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Static analysis of the 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). The roll cage forms the structural base and a 3-D shell surrounding the occupant which protects the occupant in case of impact and roll over incidents. The study is to design and optimize the roll cage under a set of particular rules given by Society of Automotive Engineers (SAE). This paper represents static analysis of the roll cage of ATV. Static analysis of the roll cage is done using ANSYS Static Structural for different impacts like front, side, rear, roll over and bump of the roll cage. The roll cage is designed in such a way where it should be very strong to bear such crash condition and at the same time its weight should be less to improve the performance of all-terrain vehicle. The results of displacement of roll cage, nodal solution and bending moment are discussed. We have focused on every point of roll cage to improve the strength of vehicle without failure of roll cage.

Index Terms: *ATV, FEA, Life, Static Structural, Impact, Automobile*

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1. INTRODUCTION

The objective of the study is to style and develop the roll cage for All-Terrain Vehicle. The automotive roll cage is tasked with holding all the components together while driving, and transferring vertical and lateral loads, caused by acceleration, on the chassis through the suspension and to the wheels. The need for design and analysis of the roll cage of a all terrain vehicle used by students during competition are to addressed because of the failure of structural members which leads to collusion the shell of a roll cage must be rigid, compact and light weight. the structural strength cannot be found directly from any empirical formulas instead has to be found out from the views of driver. of the Thickness, Outer diameter and carbon content of the roll cage material must be considered under the limiting dimensions as per SAE Baja rule book (2019).The product development process is lead to add value by improving usability, lowering production cost and developing more appealing product. The design of the vehicle should not be over engineered. A Roll cage model is prepared in Solid work software.

2. Design and Development

The design and development process of the roll cage involves various factors; namely material selection, cross-section determination, frame design, and finite element analysis. 2.1. Material choice to create roll cage steel should be used per the principles. There are many different types of steel available. Material selected for the chassis is AISI 4130 steel. The roll cage is made of hollow sections. Tubular sections supply superior loading capabilities per metric weight unit compared to solid sections or sq. sections.

Material	**AISI 1018**	**AISI 4130**	**AISI 1018**	**AISI 4130**
Outer Diameter	25.4mm	25.4mm	29.2mm	29.2mm
Wall Thickness	3mm	3mm	1.65mm	1.65mm
Bending Stiffness (Nm^2)	2758	2758	2787.51	2787.51
Bending Strength (Nm)	387	658.22	339.94	642.62

Table No.1: different materials and cross section

2.2. Roll Cage Design

To begin the initial style of the frame, some style pointers were needed to be set. They enclosed supposed transmission, steering and suspension systems and their placement, mounting of seat, design features and manufacturing methods. It is additionally needed to stay a minimum clearance of half dozen inches between the driving force and also 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 centre of gravity of the vehicle as low as possible to avoid toppling. Once modelling of the roll cage structure is done by using Solid work, the designed roll cage is then evaluated in the Solid work itself to have an idea of the physical parameters of the roll cage

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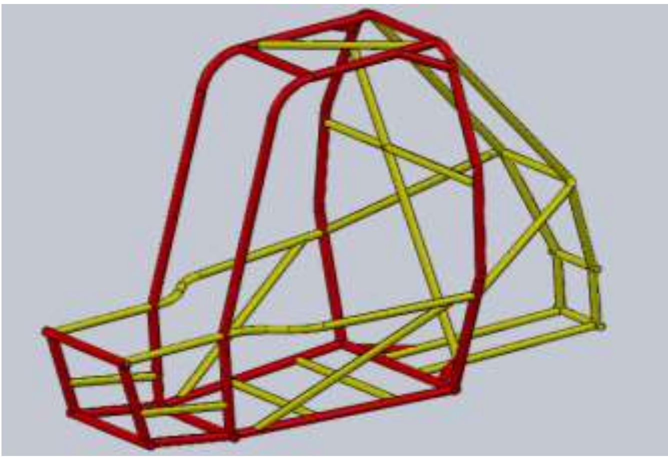

Fig. No.: 1 Roll cage model

3. Analysis Methodology

Once modelling of the roll cage structure is completed by mistreatment Solidwork, this design is checked by Finite Element Analysis. Ansys Workbench has been used for this purpose. A coordinate file is made in pad which has been foreign in Ansys via import pure mathematics, then specified material, defined the cross-section.

