Design and optimization of an All-Terrain Vehicle roll cage

***Harvir Singh[1] & Mayank Kushwaha[2]**
[1,2] Assistant professor, *Dept. of Mechanical Engineering,* ABES Engineering College, Ghaziabad, U.P., India.
[1]*harvir.singh@abes.ac.in*
[2]*mayank.kushwaha@abes.ac.in*

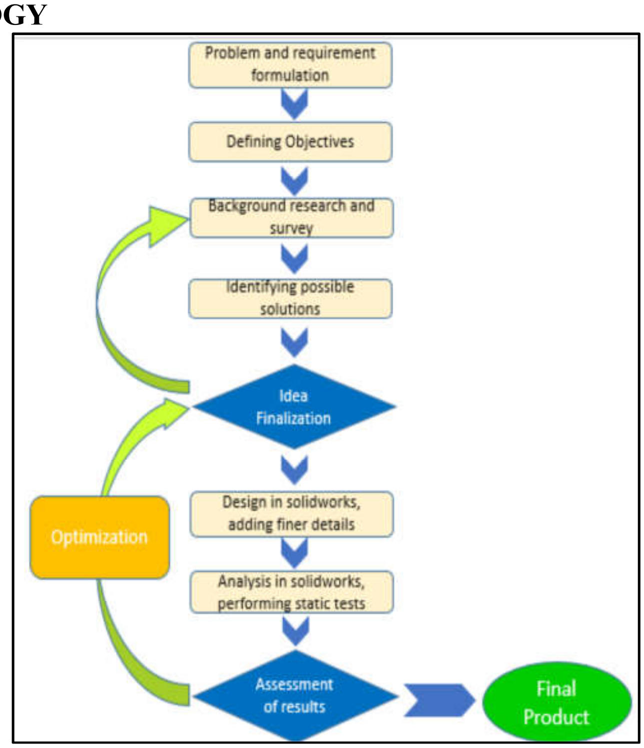
ABSTRACT
The roll cage functions as a frame of an All-Terrain Vehicle (ATV). It not only acts as a structural support but also serves the purpose of protecting the occupant. Due to above proposed functionalities, a roll cage must have some desired properties and qualities such that it would be able to withstand high stresses generated during vehicle operation as well as adhering to the prime objective of providing safety and comfort to the occupant. Increased concern regarding the roll cage design has created the importance of simulation and analysis thereby predicting failure modes of the frame. In the presented report, we have used a modelling and simulation software to investigate the response of the designed frame under various impacts, simulated on the basis of real life impact scenarios.
The simulated boundary conditions and loading application are carried out to predict the practical behavior of roll cage during impacts, helping to develop a frame design which have sufficient strength and necessary safety standards.

Keywords: *All-Terrain Vehicle, roll cage, design and analysis, simulations*

1. Introduction

An ATV (All-Terrain Vehicle) is an off-road race vehicle powered by a small gasoline engine designed to handle a wider variety of terrain than most other vehicles. This type of vehicle is capable of driving on and off paved or gravel surface and is generally characterized by having large tires with deep, open treads, a flexible suspension, and a strong chassis. ATVs are a common sight in areas having irregular or non-uniform terrain such as deserts, forests, hilly regions, country side areas, etc.

2. METHODOLOGY



3. DESIGN & DEVELOPMENT

The roll cage is designed with a two box assembly one is the driver's cabin and the other one is the engine cabin. The steering system and brake system is integrated to the driver's cabin. It is done in order to get the minimum wheel base without compromising the cabin space.

One of the main purpose of the ATV-cage is to maintain a minimum space surrounding the driver and to support all supporting system's. The ATV roll cage must be designed and fabricated to prevent any failure of the cage's integrity. For the roll cage model, few parameters have been kept in mind while designing and some points have been referred from SAEINDIA BAJA Rulebook 2016. Frame is constructed considering following given features:

Minimum space clearances between the driver and any part of frame must be at least 3 inches. Required dimensions of roll cage members are defined by measurements between member centre lines, except where noted. The helmet of the driver shall have 152 mm (6 in.) clearance to the side surfaces. And it shall have 152 mm (6 in.) clearance from any two points among those members that makeup to top of the roll cage. The vehicle must be capable of carrying one person 190cm tall weighing 113kg.

