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Design, analysis and optimization of all terrain vehicle chassis ensuring structural rigidity

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ABSTRACT

The purpose of this project is to study, analyze the previous year BAJA roll-cage chassis vehicles to fix fault and design a new chassis with better performance by optimizing the weight and ergonomics. The design panel has identified certain area to optimize the vehicle to bring down the overall volume like, engine compartments, driver cabin, legroom, suspension hard points, and steering area. Different experimental designs using the Baja SAE regulations for 2020 and Mega ATV championship 2020 directive as a standard for design selection. Primary FEA investigation was carried out on prior designs and the results are taken into account for improving the overall aesthetics of the vehicle. The conveyance is designed with given guidelines and rulebook versions of SAE BAJA 2020 and MAC 2020 in all aspects. As SAE BAJA rule book is considered to be in macrocosmic standard after the completion of the CAD model, the roll cage and other subsystems of the conveyance has been tested in FEA methods to bring out the best design output and to minimize the chance of failure of the components. Robust engineering techniques with sound knowledge on ergonomics and vehicle dynamics have allowed our team to produce an efficient vehicle for the competitions in future.

Selection and peer-review under responsibility of the scientific committee of the International Conference on Materials, Manufacturing and Mechanical Engineering for Sustainable Developments-2020.

1. Introduction

Baja is a special kind of four-wheeled vehicle used for recreational and exploration purposes. It is designed for off road usage and for endurance of a rough terrain [1,2]. Tubes formed chassis that square measure commercially obtainable within the market square measure spherical, parallelogram and sq. of those the foremost appropriate for producing an area frame are spherical tube due to its geometric property of withstanding load and undergoing deformation equally in spite of its axis [3–5]. The steel material that's selected should have the elongation property high. It should be ductile with high stiffness. The planning should even be created to realize structural rigidity instead of utterly relying upon the strength of the fabric [6–8]. So the quantitative relation of the last word strength to the operating strength should be higher. area frame being the element that weights a lot of high and also the usage volume is high its individual centre of gravity affects the centre of gravity of the vehicle[9].

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2. Methodology

The chassis or Space frame of the mini Baja is called as roll cage. The method, machinery used and possible fabrication should be thought of the design for manufacturability pointers are going to be followed to realize the specified [10–12]. The general length of the vehicle is been restricted to be but 108 in. in order that throughout the turning, performance and therefore the handling of the vehicle are going to be simple. Additionally a compact designed vehicle ought to be outcome. Since it's one sitting the motive force comfort alone are often focused. This offers United States associate difficult style part in order that the motive force applied science and therefore the engineering constrains rebel. one in all the worst state of affairs of the all-terrain vehicle is that roll over .Due to the in-consistent parcel of land the vehicle roll over upper side. It's a awfully major impact on driver's safety. FEA analysis is finished to confirm roll over safety [13–14]. Driver with such associate all-terrain vehicle should be ready to drive well. Subsystems concerns. Before taking into modifying any of the parts of the vehicle, the team required to become aware of all the elements that compose a vehicle. These systems embody

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the steering, suspension, brakes, engine, drivetrain, and frame. Each subsystem is interlinked as it is mounted on the chassis. The frame needed to be sturdy enough to withstand all the components including the mass of the driver. Suspension System Suspension is defined as a system of tires, tire air, springs, shock absorbers, and linkages that connects a vehicle to its wheels and allows relative motion between the two.

3. Material selection

The material is selected based on SAE BAJA 2020 rule book guidance. It's instructed that primary members and secondary members must be used only in specific geometrical areas (Table 1).

Table 1
Material selection.

Specifications	Characteristics
Medium	AISI 4130
Structure	Tubular
FOS	(>1.5)
CoG	Possibly low
Cost	Low
Manufacturing feasibility	High
Weld Properties	High
Ride Height	>12 in.
Crash withstand ability	High

4. CAD model

Dimensions of the primary and secondary material used are 29.2*1.65 mm & 25.4*1.25 mm. The design of the roll cage was done using SOLIDWORKS 2018 software. The shear modulus of the material is 80 GPa. The isometric view of the chassis is shown in the Fig. 1 using solid works.

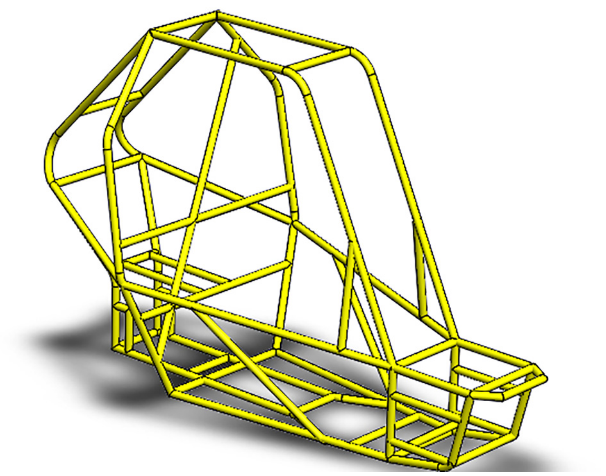

Fig. 1. Isometric view of chassis.

