Design and Analysis of BAJA ATV (All-Terrain Vehicle) Frame

Dr. V.K Saini[1], Sunil Kumar[2], Pushkar Mishra[3], Arpit Asthana[4], Vishal Choubey[5]

[1]*Professor, Mechanical Engineering, IMS Engineering College, Ghaziabad*
[2]*Assistant Professor, Mechanical Engineering, IMS Engineering College, Ghaziabad*
[3,4,5] *UG Scholar, Department of Mechanical Engineering, IMS Engineering College, Ghaziabad*

Abstract - *The aim of this study was to deal with designing and analysis of a BAJA ATV (All-Terrain Vehicle) Frame. BAJA is basically an ATV competition where students get to design and develop their own ATV keeping in mind various considerations of design as well as safety. An ATV is designed in order to run on various terrains such as soil, Gravel, pebbles, etc. so due to difficult terrain our main focus was on driver safety and better ergonomics at the same time. As the load acting on the frame is directly proportional to the weight of the frame so we also considered the factor of weight reduction as a key area of focus. In order to meet driver safety and reduce weight proper selection of material was needed to be done.*

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

1. INTRODUCTION

As per the name an ATV (All-Terrain Vehicle) is designed to run and maneuver on different terrains or in other words we can say that an ATV is designed especially for off-roading purpose. In off-roading conditions, we come across various loads which are finally transmitted to the frame. Frame is most important part of an automobile as all mountings and assemblies are done on frame itself, so it becomes necessary for an ATV frame to sustain both static and dynamic loads. In this study we have put forward a proper methodology for designing and analyzing the frame before the ATV is tested on vigorous terrains and conditions.

Various types of frames are used depending on the type of loading which they will undergo, for example a ladder frame is used in heavy commercial vehicles where load has to be transferred from one place to another, similarly there are other types such as monocoque, ULSAB, tubular space frame etc. (1) among these tubular space frame is one which we have considered for designing our ATV because it provides multi-directional impact safety as well as it is easier in fabrication.

1. DESIGNING PHASE

Designing phase basically involved following steps:

- Selection of Cross-section and Material
- Designing the Roll cage using various constraints.
- Verifying the ergonomics by construction a mock frame using PVC pipes.
- Analyzing the frame for its impact testing on ANSYS.

2. SELECTION OF CROSS-SECTION & MATERIAL

AISI grade was considered for designing purpose due to its easy availability, high yield strength and good carbon percentage which imparts rigidity to the structure, another considerable factor was its cheap availability.

Following table gives the comparison between AISI 1018 and AISI 4130 as per the rulebook of BAJA SAEINDIA it is necessary to meet the minimum tubing requirements with AISI 1018.

Table 1 Material Comparison

Property	AISI 1018	AISI 4130
Carbon %	0.18	0.282
Yield Strength	387 MPa	659.8 MPa
Ultimate Strength	440 MPa	810 MPa
Elongation	24%	30%
Density	7.8 g/cc	7.9 g/cc

In the above table (Table 1) we can see that yield strength of AISI 4130 is much higher as that compared to AISI 1018. We can also see that AISI 4130 has lesser mass density than that of AISI 1018 so we can say that with improved tensile strength we are getting the weight reduction as well.

The circular tubing which was selected for the designing purpose had to be easily available in market easier and cheaper production, so following were the dimensions:

Table 2: Selected Cross-section

Outer dia (mm)	31.75
Thickness (mm)	1.6
Moment of Inertia (mm^4)	17269

Moment of Inertia (MOI) is calculated by following formula:

$$MOI = (\pi/64) * (D_o^4 - D_i^4)$$

Where

D_o=Outer diameter of the pipe
D_i=Inner diameter of the pipe

Also Bending Stiffness and Bending Strength are calculated as they play important role during designing.
Bending Strength= σ_y*MOI/C
Bending Stiffness= E*I

Table 4-Strength and Stiffness	
Bending Strength	717.7 N-m
Bending Stiffness	3663.14 N-m

3. DESIGNING THE ROLL CAGE USING CONSTRAINTS

We designed the roll cage using the various rules prescribed in BAJA SAEINDIA rulebook 2018[2]. Some constraints that are employed in the designing phase are discussed below:

- Maximum track width of the vehicle must not be greater 64 inches.
- Maximum length of the vehicle cannot be greater than 108 inches.
- There must be minimum 6” driver head clearance from drive helmet to each frame member.
- 3” Clearance must be available from driver’s knees and the side impact member(SIM).

