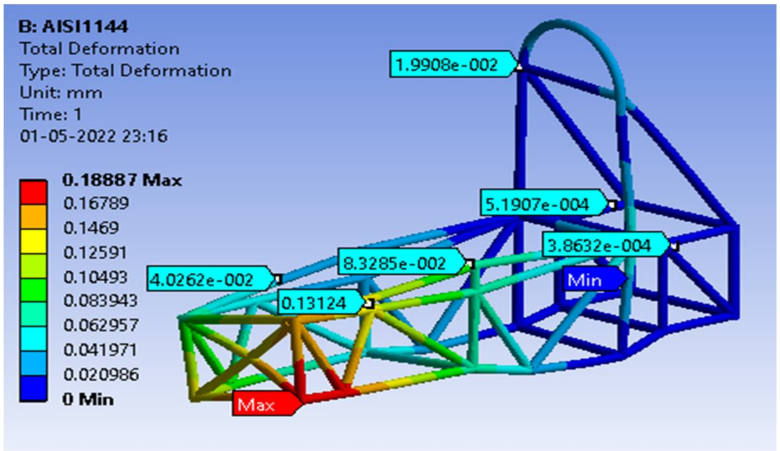
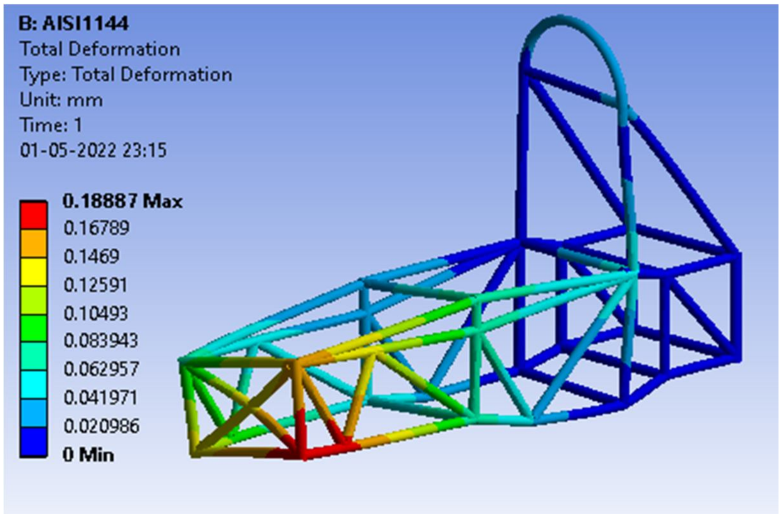
4) Step 4- Solution and Result

