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DESIGN AND STRUCTURAL ANALYSIS OF BAJA FRAME WITH CONVENTIONAL AND COMPOSITE MATERIALS

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Abstract: An all-terrain vehicle (ATV), also known as a quad, quad bike, three-wheeler, or four-wheeler, is defined by the American National Standards Institute (ANSI) as a vehicle that travels on low pressure tires, with a seat that is straddled by the operator, along with handlebars for steering control. An ATV that abides by certain rule sets that are devised by the SAE for a competition is known as BAJAS. BAJA SAE is an intercollegiate competition organized by Society of Automotive Engineers (SAE) to design, build and race off-road vehicles. Chassis is an important part of the BAJA vehicle that supports body and other different parts of the vehicle. It also surrounds and protects the occupant in case of impact and roll over incidents and also gives the aesthetics of the vehicle. These vehicles are designed to run and perform on any surface irrespective of the ground conditions. The design structure of an ATV solely depends upon it roll-cage. As an ATV is an experimental vehicle the design procedure of its roll-cage plays a critical role to give maximum possible strength while keeping the weight minimum. Roll cage of an ATV also absorbs various impacts during an event or in test runs. The aim of the project is design of Roll cage using the CATIA software and analysis is using the ANSYS software. We select two types of analysis in this project one is the static load condition and another one is the modal analysis for calculating natural frequencies of different modes, finally finding out the stresses, strains, and deformations in different cases such as front impact, side impact, rear impact by using the different materials (AISI 1018, AISI 4130, EGLASS EPOXY, CARBON FIBER) and finally concluding the material which is optimum for the Roll cage based on the values.

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I INTRODUCTION

1 Baja Vehicle

The BAJA SAE is an event for the undergraduate students of engineering, organized by the Society of Automotive Engineers. The event organized in the name of Mini-BAJA competition. It serves as a platform for young engineering students to showcase their skills by designing, fabricating and validating a single seater off road vehicle and acquire a real-life experience while overcoming obstacle and challenges .A vehicle chassis, also called as Rollcage is the main supporting structure of a BAJA SAE vehicle on which all other components are mounted.

Frame of a vehicle is act like a skeleton it holds all the important component of a automobile like engine, steering systems, suspension, drive line, differential and all the essential components which constitute together to form a chassis. Chassis Frame must be stiff enough to withstand all the forces and loads acting on it statically and dynamically and forces like shock, twist and vibration. two types of masses inside the car – Sprung and the Un-sprung mass. All the mass of other subsystem components that is damped by the spring is called as the sprung mass. Generally the sprung mass must be great than that of the un-sprung mass.

FIGURE 1 BAJA SAE VEHICLE

FIGURE 2 ATV BAJA SAE

Following are the major points which were considered for Designing the off road vehicle:

1. Endurance
2. Safety and Ergonomics.
3. Market availability.
4. Cost of the components.
5. Standardization o Safe engineering practices

1.2 ELEMENTS OF ROLL CAGE:

1.2.1 PRIMARY MEMBERS

- Rear Roll Hoop (RRH)
- Roll Hoop Overhead Members (RHO
- Front Bracing Members (FBM)
- Lateral Cross Member (LC)
- Front Lateral Cross Member (FLC)

1.2.2 SECONDARY MEMBERS

- Lateral Diagonal Bracing (LDB)
- Lower Frame Side (LFS)
- Side Impact Member (SIM)
- Fore/Aft Bracing (FAB)
- Under Seat Member (USM)
- All Other Required Cross Members

1.3 LOADS ON THE CHASSIS FRAME

The chassis frame in general are is subjected to the following loads:

- Weight of the vehicle and the passengers, which causes vertical bending of the side members
- Vertical loads when the vehicle comes across a bump or hollow, which results in longitudinal torsion due to one wheel lifted (or lowered) with other wheels at the usual road level
- Loads due to the camber, side wind, cornering force while taking a turn, which result in lateral bending of side members
- Loads due to wheel impact with road obstacles may cause that particular wheel to remain obstructed while the other wheel tends to move forward, distorting the frame to parallelogram shape
- Engine torque and braking torque tending to bend the side members in vertical plane
- Impact loads during a collision

II. LITERATURE REVIEW

A vehicle chassis, also called as Rollcage is the main supporting structure of a BAJA SAE vehicle on which all other components are mounted. The main function of a chassis is to support the vehicle's mechanical components and deal with static and dynamic loads, without undue deflection or distortion. It should be designed in an ergonomic and strong effective manner at optimum cost and weight for rough terrain purposes. In current scenario available are overdesigned i.e. their structural rigidity and sturdiness are more than requirement. This leads to increase in weight and cost of manufacturing.

