

DESIGN AND ANALYSIS OF SAE BAJA ELECTRIC VEHICLE MONOCOQUE CHASSIS

Submitted in partial fulfillment of the requirements for
the award of Bachelor of Engineering degree in
Automobile Engineering

By

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**DEPARTMENT OF AUTOMOBILE ENGINEERING
SCHOOL OF MECHANICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

**Accredited with Grade "A" by NAAC
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DEPARTMENT OF AUTOMOBILE ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **KURBAAN** (Reg. No. 38860703) and **RAHMAT ULLA** (Reg. No. 38860704) who carried out the project entitled "**DESIGN AND ANALYSIS OF SAE BAJA ELECTRIC VEHICLE MONOCOQUE CHASSIS**" under my supervision from November 2021 to April 2022.

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Internal Examiner

External Examiner

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We, **KURBAAN** (Reg. No 38860703) and **RAHMAT ULLA** (Reg. No 38860704) hereby declare that the Project Report entitled “**DESIGN AND ANALYSIS OF SAE BAJA ELECTRIC VEHICLE MONOCOQUE CHASSIS**”, done by us under the guidance of Mr. **ASHWIN JACOB** (Assistant Professor) submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in **AUTOMOBILE**.

DATE: 06/05/2022

PLACE: Sathyabama Institute of Science and Technology

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ABSTRACT

Baja SAE Racing contests are held all over the world at different Formula SAE tracks. The Society of Automotive Engineers (SAE) hosts an intercollegiate competition for off-road vehicle design, construction, and racing. The BAJA vehicle's chassis is a critical component that supports the body and other components. It also surrounds and protects the person in the event of a crash or rollover, as well as adding to the vehicle's looks. Using ANSYS workbench, the study discusses chassis material selection and frame design analysis for various loading circumstances in order to anticipate if the frame would withstand various impact scenarios. The chassis design will be based on the BAJA SAE India regulation book, which will include safety and other factors. These simulations show that the frame is secure enough for the many worst-case situations that were investigated. The chassis is created in Creo-7.0, then analyzed with ANSYS analysis software, and the best design is chosen after comparison.

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DESIGN AND ANALYSIS OF SAE BAJA ELECTRIC VEHICLE MONOCOQUE CHASSIS

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Abstract

Baja SAE Racing contests are held all over the world at different Formula SAE tracks. The Society of Automotive Engineers (SAE) hosts an intercollegiate competition for off-road vehicle design, construction, and racing. The BAJA vehicle's chassis is a critical component that supports the body and other components. It also surrounds and protects the person in the event of a crash or rollover, as well as adding to the vehicle's looks. Using ANSYS workbench, the study discusses chassis material selection and frame design analysis for various loading circumstances in order to anticipate if the frame would withstand various impact scenarios. The chassis design will be based on the BAJA SAE India regulation book, which will include safety and other factors. These simulations show that the frame is secure enough for the many worst-case situations that were investigated. The chassis is created in Creo-7.0, then analysed with ANSYS analysis software, and the best design is chosen after comparison.

Keywords: BAJA SAE, Chassis, ANSYS, AISI 1018, AI 6160.

1. Introduction

All of the car's components are supported by the chassis. It supports the vehicle's body, engine, and other components. The chassis provides all of the vehicle's support and stiffness. The purpose of an automobile chassis is to protect the vehicle's shape and to support the many hundreds that are applied to it. The chassis' protection may be a vital aspect of the style, and can be considered at all phases. A car's chassis is considered to be one of the various structures that make up the vehicle. On be more specific, an automotive chassis or vehicle chassis is a frame to which a variety of mechanical components such as the engine, tyres, brakes, steering, and shaft assemblies are bolted. Backbone, ladder, space frame, and monocoque are the most common chassis types. Different chassis styles result in different performance. Vehicle structural components are designed to boost energy absorption efficiency and hence improve the vehicle's safety and dependability. As a result, automotive safety must be improved.

2. Design Methodology

Over a different type of chassis, a space frame chassis was chosen. The basic premise of chassis design is that the chassis should be constructed to achieve torsional stiffness and low weight in order to obtain superior race car handling performance. According to the definition, the capacity of a chassis to resist twisting force or torque is referred to as torsional stiffness. To put it another way, the amount of torque required to twist the frame by one degree is referred to as torsional stiffness. If the torsional stiffness is too low during corner entry, the chassis will be thrown off. When the torsional stiffness is excessively high, corner entry becomes problematic, resulting in an understeering propensity. These characteristics were applied to the space frame chassis at the same time. Because of their construction format, the result of torsional rigidity on a space frame is often very different from that of a monocoque. Space frame chassis are light in weight because they are inexpensive to manufacture, need few tools, and can be readily repaired if damaged. The cockpit dimensions were obtained from the SAE standard with a lot of leeway to accommodate a 95th percentile male driver and more cockpit room to store batteries and attach a fuel tank. The first and most important stage in achieving the appearance of the chassis is to identify the boundary conditions and, as a result, the placement of the pieces. With this in mind, we started drawing line diagrams and then translated them to a Creo model. The first and most important stage in achieving the appearance of the chassis is to identify the boundary conditions and, as a result, the placement of the pieces. Despite the fact that analysis was on the horizon at this time, after multiple revisions and discussions, we've come up with the final chassis design that can decrease stress. The report's analytical section might focus heavily on stress management. Creo 7.0 software was used to model the design. The following is the final chassis:

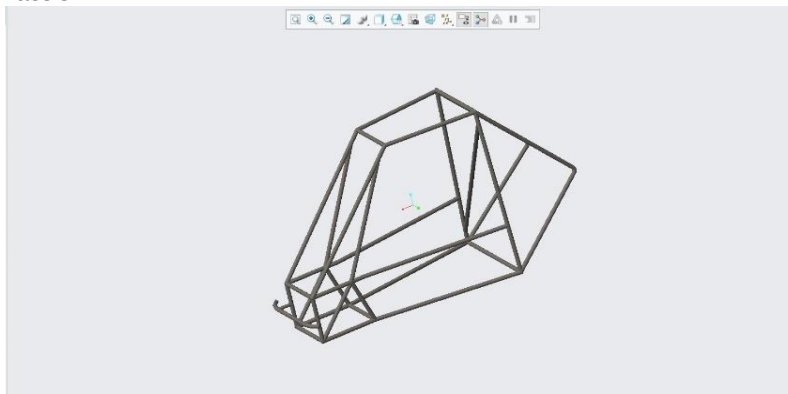


Figure-1 Final Chassis Tubing

3. Material

The key to a decent chassis is to use high-quality materials, preferably the best. This caused us to reconsider our choice of material. We conducted substantial material study for this objective. Strength, weight afford Steel is the most commonly utilised material since it possesses the properties that are necessary for the manufacture of the chassis structure. Aluminium is utilised instead of steel because of its low weight. Carbon fibre is both light and strong, but it is not inexpensive. Other materials, like as titanium, are also available, but they are not employed since they are too expensive. Important materials with their properties are stated below-

Table 1: Material properties

Material	Al 6061
Tensile strength	310MPa
Yield strength	276MPa
Poisson's ratio	0.33
Modulus of elasticity	68.9GPa
% Elongation	12-25%
Carbon	0.20%
Manganese	0.10%
Sulphur	0.60%
Aluminium	97.90
Geometry	Circular Hallow tube
Weld ability	Good

Table 2: Material properties

Material	AISI 1018
Tensile strength	630MPa
Yield strength	385MPa
Poisson's ratio	0.29
Modulus of elasticity	210Gpa
% Elongation	27.00%
Carbon	0.18%
Manganese	0.65%
Sulphur	0.64%
Phosphor	0.03%
Geometry	Circular Hallow tube
Weld ability	Good

4. ANALYSIS

Due to the difficulty of handling the equations, hand theoretical simulations of the entire chassis would be quite difficult. To reduce human effort, machine methods are often applied for analysis and validation. Finite Element Analysis is a popular form of computational approach that is accessible for commercial usage in the market. To attempt to analyse the chassis, the ANSYS Workbench R 2 software suite was selected.

4.1 Types of Analysis:

1. Front impact analysis.
2. Side impact analysis.
3. Rear impact analysis.
4. Roll over analysis.
5. Modal analysis.

General Steps done during the analysis: The following steps are used for analysis-



This procedure has been used for the analysis; Sampling points used for design of experiments are calculated by doing the sensitivity analysis.

4.2 Front Impact analysis (AISI 1018)

A G-Force of 10G is used in the front impact test. Assuming that the vehicle's mass (m) includes the driver, the front impact load is 350 kg.

$$F = m \times a$$

$$F = 350 \times 10 \times 9.81 = 34335\text{N}$$

Table 3: Showing results of the front Impact

Force acting (N)	Type	Fixing points	Max Deformation (m)	Max von mises stress (N/mm ²)	Factor of safety	Element size (mm)
34335	the impact load is applied on front	The rear section of the chassis is fixed	1.8	381.7	0.961	0.02

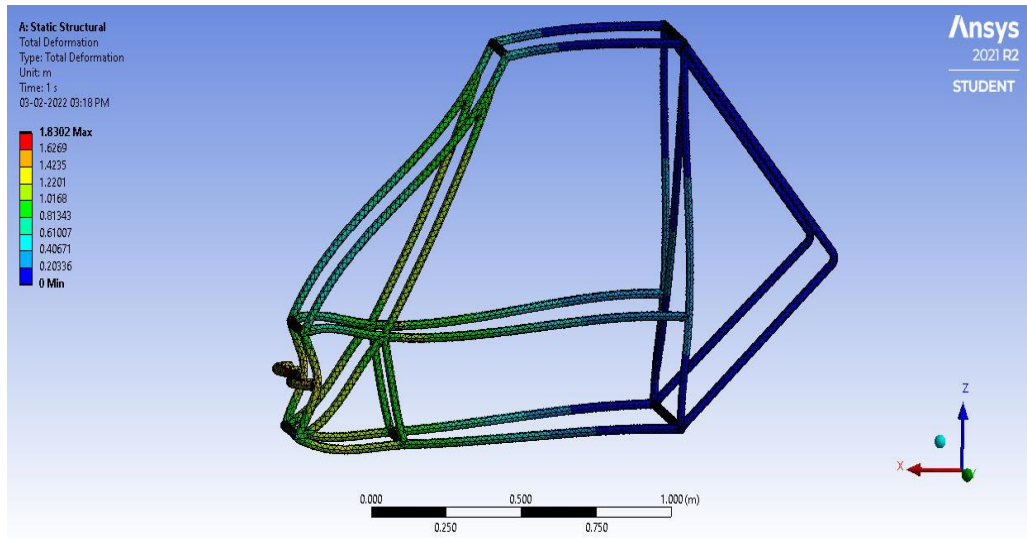


Fig-2 Front Deformation (AISI 1018)

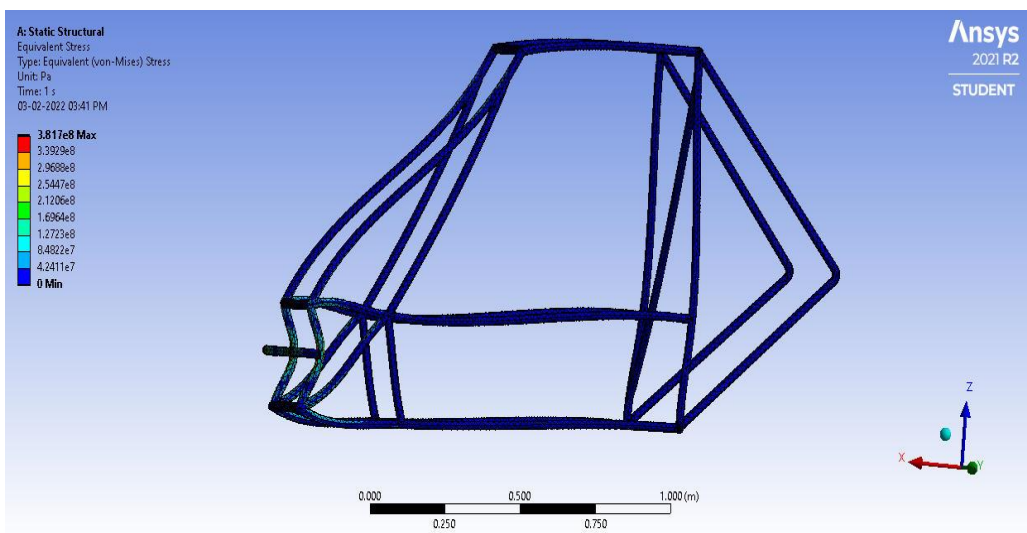


Fig-3 Von Mises Stress Pattern for Front Impact (AISI 1018)

4.3 Side Impact analysis (AISI 1018)

A G-Force of 4G is used in the Side impact test. Assuming that the vehicle's mass (m) includes the driver, the Side impact load is 350 kg.

