Design and Analysis of Roll Cage of an ATV

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Abstract- The study aims to design, develop and fabricate a roll cage for an All-Terrain Vehicle (ATV) in accordance with the rulebook of BAJA 2013 given by SAE. A roll cage is a skeleton of an ATV. The roll cage also adds to the aesthetics of a vehicle. The design and development comprises of material selection, chassis and frame design, cross section determination, determining strength requirements of roll cage, stress analysis and simulations to test the ATV against failure. Finally the roll cage is fabricated as per the tools and techniques available in the workshop

Keyword- *Rear impact, chassis model, coarse mesh.*

I. INTRODUCTION

Roll Cage can be called as skeleton of a vehicle, besides its purpose being seating the driver, providing safety.ATV means a all terrain vehicle which is specially designed for a off roads driving.ATV is designed for very rough terrain, jumps, endurance. The design process of this single-person vehicle is iterative and based on several engineering and reverse engineering processes

II. OBJECTIVE OF RESEARCH

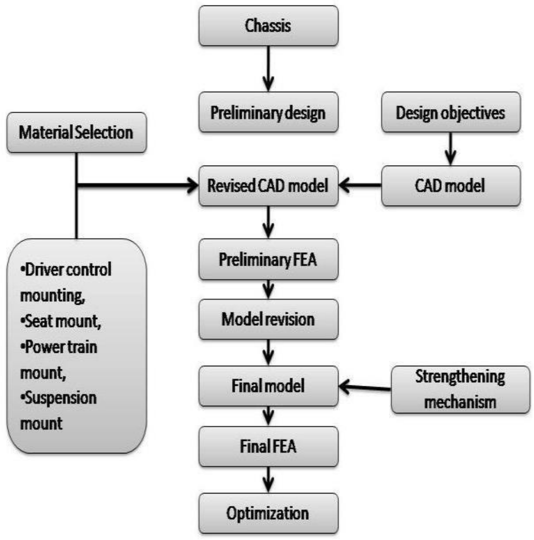
Denish S. Mevawala determined the roll cage not only forms the structural base but also a 3-D shell surrounding the occupant which protects the occupant in case of impact and roll over incidents. The roll cage also adds to the aesthetics of a vehicle. This paper deals with design of roll cage for an ATV and Various loading tests like Front Impact, Side Impact andrear impact have been conducted. They have focused on every point of roll cage to improve the performance of vehicle without failure of roll cage. They concluded after the analysis that roll cage structure for its strength against the collision from front, rear, as well as side. Factor of safety is under the safe limit.

Thanneru Raghu Krishna Prasad designed the frame & suspension of the Society of Automotive Engineers (SAE) Baja car which is a single-seated all-terrain vehicle and is used for off road usage and endurance on a rough terrain.In many aspects it is similar to an All-Terrain Vehicle (ATV) except that it is much smaller in size and has safer rollover capabilities. The modeling of the frame and suspension is done by using pro-e software. This design is checked by Finite Element Analysis after estimating the load and the weight of the frame.They decided that the usage of solidworks®was very helpful to the design and analysis of the frame and suspension for Mini Baja Car. the finite element analysis gave a very accurate prediction of where failure would occur in this situation

Khelan Chaudhari studied about design, development and fabrication of the roll cage for All -Terrain Vehicle accordance with the rulebook of BAJA 2013 given by SAE. Material for the roll cage was selected based on strength, cost and availability. The roll cage was designed to incorporate all the automotive sub-systems. A software model is prepared in Pro-engineer. Based on the result obtained from these tests the design was modified accordingly. After successfully designing the roll cage, it was fabricated. They concluded that the design, development and fabrication of the roll cage was carried out successfully. The roll cage was used to build an ATV by integrating all the other automotive systems like transmission, suspension, steering, brakes and other miscellaneous elements.

Puneet Malhotra stated that their study was to design of an All-Terrain Vehicle (ATV) in accordance with the SAE BAJA 2014 rule book. A detailed designing of components were carried out by them like Roll cage, Suspensions & Braking mechanism. The main focus of their was on Safety of driver & Stability of vehicle. Roll cage of their vehicles was designed in such a way that in case of rolling of vehicle (mostly occurs in high speed turns & off roading that it will provide double the strength to the roll cage with also considering the Aesthetic of the cage. International standards were followed by them where ever possible and an extensive market survey was also done. Finite Element Analysis was carried out on roll cage & braking mechanism for optimum safety & reliability of the vehicle.

