International Journal of Technical Innovation in Morden Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2584
Volume 3, Issue 4, April-2017

"Design, Analysis and Fabrication of a Rollcage for an All-Terrain Vehicle"

[1]Prof. Gaffar G. Momin
Dept. of Mechanical Engineering,
Pimpri Chinchwad College of Engineering,
Pune, India
gaffarmomin01@gmail.com

[2]Shital Sable, [3]Aniket Tayade, [4]Rupesh Thube, [5]Tejas Gedam
Dept. of Mechanical Engineering,
Pimpri Chinchwad College of Engineering,
Pune, India

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 2017 given by Society of Automotive Engineers (SAE). Baja SAE is an intercollegiate design competition run by the Society of Automotive Engineers (SAE). Teams of students from universities all over the world design and build small off-road cars i.e. ATV. The cars all have engines of the same specifications. 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. 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.

Keywords— ATV, off-road cars, roll cage, skeleton, impact, roll over, strength, stress analysis

I. INTRODUCTION

All-Terrain Vehicle (ATV) as defined by American National Standards Institution ANSI is a vehicle that travels on low-pressure tires driven using handle bar or steering wheel for steering control. Although ATVs were first designed only for a single operator but now-a-days many companies have developed ATVs with two or more seats occupy more people. In most of the countries around the globe, these vehicles are banned on streets.

All-Terrain Vehicle is a package of different systems, which are designed to enrich the performance and to provide comfort to the driver. Many different systems include chassis, steering system, suspension system, braking system, drive train, ergonomics and aesthetics. All these mentioned systems are inter-dependent. Failure of a single system or apart may lead to loss of the operator or driver. ATVs are also popular for their good aesthetics and their sporty look. (Refer figure 1)

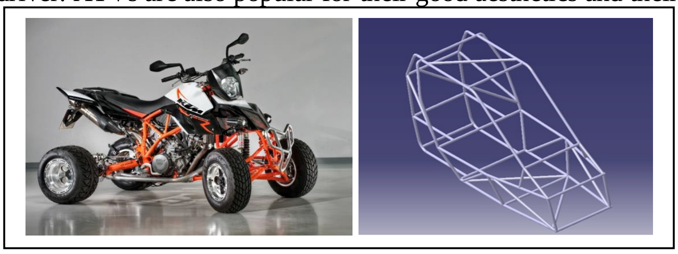


Figure 1: An ATV & Frame (Rollcage)

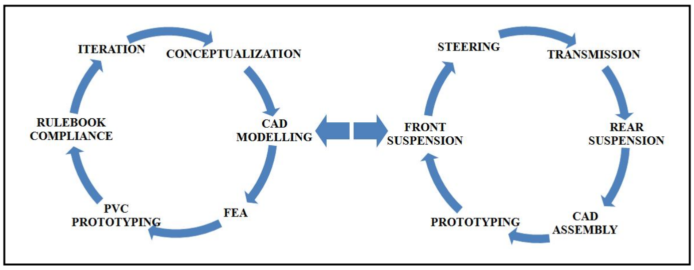
The definition of a roll-cage is a "a structural frame work designed to prevent serious body shell deformation in the case of a collision or roll-over". But a roll cage is better described as a Rollover Protection Structure (or system). The basic purpose of the roll cage is to protect the occupant in case of a roll over or a collision. It must be able to understand the weight of the car landing on the proof providing protection to riders of such vehicles from road hazard, debris and the element. It comprises a framework of a circular or hollow steel tubing welded together to form a cage having a front portion and overhead protection.

II. DESIGN OF ROLLCAGE

A. The roll cage is designed for the following objectives:

1. The roll cage must comply with the Baja SAE International rulebook 2017.
2. Ease and accuracy of manufacturing.
3. Provide full safety to the driver, by obtaining required strength and torsional rigidity, while reducing weight through diligent tubing sections.
4. Maintain serviceability by ensuring that roll cage members do not interfere with sub systems.
5. Light in weight.

Considering the above mentioned factors we proceeded to actual design of roll cage.



B. Design and Subsystem Integration Cycle:

The above cycle gives an idea about the design procedure carried out while designing the roll cage. As designing a roll cage is an iterative process the cycle is repeated until a final and satisfactory solution is obtained.