Jonathan Hastie's [1] analysis allowed the addition of three important and key structural components to help the vehicle with stand front and side impacts as well as the forces due to the loading of the shock mounts. In this analysis it was found that design was failing in Roll Over, the findings from the finite element analysis and the actual failure have allowed us to integrate a solution to this problem into their design from the beginning.

Smita, C.Saddu [4] et. al Weight reduction is now day's main issue in the automobile industry. Reducing weight while increasing or maintaining strength of product is getting to be highly important. The automobile industry has shown increasing interest in the replacement of steel spring with composite leaf spring due to high strength to weight ratio. Advanced composite materials offer significant advantages in strength, stiffness, high natural frequency and light weight relative to conventional metallic materials. This paper describes the analysis of steel and composite material leaf spring. Then these results are compared with that of the experimental results. Juvvi Siva Nagaraju

Sandip Godse D.A.Patel[6] et. Al Chassis is a major component in a vehicle system. This work involved static analysis to determine key characteristics of a chassis. The static characteristics include identifying location of high stress area. Mathematical calculations were carried out to validate the static analysis.

K.Rajasekar, R.SaravananP[7] et. Al Chassis is the most important structural member in the On-Road vehicles. In order to overcome more failure in the chassis structure and ensure the safety, the variable section chassis structure has to be designed based on the variable loads along the length of the vehicle. The present study reviewed the literature on chassis design and presented the findings in the subsequent sections.

ROLLCAGE: The chassis or Space frame of the mini Baja is called as roll cage. The roll cage serves many critical functions that include linking the power train, control, and suspension systems together. It must also be capable of protecting the driver and crucial components of the vehicle while having an impact towards rigid structures or accidents with other vehicles.

III PROJECT OVER VIEW

3.1 DESIGN OBJECTIVES OF CHASSIS ARE:-

1) To get knowledge of BAJA Chassis Design for beginner in stepwise manner so to avoid unnecessary thing and focuses on competition.

2) Focusing area of analysing Software to get desirable result.

3) To make use of welding alternative of hydraulic press.

4) Use of welding Principle effectively without increasing weight of chassis and make it simple.

3.2 PROBLEM IDENTIFICATION:

Design and carry out Finite Element Analysis and Rollover Simulations for an off road vehicle chassis with suitable tube diameter, wall thickness and material to withstand different load conditions to have a high Factor of safety, least weight and reasonable cost. Weight reduction is now the main issue in automobile industries. Because if the weight of the vehicle increases the fuel consumption increases. At the same time as the weight of the vehicle increases the cost also increases which becomes a major issue while purchasing an automobile. For example if we take frame of BAJA vehicle frame. For these reasons, fiber composites have emerged as a major class of structural material and are either used or being considered as substitutions for metals in many weight-critical components in aerospace, automotive and other industries. High damping capacity of composite materials can be beneficial in many automotive applications in which noise, vibration, and hardness is a critical issue for passenger comfort.

3.3 SCOPE OF PROJECT:

1. Baja vehicle is the wide popularity as it is suitable for most of people to make their own playing race car as well as working car by using their knowledge and competition with other in racing.

2. Making advance engineering Knowledge to use at chassis for making it better and light weight.

3. Using variety of material to make better chassis for various applications and mostly for racing purpose.

4. Practice Engineering knowledge with budgeting for making Cost effective chassis.

3.4 METHODOLOGY

Design of any component is consists of three major principles:

1. Optimization
2. Safety
3. Comfort

Step 1: Collecting information and data related to Baja vehicle chassis

Step 2: A fully parametric model of the Baja vehicle chassis is created in catia software.

Step 3: Model obtained in igs is analyzed using ANSYS 16.5 (work bench) to obtain stresses, strain, deformation etc.

Step 4: Front, rear and side impact manual calculations are done

Step 5: Finally, we compare the results obtained from ANSYS and compared different materials.(CARBON FIBER, AISI1018, E-GLASS, AISI 4130)

3.5 FUNCTIONS OF THE FRAME

1. To carry load of the passengers or goods carried in the body.

2. To support the load of the body, engine, gear box etc.,

3. To with stand the forces caused due to the sudden braking or acceleration.

4. To with stand the stresses caused due to the bad road condition.

5. To with stand centrifugal force while cornering.

3.6 MATERIAL PROPERTIES

PROPERTIES	UNITS	STEEL 1018	STEEL 4130	CARBON FIBER	E-GLASS EPOXY
DENSITY	Kg/m³	7870	7850	1500	1983
YOUNG'S MODULUS	Mpa	205000	210000	155000	78000
POSSION'S RATIO	µ	0.3	0.29	0.38	0.27
ULTIMATE TENSILE STRENGTH	Mpa	440	560	600	490
YIELD STRENGTH	Mpa	370	435	550	420

