ISSN No:-2456-2165

Design of Roll Cage System for ATV

[1]Thombre Pradeep Bhiakji, [2]Tambe Shubham Chandrakant,
[3]Sutkar shubham shashikant, [4]Tapare Bhushan Gokul
BE Mechanical

[5]Dr. Ajay Kumar G. Thakur
Vice Principal & HoD of Mechanical Dept.
Sanjivani College of Engineering kopargaon

I. OBJECTIVE

We have set some objectives behind our design team to construct optimized roll cage, they are as follow.

- To construct a 3-D space around the driver such that it can accommodate the tallest and healthiest member participating in the event which is light in weight and steady structure.
- To perform the FEA on the design Rollcage to obtain the stresses acting on members and its Deform
- Analysis of the Roll-cage after changing various Materials and determine the best condition.
- Analysis of the Roll cage after changing various Cross-Section and determine the best condition.

II. METHODOLOGY

We have started with BAJA rule book 2018, we have gone through all rules & limitations set by BAJA SAE INDIA & understood all rules related to topic. After that we done literature survey and data collection required for design and analysis. To select the material which fulfil the required condition of off-road vehicle and rules given in rulebook we done market survey, from list of some available materials we have selected suitable materials for Roll Cage. According the properties of selected materials we calculated strength and stiffness for various dimension of different materials from optimum result we chooses best material. We have designed 3D CAD model for Roll Cage on CATIA V5 R20 and did various impact test and modal analysis on Ansys 14.0 workbench. From obtained results we optimised our roll cage and redesigned our final roll cage. After completion of design and analysis we made PVC pipe model. We will do CNC programme for pipe bending. After that we will manufacture our roll cage with TIG welding.

A. Roll Cage Components

The components used to design the Roll Cage, their functions and designing procedure is mentioned below:

- Rear Roll Hoop (RRH):
- Roll Hoop Overhead (RHO):
- Lower Frame Side Members (LFS):
- Side Impact Members (SIM):
- Lateral Cross Members
- Front Bracing Member
- Aft/Fore Bracing Member
- Under Seat Member.
- Diagonal Bracing Member.

B. Design Consideration

We have started our roll cage design by considering some parameters and rules they are listed below.

- Rulebook compliance
- Driver ergonomics
- Safety
- Aerodynamics
- Ease of manufacturing
- Cost-effectiveness
- Aesthetics

Calculation for Strength and Stiffness for Selected Material

We have done various calculations for comparing stiffness, bending strength and weight for AISI4130 material of available dimensions in market.

D	T	M.M.I	Yeild strength	Y	Bending Strength	Youngs Modulus	Stiffness	Density	Mass	Material
25.4	3	13478.6388	0.365	12.7	387.3782	0.205	2763.12	7850	1.6636	1018
25.4	0.89	5152.9043	0.46	12.7	186.6497	0.21	1082.11	7850	0.538	4130
25.4	1	5723.6514	0.46	12.7	207.313	0.21	1201.97	7850	0.6017	
25.4	1.2	6695.0493	0.46	12.7	242.193	0.21	1405.96	7850	0.7162	
25.4	1.6	8508.8152	0.46	12.7	308.193	0.21	1786.22	7850	0.9391	
25.4	2	10136.7445	0.46	12.7	367.157	0.21	2128.72	7850	1.1542	
25.4	2.5	11930.31	0.46	12.7	432.121	0.21	2505.37	7850	1.4119	
29.21	0.89	7201.937	0.46	14.6	226.91	0.21	1512.41	7850	0.8623	
29.21	1	8827.0285	0.46	14.6	278.11	0.21	1853.68	7850	0.978	
29.21	1.6	13268.9	0.46	14.6	417.918	0.21	2786.47	7850	1.091	
29.21	2	15907.9974	0.46	14.6	501.21	0.21	3340.68	7850	1.3441	
29.21	2.25	17434.78	0.46	14.6	549.314	0.21	3661.3	7850	1.456	
31.75	0.89	10280.1328	0.46	15.88	297.783	0.21	2158.83	7850	0.6773	
31.75	1	11430.2124	0.46	15.88	331.101	0.21	2400.34	7850	0.7583	
31.75	1.21	13556.0623	0.46	15.88	392.68	0.21	2846.77	7850	0.9113	
31.75	1.6	17268.8399	0.46	15.88	500.23	0.21	3626.46	7850	1.1897	
31.75	2	20773.8399	0.46	15.88	601.761	0.21	4362.51	7850	1.4674	

Table 1:- Calculation for Strength and Stiffness

With the above mechanical properties and calculated values, we have come to conclude that AISI4130 having outer diameter of 29.21mm and wall thickness of 1.6mm as a primary member and 25.4mm outer diameter and 0.89 wall thickness as secondary members combination for optimized, cost-effective and lesser weighing structure.