4. FEM Analysis

Because the Roll cage was developed by plotting key points, so every member of the roll cage is considered to be properly constrained at every joint. After finalizing the frame at the side of 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 utmost safety to the driver without undergoing much deformation. Following tests were performed on the roll cage: (1) Front Impact, (2) Rear Impact, (3) Side Impact, (4) Front roll over, (5) Side roll over, (6) Front Bump and (7) Rear Bump

4.1. Meshing

The result of any FEA software depends mainly upon the kind and the quality of the mesh. Mesh size is calculated by checking the mesh independence, mesh size has been calculated by plotting the mesh convergence curve. Following are some points that are considered during mesh generation: Midsize node has been used for better accuracy.

• Pipe Idealization is applied on bends to get accurate results.
• Fine meshing is done particularly in areas having
• higher stress gradient.

4.2. Front Impact Analysis

This analysis is done to simulate those conditions when the ATV may hit a tree, another ATV or a wall. Under such conditions, the amount of forces generated reacts at the front most portion of vehicle. Analysis Condition: Using the projected vehicle + driver mass of 220 kg

,• the impact force was calculated base on a G-load of 10, was applied to the front most members of chassis. Rear suspension points are fixed.• F = ma …. (1)

• 10F = 220*9.81*10 = 21,582 N (approx).

Result discussion

- Maximum combined stress induced is 566.5MPa.

Hence FOS =2.269 with maximum deformation of 6.9mm which is within the permissible limit.

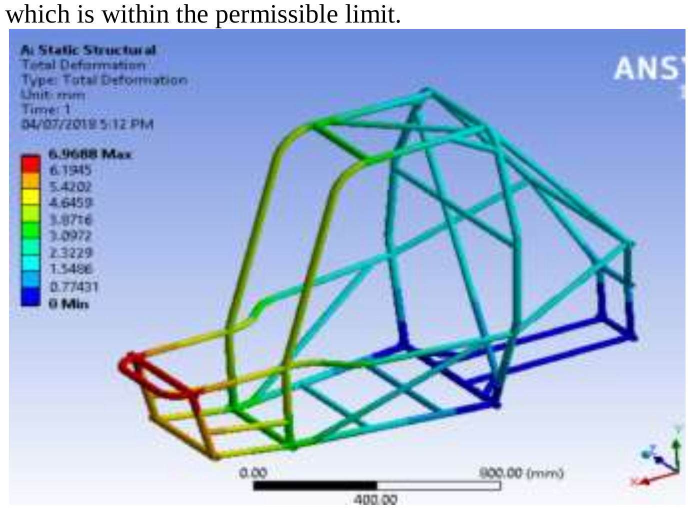

Fig. No.2: Total Deformation

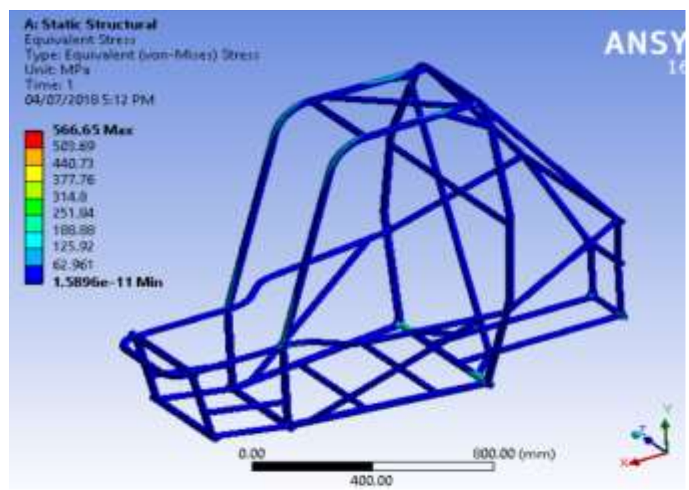

Fig.No.3: Von-Mises stress

4.3. Rear Impact Analysis

This analysis is completed to simulate those conditions once another ATV goes to hit ATV on its rear half. Under such conditions, the quantity of forces generated reacts at the rear most portion of auto. Analysis Condition: Using the projected vehicle + driver mass of 220 kg

,• the impact force was calculated base on a G-load of 10, was applied to the rear most members of chassis. Front most nodes are fixed.

