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Stress Analysis of Roll Cage for an All Terrain Vehicle

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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. A roll cage is a skeleton of an ATV. The roll cage not only forms the structural base but also a 3-D shell surrounding the occupant which protects the occupant in case of impact and roll over incidents. The roll cage also adds to the aesthetics of a vehicle. So determining strength requirements of roll cage, stress analysis is carried out using FEA software Ansys workbench. This paper deals with design of roll cage for an ATV and Various loading tests like Front Impact, Side Impact and rear impact have been conducted. The modeling and stress analysis is done by ANSYS software. We have focused on every point of roll cage to improve the performance of vehicle without failure of roll cage.*

Keywords: *ATV, FEA, Modeling, Roll Cage, Strength.*

I. INTRODUCTION

Roll Cage can be called as skeleton of a vehicle, besides its purpose being seating the driver, providing safety and incorporating other sub-systems of the vehicle, the main purpose is to form a frame or so called Chassis. We have designed the roll cage keeping in view the safety and aesthetics. These are the two factors which matters us the most, therefore they are given utmost consideration. This paper deals with design of chassis frame for an All Terrain Vehicle and Various loading tests like Front Impact, Rear Impact & Side Impact test have been conducted on the roll cage.

II. DESIGN METHODOLOGY

Design of any component is consists of three major principles: 1.optimization 2.safety 3.comfort
The primary objective of the roll cage is to provide a 3-dimensional protected space around the driver that will keep the driver safe. Its secondary objectives are to provide reliable mounting locations for components, be appealing, low in cost, and low in weight. These objectives were met by choosing a roll cage material that has good strength and also weighs less giving us an advantage in weight reduction. A low cost roll cage was provided through material selection and incorporating more continuous members with bends rather than a collection of members welded together to reduce manufacturing costs. The modeling of the roll cage structure is done by using pro-e software. This design is checked by Finite Element Analysis. We have focused on every point of roll cage to improve the performance of vehicle without failure of roll cage. We began the task of designing by conducting extensive research of ATV roll cage through finite element analysis.

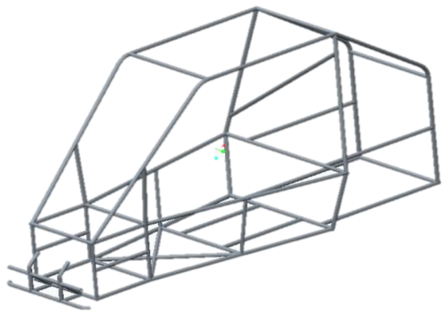


Fig. 1 3-D Model Of Roll Cage Structure

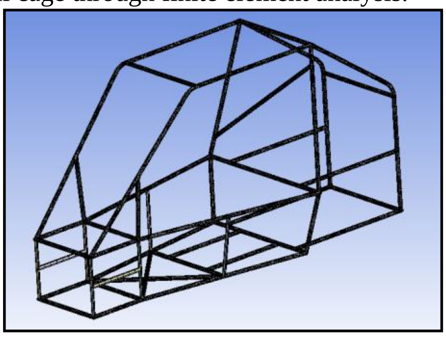


Fig.2 Meshing

To begin the initial design of the frame, some design guidelines were required to be set. They included intended transmission, steering and suspension systems and their placement, mounting of seat, design features and manufacturing methods. It is also required to keep a minimum clearance of 3 inches between the driver and the roll cage members. It is also necessary to keep weight of the roll cage as low as possible to achieve better acceleration. It is necessary to keep the center of gravity of the vehicle as low as possible to avoid toppling. Mounting heavier components such as engine, driver seat etc. directly on the chassis is one way of achieving low center of gravity. Also it is imperative to maintain the integrity of the structure. This is done by providing bends instead of welds which in turn reduces the cost. A layout of the chassis within the given geometrical constraints is as shown in Fig.1

III. MATERIAL OF THE ROLL CAGE STRUCTURE

We felt that one of the key design decisions of our frame that would greatly increase safety, reliability and performance is material selection.

Table: 1 Material Of Roll Cage

Subject	**Property**
Material	ST-52
Carbon%	0.20%
Density	7.8 *10^3 kg/m^3
Yield strength	355 MPa
Young's modulus	210 Gpa
Poisons ratio	0.30
Roll cage weight	56kg
Total weight of the vehicle	275 kg(appr)

IV. FINITE ELEMENT ANALYSIS

After finalizing the frame along with its material and cross section, it is very essential to test the rigidity and strength of the frame under severe conditions. The frame should be able to withstand the impact, torsion, roll over conditions and provide ulmost safety to the driver without undergoing much deformation. Following tests were performed on the roll cage.

(i) Front impact (ii) Side impact (iii) Rear impact

4.1 Front impact analysis

4.1.1 Impact load calculation:

Using the projected vehicle/driver mass of 400 kg, the impact force was calculated base on a G-load of **4**.

F = ma …. (1)
= 400*4*10
= 16000 N

Impulse time = weight*(velocity/load)… (2)
= 400*(16.67/16000)
= 0.32 seconds

We apply 16000 N from the front for the test of front impact of the roll cage structure of the vehicle for determining strength at the time of front collision.