Table 4: Showing results of Side impact analysis

Force acting (N)	Type	Fixing points	Max Deformation (m)	Max von mises stress (N/mm ²)	Factor of safety	Element size (mm)
13734	To the side impact members	Other side of side impact members	5.7	252.7	1.3	0.02

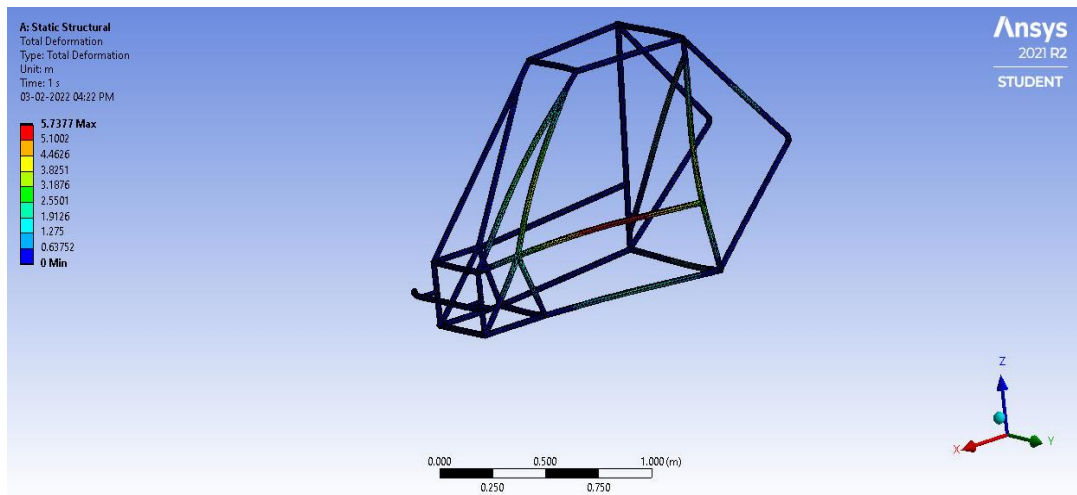


Fig-4 Side Deformation (AISI 1018)

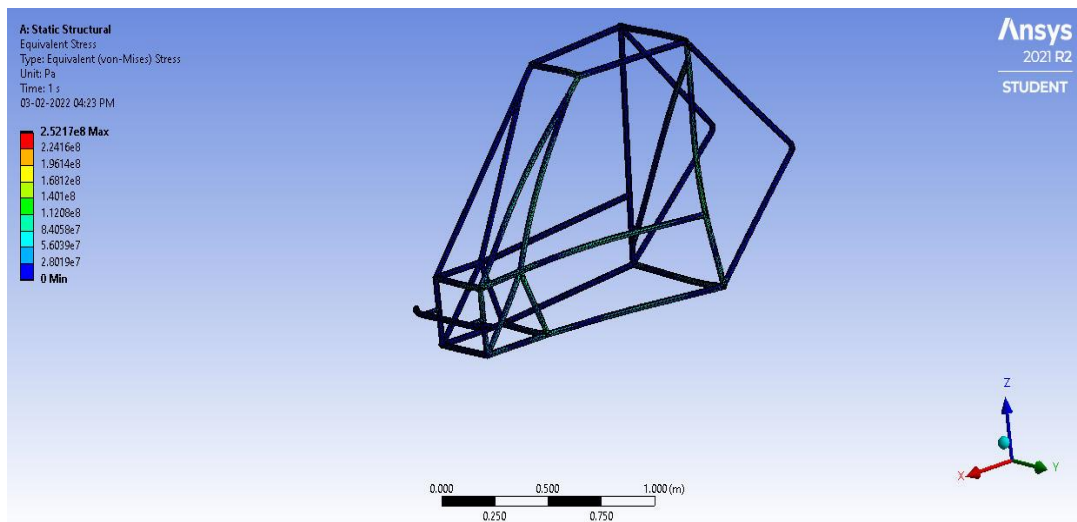


Fig-5 Von Mises Stress Pattern for Side Impact (AISI 1018)

4.4 Rear Impact Analysis (AISI 1018)

A G-Force of 3G is used in the Rear impact test. Assuming that the vehicle's mass (m) includes the driver, the Rear impact load is 350 kg.

Table 5: Showing results of Rear impact analysis

Force acting (N)	Type	Fixing points	Max Deformation (m)	Max von mises stress (N/mm ²)	Factor of safety	Element size (mm)
10300	To the rear impact members	To the front impact members	1.7	113.92	3.2	0.02