C. Material Selection

The material selected was subjected to safety regulations and weight minimization. According to the rulebook, the minimum carbon % should be 0.18%. Initially, we considered three materials –

1. AISI 1018
2. AISI 1040
3. AISI 4130

Various materials were compared and the best amongst them was selected. AISI 4130 was selected as a material for the cage because of its high bending stiffness and bending strength, low weight per meter. Analysis of the roll cage using AISI 4130 as the material proved that it was safe from various forces acting upon it.

D. Calculations:

Calculations for bending strength and bending stiffness of roll cage material are as follows:

<u>FOR AISI 1018</u>
Dimensions:
Outer diameter (Do): 25.4mm;
Inner diameter (Di): 19.4mm;
Thickness: 3mm;
C: Do/2mm; Sy: 365Mpa;
E: 205Gpa; ρ:7870kg/m3
FORMULAE:
$I = (\pi/64)*(D_o^4 - Di^4)$
Bending Strength=$(S_y*I)/C$
Bending Stiffness: E*I
Volume: area*length
$A = (\pi/4)*(D_o^2 - Di^2)$
Weight/m: volume*density

Substituting in the given formulae

$I=1.3471*10^{-8}\ m^4$
Bending Stiffness= 2761.35 Nm^2
Bending Strength= 387.129 Nm
Weight/m= 1.66 kg/m

<u>FOR AISI 4130</u>
Outer diameter (Do):29.2mm;
Inner diameter (Di): 25.9mm;
Thickness: 1.65mm
C: Do/2 mm; S_y: 712Mpa;
E: 205Gpa; ρ: 7870kg/m3
Similarly from the same calculation procedure as mentioned above,
$I=1.3590*10^{-08}\ m^4$
Bending Stiffness=2786.10371Nm^2
Bending Strength=662.7817Nm
Weight/m=1.122 kg/m

<u>FOR AISI 1018</u>
Outer Diameter (Do): 31.75mm;
Inner Diameter (Di): 27.75mm;
Thickness: 2mm
C: D_o/2 mm; Sy: 460Mpa;
E: 205Gpa; ρ: 7870kg/m3
Similarly from the same calculation procedure as mentioned above,
I=2.6051*10-8 m4
Bending Stiffness=4233.25 Nm2
Bending Strength=593.48 Nm
Weight/m=1.47 kg/m

The calculations were tabled and comparison of material properties is as shown in table:
Table 1: Comparison of material properties

Properties	AISI 1018	AISI 1018	AISI 4130
Carbon Content (%)	0.18	0.18	0.30
Tensile Strength (MPa)	440	440	760
Yield Strength (MPa)	370	370	712
Outer diameter (mm)	25.4	32	29.2
Thickness (mm)	3	2.0	1.65
Bending Strength (Nm)	392.68	477.626	662.7817
Bending stiffness (Nm2)	2763.1	4258.2	2786.10371
Weight\meter (kg\m)	1.686	1.47	1.122
Cost (Rs./metre)	325	325	920

From the above comparison it has been found that AISI 4130 is best suitable material available with us for our roll cage manufacturing.

E. Driver Ergonomics

Ergonomics is a scientific discipline that uses principles of biotechnology and engineering to make products more comfortable for consumers. The main function of ergonomics is to:

a. Maximum Driver Comfort

b. Ease of Control
c. Maximum Safety
d. Good View of the road to the driver
e. Acceptability of the vehicle interior amongst all the types of people i.e. (fat, slim, tall, strong build, lean build, etc.)

US military handbook was referred for selecting various values of ergonomic parameters shown as follows:

Table 2: Ergonomic Parameter

PARAMETER	RANGE	VALUE
Lap Angle	110°-120°	130°
Ankle Angle	85°-110°	90°
Seat Angle	95°-100°	95°
Elbow Angle	80°-165°	105°
Upper Arm Angle	0°-35°	19°
Angle of vision	20°-40°	30°
Steering Column Angle	20°-50°	50°

The CAD model was designed using Catia software. Catia model to verify the values of various ergonomic angles is shown as in figure 2.