FIGURE 3MATERIAL PROPERTIES

3.7 DESIGN OBJECTIVES:

1. Creation of a cad model of the structure.

2. Generation of mesh.

3. Application of the loads & constraints in depending.

4. Solution of the respective test Determination of the stress values and deformation forces.

5. Modification of Cad- design.

REAR IMPACT: In real conditions during rear impact, another vehicle is going to hit vehicle on its rear part. The analysis conditions and results are shown in Figures

CALCULATIONS:

From work energy principal

Work done = change in kinetic energies

$W = (0.5 \times M \times vfinal^2 - 0.5 \times M \times vinitial^2)$

$|W| = |-0.5 \times M \times (Vinitial)^2|$

$= |-0.5 \times 220 \times 16.672 \times 16.672|$

= 30575.11 Nm

Now,

Work done = force × displacement= F × s

S = impact time × Vmaximum

= 0.3 ×16.67

= 5.001 m

So, from (1) we get,

F = W/ s = 30575.11 / 5.001

= 6112.3≈ 6500 N (3G's)

SIDE IMPACT: In real conditions during rear impact, another vehicle is going to hit vehicle on its side members. The analysis conditions and results are shown in figures.

CALCULATIONS:

From work energy principal,

Work done = change in kinetic energies

$W = (0.5 \times M \times vfinal^2 - 0.5 \times M \times vinitial^2)$

$|W| = |-0.5 \times M \times (Vinitial) 2|$

$= |-0.5 \times 220 \times 16.672 \times 16.672|$

= 30575.11 Nm

Now,

Work done = force × displacement= F × s

S = impact time × Vmaximum

= 0.3 ×16.67

= 5.001 m So, from (1) we get,

F = W/ s = 30575.11 / 5.001

= 6112.3 ≈ 6500 N (3G's)

3.8 dimensions of the rollcage baja vechicle:

The design of the roll cage in any condition must always ensure enough clearances from members for safety and free movement of the driver. The diameter of the primary member is 30 (mm) with thickness of 1.65 (mm) and that of the secondary members is 25 (mm) The cross-section of the members is circular as it would bear more strength than beam section with ability to withstand torsional stresses also.

Attributes	values
Length of the vehicle	1725mm
Width of the vehicle	817mm
Height of the vehicle	900mm
Weight of the vehicle including driver	249.5kgs
Weight of the vehicle frame	38 kgs
Thickness of the tube	2.5
Inner diameter	25mm
Outer diameter	30mm
Ground clearance	320mm

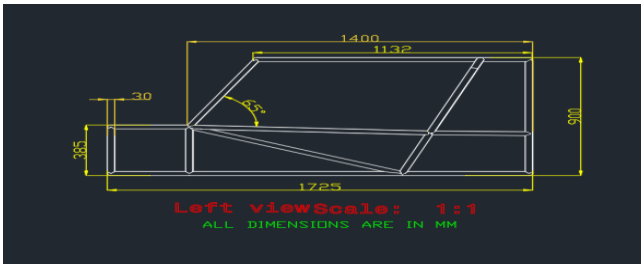

Figure 4 SIDE VIEW OF THE FRAME

IV DIMENSIONS AND DESIGN PROCEDURE IN CATIA:

Create the frame in wire frame and surface design workbench using planes, points, lines after go to the part design workbench create the diameter of inner and outer circles as per the above dimensions now go to the rib option apply each and every lines as shown below figure

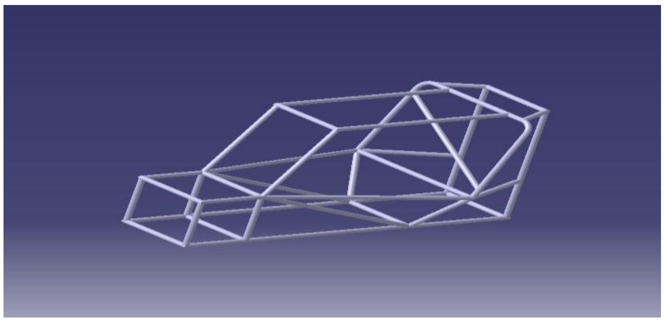

FIGURE 5 ISOMETRIC VIEW

V ANALYSIS PROCEDURE IN ANSYS:

Designed component in catia workbench after imported into ansys workbench now select the steady state thermal analysis .

1.ENGINEEERING MATERIALS (MATERIAL PROPERTIES).

2. CREATE OR IMPORT GEOMENTRY.

3.MODEL(APPLY MESHING).