Max. Deformation = 0.18887mm

Min. Deformation = 0 mm





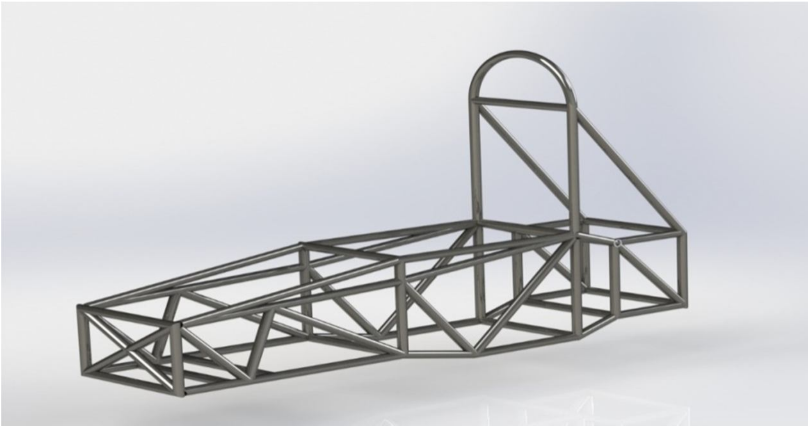
Max. Stress = 173.31 MPa

Min. Stress= 0

B. Conclusion

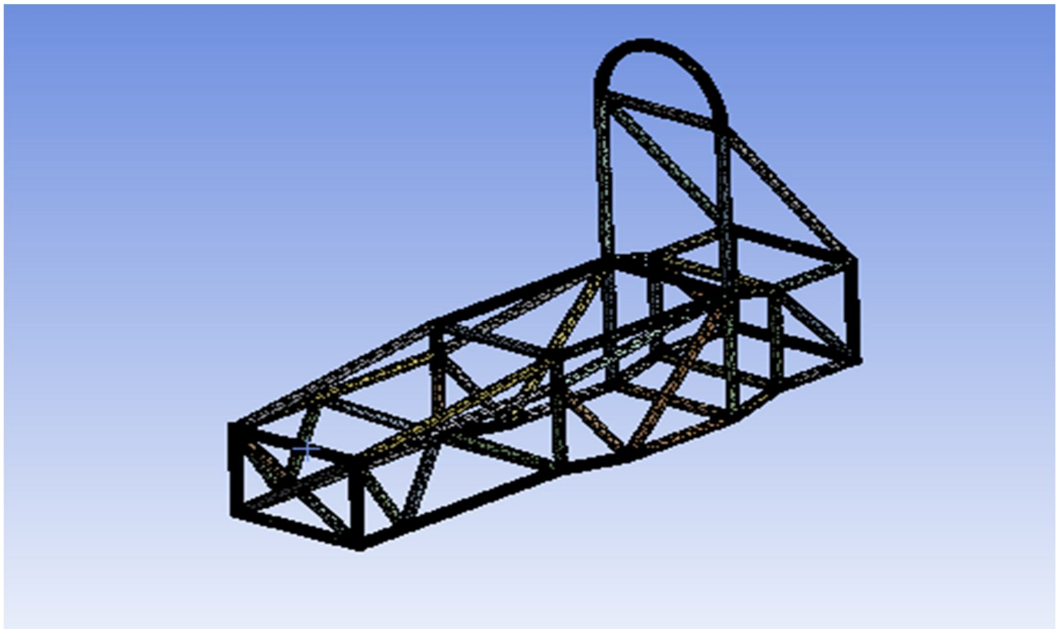
As all the values of stress are below the value which is given for material so our design is safe

1) Step 1- Geometry



2) *Step 2- Meshing*

a) Element size is Default meshing



3) *Step 3 – Setup*

Boundary condition

a) Back side Fixed

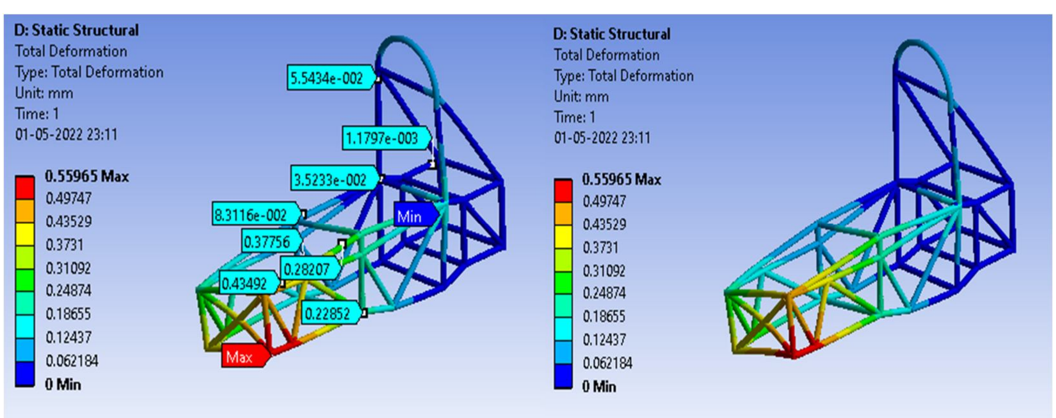
b) Front Impact Force: 2000N

c) Material is taken as Aluminium Alloy Carbon Steel

Density = 2770 kg m^-3
Young's Modulus = 7.1E+10 Pa
Poison's ratio = 0.33
Bulk Modulus = 6.9608E+10 Pa
Shear Modulus = 2.6692E+10 Pa

4) *Step 4- Solution and result*

Max. Deformation = 0.55965 mm
Min. Deformation = 0 mm
Max. Stress = 171.6 MPa
Min. Stress= 0



