DESIGN AND STATIC ANALYSIS OF CHASSIS OF ALL TERRAIN VEHICLE (BAJA SAE)

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Abstract - *An all-terrain vehicle (ATV) is specified as a motorized off-highway vehicle designed to move on four low-pressure or non-pneumatic tires, which is a land-based automobile capable of travel to remote areas where normal vehicles cannot reach. The prime focus of an ATV is to provide comfort and safety on challenging terrains and having a seat designed to be straddled by the driver and handlebars for steering control. Load coming from the road bumps, cornering, etc. are supported by the roll cage. It also protects the driver from collision and overturning incidents. The design of an ATV should be compact and capable enough to handle high speeds and sharp turns. One of the most challenging tasks while designing an ATV is to design a stable chassis that enhances the performance and safety by considering multi-dimensional factors. Therefore, considering the present industry requirements, this paper deals with the selection of material and cross-section for the chassis and analyzing the frame design for different loading conditions. Further, it proceeds to predict whether it will survive various impact scenarios that may occur during events using ANSYS workbench. This ensures that the load bearing framework is able to withstand the challenges of uneven terrains and provide the ATV is a stable support to ensure better handling and safety. The main objective is to analyses the roll cage design is to maximize the factor of safety and at the same time considering other aspects like light body weight, compact and stable design to get better performance of the vehicle.*

***Key Words*: BAJA SAE, ATV, Chassis, Static Structural Analysis, Force Calculation, Finite Element Analysis.**

1. INTRODUCTION

The chassis of an all-terrain vehicle (ATV) is a skeleton structure that not only protect the driver also supports systems such as suspension, steering, and the powertrain. For this reason, the chassis of an all-terrain is designed by considering factors such as the safety of the driver, ease of manufacturing, sustainability, compactness, light weight and ergonomics design. This paper focuses on several loading tests like Front Impact, Rear Impact, Side Impact, Rollover, Bump and torsion to check whether the chassis can withstand all types of collisions. It analyses and predicts the vehicle's ability to withstand extreme conditions. The primary function of a chassis is to backing the vehicle's mechanical part and deal with static and dynamic loads, without improper deflection or deformation. It should be designed in an ergonomic and strong effective manner at optimum cost and weight for rough terrain purposes. The special requirements of ATV's, like the need of better stability and safety is done by providing a stable chassis structure, which is the basic load bearing framework of the ATV's. The developing of the roll cage has considered the requirements through the guidelines provided in Baja SAE 2020 rulebook. It confirm the vehicle's ability to cope up with extreme situation.

❖ These are the following point that taken into consideration while designing of the chassis.

- ✓ FOS (high).
- ✓ Human ergonomics (high).
- ✓ Manufacturing (Convenient).

2. DESIGN CONSIDERATION & ESTALISHMENT

The design and establishment process of the chassis involves various considerations; namely material selection, cross-section determination, chassis design, and finite element analysis. One of the critical design decisions that enhance the reliability, safety, and performance of any vehicle structure is the material choosing.

2.1 MATERIAL SELECTION

The chassis steel must be built under the guidelines of the rule book. The material selection for the chassis is AISI 4130 STEEL as material having high strength to weight ratio and stiffness to weight is same in axial and bending point. The AISI 4130 has low carbon content, hence can be welded easily. It has also very high tensile strength and corrosion resistance as it contains chromium (0.8 to 1.1%) and molybdenum (0.4 to 0.6 %) as strengthening agents. It is suitable material for making chassis as compare to Mild steel and AISI1018.