• F = ma …. (1)• 10F = 220*9.81*10 = 21,582 N (approx).

Result discussion-

Maximum combined stress induced is 517.02MPa. Hence FOS =1.7 with maximum deformation of 1.9mm which is within the permissible limit.

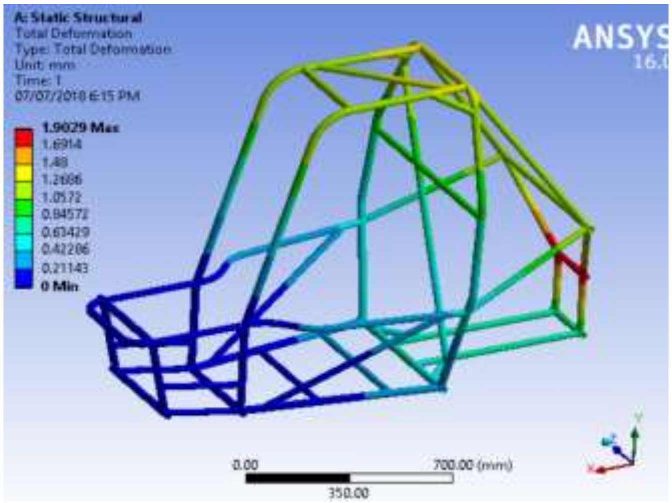

Fig. No.4: Total Deformation

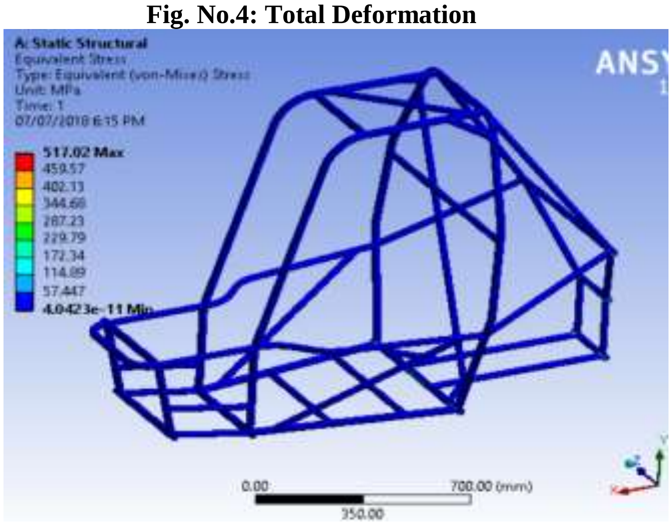

Fig.No.5: Von-Mises stress

44. Side Impact Analysis

This analysis is finished to simulate those conditions once another ATV can hit ATV on aspect. Under such conditions, the amount of forces generated reacts at the side most portion of vehicle. Analysis Condition: Using the projected vehicle + driver mass of 220 kg,

• the impact force was calculated base on a G-load of 5, was applied to the one of side most members of chassis. Other side of nodes are fixed.

• F = ma …. (1)• 5F = 220*9.81*5 = 10,791 N (approx)

Result discussion-

Maximum combined stress induced is 495.04MPa. Hence FOS =2.807 with maximum deformation of 7.3mm which is within the permissible limit.