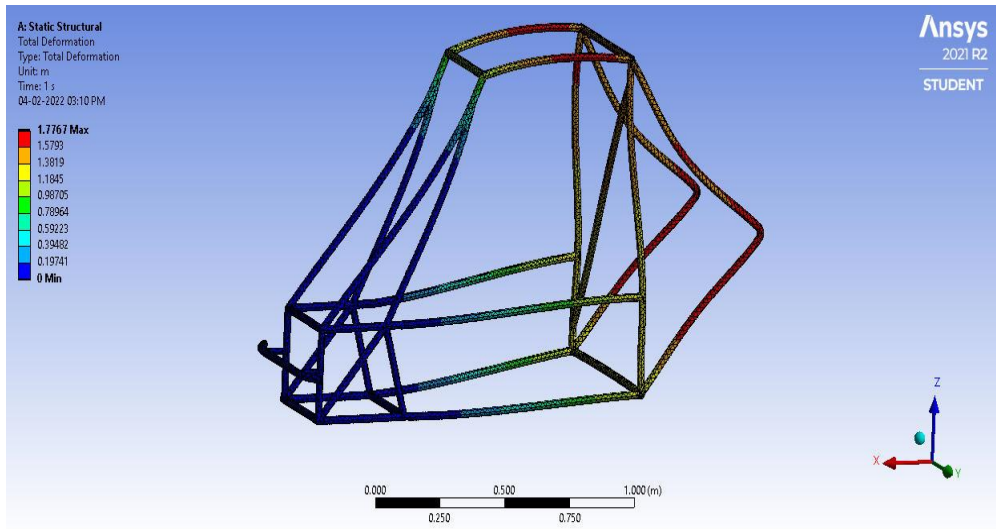


Fig-6 Rear Deformation (AISI 1018)

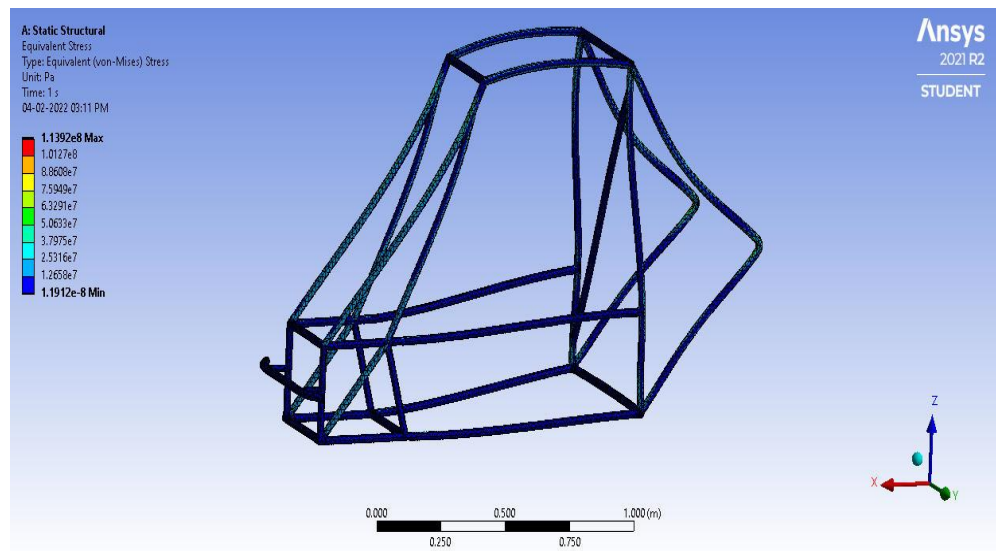


Fig-7 Von Mises Stress Pattern for Rear Impact (AISI 1018)

4.5 Roll over analysis (AISI 1018)

A G-Force of 3G is used in the Roll over analysis. Assuming that the vehicle's mass (m) includes the driver, the Roll over impact load is 350 kg.

Table 6: Showing results of Roll over analysis

Force acting (N)	Type	Fixing points	Max Deformation (m)	Max von mises stress (N/mm ²)	Factor of safety	Element size (mm)
10300	Acting on front and main roll hoop	Bottom of the chassis	1.7	189.39	1.8	0.02

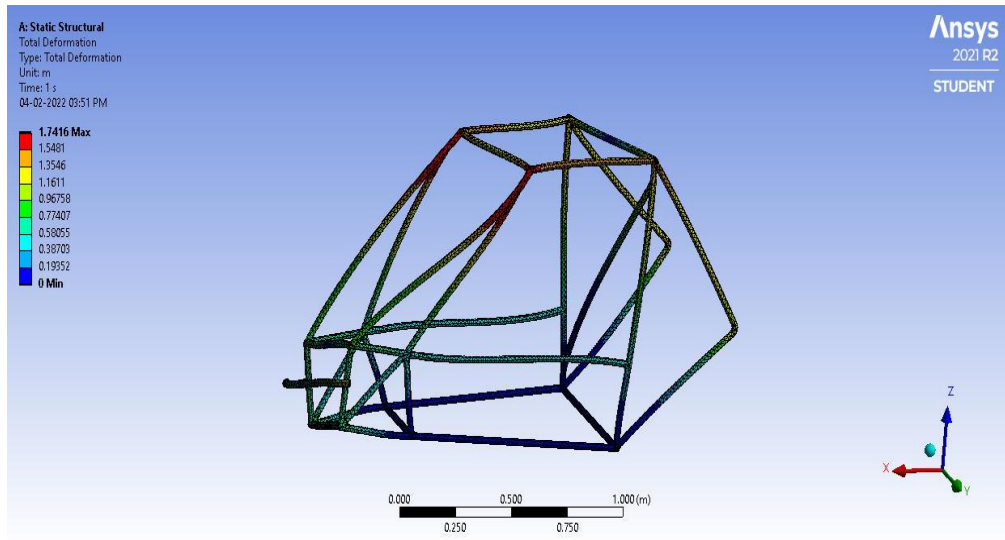


Fig-8 Roll over Deformation (AISI 1018)

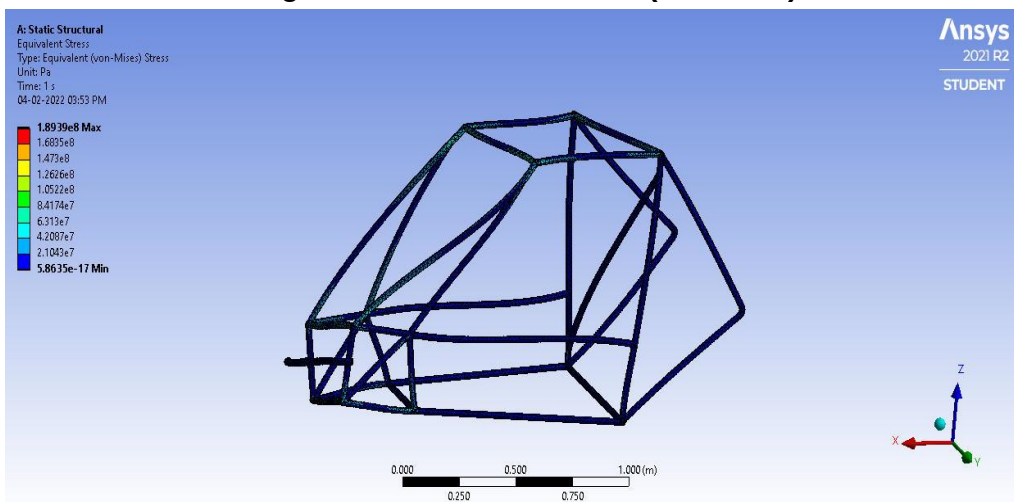


Fig-9 Von Mises Stress Pattern for Roll over Impact (AISI 1018)