3.1. Material Selection

After thorough comparison of many opted materials, final selection of material for roll cage of ATV was finalized. Important criteria for selection of material were strength, weight of roll cage, availability and cost. Finally, material selected for roll cage members was AISI 4130 (chromoly) due to its high strength to weight ratio, availability and affordable cost. Also, Chromoly (AISI 4130) has highest bending strength and bending stiffness for cross section (25.4 x 19.4 x 3 mm) amongst all options considered. After selection of material and its cross section, further stages of project development include model designing, Analysis and optimization.

Table 3.1, Comparison of Material Properties

Material	Yield Strength (MPa)	Tensile Strength (MPa)	Density Gm/cm3	Elasticity Modulus (GPa)	Poisson's ratio
AISI 1018	320	440	7.87	205	0.29
AISI 1020	380	440	7.87	205	0.29
AISI 1026	420	550	7.9	205	0.29
AISI 4130	450	560	7.87	205	0.29

AISI 4130 Chromoly composition

Fe: 97.3 to 98.2 %, Mn: 0.4 to 0.6 %, C: 0.28 to 0.33 %, S: 0 to 0.040 %, P: 0 to 0.035 %, Cr: 0.8 to 1.1%, Mo: 0.15 to 0.25%, and Si: 0 to 0.04%

3.2. FRAME DESIGNING

The goal of the frame is to epitomize all parts of the vehicle, including a driver productively and securely. Principal aspects of the casing concentrated on during the design and usage included driver security, suspension, basic unbending nature, weight, and driver ergonomics. The intended fabrication is important due to the limitations of the abilities and skills of the build team as well as design directives. The goal is to limit the quantity of welded joints on the casing for twist individuals. The following stage in the structure procedure is to investigate the frame and includes features accordingly. Hence it was considered that there ought to be an investigation of front, back, side impact, roll over and torsion test. However, before these investigations are played out an assessment of the loading force exerted on the vehicle must be finished. The FEA software program used for this project was SOLID WORKS.

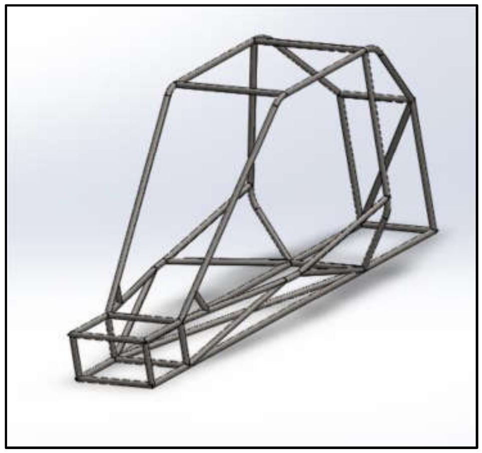
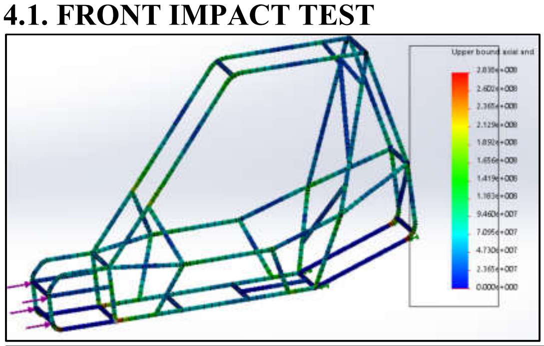


Figure 3.2

4. Finite Element Analysis (FEA)

FEA of model was carried out for various mentioned tests, considering corresponding boundary conditions and calculated forces. Analysis of each test is represented by two parameters, i.e. stress generated and the factor of safety. The frame should be ready to withstand the impact, torsion, roll over conditions and supply utmost safety to the driver without undergoing much deformation. Following tests were performed on the roll cage.

