DESIGNING AND SIMULATION OF ALL TERRAIN VEHICLE

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ABSTRACT

Multi tubular 3d space frame refers to as roll-cage which contains the various types of an automobile vehicle. That cage needs to comply with the guidelines indicated by SAE. The cage is exposed to dynamic and static burdens experienced during impacts. The edge ought to be sufficiently firm to respond against all the heaps following up on it with able solidity to weight proportion. To meet these rules we need to count on each and every parameter engaged with the structure of a move confine, right from the material to be utilized around the forces and impacts that it may experience. Through this investigation, we meant to configuration, examine, and upgrade a move confine in order to accomplish the objective of adept solidity to weight proportion. The factor of security of 2 was set which gave the traditionalist plan. Computer-aided design Modeling Software bundles and Optimization bundle in ANSYS Workbench 14.5 was utilized for the research

KEYWORDS: Analysis, SAE BAJA, All Terrain Vehicle (ATV), Off- Road Vehicle.

I. INTRODUCTION

Baja is intended for rough terrain use & for the continuance of an unpleasant landscape. In numerous viewpoints it is like an ATV except this vehicle is tiny in size and contains more secure rollover abilities. [1] Apart from that any Baja vehicle should be ergonomically comfortable, light weighted, and could be easy to transport. The national competition is organized by the SAE India for schools all through the world to structure and create their vehicles and afterward go up against one another. In this competition teams show their engineering skills and make a lightweight and ergonomically fit ATV.

A preliminary design is made with the help of the rules gave by SAE. Indian standards for driver space have been fused and a Plastic replica was created to check the driver’s comfort and ergonomics of the vehicle. This design was then checked by Finite Element Analysis for different types of loadings like Front Impact, Rear Impact, Side Impact, Heave Test, Front and Rear Bump Test, and Torsion Test. As per result we will easily modify the design of our vehicle.

II. SPACEFRAME AND ERGONOMICS

In order to achieve the desire result, we should use the SAE guidelines which ensure the driver’s safety and clearances from the roll cage members for free movement of the driver. We used two different tubular cross sections for the construction of the roll cage. The primary members has 29.2mm outer diameter and the wall thickness is 1.65mm while the secondary member has 25.4mm outer diameter and the wall thickness is 1.2mm.
### Table: 1. Specifications of Roll Cage

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions (L – B – H)</td>
<td>69” – 33” – 45”</td>
</tr>
<tr>
<td>No. of Welds</td>
<td>78</td>
</tr>
<tr>
<td>Bends</td>
<td>12</td>
</tr>
<tr>
<td>No. of Primary Members (Continuous)</td>
<td>12</td>
</tr>
<tr>
<td>No. of Secondary Members</td>
<td>30</td>
</tr>
<tr>
<td>Weight</td>
<td>25 KG</td>
</tr>
<tr>
<td>Bending Stiffness</td>
<td>2892.96 Nm^2</td>
</tr>
<tr>
<td>Bending Strength</td>
<td>444.62 Nm</td>
</tr>
</tbody>
</table>

### Fig-1: Driver’s Posture

#### III. MATERIAL

After the long analysis of different types of material we choose the [2] material AISI 4130 chromyl steel. It gives high yield strength and low weight. It is easily available and has optimum cost compared to other materials with considering other factors like strength to weight ratio.

### Table: 2. Properties of the Material

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Content (%)</td>
<td>0.32</td>
</tr>
<tr>
<td>Composition</td>
<td>C, Cr, Fe, Mn, Mo, P, S, Si</td>
</tr>
<tr>
<td>Density</td>
<td>7850 Kg/m^3</td>
</tr>
<tr>
<td>Yield Strength (Mpa)</td>
<td>435</td>
</tr>
</tbody>
</table>
IV. METHODOLOGY

To build an SAE BAJA ATV, it is important to set the guidelines which include the intended transmission, steering, and suspension systems and their mountings, manufacturing method and design features. [3] As per BAJA rulebook guidelines it is mandatory to maintain the 6 inches of clearance between the driver’s helmet and the roll cage members while the driver’s hip, torso, shoulders, knees, thighs, lower legs, hands, and elbows shall have 3 inches of clearance. It is required to keep the vehicle’s weight as low as possible to achieve the better acceleration and also provides the better stability at higher speed.