III. METHODOLOGY



A. *Selection Of Material*

1.1 Tube Specification
Tube sizes: Outer Diameter: 25.4 mm (1.00")
Wall Thickness: 2 mm (0.078")

Then design of the roll cage considering AISI 1018 Mild Steel pipes of shown dimensions was done and we might get the factor of safety more than 2,which could justified the selection.

Table No: 1.1. Chemical Composition of Material

Element	**Content**
Carbon, C	0.14 –0.20 %
Iron, Fe	98.81 –99.26 %
Manganese, Mg	0.60 –0.90%
Phosphorous, P	≤ 0.040 %
Sulfur,S	≤ 0.050 %

Table No:1.2 Physical Composition of Material

Mechanical	**Unit value**
Tensile Strength, Ultimate	410Mpa
Tensile Strength, Yield	365Mpa
Elongation	15.0%
Modulus of elasticity	205 Gpa
Machinability	70%

V. DESIGN

From the load scenario determination various test that to be conducted in the finite element analysis are
1. Front impact test

2. Rear impact test

3. Side impact test

4. Heave test

A. *Front Impact Test*

Consider two vehicles approaching each other opposite direction. To solve this consider the each vehicle separately dashes on a fixed obstacle like 1st type as shown in figure 3.1

Here mass of vehicle 1=MA, mass of vehicle 2=Mb

Force on vehicle 1 and 2 is given by

FA=MA*aA, FB=MB*a

Since both forces acts in opposite to each other of cylinder.

Figure 1. Front Impact Scenario

$FA=-FB= ½*[(M_A*M_B)/(M_A+M_B)]*(Vr^2/t)$

Vr= VA+VB (+ sign since the vehicle moves towards each other)
Vr=15.2778+0=15.2778 m/s

F= [(340*340)/(340+340)]*(15.2778/1)
=19839.94 N
F=19839.94N.

B. *Rear Impact Test*

Similar to that of front impact test type 2 but the vehicle 1 is stationary as shown in figure 3.2

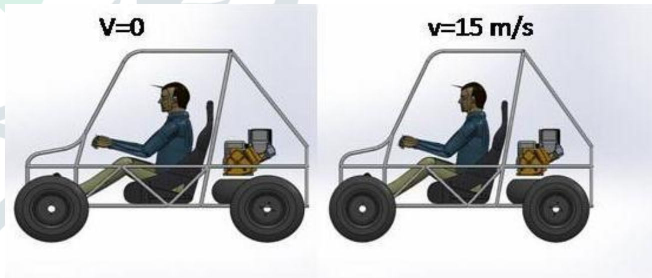


Figure 2. Rear Impact Scenario

Vr= VA+VB (+ sign since the vehicle moves towards each other but VA=0)
Vr=0+15.2778=15.2778 m/s

$FA=-FB=½*[(M_A*M_B)/(M_A+M_B)]*(Vr^2/t)$
Vr= VA+VB (+ sign since the vehicle moves towards each
other)
Vr=15.2778+0=15.2778 m/s
F= [(340*340)/(340+340)]*(15.2778/1)
=19839.94 N

F=19839.94N.

C. *Side Impact Test*

Very similar to rear impact but the position of vehicle changes as shown in figure 3.3.

Vr= VA+VB (+ sign since the vehicle moves towards each other but VA=0)
Vr=0+15.2778=15.2778 m/s

FA=-FB= =½*[(M_A*M_B)/(M_A+M_B)]*(Vr^2/t)
Vr= VA+VB (+ sign since the vehicle moves towards each other)
Vr=10+0=10

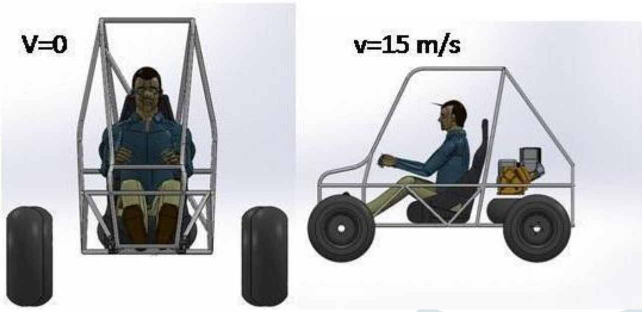


Figure 3. Side Impact Scenario

F=[(340*340)/(340+340)]*(11.11^2/1)
=10491.7285 N
F=10491.7285N

D. Heave Test

When all the four wheel drop or rise simultaneously it is called as the heaving. So dropping the vehicle from a height (drop test)is performed as showed in figure.3.4