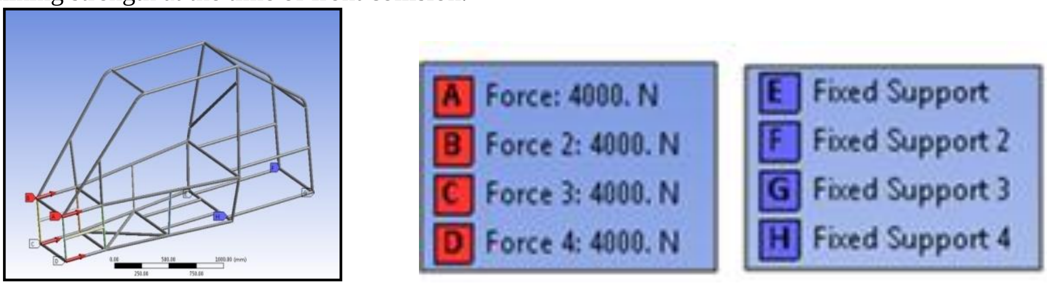
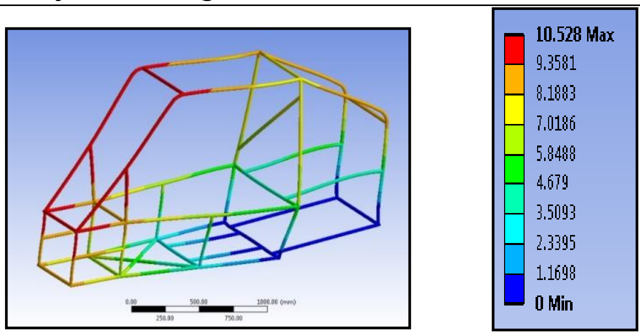


Fig.3 Load & Supports



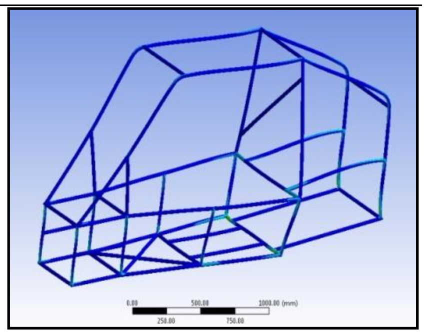


Fig.4 Front Impact Deformation **Fig.5** Front Impact Stresses

Maximum deformation: 10.528 mm

Maximum deformation is within the permissible limit. According to deformation analysis we had said that deformation at the time of collision is not affect the drivers safety.

V. RESULTS

Maximum VonMises Stress= 149.28 MPa
Incorporated Factor of Safety= σyt/σmax… (3)
= 355/149.28
= 2.38

As factor of Safety for automobiles goes up to 8, hence design is safe against specified stress.

4.2 Rear impact analysis
4.2.1 Impact load calculation:

Using the projected vehicle/driver mass of 400 kg, the impact force was calculated base on a G-load of **4**.

F = ma
= 400*4*10
= 16000 N

Impulse time = weight*(velocity/load)
= 400*(16.67/16000)
= 0.32 seconds

We apply 16000 N from the front for the test of rear impact of the roll cage structure of the vehicle for determining strength at the time of rear collision.

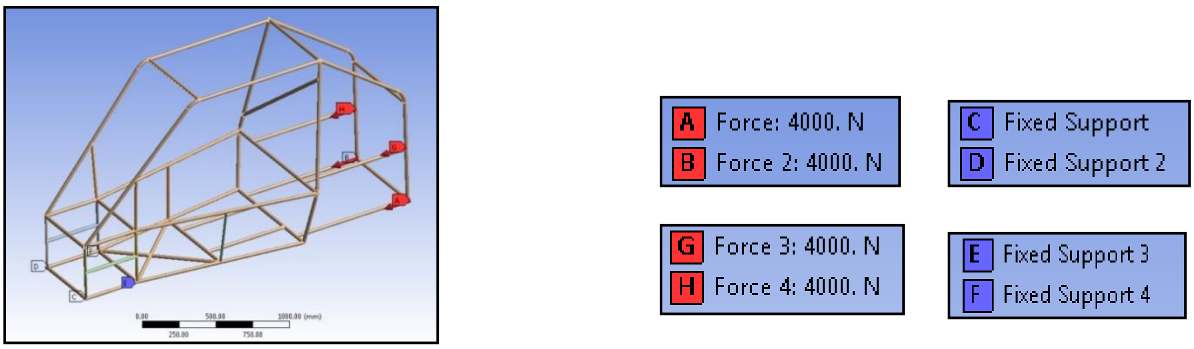
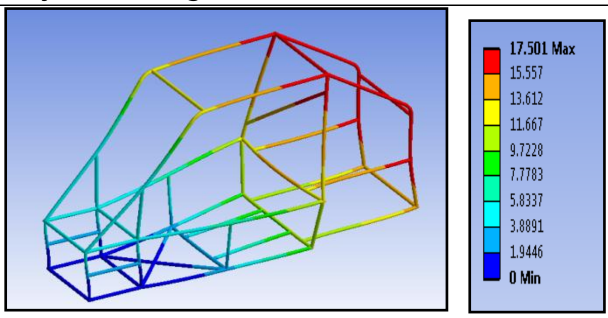


