International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 5 Issue 3 ǁ Mar. 2017 ǁ PP.08-12

Finite Element Analysis of Roll Cage

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ABSTRACT: The roll cage is used as a structural base for all terrain vehicles and it also protects the occupant in case of impact and roll-over accidents so determining the strength and impact withstanding capacity of the roll Cage plays important role for the design and it is also a supporting structure for the engine. Most of the forces are taken up by the roll cage.This paper aims at Finite Element analysis of roll cage. Stress analysis carried out using Ansys workbench and it includes torsional analysis .modal analysis for the maximum operating speed of the vehicle.

Key words: Roll cage, Modal analysis, Static analysis, Fatigue life**.**

I. INTRODUCTION

A Roll Cage is protective outer frame of an automobile, sometimes referred as skeleton of an automobile. The main function is to provide safety to the driver and passengers in case of an accident or a roll over.

II. DESIGN OF ROLL CAGE

As the roll cage is used for the protection of the driver and passenger, it has to have high strength. This might lead to heavy weight of the vehicle. For this reason the roll cage is made of hollow tubes of material C45. The model of the roll cage was generated in Solid works modelling software and later analyzed through Ansys software. Dimensions were referred from the Baja rulebook.

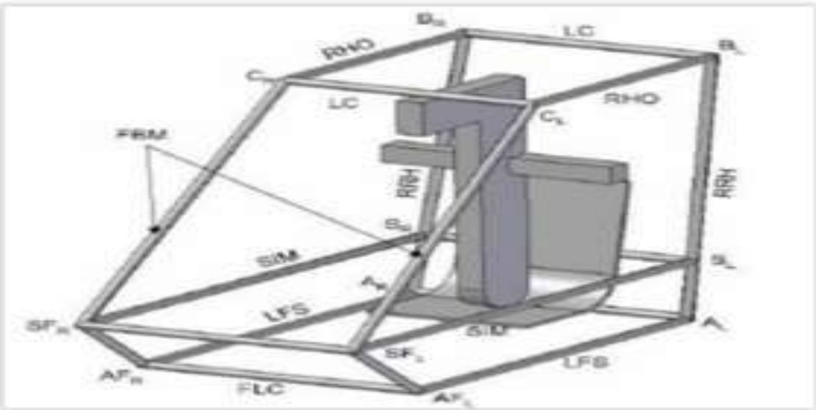


Figure 1 Dimensions of the roll cage

Roll cage members	Length (mm)
Front Lateral Cross member [FLC]	800
Lower Frame Side Member [LFS]	1800
Rear Roll Hoop [RRH]	1800
Side Impact Member [SIM]	2220
Roll Hoop Over Head Member [RHO]	850
Lateral Cross Member [LC]	800
Front Bracing Member [FBM]	1940

Table:2 Dimensions of the roll cage

III. Material

To make a high strength and low weight roll cage the material selection is a critical parameter.

The properties of the material is following.

Subject	Property
Material Name	C 45
Poisson's Ratio	0 .290
Density	7850kg/m^3
yield strength(tensile)	515MPa
Ultimate strength (tensile)	655MPa
Bulk modulus	1.627*10^2GPa
Shear modulus	79.457GPa

Table: 2 Material of roll cage

The materialcomposition isshown in below table.

Material Name	Composition
Carbon, C	0.42 - 0.50 %
Iron, Fe	98.51 - 98.98 %
Manganese, Mn	0.60 - 0.90 %
Phosphorous, P	<= 0.040 %
Sulfur, S	<= 0.050 %

Table: 3 Material composition

Later the total weight of roll cage is calculated.
Total Volume of the model: 4.872e+006 mm^3
Total Mass of the model: 38.245 kg
Max. Mass of person (assumed): 100 kg
Mass of additional parts attached to the roll cage (assumed): 60kg
Total Mass = 200 kg.
[Ref 1, 2, 3, 4, 5, 6, 7].

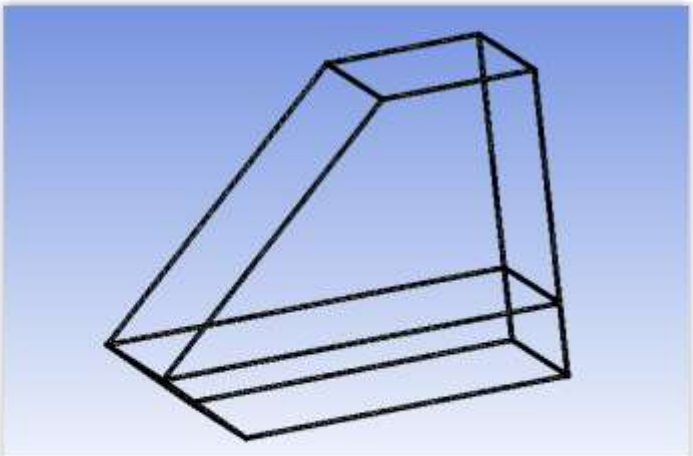
IV. FINITE ELEMENT ANALYSIS

After finalizing the material type and total weight of roll cage, we further analyze the model in Ansys software for different type of loadings.As the total weight carried by roll cage is around 200kg, the force due to acceleration is three times that of the total weight i.e. 200 X 3 =600 Kg=6000N.
By the following equation we found the velocity of the vehicle.
Kinetic energy of vehicle = kinetic energy of the roll cage.
Therefore the velocity of the vehicle is 40.8m/s.

