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Analysis and Optimisation of an Exo-Cage Material for an All-Terrain Vehicle

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***Abstract*: The present paper describes the research on Analysis and Optimisation of an Exo-Cage material structure for an All-Terrain Vehicle. To design and develop a roll cage for an All-Terrain Vehicle in accordance with the rulebook of FMAE BAJA. The design and development comprises of material selection, chassis and frame design, cross section determination and determining strength requirements of roll cage, stress analysis and simulations to test the All-Terrain Vehicle against failures.**

***Keywords*: All-Terrain Vehicle, Analysis, Exo-Cage, Roll Cage.**

1. Introduction

A roll cage is a skeleton of an All-Terrain Vehicles. The roll cage not only forms the structural base but also a 3-D shell surrounding the occupant which protects the occupant in case of impact and roll over incidents. The roll cage also adds to the aesthetics of a vehicle. A roll cage is a specially engineered and constructed frame built in (or sometimes around, in which case it is known as an Exo-cage) 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.

There are many different roll cage designs depending on the application, hence different racing organizations have differing specifications and regulations, although most of these organization harmonies their regulations with those of the FIA. Roll cages help to stiffen the chassis, which is desirable in racing applications. Racing cages are typically either bolt-in or welded in, with the former being easier and cheaper to fit while the latter is stronger. A roll bar is a single bar behind the driver that provides moderate rollover protection. Due to the lack of a protective top, some modern convertibles utilize a strong windscreen frame acting as a roll bar. Also, a roll hoop may be placed behind both headrests (usually one on older cars), which is essentially a roll bar spanning the width of a passenger's shoulders.

2. Methodology

Designing the roll cage involves with various design concerns as followed that further improves the structural rigidity and also Dynamic performance. These are discussed below:

- FMAE rules.
- Driver's and Navigator comfort and safety.
- Subsystem compatibility.
- High structural Strength and Stiffness Factor.
- Serviceability & manufacturability.

3. Literature Review

Author	Publication	Points Taken
Prakhar Agarwal, Nitish Malik, Shubam Kushwah	International Research Journal of Engineering and Technology (IRJET)	Parameter Consideration
Harshit Raj	International Research Journal of Engineering and Technology (IRJET)	Analysis References
Sudeep Roy, Rishabh Srivastava and Devesh Kumar	Journal of Material Science and Mechanical Engineering (JMSME)	Strength Factor considering Material Selection

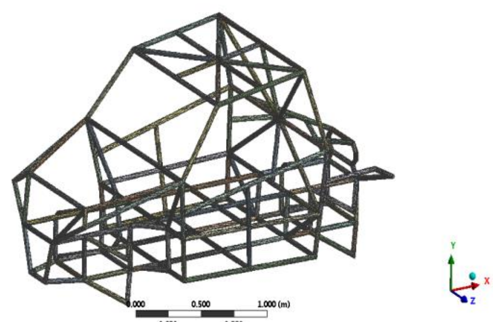

Fig. 1. Roll Cage Structure – Isometric View

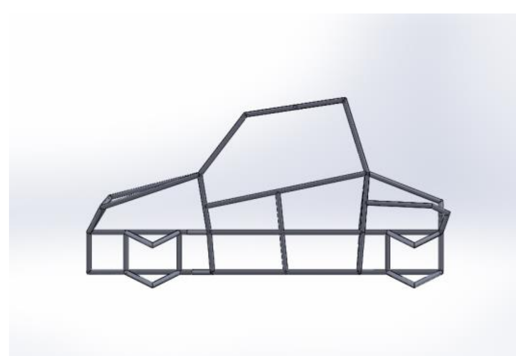

Fig. 2. Roll Cage Structure – Side View

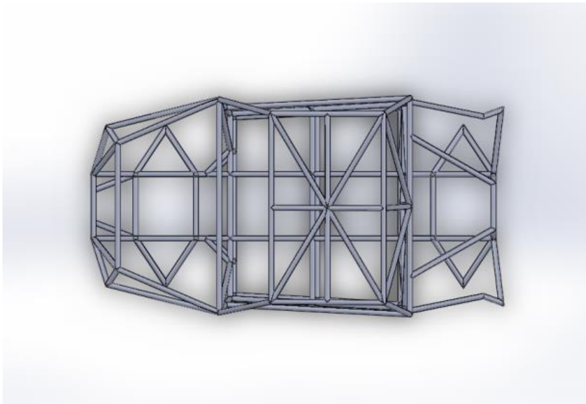

Fig. 3. Roll Cage Structure – Top View

4. Material Selection

There are a number of materials available in the market which can be used for the material of the roll cage. These include AISI 1018, AISI1026, AISI1040 and AISI 4130. Following are the material properties for the above mentioned materials.