So, after making the design on SOLIDWORKS we prepared a mock roll cage just to check driver ergonomics.

Figures below depict the designed Roll cage and the mock frame:

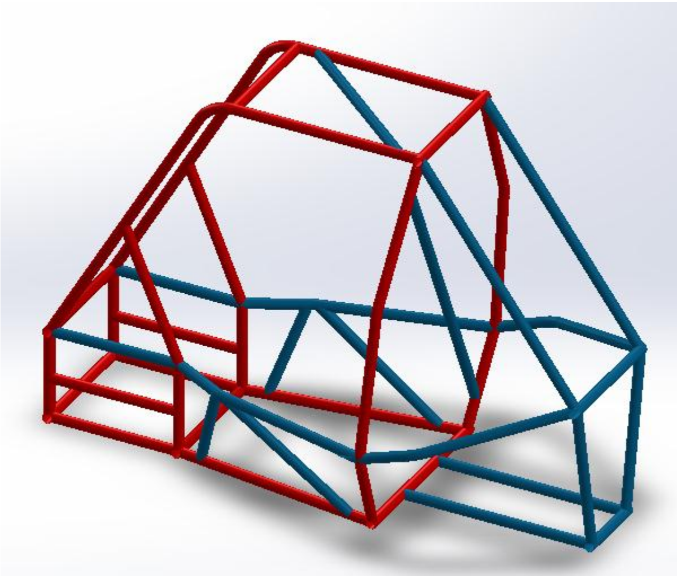

Figure 1: Designed Frame

Figure 2: Checking the ergonomics of the frame

4. ANALYSIS OF FRAME

After the design was finalized the frame was analyzed on ANSYS for various impact tests which are discussed below:

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

“G Force” method [3] was employed as it is most commonly used method for analyzing when prototype testing could not be done due to some limitations such as lack of resources.

As per calculation:

$$G=m*g=250*9.81=2452.5\ N$$

Where

m=mass of ATV

g=acceleration due to gravity

Table 2: G-Force Applied	
Front Impact	5G
Rear Impact	3G
Side Impact	2.5G
Roll-Over	1.5G

Front Impact: In case of front impact rear pick up points are fixed and 5G force is applied at the frontal nodes which will face the collision. Meshing is done with mesh size of 0.5 mm Figure 3 depicts the maximum stress generated in front impact which comes out to be 300.76 MPa whereas Figure 4 shows Maximum deformation is 4.4 mm.

