Safe Design of ATV Frame

Dr. V.K Saini1, Sunil Kumar2, Harsh Chhaunker, AmanPandey, Prashant Gupta, ShubhamYadav

1Professor, Mechanical Engineering, IMS Engineering College, Ghaziabad2Assistant Professor, Mechanical Engineering, IMS Engineering College, Ghaziabad ,UG Scholar, Department of Mechanical Engineering, IMS Engineering College, Ghaziabad

Abstract

This study is performed to analyse a BAJA ATV (All-Terrain Vehicle) Frame. BAJA is an renowned ATV competition where students design and develop their own vehicle considering in mind various constraints of design as well as safety features. A BAJA ATV is developed in such a way that it can run on various tracks such as soil, mud, Gravel, pebbles, etc. so due to tough terrain our focus was on driver safety and ergonomics simultaneously. In order to meet driver safety and reduce weight proper selection of material was done.

Key Words: *Roll Cage, Material Selection, Ergonomics, Designing, Analysis and Simulation.*

Figure A : Solidworks Model

INTRODUCTION

An ATV (All-Terrain Vehicle) is designed to run on different tracks or we can say that an ATV is designed specifically for off-roading. In these conditions, vehicle undergoes various loads that are transmitted to the ATV frame. Frame is an essential part of an automobile since all mountings and assemblies are attached on itself, so it becomes essential for an ATV frame to sustain static and dynamic load condition. A Validate design process of the frame is done before the vehicle is actually tested on various terrains.

Different frame design were used based on loading condition, example a ladder frame is used in heavy vehicles where load has to be transferred ,similarly there are some other types such as monocoque, tubular space frame etc. [1] among all these tubular space frame is the one which we consider for designing of our ATV because it provides multi-directional impact safety as well

1. DESIGNING PHASE

Designing phase involves following steps:

- Selection of proper Cross-section and good Material
- Designing the Roll cage using different constraints.
- Validating the design keeping driver safety and comfort by creating a precursor of frame using plastic pipes.
- Analyzing the frame for various impact testing on simulating software.

2. SELECTION OF CROSS-SECTION & MATERIAL

AISI 4130 grade was taken in consideration for designing purpose due to its availability, high yield strength and good carbon percentage and good weld ability and its alloying element which imparts rigidity to the material.

Table given below provides the comparison between AISI 1018 and AISI 4130 according to the rulebook provided by SAE BAJA [2].

Table 1 Material Comparison

Property	AISI 1018	AISI 4130
Carbon %	0.18	0.282
Yield Strength	386MPa	460MPa
Ultimate Strength	440 MPa	560MPa
Elongation	24%	30%
Density	7.7 g/cc	7.7 g/cc

From above table (Table 1) we observe that yield strength of AISI 4130 is much greater as compared to AISI 1018. It is also observed that AISI 4130 has lesser mass density compare to AISI 1018 so with improved tensile strength we are getting the weight reduction as well.

The circular tube that was selected for the designing purpose is easily available in market easier and cheaper & match the dimensions:

Table 2: Selected Cross-section

Outer dia (mm)	31.75
Thickness (mm)	1.5
Moment of Inertia (mm^4)	17269

Moment of inertia is calculated by formula:-

$$\mathbf{MOI= (\pi/64) *(Do^4-Di^4)} \qquad (1)$$

Where

Do- Outer Diameter of tube
Di- Inner Diameter of tube

Bending strength and bending stiffness are calculated by following formula because it plays important role in designing -

Bending Strength- σ_y***MOI/C** **(2)**
Bending Stiffness- **E*I** **(3)**

Table 3-Strength and Stiffness	
Bending Strength	747 N-m
Bending Stiffness	2787. N-m

3. DESIGNING THE ROLL CAGE USING CONSTRAINTS

Roll cage was designed according to the rules prescribed in BAJA SAEINDIA rulebook 2019. Constraints that were provided in the designing phase are mentioned:-

- Track width of the ATV cannot be greater than 64''.
- Length of the vehicle must not be greater than 108''.
- A minimum of 6 inches clearance must be available between driver's head and each frame member.
- Driver's knees and the side impact member(SIM) must be 3'.

So, after making the design on designing software we prepared a prototype roll cage to check driver's ergonomics.