Material Grade	**Alloy steel AISI4130**
Density	7850kg/m^3
Yield stress	460 MPa
Ult. tensile strength	560 MPa
Poisson ratio	0.3
Elastic strength	210 GPa

Dimensions (OD X Thickness)	P-29.2mmX1.65mm S-25.4mmX1.2mm
Carbon content	0.3%

TABLE-1: Material property

2.2 CHASSIS FRAME DESIGN

The Chassis is initially designed by using CATIA V5 as a surface model considering the minimum design requirements according to guidelines of the SAE BAJA rules. They included studies of suspension systems, steering and transmission, and their arrangement, mounting of the seat, design classification, and manufacturing methods. It required to keep a low weight of the chassis to produce better acceleration and also try to maintain the center of gravity low as much as possible to prevent the rollover. Now the modeling is done in CATIA V5, we will go for analysis of the chassis in ANSYS software

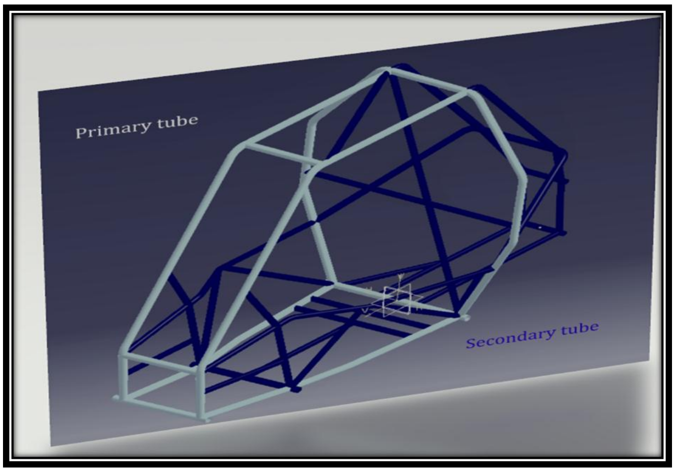


Fig-1a: **3D model of chassis**

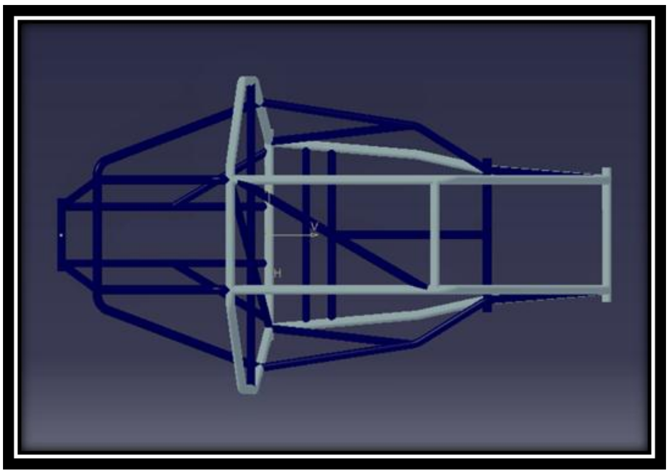


Fig-1b: Top view of chassis.

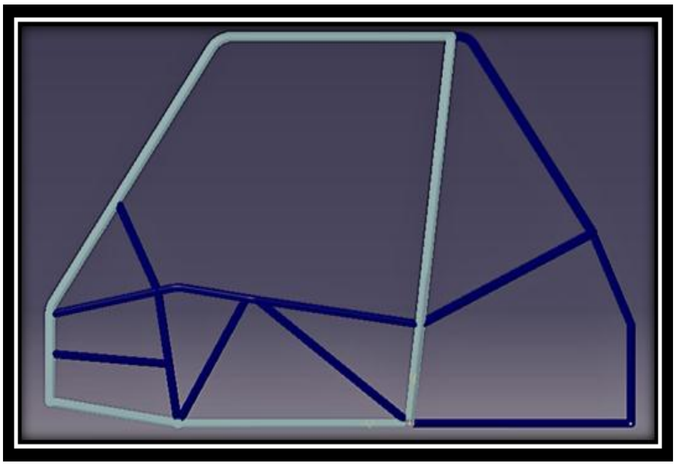


Fig-1c: Side view of chassis.