C. Pipe selection

- Primary members = AISI 4130 having outer dia. 29.21mm and wall thickness of 1.6mm.
- Secondary members = AISI 4130 having outer dia. 25.4mm and wall thickness of 0.89mm

D. Design of CAD models

The vehicle roll cage and whole vehicle is designed in CATIA V5 R21 software. The design considerations for the modeling are given below.

E. Steering and Motor Accommodation

Front cross members of width 12" were selected for easy accommodation of steering rack, for accommodation of the two pedals and the spacing was comparable to Driver. We designed the rear half to fit the motor, batteries, motor controller, IEMS, charger and the rest of the drive train.

F. Aerodynamics

This time we have designed our roll cage without nose and given the caster angle of 17^0 to get best aerodynamic structure as well as to get best performance of suspension.

Parameter	Allowable Value	Designed Value
Maximum vehicle width (inches)	64	58
Max. vehicle length (inches)	108	71
Min. firewall width at 27" above seat	29"	30"
Material used	AISI 1018 or Steel alloys	AISI 4130
Vertical distance of S.I.M. from seat (inches)	8 -14	13
Firewall angle	Maximum 20°	0°
Firewall triangulation members – Upper	Distance - less than 5 inches Angle - Greater than 20°	5 inches; 48.9^0 5 inches; 49.7°
F.B.M. angle	Less than 45°	30.68°
Vertical Distance between seat and R.H.O.	Greater than 41"	42"

Table 2:- Rulebook Conformance

III. FINITE ELEMENT ANALYSIS OF ROLL CAGE

After designing of the Roll Cage in CATIA V5, Finite Element Analysis (FEA) was performed on the Roll Cage using ANSYS 14.0 workbench to ensure expected loadings do not exceed material specifications. The line diagram of the roll cage was imported into the Ansys which is prepared on CATIA; cross section was assigned as for the dimensions of pipe. The material properties and mass was added as for the specification of the AISI4130 material. The meshing was done with a fine element size of 10mm and smooth transition in mesh and the results were obtained for Frontal Impact, Side Impact, rear impact and tensional impact test.