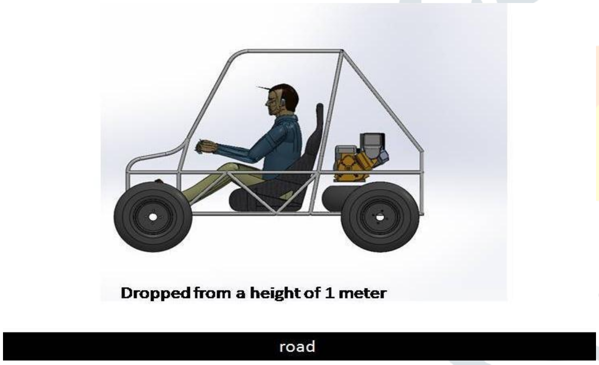


Figure 4. Heave Test Scenario

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=√(2*g*h)
V=√(2*9.81*1) ie dropped from a height of 1 m
V=4.427 m/s
K.E =1/2*(m*v^2)
K.E = 1/2*(350*4.427^2)
K.E= 3429.70
Considering the vehicle a free falling object
V^2=u^2+2*g*s
4.427^2=0^2+2*9.81*s
Therefore s=0.99
Force = K.E/s=3433.49
F=3433.49 N

E. PRELIMINARY FINITE ELEMENT ANALYSIS

The 3D chassis model was created using Solid Works and the FEA was performed using the Solid works simulation analysis. All analyses were run using a Beam Mesh which partitions the annular frame members into tiny sections and then calculates the load distribution and resulting stresses.

The finite element analyses of the preliminary stage are

Beam element

Axial and bending strength

Free coarse mesh type.