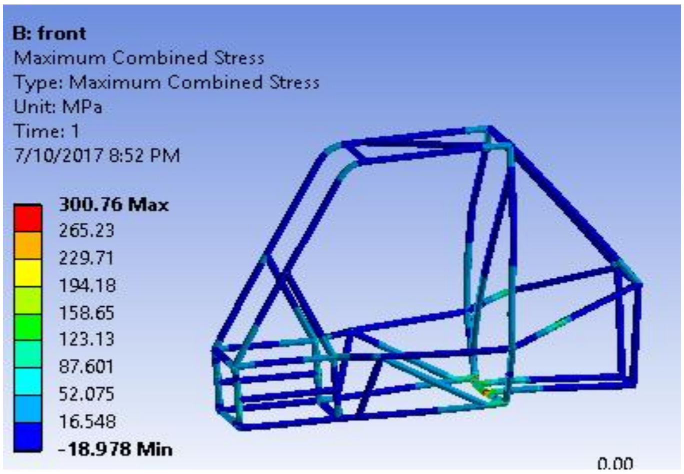

Figure 3: Maximum Stress in Front Impact

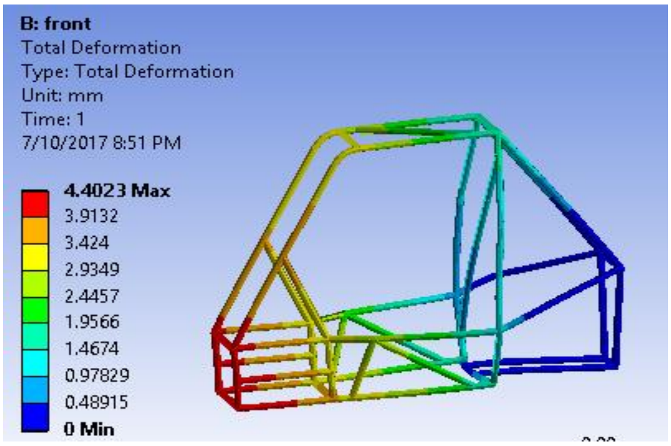

Figure 4: Maximum Deformation in Front Impact

Rear Impact: In case of Rear Impact analysis forward pickup points are fixed and 3G force is applied at rear nodes which will undergo collision. Meshing size was 0.5 mm and Maximum stress which was generated was 224.65 MPa as shown in Figure 5 and Figure 6 show maximum deformation of 2.64 mm in case of rear impact.

Figure 5: Maximum Stress in Rear Impact

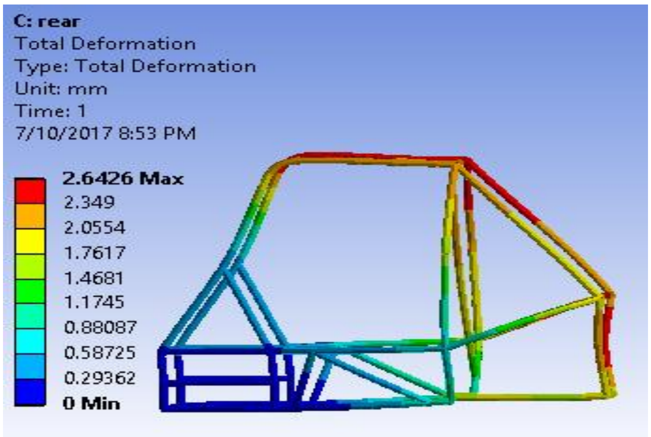

Figure 6: Maximum deformation in Rear impact

Side Impact: In case of Side Impact the opposite pickup points to which the load of 2.5G is applied are fixed and load is applied at the most protruding node of Side Impact member (SIM). Meshing size was 0.5 mm and Maximum Stress that was generated was 435.7 MPa as shown in figure 7, whereas figure 8 shows maximum deformation of 9.23 mm in case of side impact.

The deformation of 9.23 mm in this impact comes out to be maximum but it should not be paid much attention as during the designing phase we considered a 4" allowance for SIM.