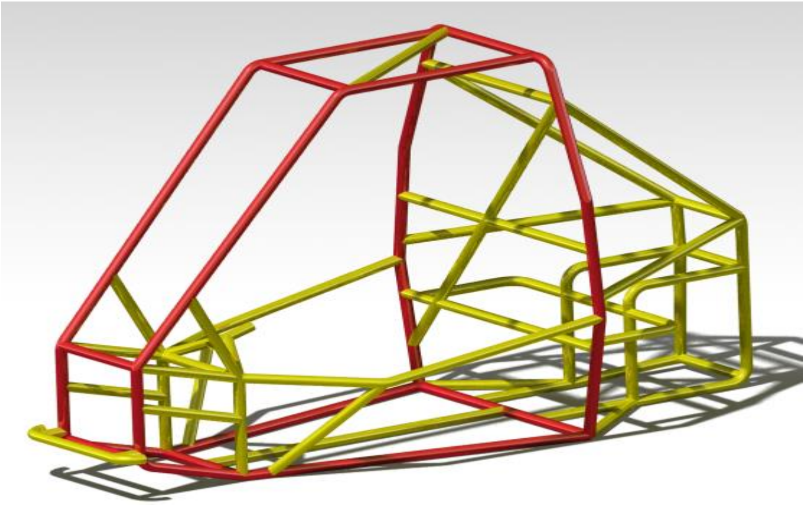


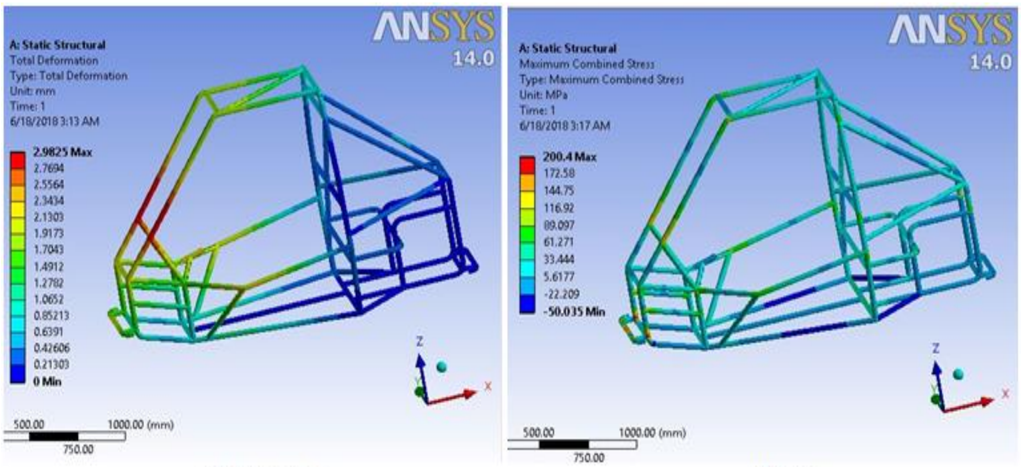
Fig 1:- Designed CAD Model

A. Impact Analysis

The forces were calculated using impulse moment equation law which states that the net force acting on a body is equal to the product of mass and change of velocity of the body.

- *Front Impact*

In actual conditions, the car is going to hit a tree, another car or a wall. In the first 2 cases, the tree and the other car are deformable bodies. So the time of impact will be greater, around 0.3 seconds, while the wall is considered as non-deformable i.e. a rigid body. Hence the time of impact will be obviously less than that in the above case. It is obvious that the impact force in the case of wall will be more than the first two cases. The vehicle was considered to be moving with a velocity of 40 kmph and time of impact as 0.13 seconds.



Deformation Stress

Fig 2:- Front Impact Analysis

- *Side Impact*

Since both bodies involved are deformable, the time of impact is slightly more than that of front impact. In case of side impact, the vehicle was considered to be in a stationary state. Impact was subjected on the side by an identical vehicle at a speed of 40 kmph. Time of impact is taken as 0.3 seconds because both the bodies are deformable.

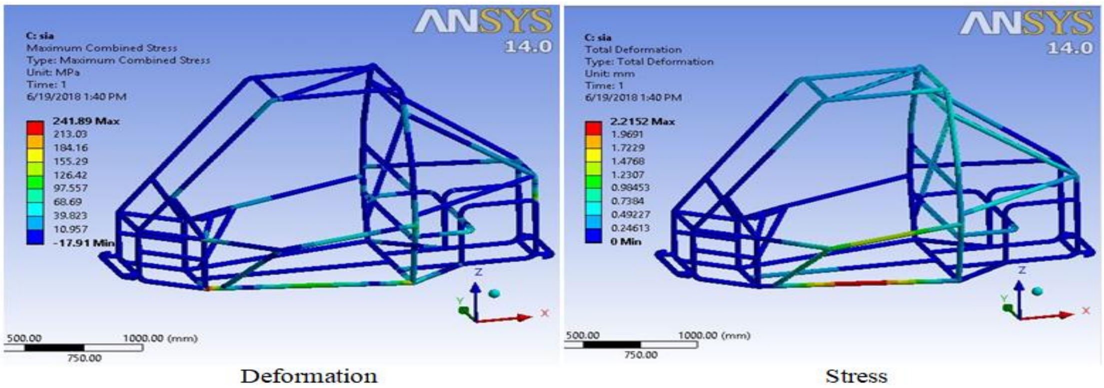


Fig 3:- Side Impact Analysis

➢ *Rear Impact*

In these case the ATV is hitted by another Vehicle from rear side of the vehicle. For analysis, ATV is considered to be in static state and force corresponding to velocity 40 km/h with impact time 0.1 seconds is applied to rear part of the roll cage of ATV keeping front suspension members fixed.

