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Analysis of All-Terrain Vehicle Chassis

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***Abstract*: This study provides detailed description of the static analysis and mathematical data involved in the design of a BAJA ATV (All-Terrain Vehicle) chassis. BAJA is an ATV competition where students get to design and develop their ATV keeping in mind various considerations of design as well as safety and according to the rules provided by SAEINDIA. The chassis design is based on BAJA SAE India 2022 rule book. With the characteristic abilities of an ATV to get through any terrain along with their simple and compact structure a new field of engineering research has been developed because of the increasing number of ATV accidents. As many crashes or accidents takes place during the event or testing and it is necessary to prevent these accidents so series of tests were conducted to analyse the reasons and eradicate them. The analysis is performed using computer aided design (CAD) software which is ANSYS 18.1.**

***Keywords*: roll cage, chassis analysis, static analysis, atv analysis, baja, safety, chassis, atv.**

1. Introduction

ATV (All-Terrain Vehicle) are 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. A Roll cage is an engineered frame built in the passenger compartment of a vehicle to protect its occupants from being injured or killed in an accident, particularly in the event of a rollover and as all the mounting and assemblies are done on it, it is necessary for the roll cage to withstand static as well as dynamic loads. Here, we will discuss about static analysis and the mathematical data involved. A tubular space frame is considered for manufacturing of the ATV because it provides multi-directional impact safety as well as it is easier in fabrication. All the parts of the vehicle are designed in SOLIDWORKS 2020 and analysed in ANSYS 18.1 with extreme boundary conditions.

2. Research Gap

Boundary conditions calculation was required along with a design for the parts of a light ATV capable of absorbing extreme loads.

According to already existing studies, they either can't consider all the forces required or explain the calculations.

They failed to explain why they are doing 1D meshing which from our point of view is not that accurate.

3. Methodology

A. Material Selection

There is various option available in the market which can be used for the material of the roll cage. We have selected AISI 4130 because AISI 4130 grade is a low-alloy steel containing chromium and molybdenum as strengthening agents. The steel has good strength, toughness, weldability and machinability. AISI 4130 grade is a versatile alloy with good atmospheric corrosion resistance and reasonable strength. It shows overall good combinations of strength, toughness. and fatigue strength. Comparison between different materials is shown in table below.

Table 1
Comparison between different materials

Properties	AISI 4130	AISI 1018	AISI 1020
UTS, MPa	820	440	395
Yield, MPa	700	370	295
Stiffness to Weight, KNm/kg	72-130	54-59	56-90
Elongation	21.5%	15%	36.5%

The chemical properties of AISI 4130 are as follows;

Table 2
Chemical properties of AISI 4130

Element	AISI 4130 (%)
Fe	97.03-98.22
C	0.28-0.33
Cr	0.80-1.10
Si	0.15-0.30
Mn	0.40-0.60
Mo	0.15-0.25
S	0.040
p	0.035

More properties of AISI 4130 are as listed:

1	Property	Value	Unit
2	Density	7850	kg m^-3
3	Isotropic Elasticity		
4	Derive from	Young's Modulus and Poisson's...	
5	Young's Modulus	1.9E+11	Pa
6	Poisson's Ratio	0.28	
7	Bulk Modulus	1.4394E+11	Pa
8	Shear Modulus	7.4219E+10	Pa
9	Tensile Yield Strength	7E+08	Pa
10	Tensile Ultimate Strength	8.2E+08	Pa

4. Finite Element Analysis

A. Meshing

2D meshing is done on the roll cage because 1D meshing is not that accurate and the level of assumption are more, it doesn't

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capture the geometry and calculation on the points are not captured. 2D meshing is more accurate and preferable because the level of assumption is less and it capture the geometry and give results on joints. 3D meshing is not required because as per the definition of 3D meshing all the 3 dimensions has to comparable, which is not the case here, the level of assumption in 3D meshing are average. Triangular mesh method is used because it is one of the simplest types of mesh and is quick and easy to create. Element size is taken as 6mm.