4.6 Front Impact analysis (AI 6061)

A G-Force of 10G is used in the front impact test. Assuming that the vehicle's mass (m) includes the driver, the front impact load is 350 kg.

Table 7: Showing results of the front Impact

Force acting (N)	Type	Fixing points	Max Deformation (mm)	Max von mises stress (N/mm ²)	Factor of safety	Element size (mm)
34335	the impact load is applied on front	The rear section of the chassis is fixed	0.005	380.25	0.6	0.02

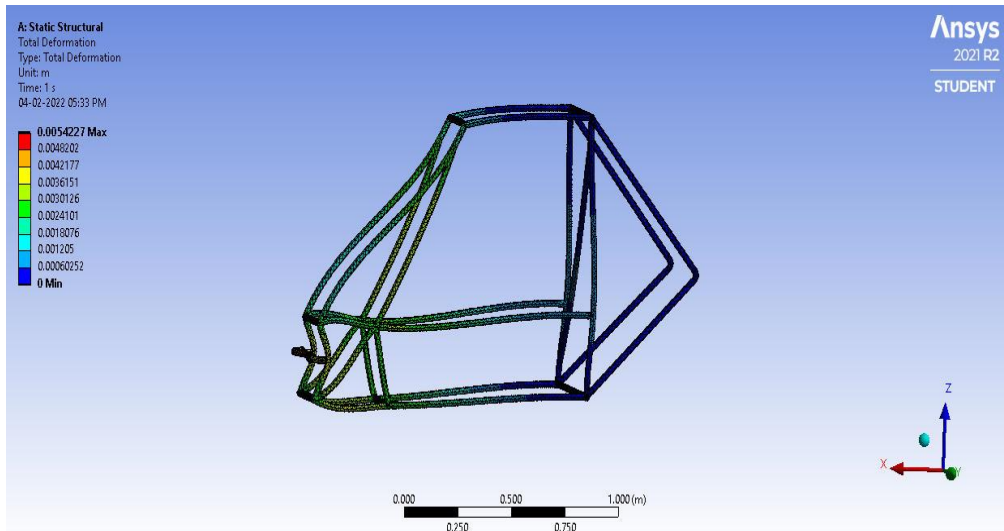


Fig-10 Front Deformation (AI 6061)

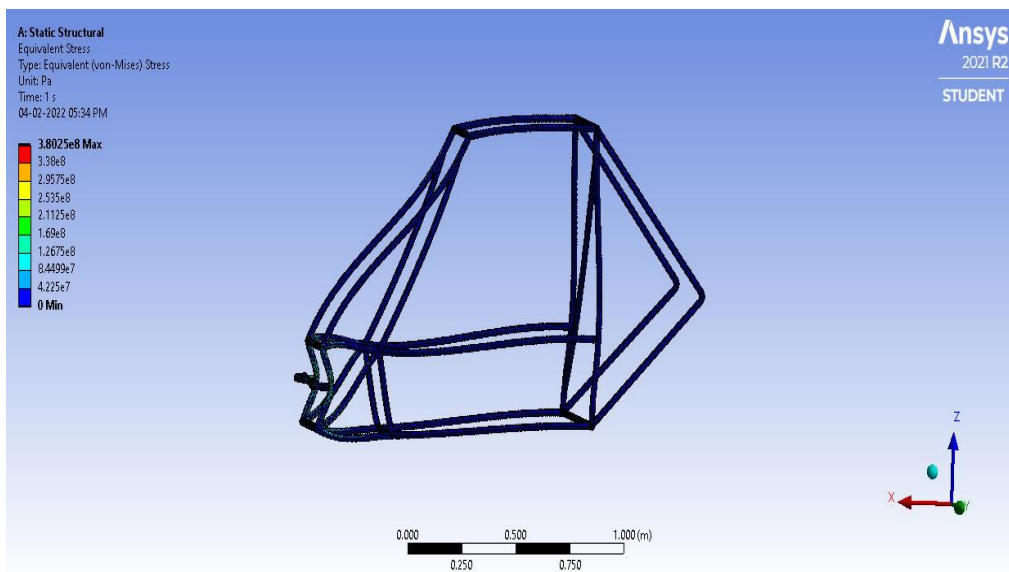


Fig-11 Von Mises Stress Pattern for Front Impact (AI 6061)

4.7 Side Impact analysis (AI 6061)

A G-Force of 4G is used in the Side impact test. Assuming that the vehicle's mass (m) includes the driver, the Side impact load is 350 kg.