4.1 Meshing the model

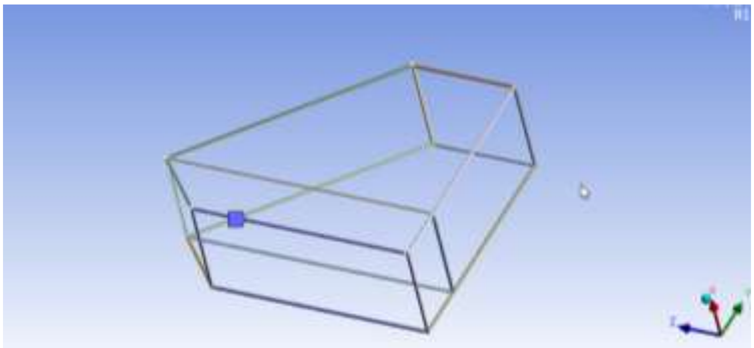
The meshing is done by Ansys pre-processor. Default mesh control with 18318 elements and 39412 nodes are generated.

Figure 2 Meshing of roll cage



4.2 Static structural analysis
4.2.1 Boundary Conditions
Initially the base is fixed assuming that the loading takes place on the upper plane of the base due to these:

- **i.** Weight of the roll cage and vehicle parts.
- **ii.** Weight of person.
- **iii.** Acceleration of the vehicle.



Figure

3 Fixed Support
This type of the analysis is carried out because of the load of the vehicle acts on the roll cage.
The load acts on the four parts where the wheels are fixed.
Figure 3 Method 1