4.SET UP(BOUNDARY CONDITIONS)

5.SOLUTION

6.RESULTS

5.1 STATIC STRUCTURAL ANALYSIS

The static structural analysis calculates the stresses, displacements, strains, and forces in structures caused by a load that does not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that the loads and the structure's response are assumed to change slowly with respect to time. A static structural load can be performed using the ANSYS WORKBENCH solver. The types of loading that can be applied in a static analysis include.

5.2 MODAL ANAYSIS:

In modal analysis free natural vibration frequencies of roll cage frame was found out for the first 6 modes keeping the suspension members and the attached member of the mounts constrained. All the modes that were found out were rigid body mode.Vibrations can also be induced due to the bumps or road but as their intensity would be low it is not considered. Although the bumps and vibration due to reciprocating engine .

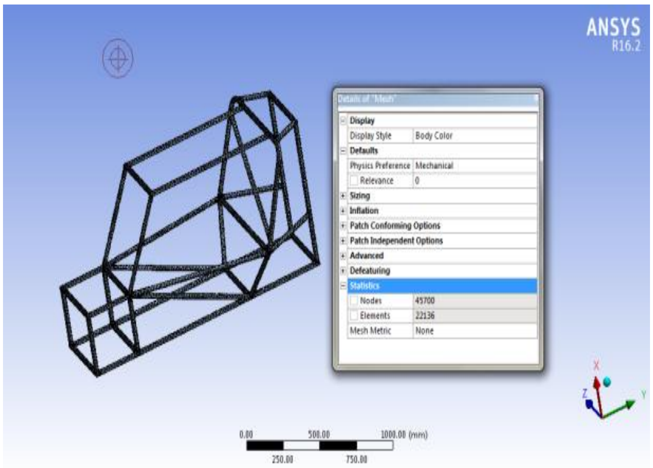

Figure 6 MESH: NODES, ELEMENTS:

VI RESULTS AND DISCUSSIONS

6.1 STATIC ANALYSIS RESULTS:

This analysis is performed to find Structural parameters such as Stresses, Strains, Deformation, Here we observed results on two materials namely **(AISI 1018, AISI 4130, EGLASS EPOXY, CARBON FIBER)**.

6.1.1FRONT IMPACT ANALYSIS OF AISI 1018 MATERIAL:

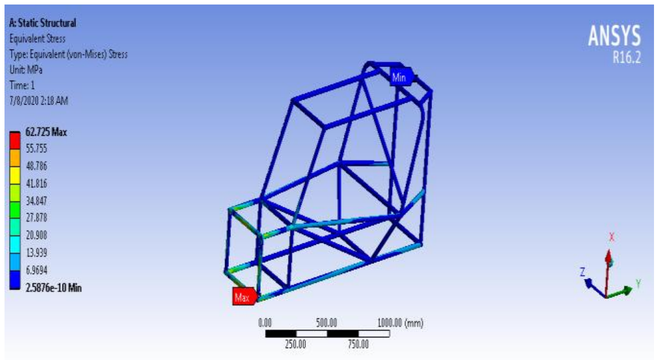

Figure 7 VON-MISSES STRESS OF AISI 1018 MATERIAL

6.1.2FRONT IMPACT ANALYSIS OF AISI 4130 MATERIAL:

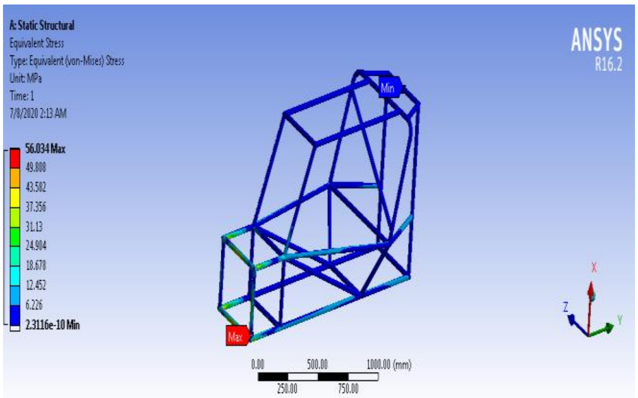

Figure 8 VON-MISSES STRESS OF AISI 4130 MATERIAL

6.1.3FRONT IMPACT ANALYSIS OF CARBON FIBER MATERIAL:

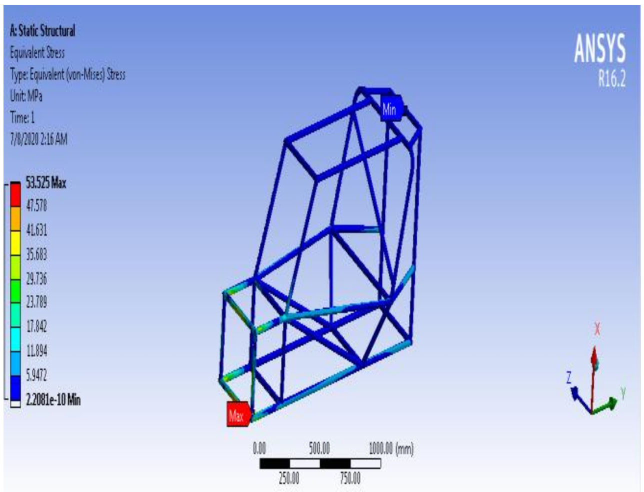

Figure 9 VON-MISSES STRESS OF CARBON FIBER MATERIAL

6.1.4 FRONT IMPACT ANALYSIS OF EGLASS FIBER MATERIAL:

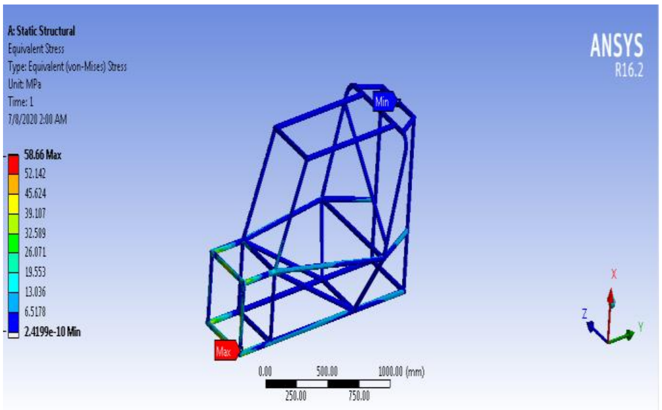

FIGURE 10 VON-MISSES STRESS OF E-GLASS FIBER MATERIAL

6.2 REAR IMPACT:

6.2.1 REAR IMPACT ANALYSIS OF AISI 1018 MATERIAL:

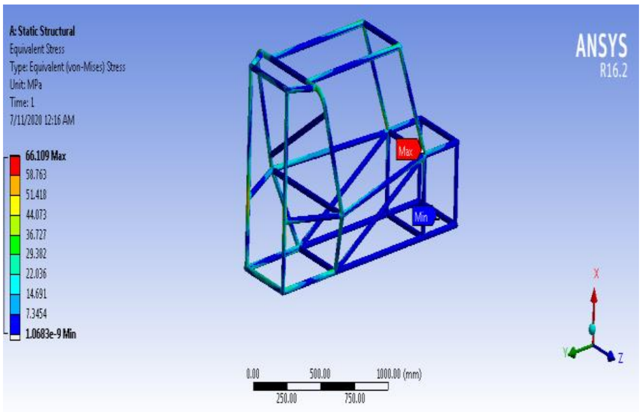

FIGURE 11 VON-MISSES STRESS OF AISI 1018 MATERIAL

6.2.2 REAR IMPACT ANALYSIS OF AISI 4130 MATERIAL:

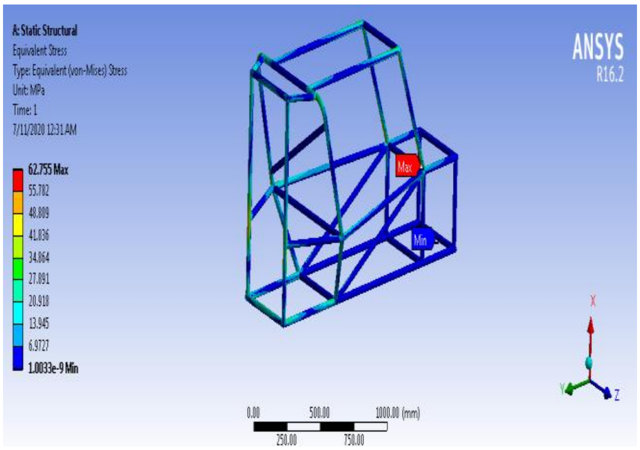

FIGURE 12 VON-MISSES STRESS OF AISI 4130 MATERIAL

6.2.3REAR IMPACT ANALYSIS OF CARBON FIBER MATERIAL:

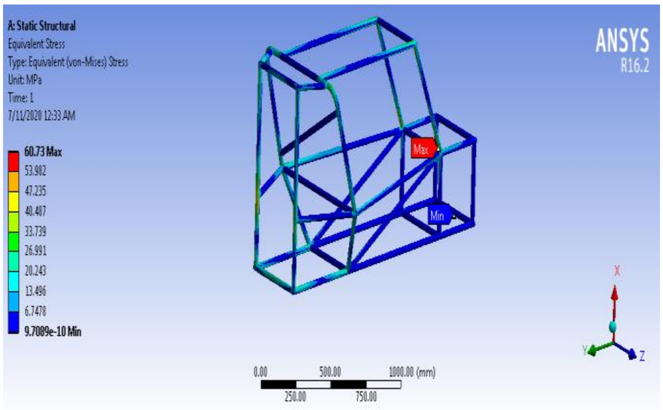

FIGURE 13 VON-MISSES STRESS OF CARBON FIBER MATERIAL

6.2.4 REAR IMPACT ANALYSIS OF E-GLASS FIBER MATERIAL:

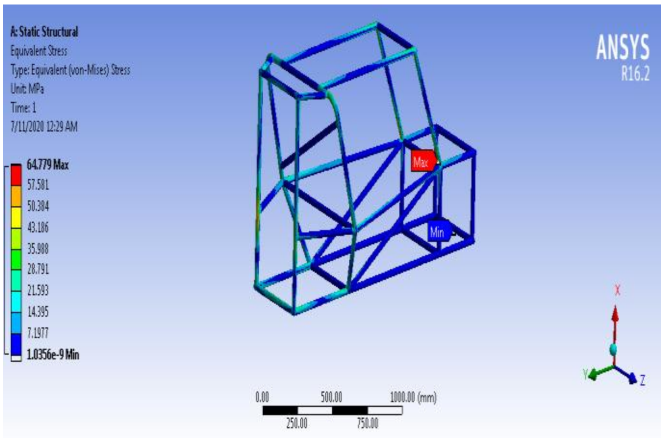

FIGURE 14 VON-MISSES STRESS OF E-GLASS FIBER MATERIAL

6.3 SIDE IMPACT

6.3.1 SIDE IMPACT ANALYSIS OF AISI 1018 MATERIAL:

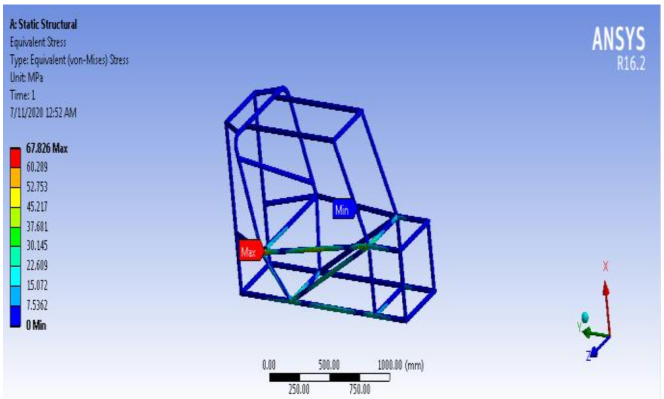

FIGURE 15 VON-MISSES STRESS OF AISI 1018 MATERIAL

6.3.2 SIDE IMPACT ANALYSIS OF AISI 4130 MATERIAL:

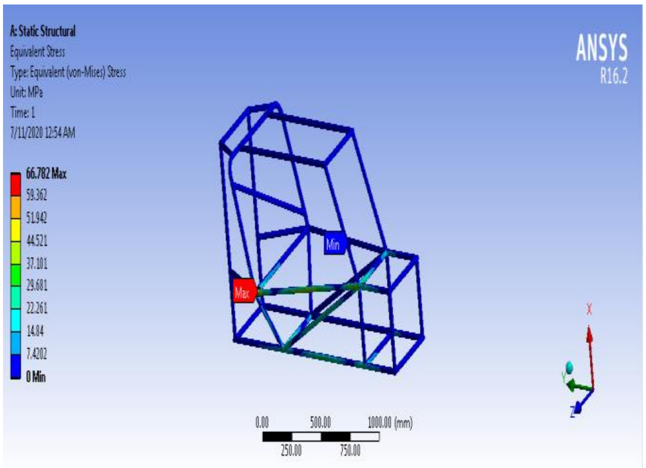

FIGURE 16 VON-MISSES STRESS OF AISI 4130 MATERIAL

6.3.3SIDE IMPACT ANALYSIS OF CARBON FIBER MATERIAL:

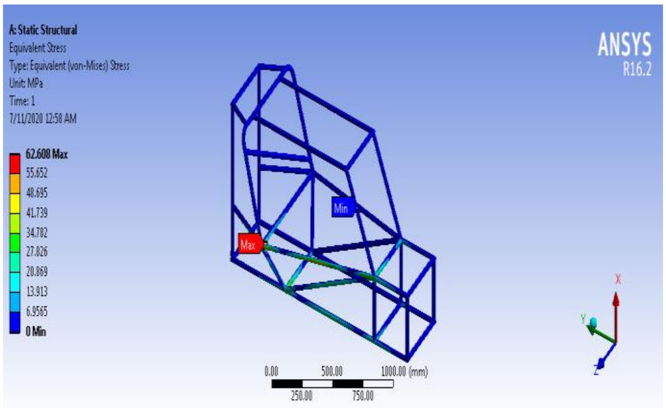

FIGURE 17 VON-MISSES STRESS OF CARBON FIBER MATERIAL

6.3.4 SIDE IMPACT ANALYSIS OF E-GLASS FIBER MATERIAL:

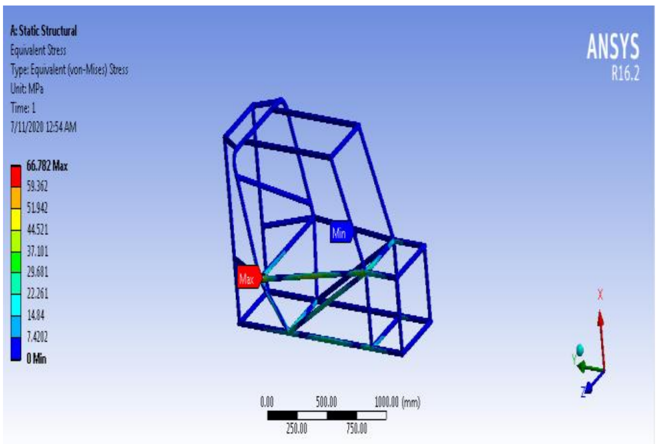

FIGURE 18 VON-MISSES STRESS OF E-GLASS FIBER MATERIAL

6.4 MODAL ANALYSIS OF AISI 4130 MATERIAL:

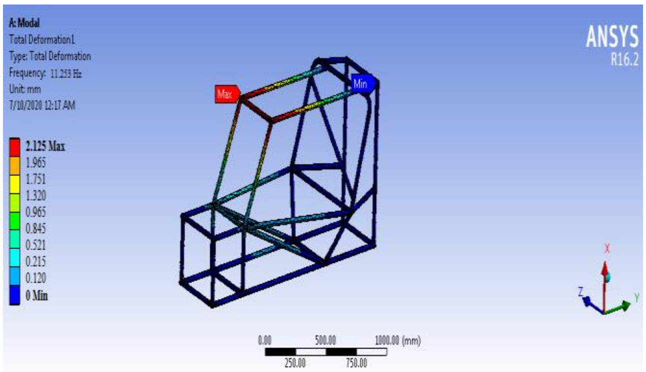

Figure 19 MODE 1 OF AISI 4130 MATERIAL

6.5 MODAL ANALYSIS OF CARBON FIBER MATERIAL:

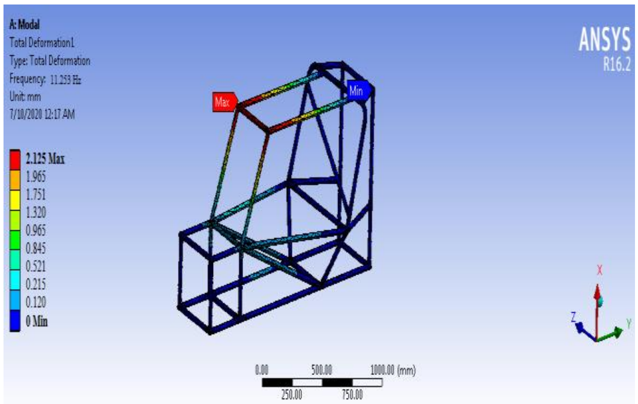

Figure 20 Mode 1 OF CARBON FIBER MATERIAL

6.6 GRAPHS

6.6.1 FRONT IMPACT:

From below figure, we can observe that in case of equivalent (von-misses) stress, Total deformation, shear stress, strain BAJA CHASSIS .Apply front impact load on chassis fixed back end and it is made up of (AISI1018, AISI 4130, Carbon fiber, E-Glass epoxy) carbon fiber is Observed to have least (von-misses) stress, Total deformation, shear stress, strain comparison with remaining materials including the present material is AISI 1018 material as shown below figure.

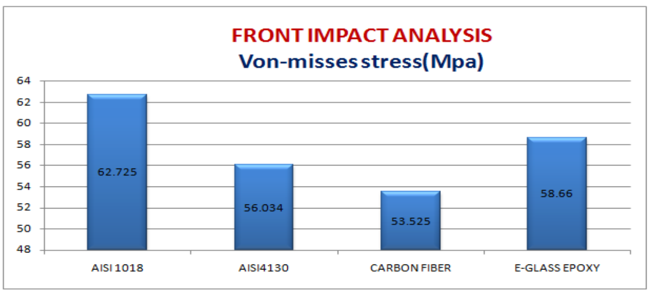

FIGURE 21 VONMISSES STRESS OF FRONT IMPACT

6.6.2 REAR IMPACT:

From below figure, we can observe that in case of equivalent (von-misses) stress, Total deformation, shear stress, strain BAJA CHASSIS .Apply Rear impact load on chassis fixed Front end and it is made up of (AISI1018, AISI 4130, Carbon fiber, E-Glass epoxy) carbon fiber is Observed to have least (von-misses) stress, Total deformation, shear stress, strain comparison with remaining materials including the present material is AISI 1018 material as shown below figure.