Table 8: Showing results of Side impact analysis

Force acting (N)	Type	Fixing points	Max Deformation (m)	Max von mises stress (N/mm ²)	Factor of safety	Element size (mm)
13734	To the side impact members	Other side of side impact members	0.04	645	0.3	0.02

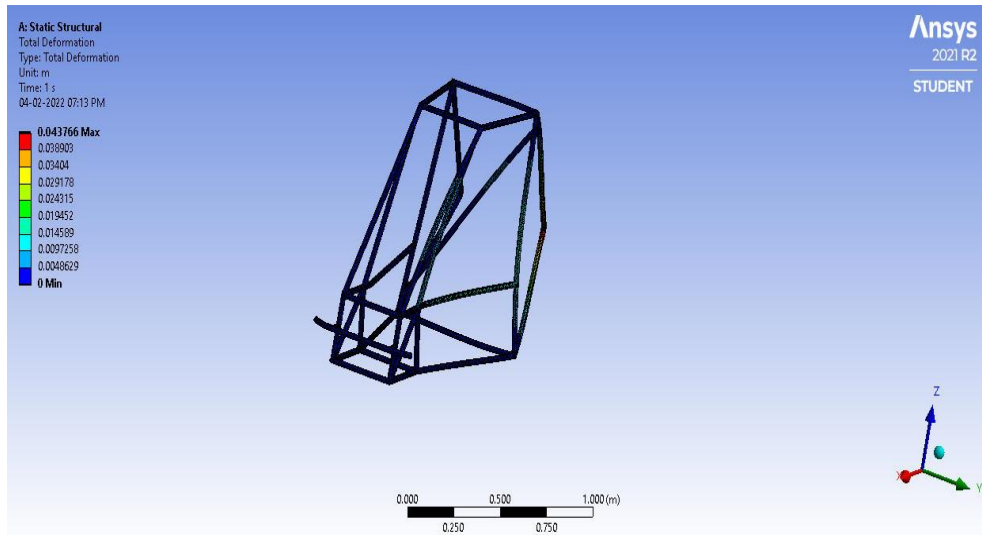


Fig-12 Side Deformation (AI 6061)

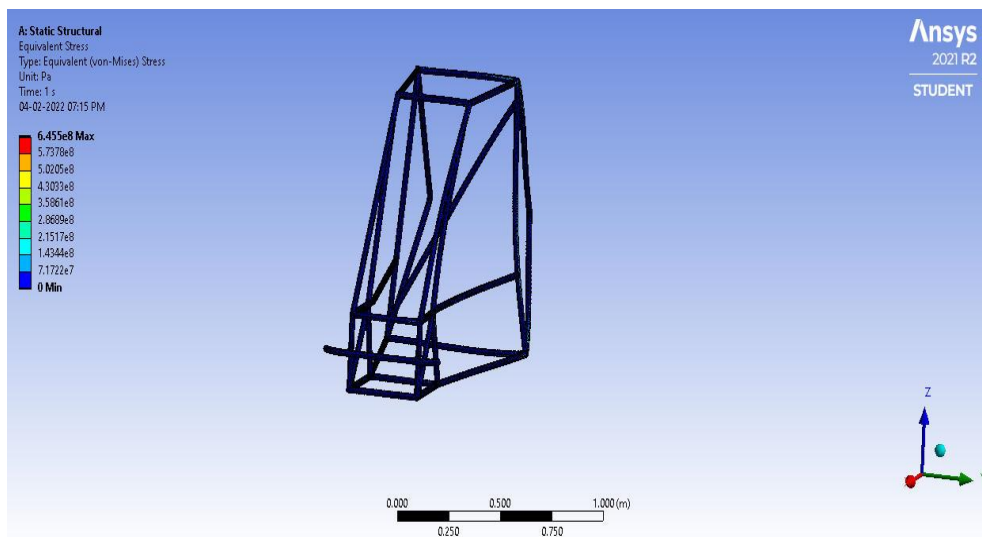


Fig-13 Von Mises Stress Pattern for Front Impact (AI 6061)

4.8 Rear Impact Analysis (AI 6061)

A G-Force of 3G is used in the Rear impact test. Assuming that the vehicle's mass (m) includes the driver, the Rear impact load is 350 kg

Table 9: Showing results of Rear impact analysis

Force acting (N)	Type	Fixing points	Max Deformation (m)	Max von mises stress (N/mm ²)	Factor of safety	Element size (mm)
10300	To the rear impact members	To the front impact members	0.005	114.48	2.2	0.02

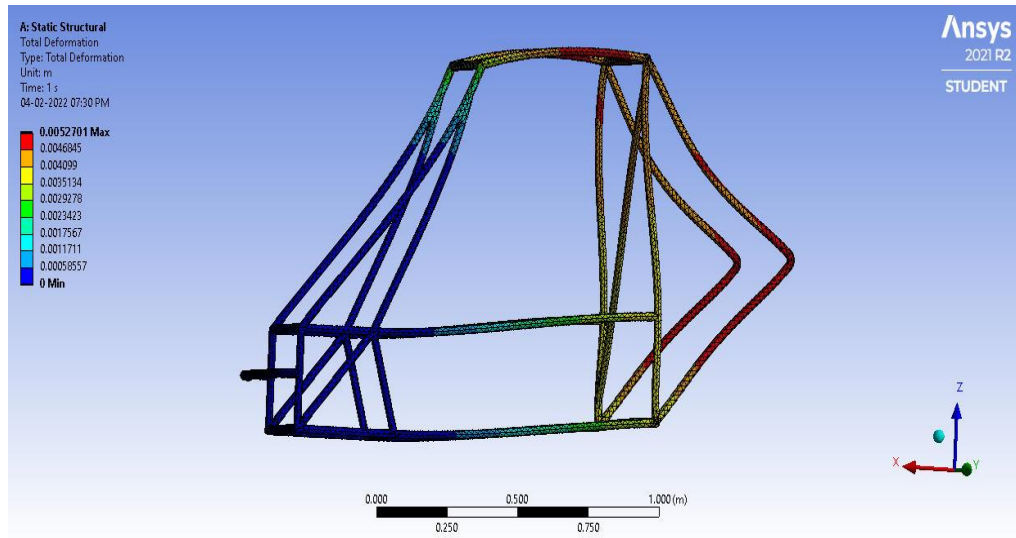


Fig-14 Rear Deformation (AI 6061)