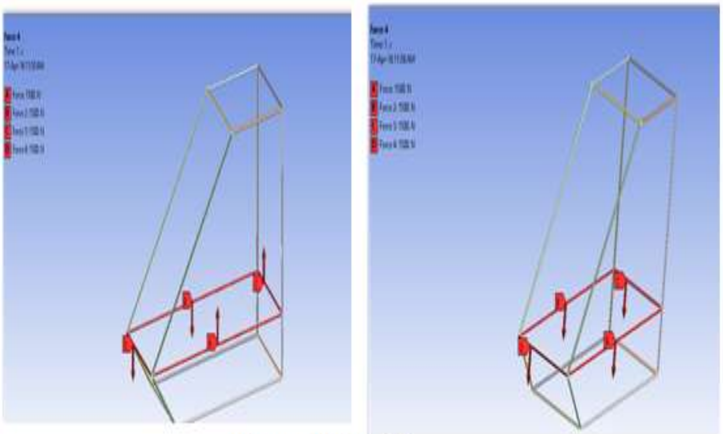


Figure 4 Method 2

4.2.2 Results of static analysis

Figure 5 Stress for Method 1

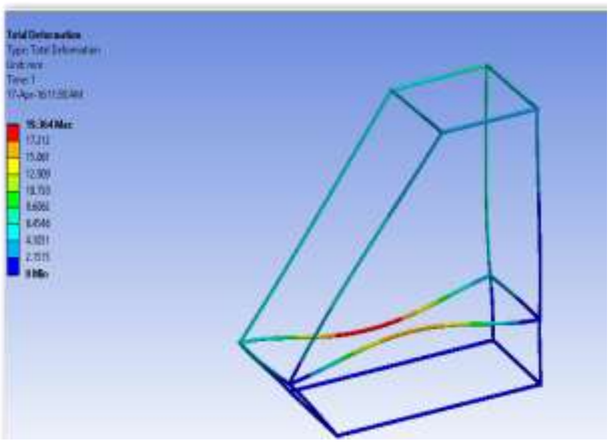


Figure 6 Stress for Method 2

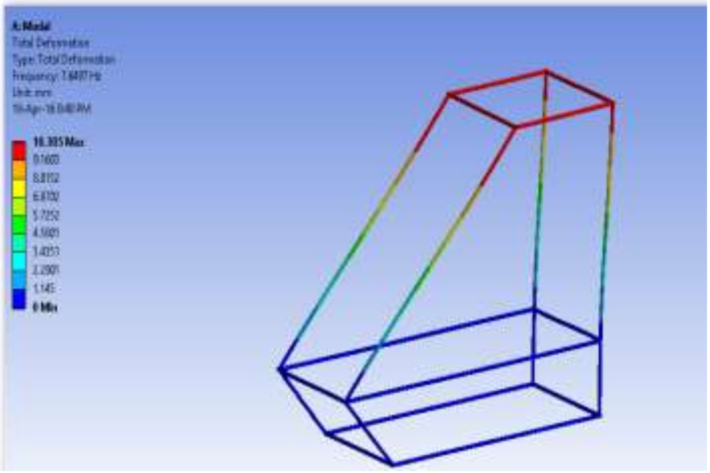


Figure 7 Deformation for Method 1

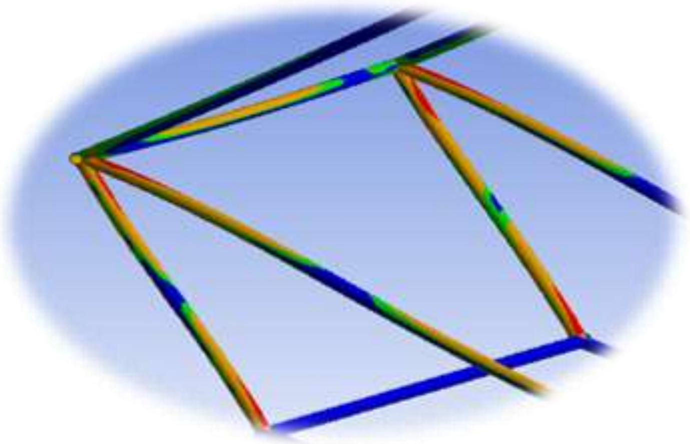


Figure 8 Deformation for Method

	Loading Type1	Loading Type 2
Equivalent stress	307.59Mpa	277.83Mpa
Total deformation	20.854 mm	19.364 mm

Table: 4 Static analysis results

As the maximum deflection of the model is 20.854mm which is less than 76.2(3 inches) hence the design is safe. The deflection is considered because it is the clearance between the rider and the roll cage. [Ref 8]

4.3 Modal Analysis:

The modal analysis is done to know the different natural frequency of the roll cage, because the resonance occur when the external frequency matches the natural frequency of the vehicle. So the vehicle is not run at these speeds or these speeds are past by very quickly.

Figure 9 Modal analysis: Mode1

Figure 11 Modal analysis: Mode3

	Mode 1	Mode2	Mode3
Frequency (Hz)	7.6497	10.422	16.498
Total deformation	10.305 mm	9.7753 mm	10.624 mm

Table: 5 Modal Analysis result

4.4Fatigue Analysis:

As it is the all-terrain-vehicle cyclic load acts on it, hence the fatigue analysis has to be done on the vehicle.

Figure 12 Fatigue Analysis: Safety Factor

Figure 13 Fatigue Analysis: Safety Factor critical section

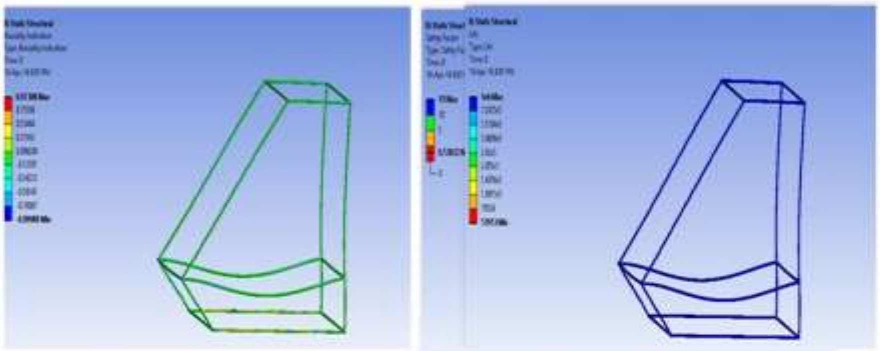


Figure 14 Fatigue Analysis: Bi-axility indication **Figure 15** Fatigue Analysis: Life

Results of fatigue analysis:

i. The equivalent alternating stress obtained is 160.13Mpa and it is less than the 327.5Mpa.i.e. it is less than the endurance limit of the material.[ref 1-7]

ii. According to the above analysis maximum fatigue life for the roll cage is 10^6.

iii. Factor of safety for the design varies from 0-15 and we obtained the factor of safety as 0.538.

Name	Figure	Design life	Minimum	maximum
Life	Fig 15		52953	$1.0X10^6$
Damage	None	$1.0X10^6$	1000	1000
Safety factor	Fig 12&13	$1.0X10^6$	0.538	15
Bi-axiality indication	Fig 14	- -	-0.9999	0.9998
Equivalent alternating stress	None	- -	0.01Mpa	160.13Mpa

Table:6 Fatigue results

III. CONCLUSION

Roll cage used for the all-terrain vehicles is necessary to be analyzed in the context of maximum safe load that the design can withstand and hence from the static structural analysis of the roll cage it is clear that for the overall load of 6000N which is acting on the roll cage generates a stress of 307.59 MPa and it is within the yield stress which is 515Mpa hence the design is safe. From the modal analysis of roll cage 3 modes of vibrations are obtained (table 4) and from the fundamentals of vibrations it is clear that any force corresponding to those natural frequencies should not act on the roll cage and the roll cage should not be subjected any load corresponding to those frequencies .From the fatigue analysis of the roll cage maximum alternating stress developed was 160.13Mpa which is less than the endurance limit of 327.5 Mpa and the design is safe for the fatigue load also and it has a design life of 10^6 cycles.

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