Fig. 6 Load & Supports



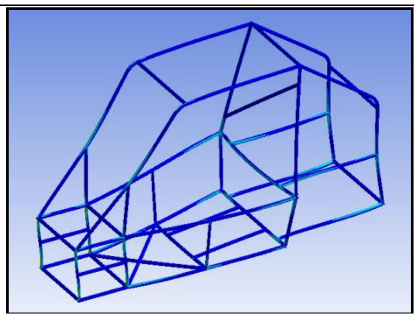


Fig.7 Rear Impact Deformation **Fig.8** Rear Impact Stresses

Maximum deformation: 17.501 mm

Maximum deformation for the rear impact is also under the safe limit & not affects the safety of driver.

RESULTS:

Maximum VonMises Stress= 156.86 MPa

Incorporated Factor of Safety= σyt/σmax

= 355/156.86

= 2.26

As factor of Safety for automobiles goes up to 8, hence design is safe against specified stress.

4.3 Side impact analysis

4.3.1 Impact load calculation:

Using the projected vehicle/driver mass of 400 kg, the impact force was calculated base on a G-load of **2**.

F = ma

= 400*2*10

= 8000 N

Impulse time = weight*(velocity/load)

= 400*(16.67/8000)

= 0.16 seconds

We apply 8000 N from the side for the test of side impact of the roll cage structure of the vehicle for determining strength at the time of side collision.

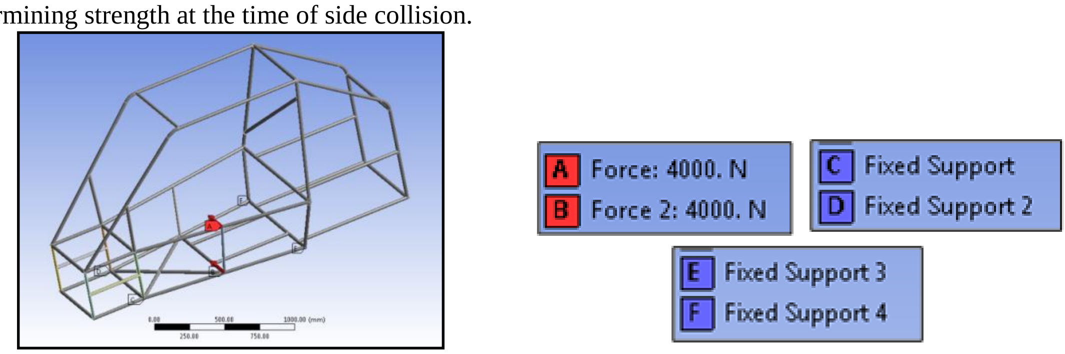


Fig.9 Load & Support

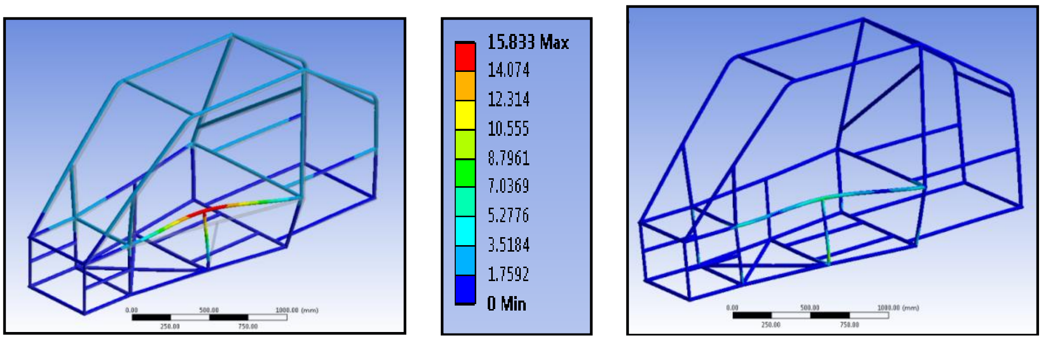


Fig.10 Side Impact Deformation

Fig.11 Side Impact Stresses

Maximum deformation: 15.833 mm
Maximum deformation for the side impact is also under the safe limit & not affects the safety of driver.

RESULTS:
Maximum VonMises Stress= 184.71 MPa
Incorporated Factor of Safety= $\sigma yt/\sigma max$
= 355/184.71
= 1.92
As factor of Safety for automobiles goes up to 8, hence design is safe against specified stress.

VI. CONCLUSION

We had successfully analyzed the roll cage structure for its strength against the collision from front, rear, as well as side. Factor of safety is under the safe limit. The roll cage is sustained 4G force from front as well as rear & 2G force from side. Hence, deformation & stresses are under the limit.

REFERENCE

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