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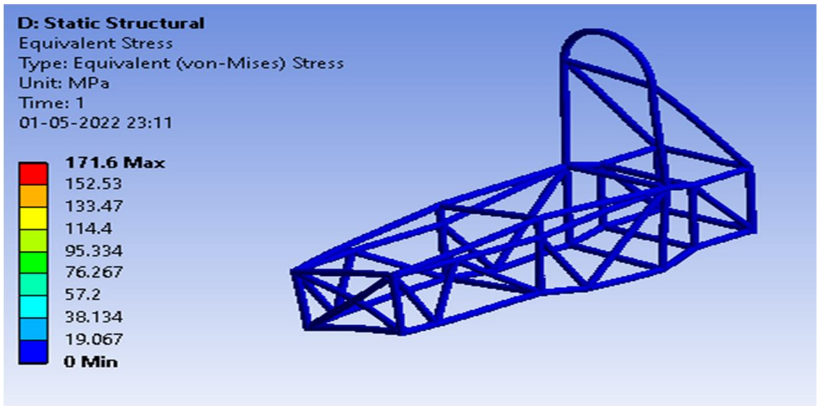
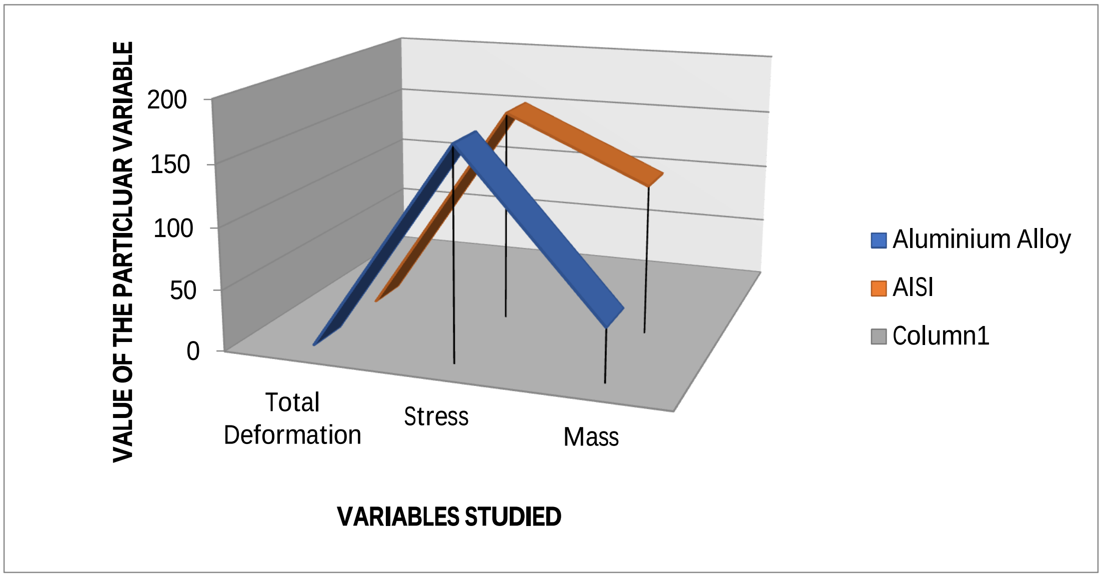


Table no -1 Comparison between AISI 1144Carbon Steel & Aluminum Alloy

S. No	Result	Aluminum Alloy	AISI 1144
1.	Total Deformation (mm)	0.55965	0.18887
2.	Stress (MPa)	171.6	173.31
3.	Mass (Kg)	43.14	122.256



V. CONCLUSION

It is clear from the analysis both the material, Aluminum Alloy and AISI 1144 Carbon steel both are strong enough to use mechanical but for chassis is based of any automobile vehicle for this require some mechanical property such as internal resistance of the material should be excellent, material should be less deformation or rigid and less in weight . Aluminum alloy is less in weight compare to AISI 1144 Carbon steel, but the internal resistance of Aluminum alloy is less then the AISI 1144 carbon steel. Internal resistance is inversely proportional to deformation so aluminum alloy is more deformable than AISI 1144 carbon steel. Model enquiry and stationary mechanical study were carried out on the F1 car. From the above results for different grades of carbon steel the maximum shear stress, maximum mass and displacement were compared.