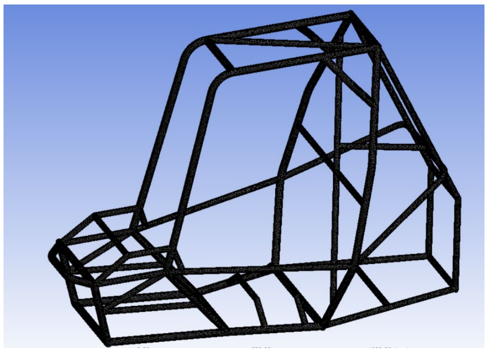

Fig. 1. Mesh generated

Boundary Conditions:

1. Roll cage is deformable body.
2. Impact time in case of deformable body is taken as 0.30seconds.
3. Impact time in case of rigid body is taken as 0.13seconds.
4. Suspension points are restricted from undergoing any rotation and translation motion in all analyses.

B. *Front Impact Analysis*

The front impact analysis is done on the assumption that when the impact will occur at the front hitch the stresses will be generated at the front part, so the deformation is observed. The Load required for frontal impact is obtained by creating a scenario where the car is moving at a top speed of 60 kmph or 16.67 mps undergoing a head on collision with rigid body. The mass of the car including the driver is assumed to be 210 kg. Impact time is taken as 0.13 seconds and the load is applied on front hitch while the nodal rotation and nodal orientation of suspension points are constrained.

Calculations:

$Few\ Approximations\ are\ taken-$
$Weight{=}210kg$
$v_{initial}{=}16.67 m/s$
$v_{final}{=}0 m/s$
$Impact\ Time{=}0.13\ sec$
$Work\ Done{=}|\text{-}Mv^2/2|$
$Work\ Done{=}|-210*16.67^2/2|{=}29178.3345\ Nm$
$Work\ Done{=}F*d$
$d{=}v*t{=}0.13*16.67{=}2.1671\ m$
$F{=}Work\ Done/d{=}29178.3345/2.1671\approx 14KN$
F(applied)=14KN−Front Hitch Point
Collision Time=0.13

The following points were observed:

$\mathbf{FOS_{min}} = 1.6613$
$\mathbf{Deformation_{max}} = 1.5028\ \mathbf{mm}$
$\mathbf{Equivalent}$ (von-Mises) $\mathbf{Stress_{max}} = 421.36\ \mathbf{MPa}$

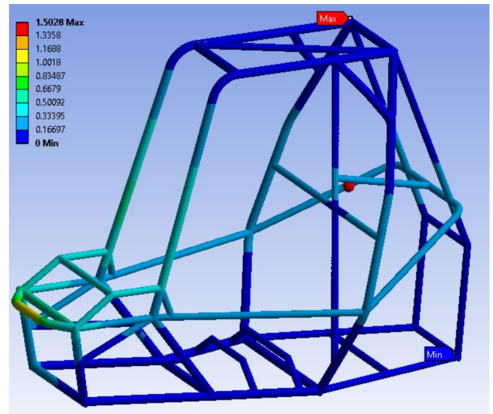

Fig. 2. Maximum deformation in front impact test

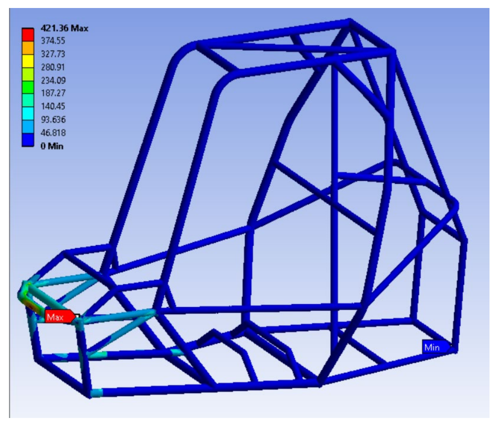

Fig. 3. Maximum equivalent (von-mises) stress in front impact test

C. *Rear Impact Analysis*

The Rear Impact Analysis is done on the assumption that another vehicle or ATV is going to hit the ATV on the rear most portion. The stresses will be generated at the rear part so that the deformation can be observed and analysed. The Load required for rear impact is obtained by creating a scenario where the car is moving at a top speed of 60 kmph or 16.67 mps undergoing a rear collision with rigid body. The mass of the car including the driver is assumed to be 210 kg. Impact time is taken as 0.3 seconds. The load is applied on rear most part while the nodal rotation and nodal orientation of suspension points are constrained.