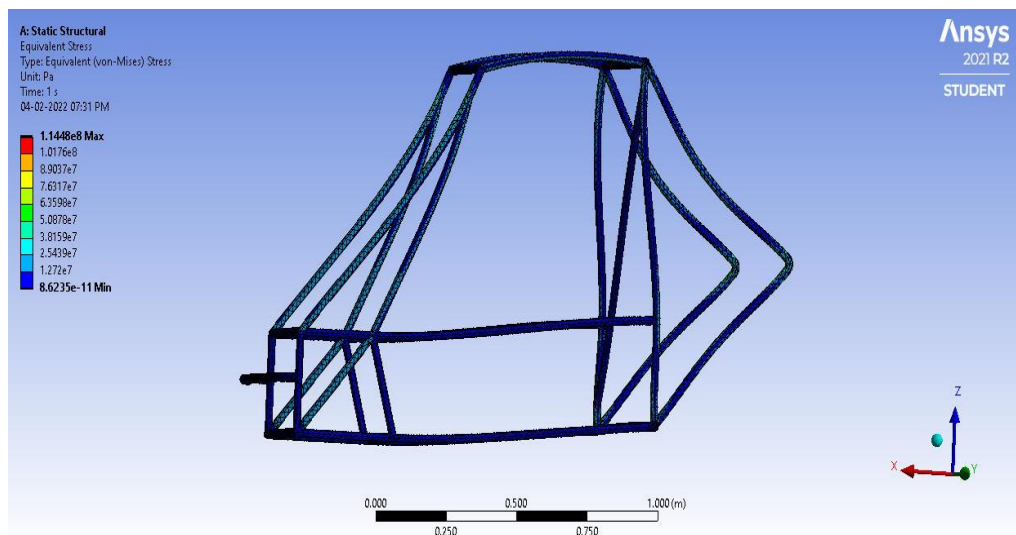


Fig-15 Von Mises Stress Pattern for Rear Impact (AI 6061)

4.9 Roll over analysis (AI 6061)

A G-Force of 3G is used in the Roll over analysis. Assuming that the vehicle's mass (m) includes the driver, the Roll over impact load is 350 kg.

Table 10: Showing results of Roll over analysis

Force acting (N)	Type	Fixing points	Max Deformation (m)	Max von mises stress (N/mm ²)	Factor of safety	Element size (mm)
10300	Acting on front and main roll hoop	Bottom of the chassis	0.003	120.7	1.9	0.02

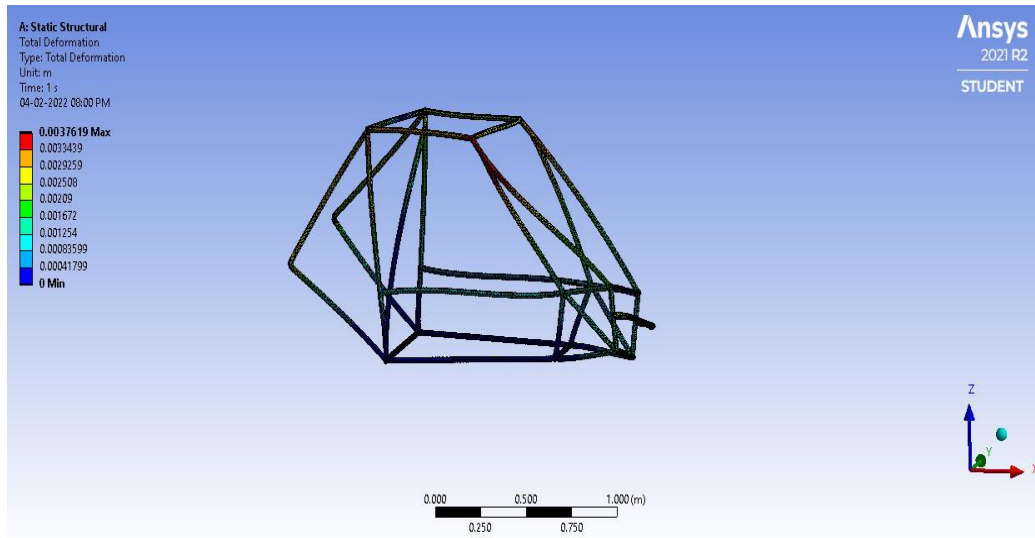


Fig-16 Roll over Deformation (AI 6061)

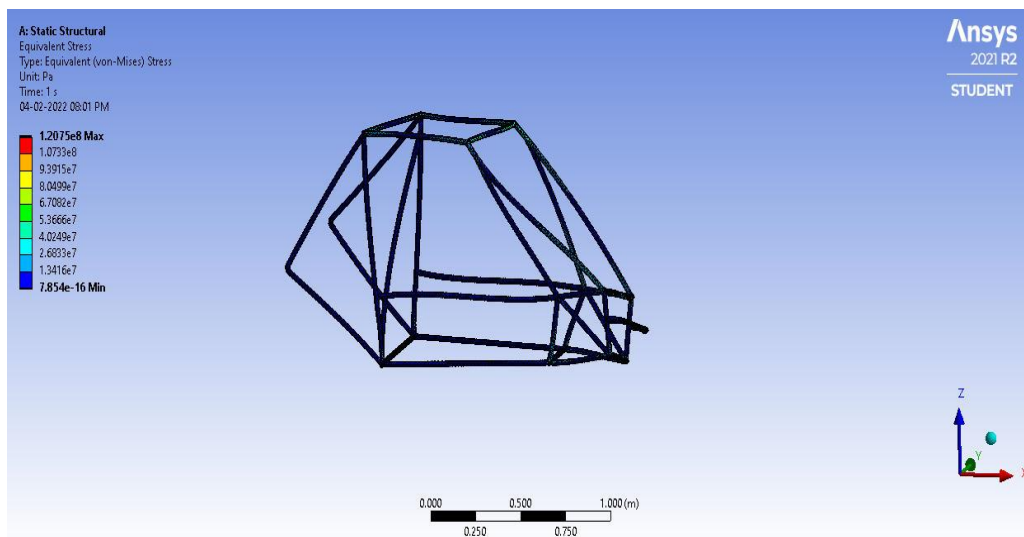


Fig-17 Von Mises Stress Pattern for Roll over Impact (AI

5. Modal analysis

The vibration mode forms and frequencies are determined via modal analysis. It is commonly understood that structures can reverberate, meaning that small stresses can result in required deformation and, presumably, injury within the structure. Many of the vibration and noise-related problems that arise in structures and working machinery are caused by resonance, or at least exacerbated by it. The resonance frequencies of a structure should be known and quantified in order to better comprehend any structural vibration problem. Modal analysis has evolved into a powerful tool for determining a system's or structure's vibration modes. Following the creation of the chassis finite element model, a modal analysis was done. The mode forms are depicted in the diagram below.