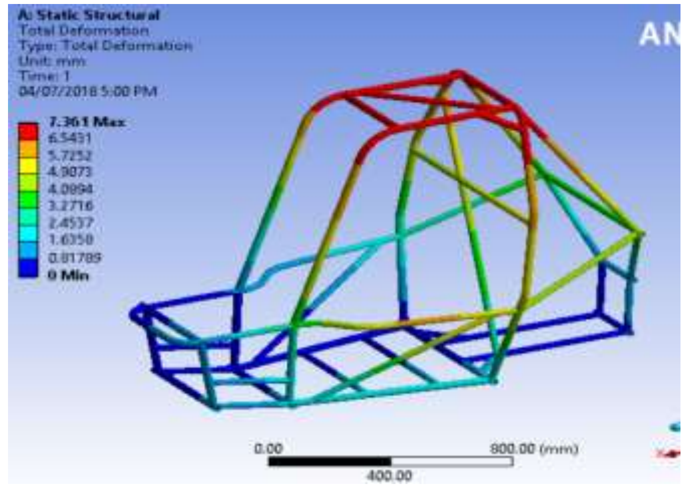

Fig. No.6: Total Deformation

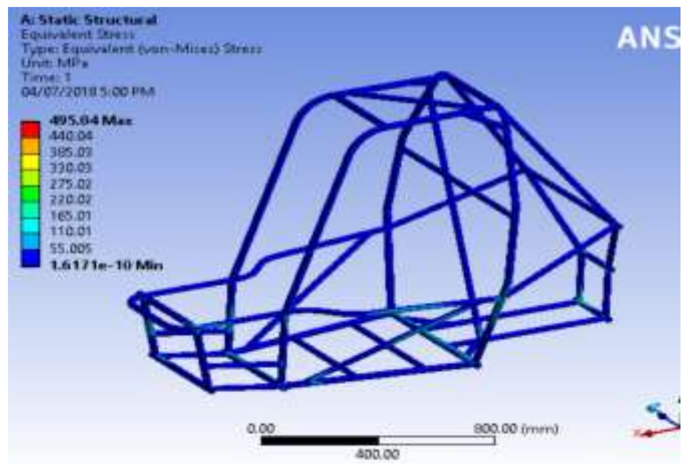

Fig.No.7: Von-Mises stress

4.5. Front Roll Analysis

This analysis is finished to simulate those conditions once the ATV is taken into account to be born on its roof on road or ground from a height. Under such conditions, the amount of forces generated reacts at the top most portion of vehicle. Analysis Condition: Using the projected vehicle + driver mass of 220 kg,• the impact force was calculated base on a G-load of 2.5, was applied to the Front Lateral Cross members of chassis. Base Plane members are fixed.• F = ma …. (1)• 2.5F = 220*9.81*2.5 = 5,395.5 N (approx).

Result discussion-

Maximum combined stress induced is 174.4MPa. Hence FOS =2.56 with maximum deformation of 1.03mm which is within the permissible limit.

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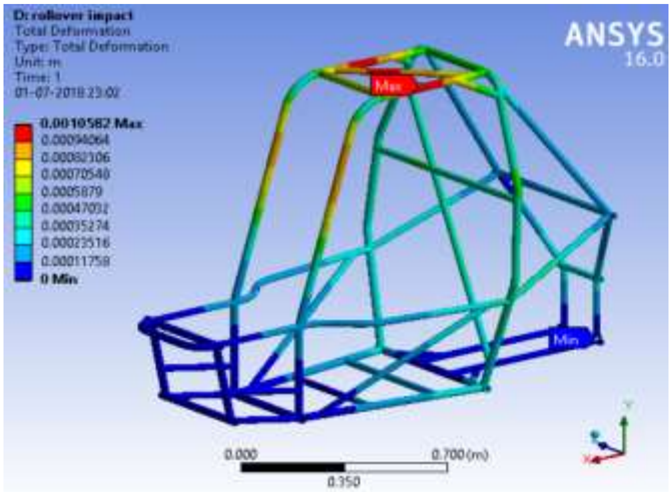

Fig. No.8: Total Deformation

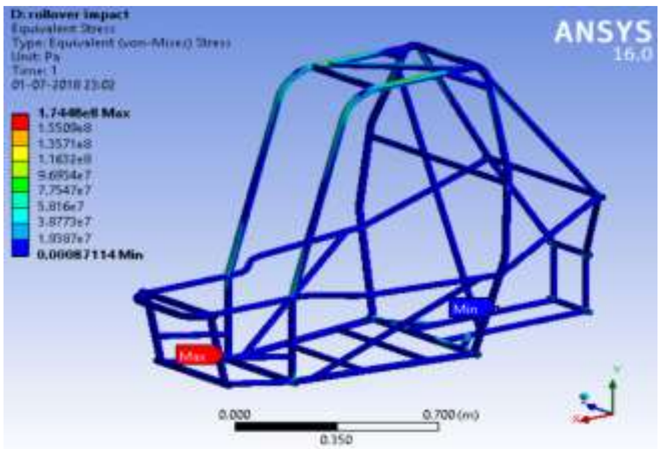

Fig.No.9: Von-Mises stress

4.6. Side Roll Analysis

This analysis is finished to simulate those conditions once the ATV rolls sideways thanks to some excessive cornering angle. Under such conditions, the amount of forces generated reacts at the Side most portion of vehicle. Analysis Condition: Using the projected vehicle + driver mass of 220 kg

,• the impact force was calculated base on a G-load of 5, was applied to the Side members of chassis. Base Plane members are fixed

.• F = ma …. (1)

• 5F = 220*9.81*5 = 10,791 N (approx).