1. Front Impact Test

Loading= 19839.94 N

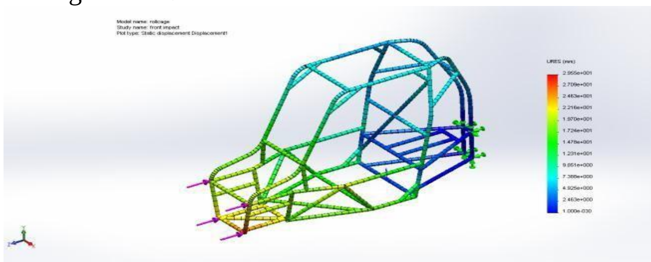


Figure 1.1 PFEA Front Impact Displacement

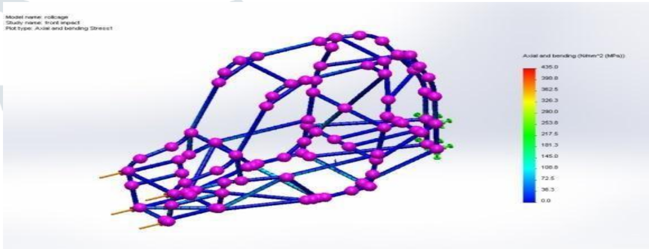


Figure 1.2 PFEA Front Impact Stress

Result
Max stress=202.9 N/mm2
Factor of safety=1.922 47 Result

2. Rear Impact Test

Loading=19839.94N

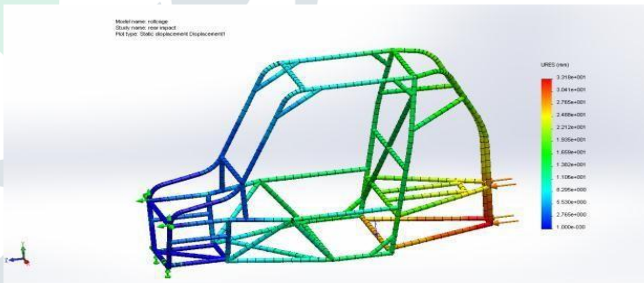


Figure.2.1 PFEA Rear Impact Displacement

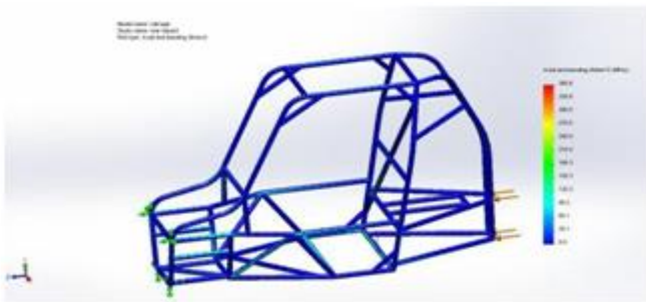


Figure 2.2 PFEA Rear Impact Displacement

Result
Max stress=127.2 N/mm2
Factor of safety=3.066

3. **Side Impact Test**

Loading= 10491.7285 N

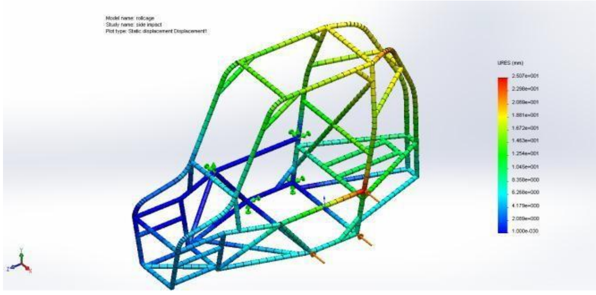


Figure 3.1. PFEA Side Impact Displacement

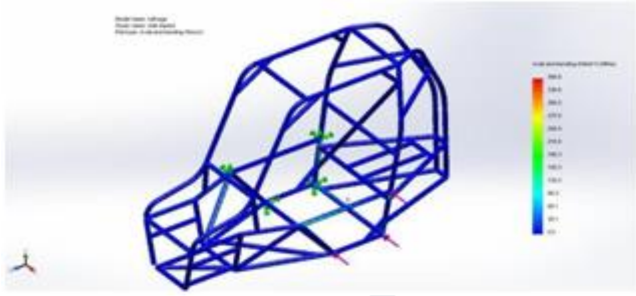


Figure 3.2. PFEA Side Impact Stress

Result
Max stress=239.3 N/mm2
Factor of safety=1.629 48

4. **Heave Test**

Loading= 3433.49 N

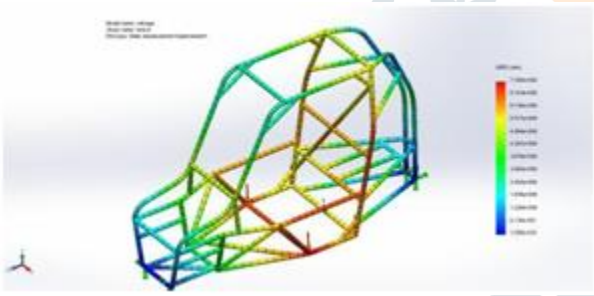


Figure 4.1. PFEA Heave Test Displacement

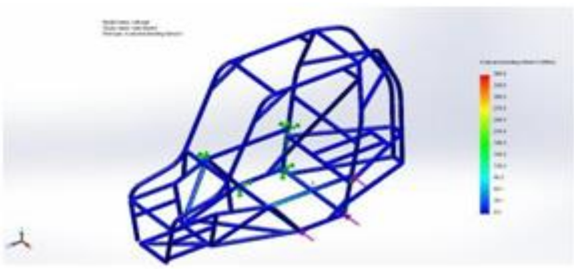
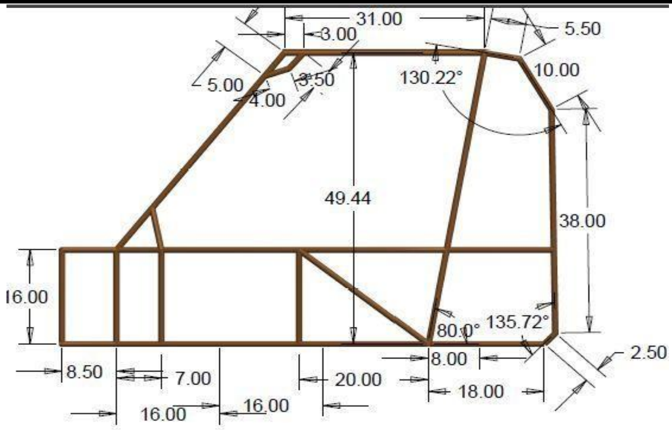
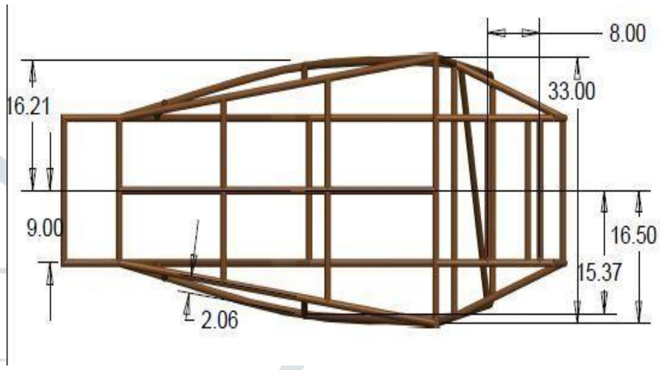


Figure 4.2. PFEA Heave Test Stress

Result
Max stress=69.5 N/mm2
Factor of safety=5.6

F. PROJECT LAYOUT





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