Table 1
Material Property

Property	ASTM a106	AISI 1141	AISI 4130
Yield Tensile Strength(MPa)	312	353	435
Ultimate Tensile Strength(MPa)	630	598	670
Modulus of Elasticity(GPa)	205	210	205
Poisson Ratio	0.30	0.30	0.29

Selecting the material on the basis of Yield strength and requirement in accordance with the respective specification.

Once you have sorted the material for the roll cage you can begin the analysis of the roll cage.

5. Design Analysis

A. Front impact test

Few approximations were taken
Weight of ATV =1166kg
Velocity(initial), v=12.5m/s
Velocity(final), v=0
Impact time, t=1sec
Work done,W=|-0.5M*v|
=|-0.5x1166*(12.5)^2|
= 91093.75Nm
Work done, W=F*d
d =t*v(initial)
=1x12.5
=12.5m
F = 91093.75/12.5
=7287.5N

Now this is the impact force applicable on the front of the Roll Cage and by Ansys we came with the following results:

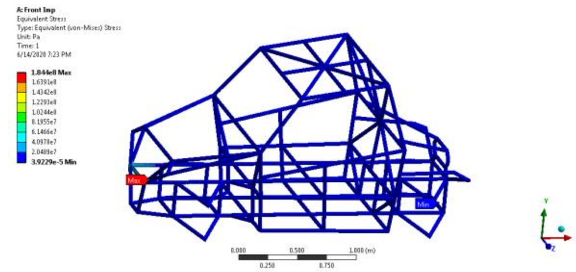

Fig. 4. Equivalent Stress Concentration

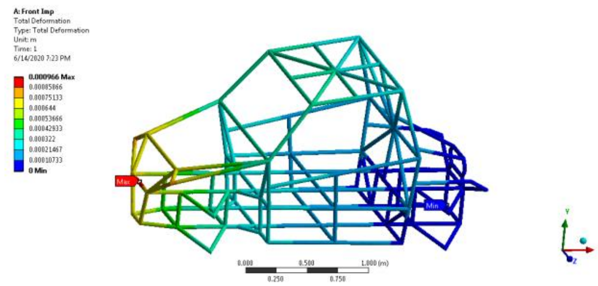

Fig. 5. Front Impact

FOS stands for factor of safety and it's suitable to have a FOS of 1.5 or above. We took impact force as 7500N and got a max stress concentration of 184.40MPa. We took the tube material as AISI 4130 so all the calculations are done with respect to that.

FOS=yield strength of the material/max stress
=435/184.40
=2.35

B. Side impact test

Here we will test how much stress the roll cage can take from sideways.

Impact time (t) =1sec
Velocity(v)=12.5m/s
Again by same method we have calculated the work done.
Work done, W=55080.90Nm
d=v*t
d=9.72m
F=work done/d
F=5700N

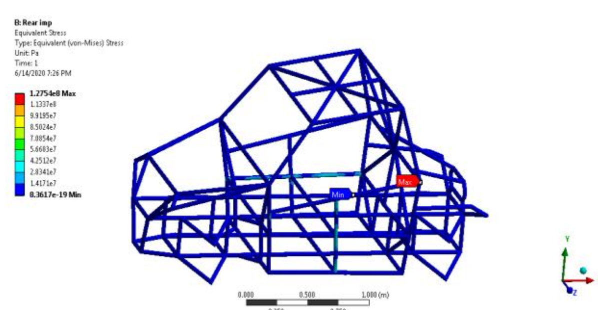

Fig. 6. Equivalent Stress Concentration

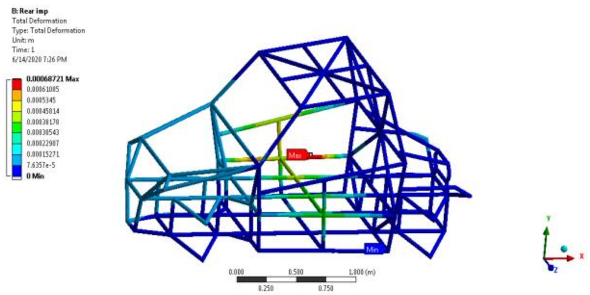

Fig. 7. Front Impact

Factor of Safety = 3.41

C. Rear impact test

Here we test how much stress the rear part of the roll cage can take.