5.1 The first 10 modes of frequency are shown below

Table 11: Frequency of AISI 1018

Table 12: Frequency of AI 6061

Mode	Frequency [Hz]	Mode	Frequency [Hz]
1.	0.72588	1.	22.715
2.	0.93937	2.	29.338
3.	1.1691	3.	36.46
4.	1.2467	4.	38.894
5.	1.852	5.	57.853
6.	2.067	6.	64.569
7.	2.1173	7.	66.096
8.	2.1875	8.	68.348
9.	2.6175	9.	81.725
10.	2.6517	10.	82.823

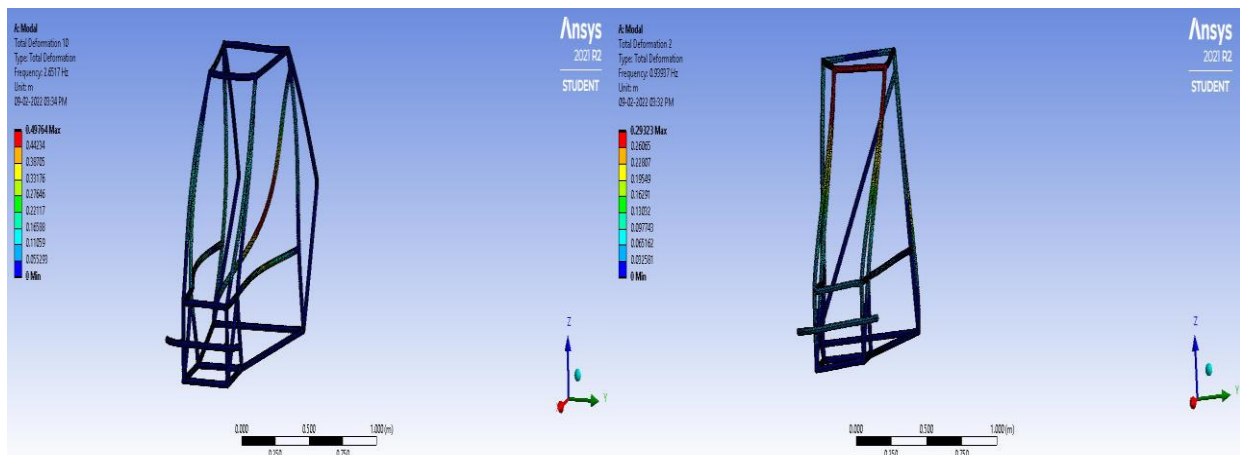


Figure 18: 1st mode displacement at the 0.72 Hz frequency (AISI1018)

Figure 19: 10st mode displacement at the 2.65 Hz frequency (AISI1018)

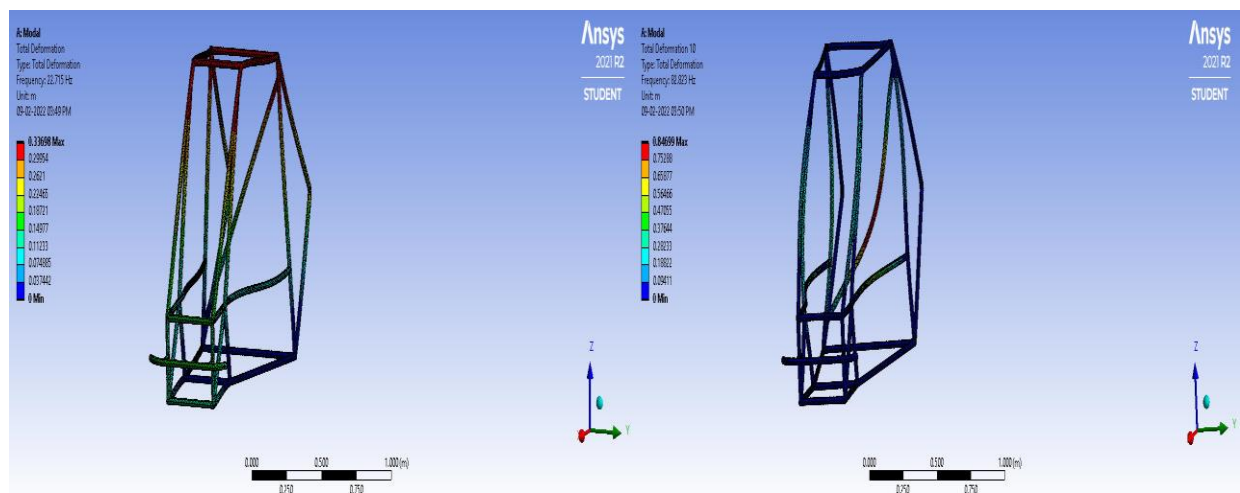


Figure 20: 1st mode displacement at the 22.71 Hz frequency (AI 6061)

Figure 21: 10st mode displacement at the 82.8371 Hz frequency (AI 6061)

6. Conclusion

AISI 1018 and Al 6061 material was selected for the chassis as it has high yield strength and strength to weight ratio as compared to each other's. The chassis of BAJA vehicle was selected as it has very high torsional rigidity and uniform distribution of forces which results in improving strength of the chassis. A preliminary design of the chassis is made using Creo 7.0 software. Al 6061 material better than AISI 1018 for stress analysis results and Deformation pattern from ANSYS workbench. In modal analysis AISI 1018 better than Al 6061 for low vibration and low frequency.

Table 13: Material Al 6061 and AISI 1018

Test	Load Applied (N)	Maximum Von Mises Stress (N/mm ²)		Maximum Displacement (mm)		FOS	
		M1	M2	M1	M2	M1	M2
Front	34335	0.005	1.8	380.25	381.7	0.6	0.9
Rear	10300	0.005	1.7	114.48	113.9	2.2	3.2
Side	13734	0.04	5.7	645	252.7	0.3	1.3
Roll over	10300	0.003	1.7	120.7	189.3	1.9	1.8

NOTE-

M1= Al 6061

M2= AISI 1018

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