Once the modeling of the roll cage is done on Solidworks, the designed model is checked on Solidworks itself about the physical parameters of the roll cage. Once it is done, this design is checked on FEA.

Amsys 14.5 workbench is used for this purpose. The igs file of roll cage is created on Solidworks and imported to Ansys workbench where we specify the material properties and define the cross-section for the analysis.

We follow the methodology chart for the required iterations.

As per earlier studies [4] the mesh size is found by simulating the model with different mesh size varied from 1mm to 15mm. It was graphically seen on the graph plotted between deformation and the mesh size and the optimal result is received while using the mesh size 4mm where after the deformation becomes constant.

Fig-2: Roll Cage Building Methodology Chart
V. MODELING AND ANALYSIS

Finally after building the roll cage on the Solidworks it is imported in the Analysis for FEA. Various forces acting on the roll cage while event is simulated to check the rigidity and the safety of the roll cage. The tests performed on the roll cage are: Front Impact Test, Rear Impact Test, Side Impact Test, Heave Test, Front and Rear Bump Test, Torsion Test.

a) Front Impact Test: Consider our vehicle is approaching a static solid object (like a wall or another vehicle). To solve this consideration, let’s assume the total weight of the vehicle including the driver to be 250kg (27kg roll-cage weight calculated in Solidworks while the remaining weight is assumed from previous year data), and our vehicle is moving with a velocity of 60 Kmph (16.667 m/s) and the impulse time to be 0.15second as per Indian Standards.

Force on vehicle given by -
\[ F = M \times a \]
\[ F = M \times \frac{v}{t} \]
\[ F = 250 \times \frac{16.667}{0.15} \text{ N} \]
\[ F = 27778.33 \text{ N} = 27.8 \text{ KN} \]

The G-force exerted on the vehicle would be:
\[ G\text{-force} = \frac{\text{acceleration}}{9.81} \]
\[ G\text{-force} = \frac{111.113}{9.81} = 11.32 \approx 11g \]

The force exerted during the front impact would be 27.8 KN while the G-force acting during the front impact would be 11g.
Fig-5: Front Impact Maximum Stress

b) Rear Impact Test: Similar to the front-impact test, but here our vehicle is stationary while another vehicle of the same weight with the velocity 60 kmph (16.667 m/s) is moving towards our vehicle and collides on the rear end of our vehicle.

Force on vehicle given by -
\[ F = M \times a \]
\[ F = M \times \frac{v}{t} \]
\[ F = 250 \times \frac{16.667}{0.15} \text{ N} \]
\[ F = 27778.33 \text{ N} \approx 27.8 \text{ KN} \]

The G-force exerted on the vehicle would be;

G-force = acceleration/9.81
-force = 111.113/9.81 = 11.32 \approx 11g

The force exerted during the rear impact would be 27.8 KN while the G-force acting during the front impact would be 11g.

Fig-6: Rear Impact Deformation
c) **Side Impact Test:** Let’s assume that another vehicle is coming towards our vehicle with the velocity of 60 Kmph (16.667 m/s) and our vehicle is at a stationary position which is the worst condition; our vehicle’s side body is in the front of another vehicle. So, the impact force will be applied on one side of the SIM members of the vehicle while we constraint the other side’s SIM Member.

\[ F = M \times \frac{v}{t} \]

\[ F = 250 \times \frac{16.667}{0.15} \text{ N} \]

\[ F = 27778.33 \text{ N} \approx 27.8 \text{ KN} \]

The G-force exerted on the vehicle would be:

\[ \text{G-force} = \frac{\text{acceleration}}{9.81} \]

\[ \text{G-force} = \frac{111.113}{9.81} = 11.32 \approx 11g \]

The force exerted during the rear impact would be 27.8 KN while the G-force acting during the front impact would be 11g.

**Fig-7:** Rear Impact Maximum Stress

**Fig-8:** Side Impact Deformation
**Fig-9:** Side Impact Maximum Stress

d) **Heave Test:** Assume the situation when all the four-wheel drop or rise simultaneously is called as the heaving. So dropping the vehicle from a height (drop test) is performed.