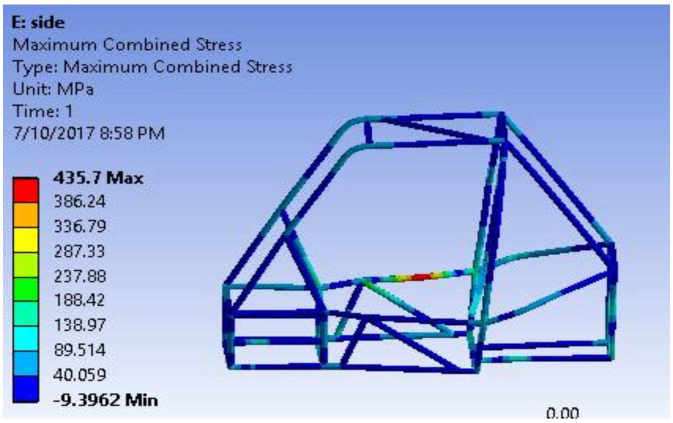

Figure 7: Maximum Stress in Side Impact

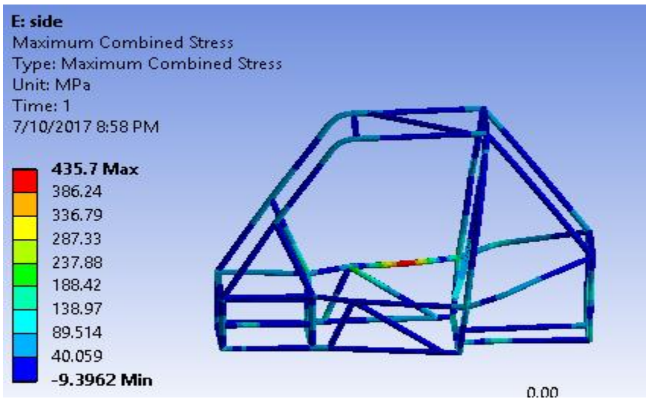

Figure 8: Maximum Deformation in Side Impact

Roll Over: In case of Roll over 1.5G load is applied through a reference plane which is at 45° to Cartesian co-ordinate plane the top of front bracing member. The Maximum stress of 152.51 MPa is developed in case of roll over as shown in figure 9. Figure 10 show maximum deformation of 3.38 mm in Roll-over.

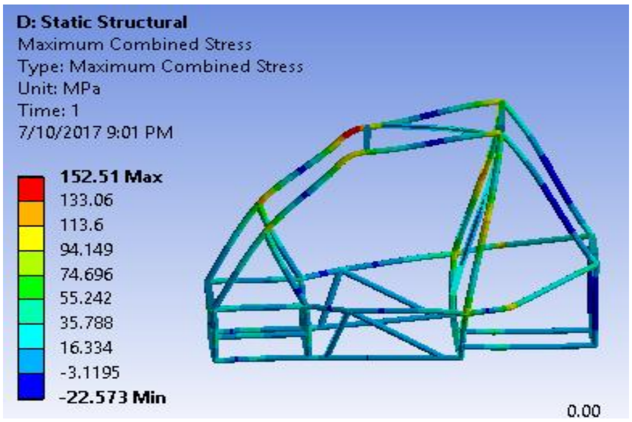

Figure 9: Maximum Stress in Roll Over

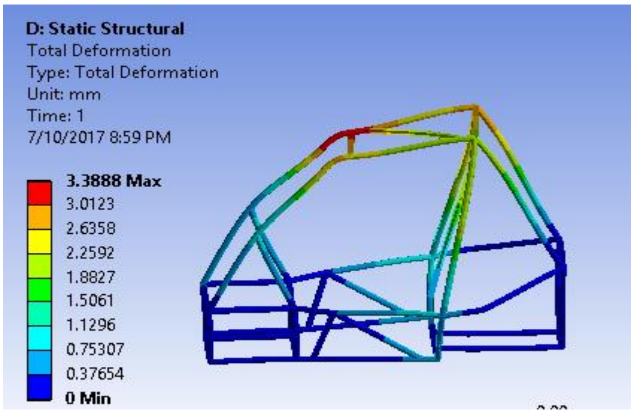

Figure 10: Maximum Deformation in Roll Over

Now we will be analysing the Factor of Safety of the material, FOS helps us in ensuring that the design will be safe for the use.

Mathematically,

$FOS = \sigma_y / \sigma_{max}$

Where

σ_y is yield stress of material

σ_{max} is maximum induced stress

Table 5: Results

Impact	Maximum Stress (MPa)	Total Deformation (mm)	FOS
Front	300.76	4.4	2.19
Rear	224.65	2.64	2.93
Side	435.7	9.23	1.51
Roll over	152.51	3.38	4.32

5. CONCLUSION

The maximum deformation is observed in case of side impact i.e. 9.23 mm but we have considered allowance of 4" in the designing phase as well as factor of safety is observed to be greater than 1.5 so we can say that our design is safer and by iterations we can also conclude that ergonomically better.

REFERENCES

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

[2] BAJA SAEINDIA Rulebook 2018.

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