The result reveals that there is slight difference among all the grades where as AISE 1144 gives lease displacement and the stress so this can be used for the manufacturing of Chassis. The weight of the product in the automobile industry is a major factor for design and the stress values of carbon steel are within acceptable limits. Carbon steel AISI 1144 is therefore suitable as a chassis material for vehicles due to its high strength and light weight. For the same load-carrying capacity, carbon steel 1144 gives better performance than others two carbon steel for building F1 car chassis, as this reduces the chassis frame and increases the rigidity of the chassis frame. To conclude, by prodigious FEM software we can optimize the frame weight and conclude that it is suitable for chassis construction.

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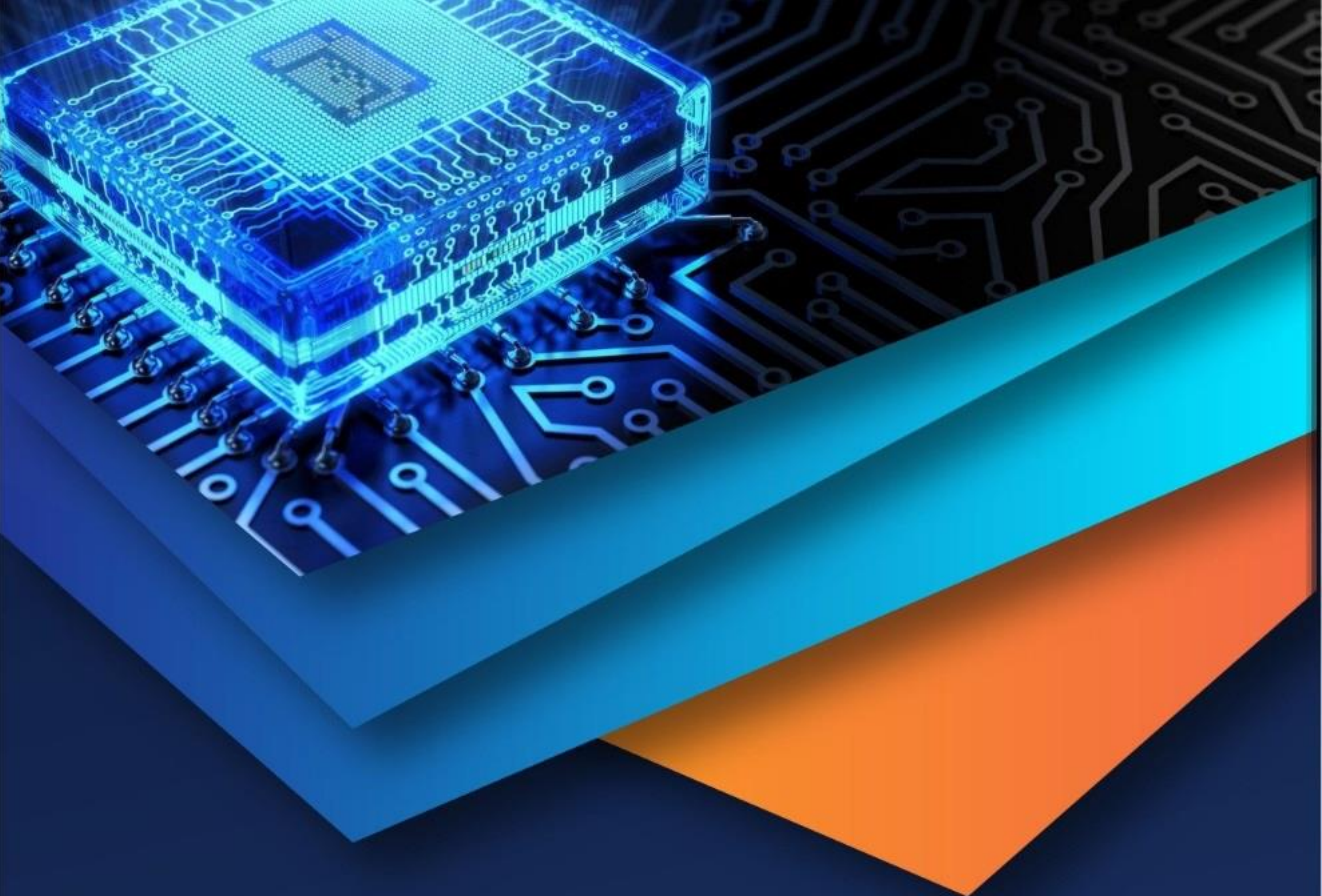

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