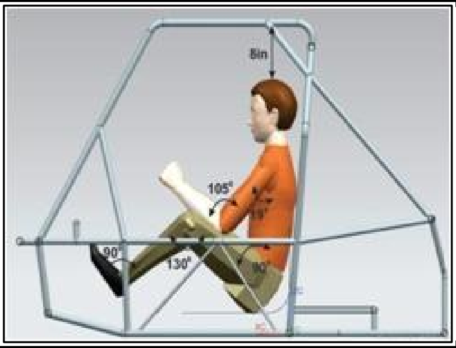


Figure 3: Catia model verifying ergonomic values.

F. PVC MODEL

To cross verify the points considered during the design of rollcage such as ergonomics, various subsystem mountings and accommodation of the smallest and the heftiest driver actual PVC model of rollcage was constructed as shown in figure 4.

Figure 4*:* Driver accommodation in rollcage PVC model

G. 3-D Model:

The initial frame design was first modeled and dimensioned in CATIA. As other areas of the vehicle design evolved, the model of the frame changed several times until a design that integrated well with all other components was achieved. This model was perfected and finalized in Catia. It gave us a chance to go over the dimensions of the vehicle and to make sure that they met all requirements. It provided us with a 3-D visualization of the frame, which ensured that the frame would be aesthetically appealing. One of our goals was to incorporate bends wherever possible so as to minimize the number of welded joints. The following figure is the final model of the roll cage.

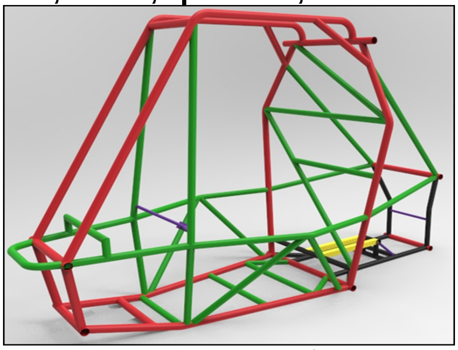


Figure 5: Catia model of Rollcage

III. ANALYSIS OF ROLLCAGE:

After completion of design of the roll cage we need to find that our roll cage will perform well in field so we performed analysis in Ansys software. Analysis was performed in order to determine the maximum stress and deformation. For the analysis purpose, our vehicle was considered to be moving with a maximum velocity and hitting a stationary wall (in case of front impact) and hit by the another moving vehicle (in case of side and rear impact). The stresses and deformation developed were under the limit does the design was considered to be safe.

FMVSS Rule 214 for Side Impact:

In this case, a sideways impact into an obstruction.22miles/hr.=35 km/hr. and time of impact comes out to be 0.349sec.The next step in the analysis was to analyse a side impact with a 2.83G load. The model is impacted on its side. The detailed view of the resulting stress is shown.

Load= 5830.1 N

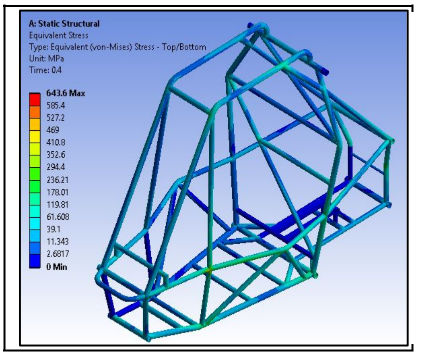


Fig 4. Stress generated due to Side Impact

FMVSS Rule 208 for Front Impact

In this case, the front of the car, disregarding the impact attenuator is considered to collide with a stationary object in a head-on collision. 34miles/hr.=55 km/hr. and time of impact comes out to be 0.3sec. The first analysis to be completed was that of a front collision with a stationary object. The model is supposed to make contact at its front junctions where FBM (Front Bracing Members), SIM (Side Impact Members) and LFS (Lower Frame Side) members join. So the loads act horizontally in positive X direction on this point.