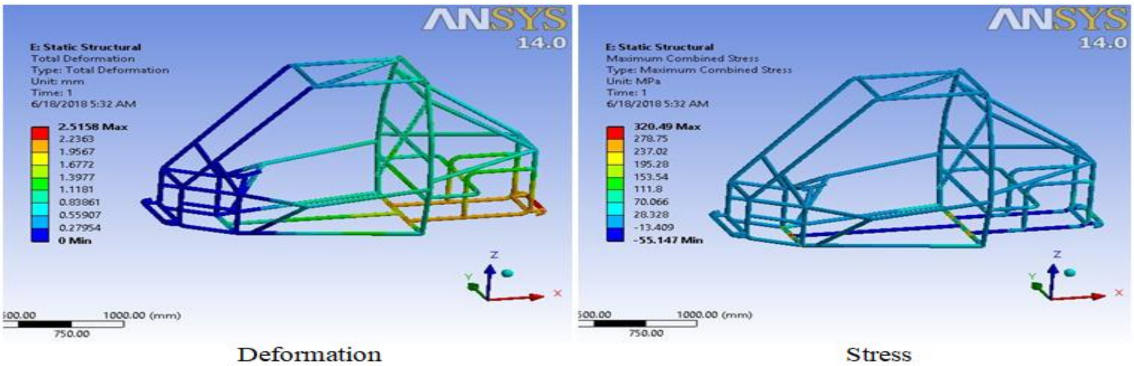


Fig 4:- Rear Impact Analysis

B. Supporting Calculations

➢ *Roll Cage Equivalency Calculations*

Bending Strength and Bending Stiffness Comparison

- *Definition*
- ✓ E=Modulus of elasticity
- ✓ I-Area Moment of Inertia about the weakest axis

- *Required Tubing Specifications*
- ✓ Diameter : 1 inch (25.4mm)
- ✓ Wall Thickness : 0.1181inch (3mm)
- ✓ Material : 1018 steel

- *From Tubing Geometry*
- ✓ Modulus of elasticity=205Gap (29732.kpsi)
- ✓ Outer Diameter, Do=25.4mm
- ✓ Thickness=3mm
- ✓ Inner Diameter, Di=19.4mm
- ✓ Area Moment of Inertia, *I*= $[\pi*(D_o^4-D_i^4)]/64=13478.6mm^4$
- ✓ Yield Strength, Sy=365MPa [52938.77psi]
- ✓ Distance to extreme fibre, C=12.7mm
- *Calculations for bending strength.*
- ✓ $S_{y*}I/c=3.8737*10^5$N-mm

- *Calculationsfor bending stiffness.*
- ✓ Bending stiffness (Ex*Ix) $=205*10^9*13478.6$
- ✓ $=2763.11Nm^2$

- *Designed Tubing Specifications*
- ✓ Diameter : 1.15 inch (29.21mm)
- ✓ Wall Thickness : 0.065inch (1.6mm)
- ✓ Material : 4130 steel

- *From Tubing Geometry*
- ✓ Modulus of elasticity=210Gpa(30457.9ksi)
- ✓ Outer Diameter, $_{Do}$=29.21mm
- ✓ Thickness=1.6mm
- ✓ Inner Diameter, Di=26.01mm
- ✓ Area Moment of Inertia, *I*= $[\pi*(D_o^4-D_i^4)]/64=17268.83mm^4$
- ✓ Yield Strengths=460MPa[66717.4psi]
- ✓ Distance to extreme fiber,C=14.605mm

- *Calculations for bending strength.*
- ✓ $S_{y*}I/c=5.003*10^5$N-mm

- *Calculations for bending stiffness.*
- ✓ Bending stiffness (Ex*Ix) $=210*10^9$
- ✓ $=3626.45Nm^2$

- *Percentage difference of stiffness=*
- ✓ $100*[EI_{rf}-EI_{re}]/EI_{rf}$ =23.80% Better than ref. Element

ISSN No:-2456-2165

IV. RESULTS

Parameters	Rear Impact	Front Impact	Side Impact	Torsional
Number of nodes	5802	5802	5802	5802
Number of elements	2918	2918	2918	2918
Element size	10mm	10mm	10	10mm
Time of impact	1sec	1	1sec	1 sec
Constraints	Front suspension points fixed	Rear suspension pts fixed	Side most pts fixed	Rear suspension points fixed
Max Forces	4g force on rear most points	4g force on front most pts.	2g force on opposite side most pts.	4g force on front most one side of suspension points
Deformation(mm)	2.1749	2.365	2.7951	5.0301
Stresses(Mpa)	233.6	283.05	414.6	188.64
FOS	1.9691	1.6251	1.1095	2.4380

Table 3:- Result Table

V. CONCLUSION

- After performing the static structural analysis in Ansys the designed roll cage it is found to be the safe and FOS in the range of 1.8 to 2.7 which is safe in the off road conditions.

REFERENCES

[1]. Amit R. Parate, "Design Analysis and Fabrication of Roll Cage of M-BAJA ATV",International Research Journal of Engineering and Technology, e-ISSN: 2395-0056, p-ISSN:2395-0072 Volume:05 Issue:07, July 2018

[2]. Prof. Dipl.-Ing. Jornsen Reimpell, Prof. Dr.- Ing. Jurgen W. Betzler, "The Automotive Chassis: Engineering Principle", Second Edition SAE International

[3]. 'eBaja SAE India rulebook 2019', www.bajasaeindia.org , www.bajasaeindiaforum.com