Impact time(t)=0.30sec
Velocity, v=16.67m/s
work done is again calculated y same method and is
41683.33N
d=t*v
d=5.001m
F=work done/d
F=8335N

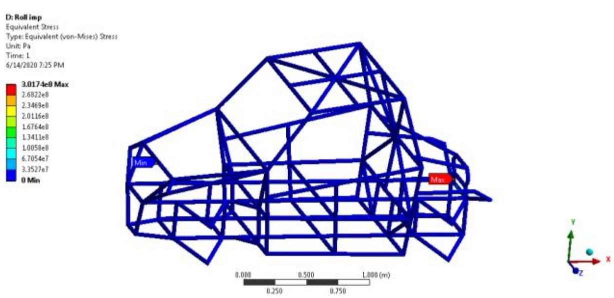

Fig. 8. Equivalent Stress Concentration

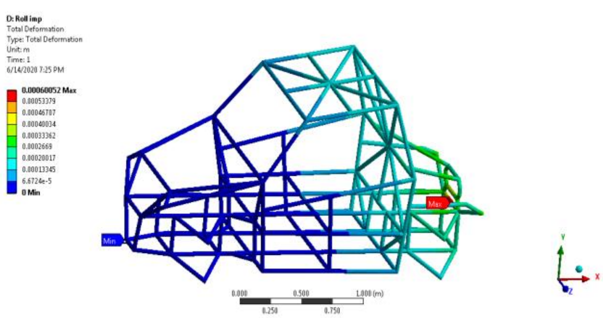

Fig. 9. Rear Impact

F.O.S = 1.5

D. Roll over test

Here we basically test how much stress the roll cage can take in an inverted fall.

Impact time(t)=1sec
Velocity, v=11.11m/s

Work done is again calculated by same method and obtained as,

71960.91N
d=t*v
d=11.11m
F=work done/d
F=6500N

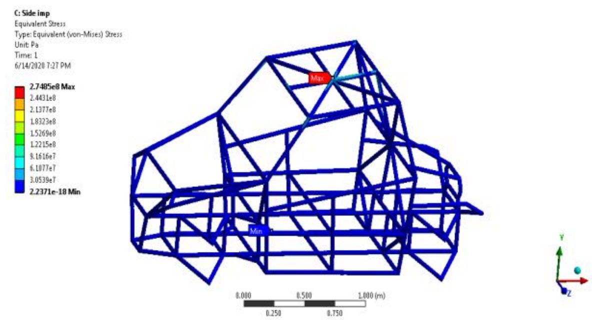

Fig. 10. Equivalent Stress Concentration

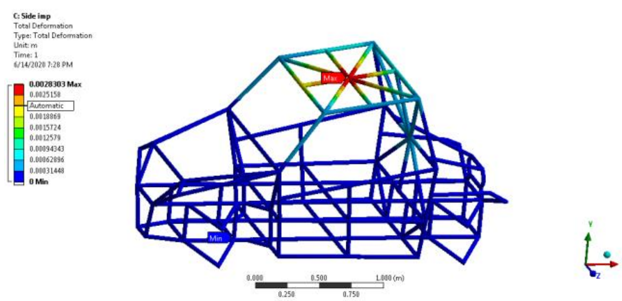

Fig. 7. Rollover Impact

F.O.S = 2

On consideration of Factor of Safety having greater than 1, Roll Cage Design with the respected material is Safe.

6. Conclusion

This paper explores the ways of designing the Exo-cage of an All-Terrain Vehicle and also focuses on possible key points for designing. You can also find analysis results in this paper along with their respective results and formulae used. During the static analysis of the roll cage the design of the roll cage was changed several times in order to obtain a higher FOS. A higher value of factor of safety insures the durability of the roll cage in the most extreme conditions and hence makes the roll cage safe in terms of production.

References

[1] Harshit Raj, "Design and Analysis of the Roll Cage of an ATV", International Journal of Research and Technology, Vol. 6, Issue 09, September – 2017.
[2] Mr. Mohd Abu Bakar, Vaibhav Bankar, "Design & Analysis of Structure of Roll Cage for SUPRA SAE: A Review", International Journal for Scientific Research & Development, Vol. 6, Issue 03, 2018.
[3] Prakhar Agarwal, Nitish Malik, Shubam Kushwah, "Design, Simulation and Optimization of Multitububular Rollcage of an All-Terrain Vehicle", International Research Journal of Engineering and Technology, Vol. 4, Issue 10, October 2017.

[4] Sudeep Roy, Rishabh Srivastava and Devesh Kumar, “Roll Cage Design for an All-Terrain Vehicle with Reduced Weight and Improved Strength”, Journal of Material Science and Mechanical Engineering, Vol. 2, Issue 10, April-June 2015.

[5] S. Venkatesh, R. Soundararajan, P. Ashoka Varthanan, “Conceptual Design and Analysis of an All-Terrain Vehicle Roll Cage”, SSRG International Journal of Mechanical Engineering, Volume 4, Issue 7, July 2017.

[6] FMAE Rule Book.