Figures 1 depict the design of Roll cage and figure 2 represnet the mock frame:

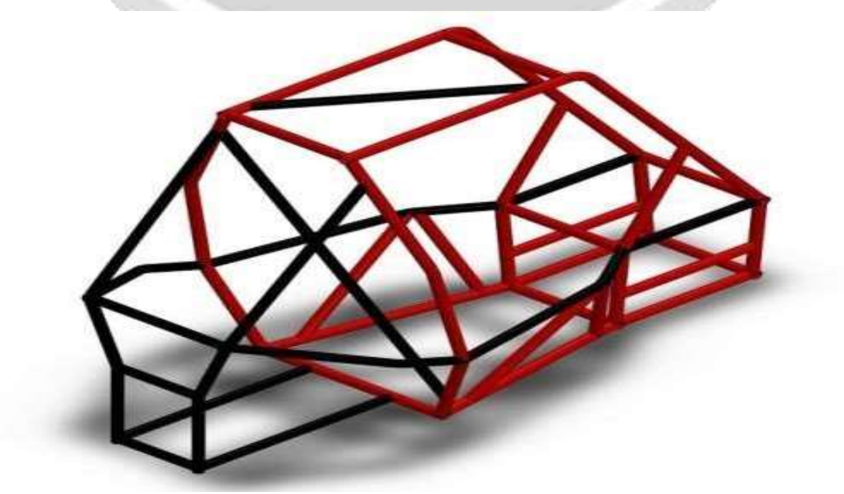

Figure 1: Designed Frame

2a 2 b

Figure 2 (a & b) : Checking the ergonomics of the frame

4. ANALYSIS OF FRAME

After the final design , the frame was analyzed on testing software ANSYS 16 for impact tests which are given below:

- Front Impact
- Rear Impact
- Side Impact
- Roll Over

In order to calculates force that is going to induce in vehicle after the collision is calculated by **" work energy principal"** in which the **"work done is equal to change in kinetic energy"** and the forces applied on frame are given in table 4.

Table 4: Force Applied	
Front Impact	12820N
Rear Impact	6410N
Side Impact	7700N
Roll-Over	31900N

4-A. CALCULATION

Considering Weight of the ATV, M =230 kg (including driver weight)
Initial velocity before impact, v initial = 16.67 m/s
Final velocity after impact, v final=0
Impact time = 0.15 sec.
From work energy principal
Work done = change in kinetic energy.
$|W| = |-0.5 \times M \times v_{initial}^2| = |-0.5 \times 230 \times 16.67^2| = 32056.9216$ Nm
Work done = force × displacement= F × s

Front impact

ATV is considered to be in static state and force corresponding to velocity 60 km/h with impact time 0.15 seconds is applied to front part of the roll cage of ATV keeping rear suspension members fixed.

Work done = force × displacement= F × s

s = impact time × v maximum = 0.15 ×16.67 = 2.5008m

So, from work done equation, we get, F = W/ s =32056.9216/2.5008 = 12818.67N≈12820N

Side impact

For analysis, ATV is considered to be in static state and force corresponding to velocity 60 km/h with impact time 0.25 seconds is applied to side of the roll cage of ATV keeping suspension members of other side fixed.

s = impact time × v maximum = 0.25 ×16.67 = 4.168m

So, , from work done equation, we get, F = W/ s = 32056.9216/4.168=
7691.2N≈7700N

Rear impact

For analysis, ATV is considered to be in static state and force corresponding to velocity 60 km/h with impact time 0.30 seconds is applied to rear part of the roll cage of ATV keeping front suspension members fixed.

s = impact time × v maximum = 0.3 ×16.67 = 5.001m

So, from work done equation, we get, F = W/ s = 32056.9216/5.001=6410.102N

Roll over

For analysis, ATV is considered to be in static state and force corresponding to the calculated velocity 27.83 km/h for 10 feet with impact time 0.15 seconds is applied to top of the roll cage of ATV keeping bottom members fixed. During the fall, the whole potential changes into kinetic energy,

$M \times g \times h = 0.5 \times M \times v^2$

$v = \sqrt{(2 \times g \times h)} = \sqrt{(2 \times 9.81 \times 3.048)} = 7.73$ m/sec (or 27.83 km/h)

$|W| = |-0.5 \times M \times v_{initial}^2| = |-0.5 \times 300 \times 7.732| = 8962.935$ Nm

s = impact time × v maximum = 0.13 × 7.73 = 1.0049 m

So, , from work done equation, we get, F = W/ s =32056.9216/1.0049=31900.6N

4-B. RESULTS

Front Impact:

In this case rear points are fixed and 12800N force was applied at the front nodes which will suffer the collision. Meshing was done considering mesh size of 3 mm Figure 3 shows the maximum stress generated at front which was found out to be 184.85 MPa and Figure 4 shows Maximum deformation as 1.2002mm.