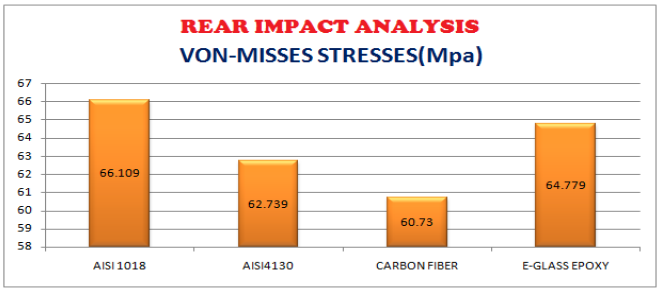

FIGURE 22 VONMISSES STRESS OF REAR IMPACT

6.6.3 SIDE IMPACT:

From below figure, we can observe that in case of equivalent (von-misses) stress, Total deformation, shear stress, strain BAJA CHASSIS .Apply Right side impact load on chassis fixed at left end and it is made up of (AISI1018, AISI 4130, Carbon fiber, E-Glass epoxy) carbon fiber is Observed to have least (von-misses) stress, Total deformation, shear stress, strain comparison with remaining materials including the present material is AISI 1018 material as shown below figure.

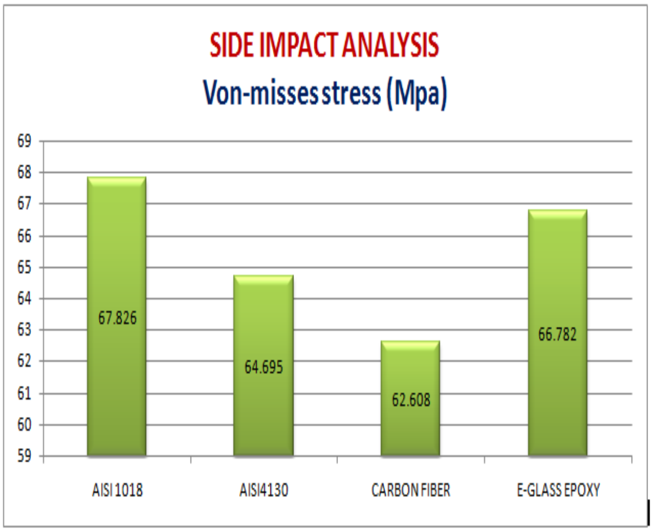

FIGURE 23 VONMISSES STRESS OF SIDE IMPACT

6.4 MODAL ANALYSIS OF AISI 4130 MATERIAL:

Modal analysis graph is the study of the dynamic properties of systems in the frequency domain as shown below figure in different modes shows the total deformation and frequencies of AISI 4130 & Carbon fiber.

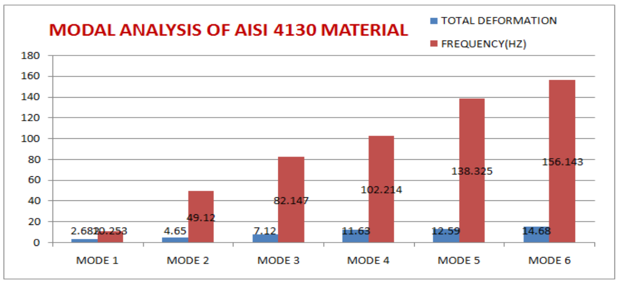

FIGURE 24 MODAL ANALSYSIS OF AISI 4130 MATERIAL

VI CONCLUSION

We had successfully analyzed the roll cage structure for its strength against the collision from front, rear as well as side. This project thoroughly deals with various load analysis on BAJA roll cage and optimization has been achieved by reducing the weight of the roll cage. Roll cage designed is perfect for use in BAJA SAE Parameters taken in rule book. Perhaps the biggest advantage of composites is their high strength-to-weight ratio. As per the above experiments we can conclude that Carbon fiber material is best for the Frame and AISI 4130 is also suitable when we prefer conventional materials. Analysis performed using finite element method was successfully and carried out on the Rollcage. Hence the chassis design is safe to manufacture with composite material (Carbon Fibre) when compared to other specified materials.

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