Load=10692 N

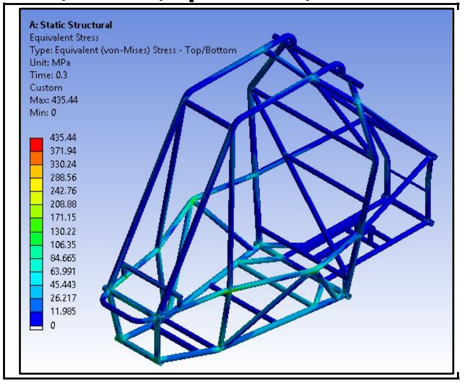


Fig 6: Stress generated due to Front Impact

FMVSS rule 224 for Rear Impact:

In this case, another car is considered to collide head-on with the rear of the car 28miles/hr. =45 km/hr. and time of impact comes out to be 0.4sec. The next step is to analyse the model for Rear impact with 3.19G. The point of application is shown.

Load= 6571.7 N

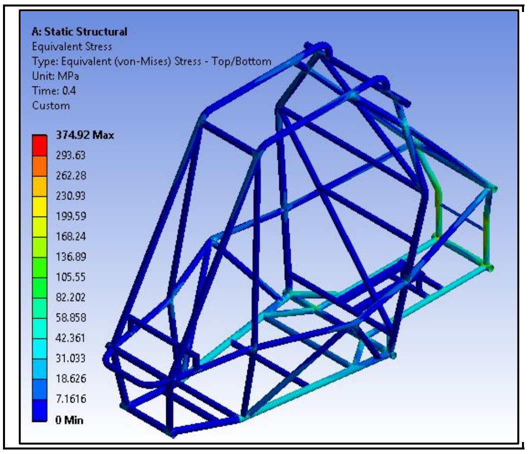


Fig 8: Stress generated due to Rear Impact

FMVSS rule 201 for Rollover:

In this case, overturning or rollover of the chassis is considered and the effect of self-weight is considered as an impact load. From a height of 0.5 m and time of impact comes out to be 0.2sec. The Final step in the analysis was to analyse the stress on the roll cage caused by a rollover. Loading was applied to the upper forward corners of the perimeter hoop with a combination vector sideways and downward shows the point of application for the loading on the roll cage.

Load= 5850.7 N

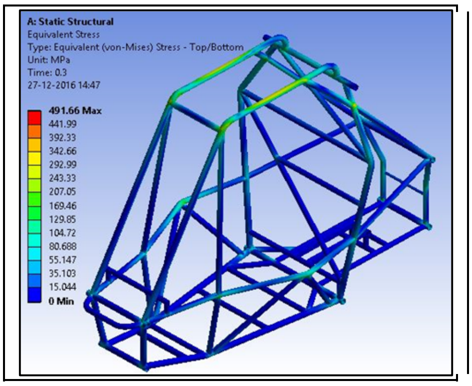


Fig 10: Stress generated due to Roll Over

IV. CONCLUSION

Hence, design output is for no plastic deformations. The vehicle should remain in the elastic region. The Safety of the driver in case of crash is taken care of by safety equipment, which includes special helmets, foam padding on bars and seat belts. Further, software analysis shows us that the vehicle can take frontal impacts of up to approx. 11,000 Newton and side impacts of up to approx. 6,000 Newton. This clearly reaffirms the vehicle's ability to withstand extreme conditions.

V. REFERENCES

[1]Amrit Om Nayak, S.Kalaivanan, D.Manikandan, G.Ramkumar, T.Manoj, M.A.Kannan (2012), Complete Design and Finite Element Analysis of an all Terrain Vehicle, International Journal of Mechanical and Industrial Engineering (IJMIE), ISSN No. 2231 –6477, Volume-1, Issue-3.

[2]GautamYadav,Ankit Jain (2012), Design and Front Impact Analysis of Rollcage, International Conference on Challenges and Opportunities in Mechanical Engineering, Industrial Engineering and Management Studies (ICCOMIM - 2012).

[3]Harsh Raghuvanshi, N.S. Ramnaveen, PuneetMalhotra, Rakshit, AnuragKhatri (2013), Innovative Design of an All-Terrain Vehicle (ATV), International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-3, Issue-2

[4] Fundamentals of Vehicle Dynamics – Thomas D. Gillespie.

[5] www.bajasaeindia.org/rulebook (Design Specification).

[6] William B. Riley and Albert R. George (2002), Design, Analysis and Testing of a Formula SAE Car Chassis, SAE TECHNICAL PAPER SERIES 2002-01-3300.

[7] Dr. N.K.Giri, Automobile Mechanics, Khanna Publishers.