Calculations:

$Few\ Approximations\ are\ taken-$
$Weight{=}210kg$
$v_{initial}{=}16.67\ m/s$
$v_{final}{=}0\ m/s$
$Impact\ Time{=}0.3\ sec$
$Work\ Done{=}|-Mv^2/2|$
$Work\ Done{=}|-210*16.67^2/2|{=}29178.3345\ Nm$

$Work\ Done = F*d$
$d = v*t = 0.3*16.67 = 5.001\ m$
F=$Work\ Done/d = 29178.3345/5.001 \approx 6KN$
F(applied)=6 KN (Nodes contained in rear envelope)
Collision Time=0.3secs

The following points were observed:

FOS$_{min}$ = 2.2866
Deformation$_{max}$ = 2.43 **mm**
Equivalent (von-Mises) **Stress$_{max}$** = 306.13 **MPa**

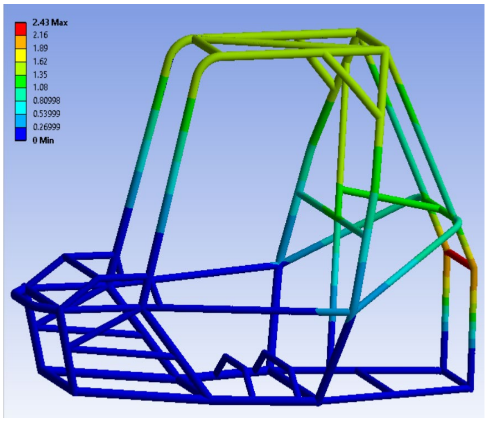

Fig. 4. Maximum deformation in rear impact test

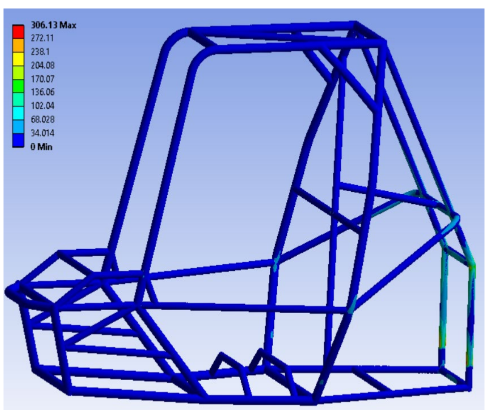

Fig. 5. Maximum equivalent (von-mises) stress in rear impact test

D. *Side Impact Analysis*

The Side Impact Analysis is done on the assumption that another vehicle or ATV is going to hit the ATV on the side portion. The stresses will be generated at the side part so that the deformation can be observed and analysed. The Load required for side impact is obtained by creating a scenario where the car is moving at a top speed of 60 kmph or 16.67 mps undergoing a side collision with rigid body. The mass of the car including the driver is assumed to be 210 kg. Impact time is taken as 0.3 seconds. The load is applied on side part while the nodal rotation and nodal orientation of suspension points are constrained.

Calculations:

$Few\ Approximations\ are\ taken -$

$Weight = 210kg$
$v_{initial} = 16.67\ m/s$
$v_{final} = 0\ m/s$
$Impact\ Time = 0.3\ sec$
$Work\ Done = |-Mv^2/2|$
$Work\ Done = |-210*16.67^2/2| = 29178.3345\ Nm$
$Work\ Done = F*d$
$d = v*t = 0.3*16.67 = 5.001\ m$
F=$Work\ Done/d = 29178.3345/5.001 \approx 6KN$
F(applied)=6 KN (Nodes at ROI of RRH and SIM)
Collision Time=0.3secs

The following points were observed:

FOS$_{min}$ = 1.1791
Deformation$_{max}$ = 4.3898 **mm**
Equivalent (von-Mises) **Stress$_{max}$** = 593.67 **MPa**