5. Calculations

5.1. Considerations

The chassis is subjected to undergo various impacts forces in an event of collision like, front impact, rear impact, and side impact and roll over impact. These conditions were taken into account and given a boundary condition in each test process.

We know that,

Calculated mass of the vehicle (including driver) = 230 kg. (170 kg + 60 kg)

Acceleration of the vehicle = v/t = 12.89/0.1.

G = 9.81 m/s.

F = m*a.

Front Impact.

F = m*a.

F = 230*12.89 m/s * 0.1 s^{-1} => 29647 N (rounded to 30KN)

This means the force is 13 times of the g-force action on the frontal area.

Rear Impact.

The rear impact is estimated to 7 times of g-force depends upon the mass and acceleration of other vehicle during impact. Hence,

F = 230*9.81*7 => 15778 N (rounded to 16KN)

Side Impact.

The side impact is estimated to 4 times of g-force acting on the side member of the chassis. Hence,

F = 230*9.81*4 => 9016 N (rounded to 9KN)

Roll over Impact.

The side impact is estimated to 2.5 times of g-force acting on the side member of the chassis. Hence,

F = 230*9.81*2.5 => 5640.75 N (rounded to 6KN)

6. Finite element analysis

The impact test are carried out in ANSYS 19.0 R2 software to get accurate results. These test are done based of SAE guideline of impact tests whose goal is to ensure the safety of the passenger and driver. The initial boundary conditions for FEA is set and portrayed based on the real time scenarios during an event of collision if any. As the main goal of the analysis is to find the total deformation and stress as the output and to study the behavior of the chassis based on this simulated results.

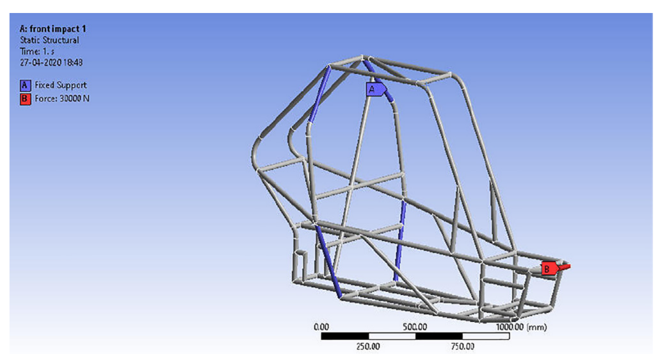

Fig. 2. Boundary conditions – Front impact.

6.1. Front impact test

In this condition the rear suspension mounts are fixed or the firewall beams are considered fixed as both condition gives similar output. Force is applied on front toe bar in this scenario (Figs. 2–4).

6.1.1. Observation

In the result, it's observed that the maximum stress can be seen only in the toe bar and the driver cabin received only minimal amount of stress. Hence safety of driver is ensured.

6.2. Rear impact test

In this condition the front swing arm mounts are fixed and force is given at the rear side of the vehicle (Figs. 5–7).

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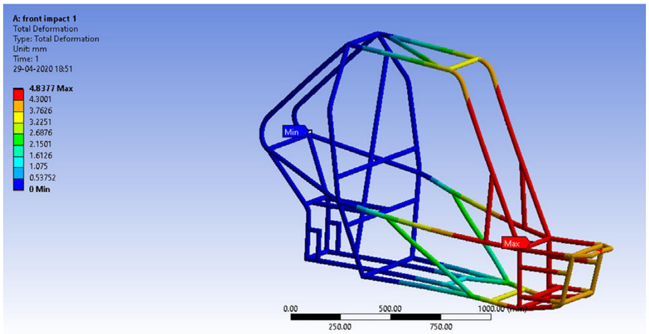

Fig. 3. Total deformation – Front impact.

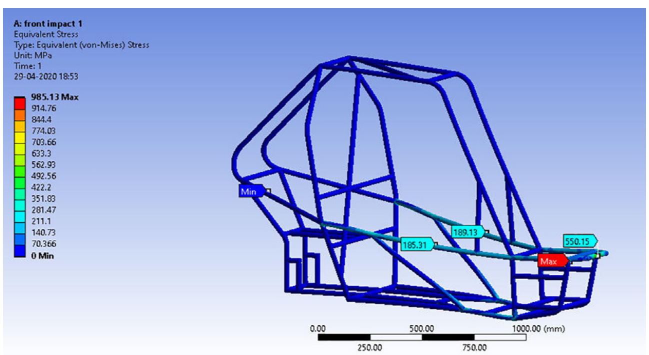

Fig. 4. Equivalent stress – Front impact.