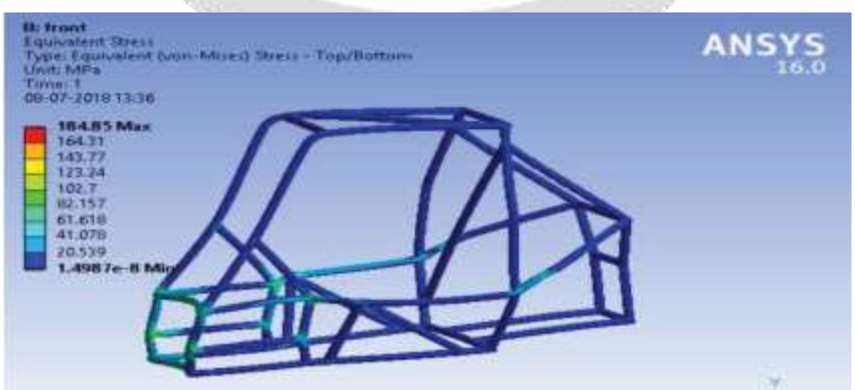

Figure 3: Maximum Stress in Front Impact

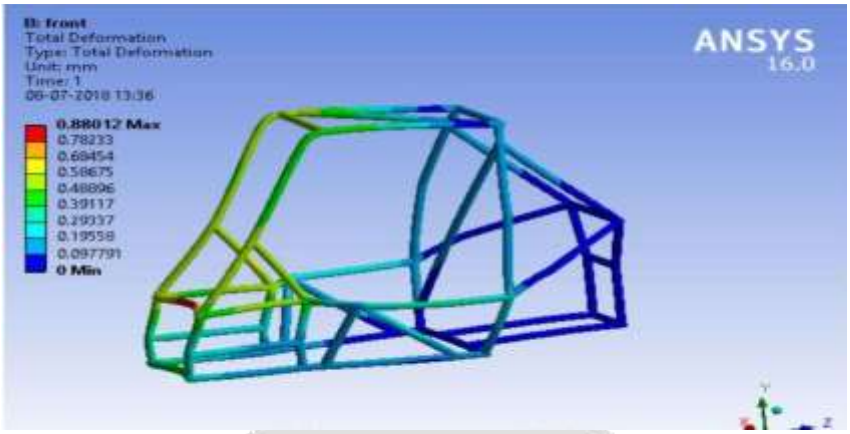

Figure 4: Maximum Deformation in Front Impact

<u>Rear Impact:</u>

In this case frontal points are fixed and 6410N force was applied on rear nodes that undergoes collision. Meshing size was 3 mm and Maximum stress that was generated was 241.86 MPa as shown in Figure 5 whereas Figure 6 show maximum deformation of 1.63 mm.