Potential energy (P.E) = Mgh

Thereby this potential energy converts into kinetic energy when dropped and reaches the ground with impact velocity

Impact velocity, \( V = \sqrt{(2\times g\times h)} \)

Thus, \( V = \sqrt{(2\times 9.81\times 1)} \) i.e. dropped from a height of 1 m

\( V = 4.427 \text{ m/s} \)

Force = M*a

\( F = M \times \frac{v}{t} \)

\( F = 250 \times 4.427/0.15 \text{ N} \)

\( F = 7378.333 \text{ N} \approx 7378 \text{ N} \)

**Fig-10:** Heave Test Deformation
**Fig-10:** Heave Test Maximum Stress

e) **Rollover Test:** To analyze force consider vehicle falling upside down from a ride-height of 1.397 meters.

Potential energy (P.E) = Mgh

Thereby this potential energy converts into kinetic energy when dropped and reaches the ground with impact velocity

Impact velocity, \( V = \sqrt{(2 \times g \times h)} \)

\( V = \sqrt{(2 \times 9.81 \times 1.397)} \) i.e. dropped from a height of 1 m

\( V = 5.235 \text{ m/s} \)

Force = \( M \times a \)

\( F = M \times \frac{v}{t} \)

\( F = 250 \times 5.235/0.15 \text{ N} \)

\( F = 8725 \text{ N} \)

**Fig-11:** Roll over test Deformation
f) **Front and Rear Bump Test:** Let’s assume that when the vehicle passes over the bumper, the weight of the vehicle is divided into point force which transmitted through the suspensions of the vehicle. But what if the suspensions fail too, we have to design the chassis not to fail in those circumstances. The two-point forces would be equivalent to the vehicle’s weight.

For low circuit speed race cars, the 2 g force considerations are used

Hence, \( 2F = m \times 2g \)

\( F = \frac{1}{2} m \times g \)

\( F = \frac{1}{2} \times 340 \times 9.81 \times 2 \)  

\( F = 3335.4 \text{ N} \)

![Fig-12: Roll over test Maximum Stress](image)

![Fig-13: Front Bump Deformation](image)
Fig-14: Front Bump Maximum Stress

Fig-15: Rear Bump Deformation

Fig-16: Rear Bump Maximum Stress

g) Torsion Test: Apply Bump force on one wheel only
F = 3335.4 N
VI. RESULTS OF ANALYSIS

Finally, the results we have achieved from the above analysis is given below-

1. Below table gives the proof of safety of the vehicle as per SAE Standards.
2. The Max Stress shouldn't exceed from 435 Mpa, which is the yield strength of the material, otherwise roll cage would collapse.
3. The maximum deformation should be constrained up to 20mm, not more than that can be considered under SAE Standards.
4. FOS we have achieved is more than 1.2, which is our targeted value.

<table>
<thead>
<tr>
<th>Load Cases</th>
<th>Force Applied</th>
<th>Maximum Stress</th>
<th>Deformation</th>
<th>FOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front Impact</td>
<td>27778.33N</td>
<td>283.67 MPa</td>
<td>1.21 mm</td>
<td>1.53</td>
</tr>
<tr>
<td>Rear Impact</td>
<td>27778.33 N</td>
<td>315.76 MPa</td>
<td>3.18 mm</td>
<td>1.38</td>
</tr>
<tr>
<td>Side Impact</td>
<td>27778.33 N</td>
<td>357.28 MPa</td>
<td>15.75 mm</td>
<td>1.22</td>
</tr>
<tr>
<td>Roll Over</td>
<td>8725 N</td>
<td>196.7 MPa</td>
<td>3.21 mm</td>
<td>2.21</td>
</tr>
</tbody>
</table>
VII. CONCLUSION

The goal of this project was to design a frame for an off-road capable vehicle under specific guidelines from SAE Baja. The frame was required to withstand certain impact forces and was designed with specific subsystem integration in mind. We could accomplish these goals through our research and design process. Our design is sustainable for future work to be done and can be used to create a competition-ready vehicle by a future project team. We were aware that a future team may continue our project and so documented important information for the future team to easily work with our design. Our recommendations for furthering this project include the use of specific suspension designs, use of the engine and transmission we researched for the vehicle, and more detailed research into vehicle components such as shock absorbers. The suspension design we suggest is a double A-arm for the front and a 3-point semi-trailing suspension for the rear. The engine used is the Briggs and Stratton model 19 engine as specified by SAE. Further research into suspension components and the other subsystems such as steering, braking, and throttle control must be conducted for the next portion of this project. With these tasks completed, the frame and further work will produce a vehicle that can compete and represent our team at the next SAE Baja competition.

VIII. REFERENCES