3. ANALYSIS OF CHASSIS AND METHEDOLGY

When the modeling of chassis is done by using CATIA V5 software, afterwards we use the ANSYS Workbench for the finite element analysis. Then we generate a file (igs) and import it to geometry and add the material, thickness, and definable cross-section.

3.1. FINITE ELEMENT ANALYSIS

After completing the chassis frame along with giving material and thickness, we go for the static analysis along with model analysis. We include the impulse-momentum equation and work-energy principle with a time of collision of 0.15 sec to 0.3 sec to find out the forces which are utilized as input conditions in the static analysis under several conditions. The chassis should be capable to withstand the impact, torsion, rollover conditions, and offers maximum safety to the driver without go through any damage. The different tests carried out are Front impact, Side impact, Rear impact, Rollover, torsion & bump.

3.2. MESHING

By **meshing,** the domain can break up into pieces, each piece representing an element. Finite element analysis method lower the degree of freedom from the infinite to some finite value which helps the meshing. For the selection of the mesh element size, we select the size of an element where the deformation is almost constant throughout the range to get better accuracy. Fine meshing is done in areas having a higher stress concentration.

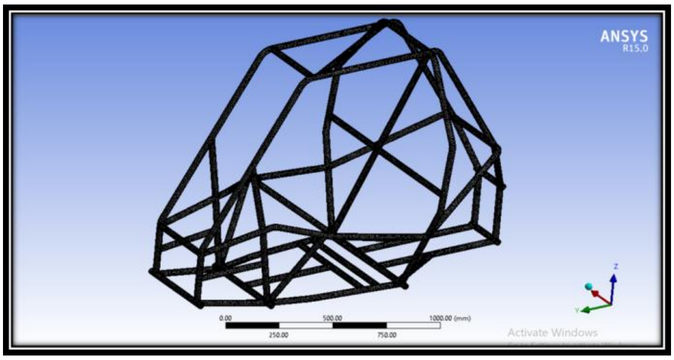


Fig-2: Meshed Model in Ansys R15.0

Point that taken in consideration:-

- ✓ Chassis is a deformable body.
- ✓ Element size is 8 mm.
- ✓ Impact time is 0.15 sec and 0.3 sec in different scenario.

4. CALCULATION AND IMPACT ANALYSIS

4.1. FRONT IMPACT ANALYSIS

By considering the vehicle + driver mass of 235 kg, (v - 175kg+d-60kg) & ATV is moving with 45km/hr.(12.5m/s) get collide with other ATV and the front impact time is consider to be 0.15 sec. The force calculated by above consideration is applies on the front part of the chassis keeping rear suspension mounting point to be fixed.

F = -m×v/t

F= 235×12.5/.15 N

= 19583.34N ≈ 8.5G (G =m×g)

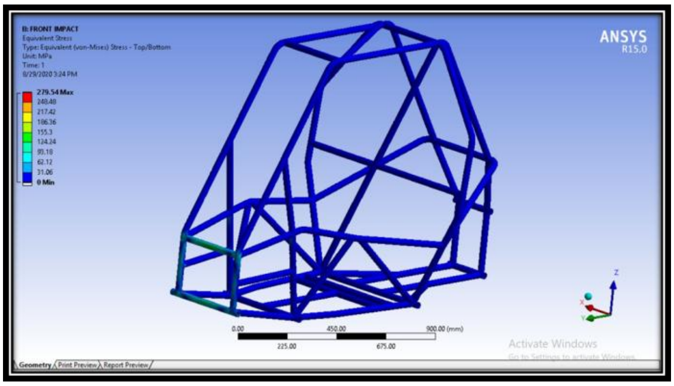


Fig-3: Equivalent stress in front impact

4.2. REAR IMPACT ANALYSIS

During the rear impact, the vehicle may get hit on the backside by other ATV during the event. The impact time for rear impact is 0.3sec. Mass of vehicle 235kg and speed is 45km/hr. (12.5m/s) at the time collision. We calculate the force by above consideration for rear impact by taking front suspension mounting point fixed.