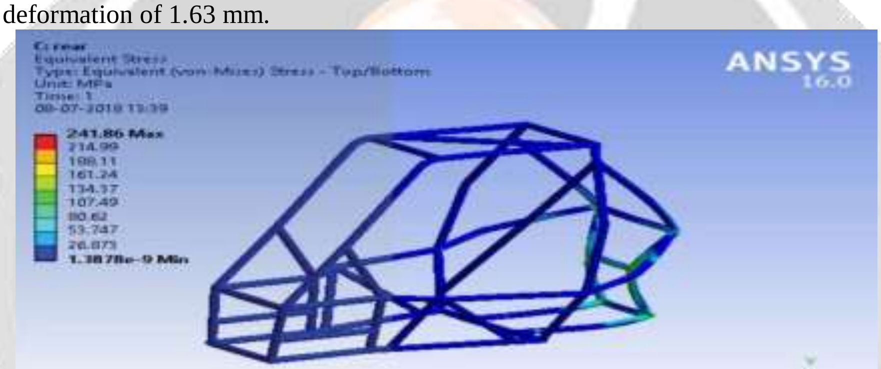

Figure 5: Maximum Stress in Rear Impact

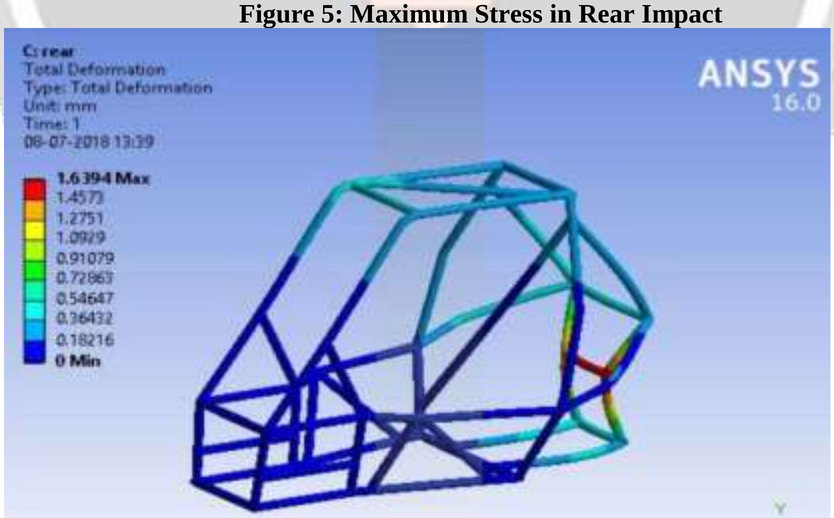

Figure 6: Maximum deformation in Rear impact

<u>Side Impact:</u>

In this case the opposite points on which the load of 7700N is applied and are fixed and load is applied on the obtruded node of Side impact member (SIM). Meshing size was 3 mm and Maximum stress that was generated was 277.9MPa as shown in Figure 7 whereas Figure 8 show maximum deformation of 4.471 mm.

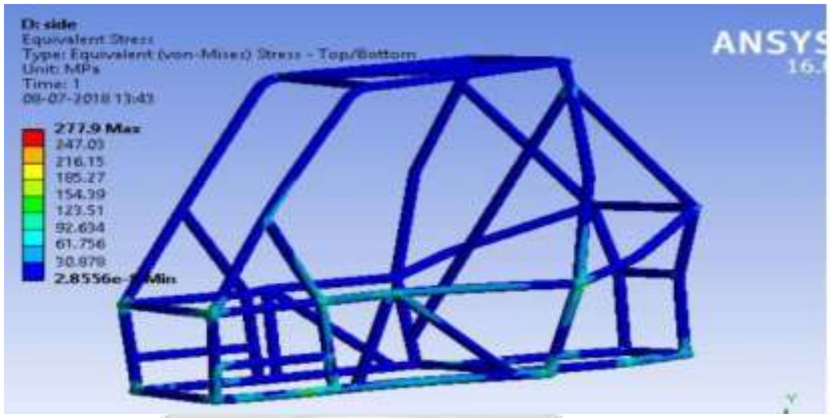

Figure 7: Maximum Stress in Side Impact

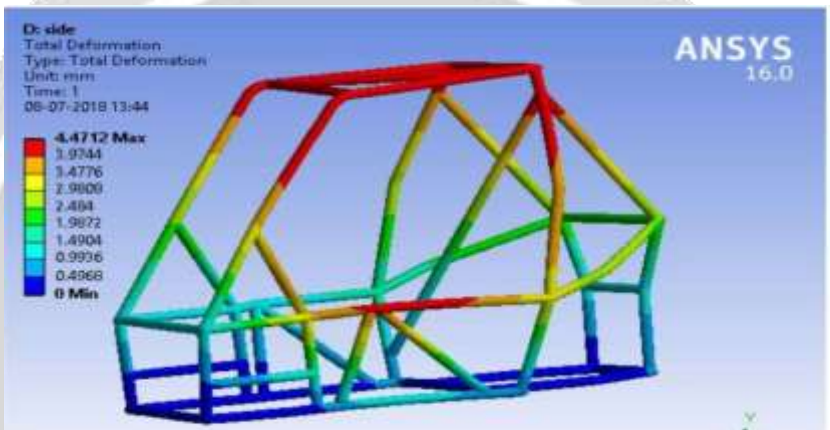

Figure 8: Maximum Deformation in Side Impact

<u>Roll Over</u>:

In this case 31900N load was applied through a plane which is at 45° to Cartesian co-. The Maximum stress of 221.6 MPa was developed in case of roll over as shown in figure 9 and Figure 10 shows maximum deformation of 1.64 mm in Roll-over

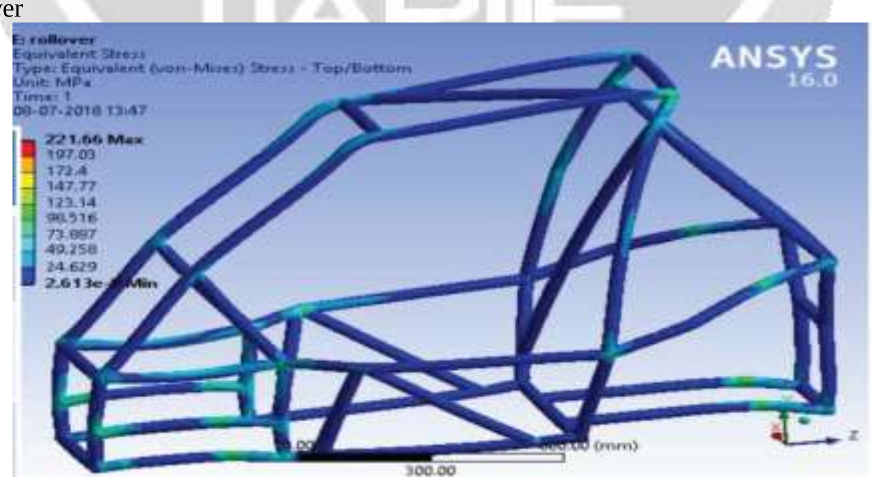

Figure 9: Maximum Stress in Roll Over

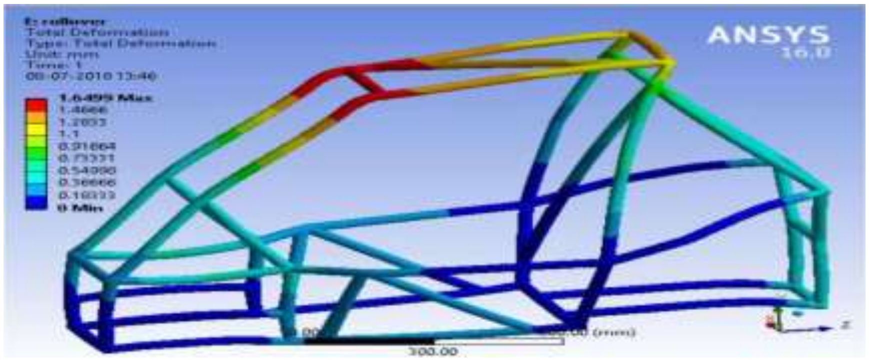

Figure 10: Maximum Deformation in Roll Over

Factor Of Safety

FOS = σ_y / σ_{max}

Where-

σ_y - yield stress of material

σ_{max} - maximum induced stress

Calculated factor of safety is given below in table 5.

Table 5: Results

Impact	Maximum Stress (MPa)	Total Deformation (mm)	FOS
Front	184.8	0.88	2.4
Rear	241.8	1.63	1.9
Side	277.9	4.47	1.6
Roll over	221.6	1.64	2

5. CONCLUSION

While in the designing phase we consider to achieve the maximum deformation less than 10 mm and factor of safety greater than 1.5 and thus we achieved Maximum deformation in case of the case is less than 10mm and the factor of safety is greater than 1.5 in each case. Thus our design is safe.

REFERENCES

[1] Thomas D. Gillespie, Fundamentals of Vehicle Dynamics, Research Professor Emeritus, University of Michigan Transportation Research Institute (UMTRI).

[2] BAJA SAEINDIA Rulebook 2019.

[3] IOSR Journal of Mechanical and Civil engineering (IOSR-JMCE), e-ISSN: 2278-1684, p-ISSN: 2320-334X PP 49-53