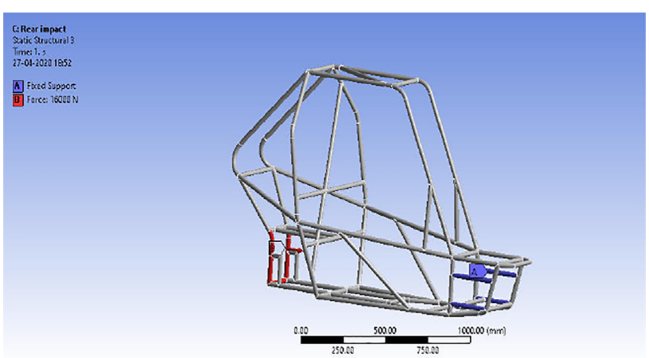

Fig. 5. Rear impact – Boundary conditions.

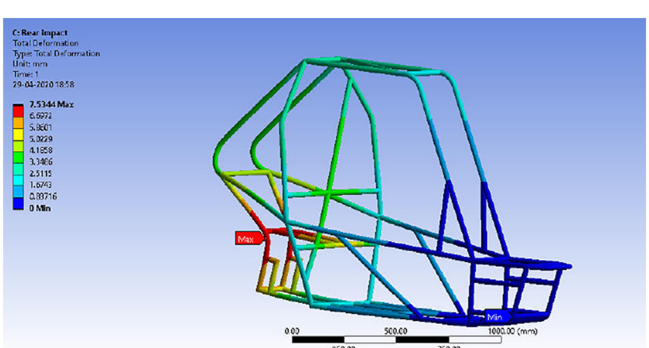

Fig. 6. Rear impact – Total deformation.

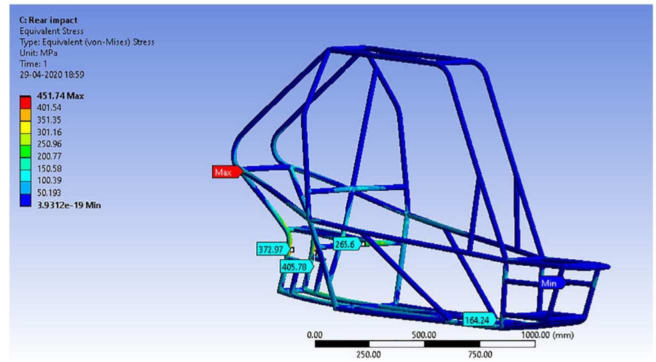

Fig. 7. Rear impact – Equivalent stress.

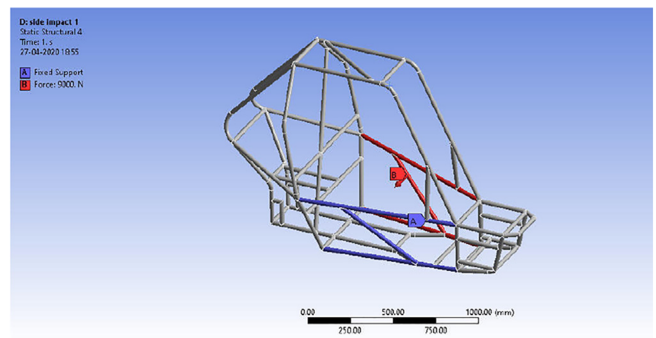

Fig. 8. Side impact – Boundary condition.

6.2.1. Observation

In the result, it's observed that the maximum stress can be seen only in the rear support member and the driver cabin received only minimal amount of stress when compared. Hence safety of driver is ensured.

6.3. Side impact

In this condition the side impact members of right side of vehicle are fixed and force is given on the side impact member of left side of the vehicle (Figs. 8–10).

6.3.1. Observation

In the result, it's observed that the maximum stress can be seen only in the weld joints of the SIM (side impact member) and the driver cabin received only minimal amount of stress when compared. Hence safety of driver is ensured.

6.4. Roll over impact test

In this condition the LFS (lower frame side members) of the vehicle are fixed and force is given on the Roll Hoop Overhead Members of the vehicle (Figs. 11–13).

6.4.1. Observation

In the result, it's observed that the maximum stress can be seen only in the weld joints of the RHO (Roll hoop overhead member) and the driver cabin received only minimal amount of stress when compared. Hence safety of driver is ensured.