F = -m×v/t

F= 235×12.5/0.3 (N)

= 9791.67N ≈ 4G (G =m×g)

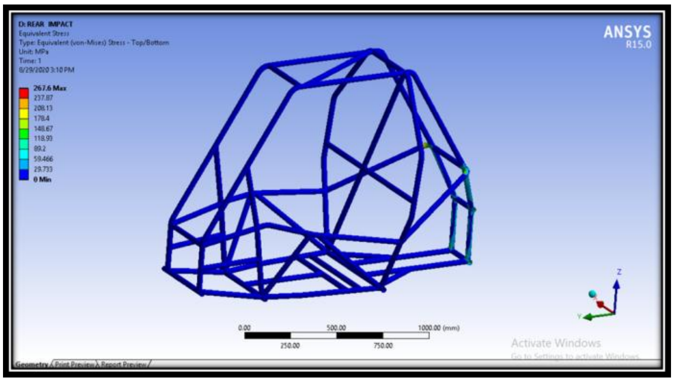


Fig-4: Equivalent stress in rear impact

4.3. SIDE IMPACT ANALYSIS

During the side impact analysis, the analysis is done to simulate those conditions when another ATV will hit ATV on side. Force corresponding to velocity 45 Km/hr. and vehicle mass 235kg with the impact time 0.3seconds and is applied to the side part of the chassis keeping front and rear suspension mounting point to be fixed.

F = -m×v/t

F= 235×12.5/0.3 N

= 9791.67N ≈ 4G (G =m×g)

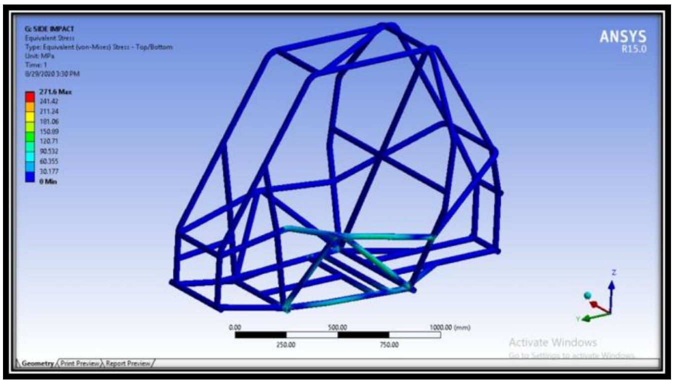


Fig-5: Equivalent stress in side impact

4.4. ROLL OVER ANALYSIS

During the roll-over impact, the vehicle have high probability to rolling over its hoop member while going on a hill or valley area. In this conditions the ATV is considered to be fallen on its top on the track or ground from a height. In this case the force is calculate by using work-energy principal & in this situation top portion of ATV experience more force. As the track and ground are stiff, so collision time for this event is 0.15 sec and force applied on the top part of the ATV by keeping the front and rear suspension constraint constant.

Impact time (t) = 0.15sec, h= height of ATV =1.49m, m=mass of ATV =235kg

v = velocity (m/s)

By work energy principal

Change in potential energy = Change in kinetics energy

$0 - m\times g\times h = 1/2m0^2 - 1/2mv^2$ (final velocity is zero)

$\Rightarrow m\times g\times h = 1/2mv^2$

$\mathbf{v=\sqrt{2gh}} = \sqrt{2\times9.81\times1.49}$

$v\approx5.5$ m/s ≈19.5km/hr.

Again, work done = change in kinetic energy

$|W|=|1/2\ mv^2|$

$= |1/2\times235\times5.5^2| \approx 3555$Nm.