4.1. FRONT IMPACT TEST



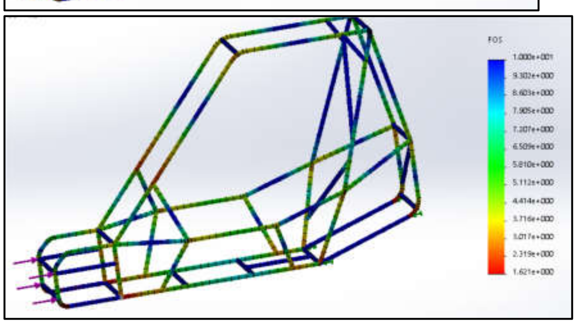


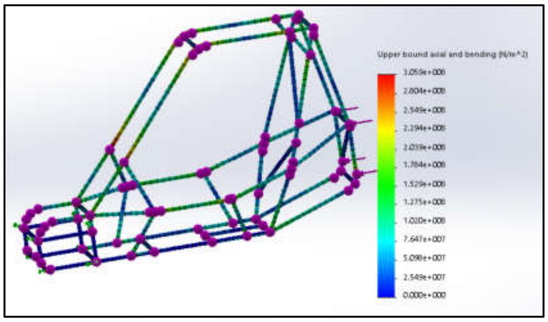
Figure 4.1.1, Maximum stress–front impact Figure 4.1.2, Minimum FOS–front impact

Result

Maximum stress generated = 283.8 MPa

Minimum factor of safety = 1.621

4.2. REAR IMPACT TEST



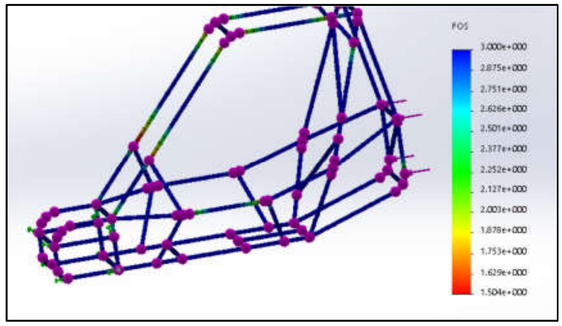


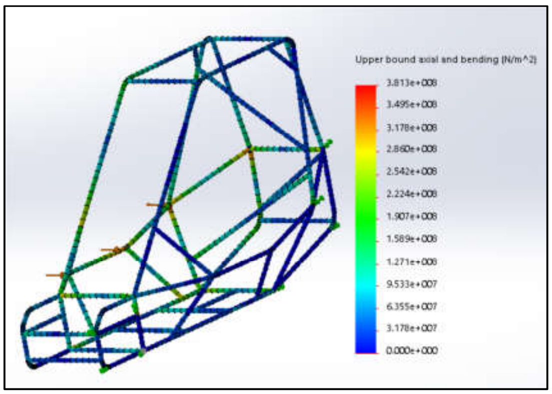
Figure 4.2.1, Maximum stress–rear impact Figure 4.2.2, Minimum FOS–rear impact