Result discussion-

Maximum combined stress induced is 350.76MPa. Hence FOS =2.36 with maximum deformation of 1.347mm which is within the permissible limit.

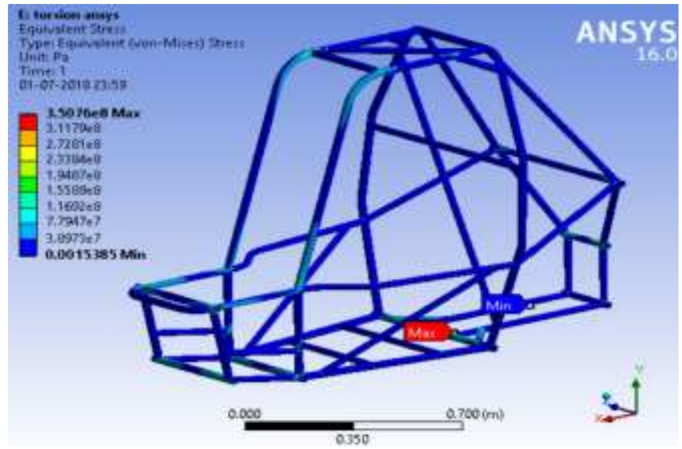

Fig.No.10: Von-Mises stress

4.7. Bump Analysis

This analysis is done to simulate those conditions when the rear wheels of ATV pass over a bump, roll cage is subjected to a moment Analysis Condition: 60% of the vehicle weight (1,294.92 N) is equally

• distributed to rear suspension mounting member. Front s•

Result discussion-

Maximum combined stress induced is 421.36MPa. Hence FOS = 3.77with maximum deformation of 5.76mm which is within the permissible limit.

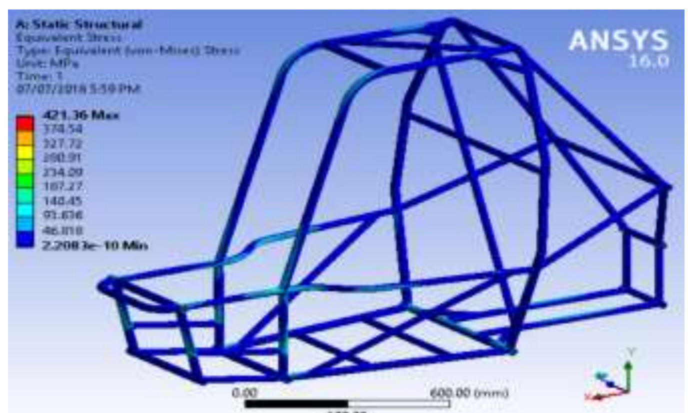

Fig.No.11: Von-Mises stress

5. Results of Analysis

The results of the above analysis have been tabulated below:-

	Front Impact	Rear Impact	Side Impact	Front Roll	Side Roll	Bump
Stress Mpa	566.5	517.02	495.04	174.4	350.76	421.36
Displacement	6.9	1.9	7.3	1.03	1.35	3.77
F.O.S.	2.27	1.7	2.8	2.56	2.36	5.76

Table No. 2: Results of Analysis

6. Conclusion

The FEA analysis incontestable the structural superiority whereas maintaining a lower weight to strength magnitude relation. Safety is of utmost concern in each respect; for the motive force, crew & environment. The analysis was useful to find out the utmost deformation, Von Mises stress and the factor of safety. The design of the vehicle is unbroken terribly easy keeping in sight its manufacturability. The design, development and fabrication of the roll cage is allotted with success. The roll cage is used to build an ATV by integrating all the other automotive systems like transmission, suspension, brakes, steering, etc.

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