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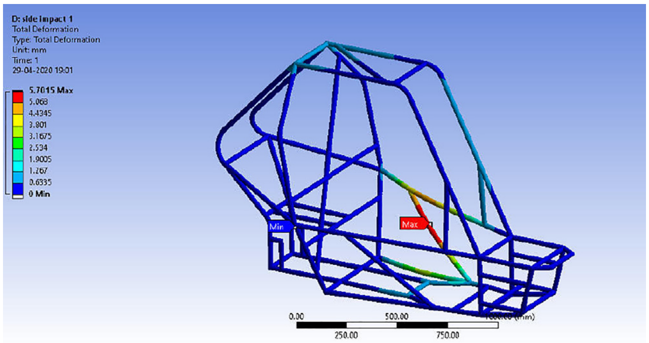

Fig. 9. Side impact – Total deformation.

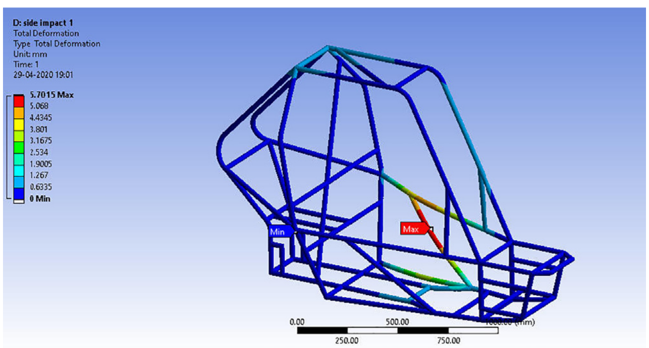

Fig. 10. Side impact – Equivalent stress.

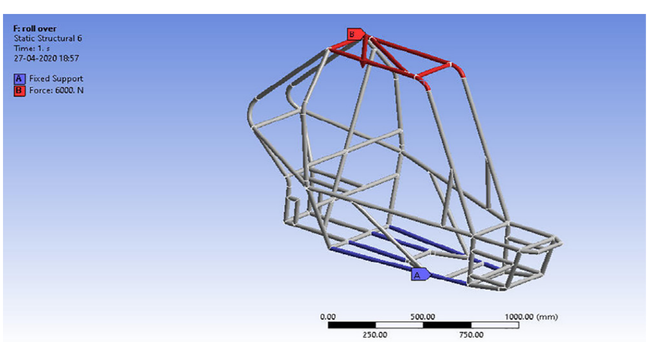

Fig. 11. Roll over impact – Boundary conditions.

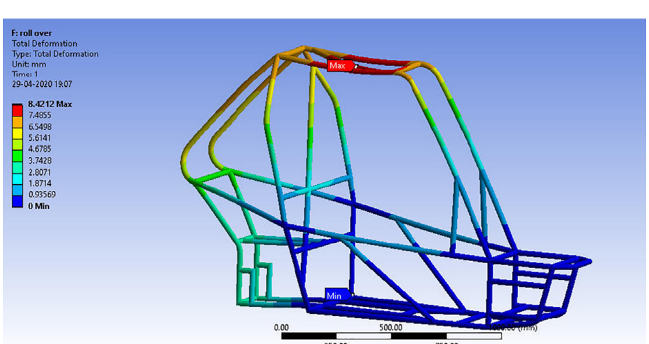

Fig. 12. Roll over impact – Total deformation.

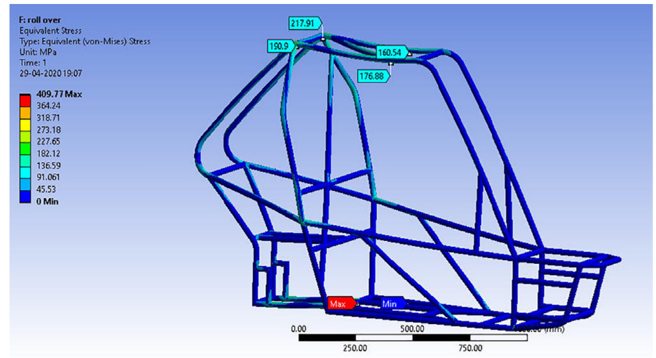

Fig. 13. Roll over impact – Total deformation.

Table 2
Results.

Results			Type of impact test
	Deformation	Stress	
Minimum	0. mm	0. MPa	Front
Maximum	4.8377 mm	985.13 MPa	
Average	1.8728 mm	32.7 MPa	
Minimum	0. mm	3.9312e-019 MPa	Rear
Maximum	7.5344 mm	451.74 Mpa	
Average	2.3 mm	34.792 Mpa	
Minimum	0. mm	0. MPa	Side
Maximum	5.7015 mm	649.13 MPa	
Average	0.5146 mm	18.726 MPa	
Minimum	0. mm	0. MPa	Roll over
Maximum	8.4212 mm	409.77 MPa	
Average	2.226 mm	26.86 MPa	

7. Conclusion

All the outputs of finite element analysis are studied and results were verified. The observations states that the impact regions are vulnerable but the geometry of the chassis structure is rigid enough to restrain the impact stress to the cockpit region. Hence safety of the driver is assured with or without other safety equipments (Table 2).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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