Result

Maximum stress generated = 305.9 MPa

Minimum factor of safety = 1.5

4.3.SIDE IMPACT TEST



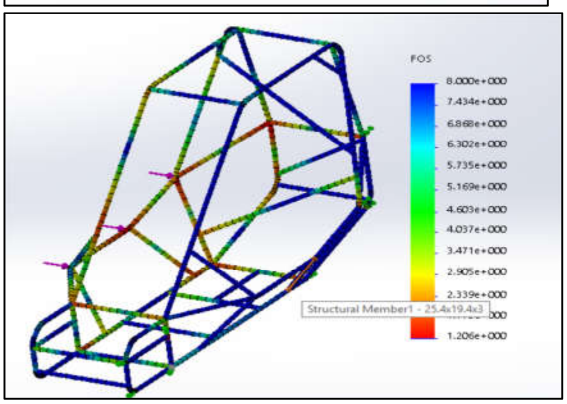


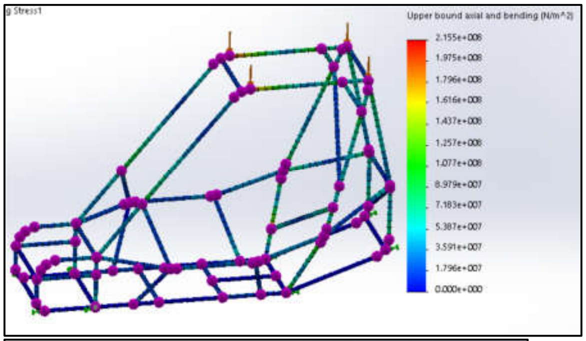
Figure 4.3.1, Maximum stress–side impact Figure 4.3.2, Minimum FOS–side impact

Result

Maximum stress generated = 381.3 MPa

Minimum factor of safety = 1.2

4.4. ROLL OVER TEST



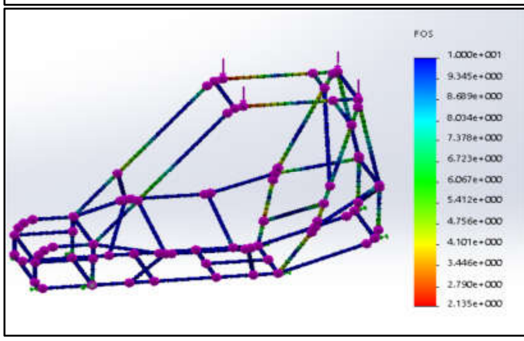


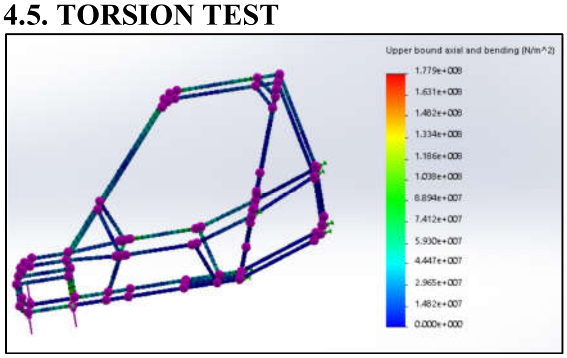
Figure 4.4.1, Maximum stress–roll over Figure 4.4.2, Minimum FOS–roll over

Result

Maximum stress generated = 215.5 MPa

Minimum factor of safety = 2.135

4.5. TORSION TEST



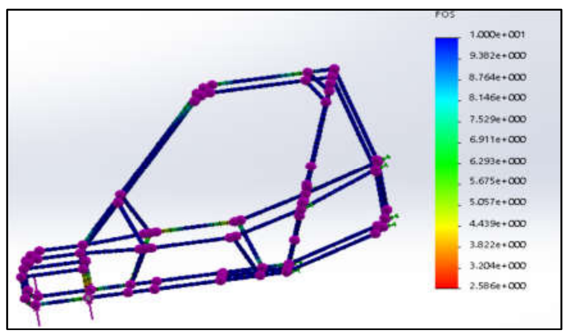


Figure 4.5.1, Maximum stress–torsion Figure 4.5.2, Minimum FOS–torsion

Result

Maximum stress generated = 177.9 MPa

Minimum factor of safety = 2.586

5. FINAL RESULT

After the complete analysis roll cage for its strength against the collision from front, rear, side, roll over as well as torsion. The study defines that the Factor of safety is under the safe limit, Hence design is safe against specified loads.

Table 5: Final results

	Front Impact	Rear Impact	Side Impact	Roll Over	Torsion
Maximum Stress (MPa)	283.8	305.9	381.3	215.5	177.9
Factor Of Safety	1.621	1.5	1.2	2.135	2.586

6. CONCLUSION

In this observations taken from the diverse basic investigation gives the framework and outline of the exploration performed on a roll cage frame. The use of finite element analysis is priceless to the structure and investigation of the casing for an ATV. The target of the current exploration is to perform a limited component basic investigation on the roll cage frame and improve the structural design for various loading conditions. The static investigation was expected to decide the ideal mesh size and to consider the impacts of stress and displacement on the roll cage frame. Considering yielding is the failure criteria for the static analysis.

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