Stopping displacement(S) = $|0-5.5|\times.15\approx 0.83$ m

Roll over impact force, F

F=W/S

F =3555/.83 = 4283.13N. ≈2G (G= m×g)

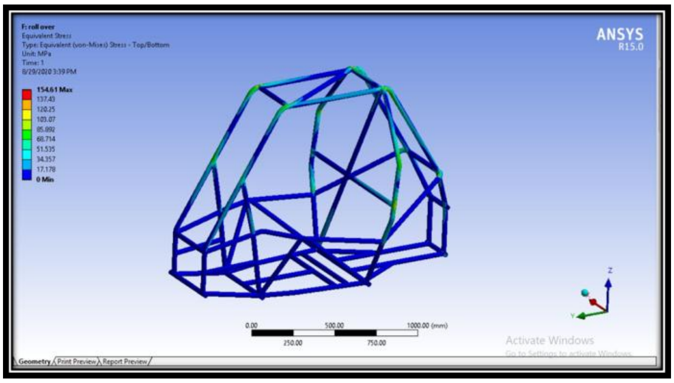


Fig-6: Equivalent stress in roll-over

4.5. BUMP ANALYSIS

For the bump analysis done, when the ATV undergoes to the bump when it passes over speed breaker and chassis is subjected to a moment. During this analysis, we considered that 45% of vehicle weight is supported by front suspension mounting and 55% of vehicle weight is supported by in rear suspension mounting and moving with velocity of 45km/hr. (12.5m/s). The impact time is taken 0.3sec & rear suspension mounting point are fixed.

Bump impact force

F=45%×m×v/t

F =.45×235×12.5/.3 ≈4406.25N

F≈2G (G= m×g)

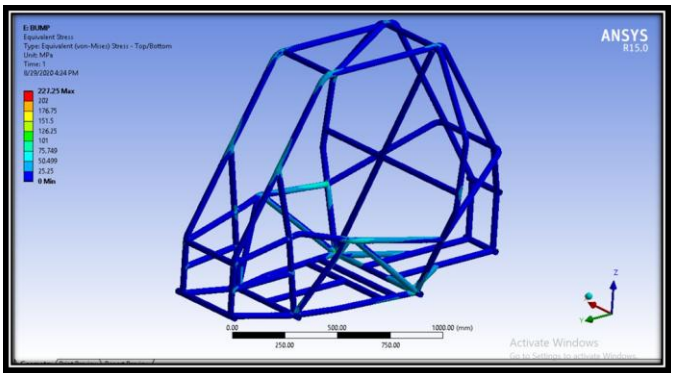


Fig-7: Equivalent stress in bump

4.6. TORSIONAL ANALYSIS

In the torsional analysis, the analysis is done for measuring the torsion stiffness in chassis over the cross bump in the rear and the front part of ATV. The prime aim of doing the torsional analysis is to find a high range of stiffness chassis to withstand dynamic suspension loads. During this analysis, we considered that 45% of vehicle weight is supported by front suspension mounting and 55% of vehicle weight is supported by rear suspension mounting. The forces that are implemented are equal in magnitude but opposite in direction. Using this loading condition will make the case of pure torsion by the fixed constraint that is used to implement in the rear wheel. The front weight of vehicle is distributed on both side equally, so the torque acting on member T (Nm) is given by

T = (FR + FL)/2×L

L= Track Width, FR = right side weight, FL =left side weight, FW = front weight of ATV.

T = (0.45×235×9.81)/2×1.27

T ≈ 660Nm

$\boldsymbol{\theta}$ = arc tan (u1+u2/L1) u1 = deflection in right side, u2 = deflection in right side L12 = nose length (16in).