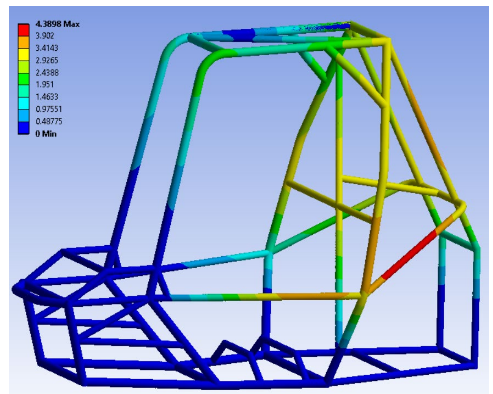

Fig. 6. Maximum deformation in side impact test

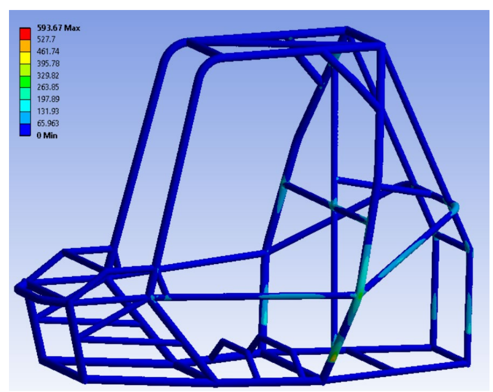

Fig. 7. Maximum equivalent (von-mises) stress in side impact test

E. *Roll Over Impact Analysis*

As BAJA ATV is All Terrain-Vehicle and there are always chances of the vehicle to roll over or topple about its longitudinal axis while negotiating a turn in a rough terrain or at high speeds. The Roll Over Impact Analysis is done on the assumption that the vehicle will roll over. The stresses will be generated at the RHO and CLC part so that the deformation can be observed and analysed. The Load required for roll over impact is obtained by creating a scenario where the car is moving at a top speed of 7.733 mps undergoing a roll over. The mass of the car including the driver is assumed to be 210 kg.

Table 3
Results

Test	Constraints	FOSMin	Equivalent (von-Mises) Stress $_{Max}$	DeformationMax
Front Impact	14 KN distributed on front nodes, rear suspension points constrained	1.6613	421.36 MPa	1.5028 mm
Rear Impact	6 KN distributed on the rear members, suspension points constrained	2.2866	306.13 MPa	2.43 mm
Side Impact	6 KN distributed over outermost part of RRH and SIM suspension points constrained	1.1791	593.67 MPa	4.3898 mm
Rollover	7 KN applied on CLC and suspension points constrained	1.2493	560.33 MPa	2.9094 mm

Impact time is taken as 0.3 seconds. The load is applied on FBM and CLC while the nodal rotation and nodal orientation of suspension points are constrained.

Calculations:

During the fall, overall potential energy will be converted into Kinetic energy. Hence, $M*g*h=Mv^2/2$

$v=\sqrt{2*g*h}$

$Assuming\ height\ of\ fall=10ft=3.048m$

$v=7.733m/s$

$Impact\ Time=0.3\ sec$

$Work\ Done=6278.93\ J$

$Work\ Done=F*d$

$d=v*t=1.005\ m$

F=$Work\ Done/d \approx 7KN$

F(applied)=7 KN (Nodes in region of FBM and CLC)

Collision Time=0.3secs

The following points were observed:

FOS$_{min}$ = 1.2493

Deformation$_{max}$ = 2.9094 **mm**

Equivalent (von-Mises) **Stress$_{max}$** = 560.33 **MPa**

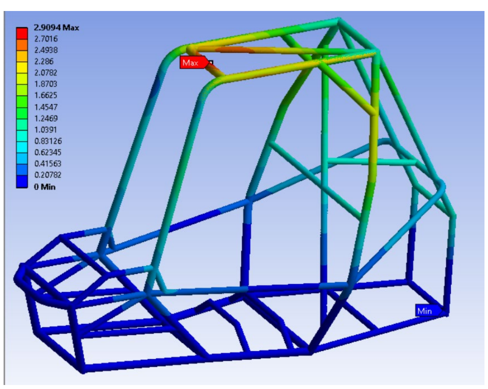

Fig. 8. Maximum deformation in roll over impact test

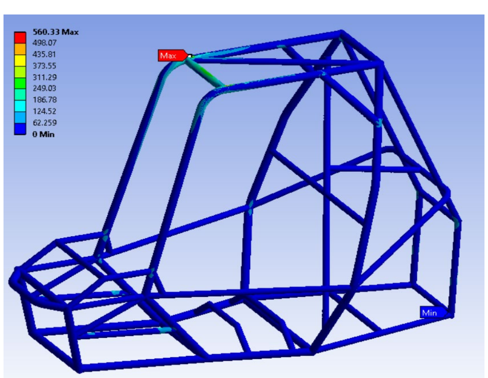

Fig. 9. Maximum equivalent (von-mises) stress in roll over impact test

5. Conclusion

Using Finite Element analysis, we have successfully done the analysis of the roll cage, considering safety point of view all tests can be performed in ANSYS 18.1.

Our research concludes that the design put into consideration by us was able to under all constraints perform well up to the desired outcomes, the "rear impact" aspect being the most successful with the maximum factor of safety, followed by front, rollover and side impact respectively (decreasing order of their FOS).

We tried making further changes to the design to enhance the strength of withholding the side impact as well but it came with the compromise of the other three aspects and hence, we concluded or ended up with the most efficient and balanced design considering all the aspects and their outcome in the well desired region.

The results which were put forward points towards the success of this study.

All the impact tests done above on the designed roll cage are in acceptable range with good factor of safety.

Acknowledgement

We would also like to show our gratitude to our seniors, professors and institution for sharing their pearls of wisdom with us during the course of this research. We want to thank the below mentioned references we referred to which gave a lot of input to our project and helped us move forward into the world of engineering. We are able to put forward this paper with the continuous support of our professor and our friends who helped us in every way possible.

References

[1] Savari Goutham, Arun Raj Dandothkar, "Design and Optimization of BAJA ATV Chassis".

[2] William B. Riley and Albert R. George, "Design, analysis and testing of a SAE car Chassis", SAE Technical paper series 2002-01-3300, 2 December 2002.

[3] U.S. Consumer Product Safety Commission, All-Terrain Vehicle Exposure, Injury, Death and Risk Studies, April 1998:51.

[4] A.H. Fonseca, M.G. Ochsner, W.J. Bromberg, D. Gantt: All-terrain vehicle injuries: are they dangerous? A six-year experience at a level I trauma center after legislative regulations expired, The American Surgeon, vol. 71, no.11(2005), pp. 937-940.

[5] Anshul Dhakar and Rishav Ranjan, "Force calculation in upright of a FSAE race car," International Journal of Mechanical Engineering and Technology, vol. 7, no. 2, 168–176, 2016.

[6] Amit R Parate," Design and fabrication of roll cage," International research journal on research and technology, vol. 5, no. 7, July 2018.

[7] U. Yashvanth, Mohammad Raffi, G. Raghu Vamsi Reddy, "Dynamic impact analysis on ATV upright. International Journal of Mechanical and Production Engineering Research and Development, vol. 9, no. 5, pp. 689– 698, 2019.

[8] Abhinav Mishra, Aniket Kumar Sahum "Design Analysis and Optimization of an All-Terrain Vehicle (ATV)," International Journal of Engineering Research & Technology, vol. 10, no. 1, pp. 271-281, 2021.
[9] Abhishek Pandey, Ayush Nigam, Saumya Singh Tiwari, "Design, Analysis and Manufacturing of SAE India Baja ATV Roll cage," International Research Journal of Engineering and Technology, vol. 9, no. 3, pp. 667-675, 2022.
[10] Chetan N., Darius Chirag, Harshith B. R, Akshay Jayaraj, Balaji. S., "Design and Analysis of ATV Chassis," JETIR, vol. 8, no. 8, pp. 125-134, 2021.