$\boldsymbol{\theta}$ = arc tan (.053+.053/.4064)

$\boldsymbol{\theta}$ =14.62 deg. Or, $\boldsymbol{\theta}$ = .255rad

K = torsional stiffness = **T/ $\boldsymbol{\theta}$**

= 660/.255

K ≈**2600Nm/rad or 2.6kNm/rad**

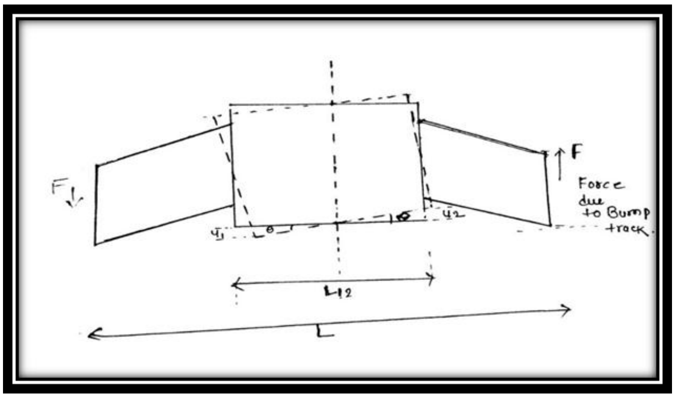
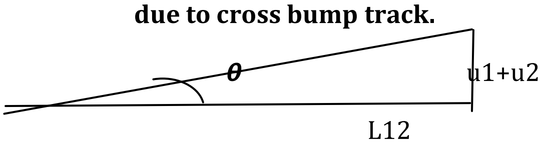


Fig-8a: Front view of ATV when experience torsion due to cross bump track.



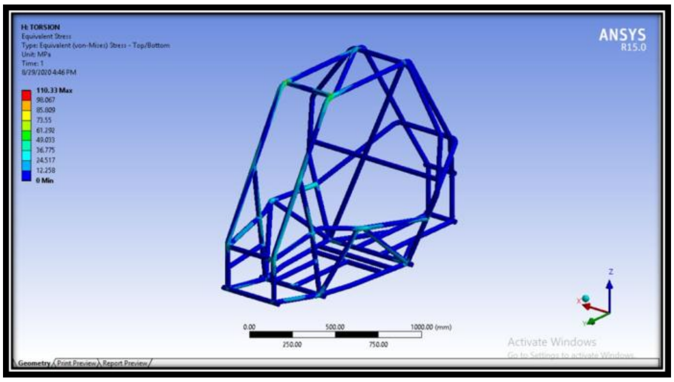


Fig-8b: Equivalent stress in Torsional.

5. FINAL RESULT OF ANALYSIS

Test	Load applied (N)	Max Eqv. Stress(MPa)	Total deformation(mm)	FOS
Front	19583.34	279.54	0.358	1.65
Rear	9791.67	267.60	0.715	1.72
Side	9791.67	271.60	1.230	1.70
Rollover	4283.13	154.61	2.646	2.98
Bump	4406.25	227.25	1.798	2.02
Torsion	518.71(equal and opposite)	110.33	1.259	4.17

Table. 2. Analysis results

6. Conclusion

Safety is one of the most important factors to ensure least risk to ATV's in case of rollovers, collisions particularly at high speeds. Therefore, a significant value of safety factor is dependent on the chassis of ATV, which reduces the risk of any damage or any injury to the driver, squad and environment. Chassis being the basic framework of the vehicle adds to the quality of ATV by ensuring a stable design structure. By carrying out the analysis we can measure Equivalent stress (Von-Mises), total deformation, and factor of safety. If the value of FOS is high it will be able to withstand all kinds of load or impact under any critical situation. While working on the design, we should always try to keep vehicle weight as low as possible, and chassis should be compact and easy to manufacture. Lightweight ATV are capable of handling sharp turns with ease, owing to their small size and capability of easy and instant breaking as well as quick accelerating. Therefore an ATV with high FOS Value, low weight, compact chassis will have numerous advantages in terms of better handling, balance, power to weight ration which would further add to the safety to meet the current requirements of a standard and ideal ATV.

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BIOGRAPHIES

ASHUTOSH KASHYAP is currently in final year of Mechanical Engineering at NIT JAMSHEDPUR. Mr. Ashutosh is a Design head of TEAM DAKSH. In Jan2020, Ashutosh participated in SAEINDIA BA-JA 2020 and represent his team at virtual and dynamics event and success fully completed all event.