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STRUCTURAL AND MODAL ANALYSIS OF DIFFERENT ROLL CAGE MODELS IN ON-ROAD TRANSPORT VEHICLE.

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Abstract-Roll cage is specially engineered structure developed by joining the individual roll bars by welding or bolting them together in the passenger compartment of a vehicle to protect occupants in it from being injured in an accident conditions, particularly in the event of roll-over cases of the vehicle. They are also known as Exo-cages when built around the vehicle. The objective of the study is to select material, frame design, determination of cross section of frame, finite element analysis to test the strengths of frame. Three different models of roll cages are designed, which can be fixed in lorry cabin. Using 3d modeling software CATIA V5 R20 these models are easily designed. The chassis of the vehicle is already built strong, so the design selected is fixed to the chassis of the vehicle. Later, using ANSYS 14.5 finite element analysis software structural static analysis and dynamic modal analysis are applied on these models. In static analysis a pressure of 40kpa and 60kpa are applied to evaluate the deformations, von-mises stresses and strains. Modal analysis is used to find mode shapes and corresponding frequencies of roll cage models so designed. The main aim of this study is to develop a light weight Roll over protection system. The model which gives better results after structural and modal analyses are done on these models is selected.

Key Words: Roll cage, DOM steel, Structural Analysis, Modal analysis.

1. INTRODUCTION

Roll cages

Roll cages are specially engineered and constucted frame built in the passenger compartment of a vehicle to protect occupants from being injured in the event of accidents.

Fig. 1.Sports car undergoes a crash test

A sports car having roll over protection system has been tested by crash test to check whether it is safe for its occupants or not. Its shows that the front and rear sides of car have crushed but the roll cage shows how stiff it is. We cannot completely avoid accidents, but we can reduce number of fatalities during these accidents by taking safety actions. For this, some automobile manufactures provide different protection systems like air bags, seat belt, stronger vehicle body etc as their step in providing safety.

2. ABOUT MATERIAL

DRAWN OVER MANDREL ELECTRICALLY WELDED TUBE (DOM): Tubular Products 'DOM tubing is roll-formed, electric-welded and sized on modern mills designed especially for high-quality, high-speed tube production. Inside and outside weld flash is removed during the process, and every foot is tested for weld integrity with sophisticated in-line equipment.

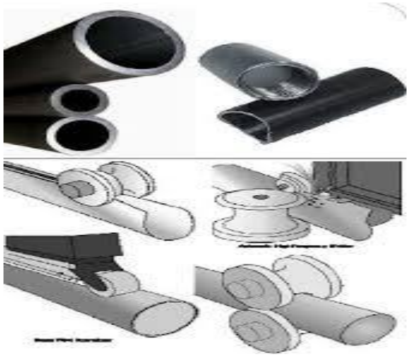


Fig. 2.Tube Forming and Welding Process

The tubing is then cold-drawn over a mandrel and through a die. This operation trans-forms it in size, appearance and homogeneity and improves its dimensional accuracy and strength. The best Characteristics of the as-welded tube are retained and refined, and the DOM product assumes dynamic new characteristics. The cold drawing operation reduces the diameter of the as-welded tube shell and thin sits wall to required dimensions in a controlled fashion to provide the properties desired in the finished product. This process improves the tube's concentricity, tensile strength, hardness and machinability. Close dimensional accuracy is achieved through positive control of both inside and outside diameter.

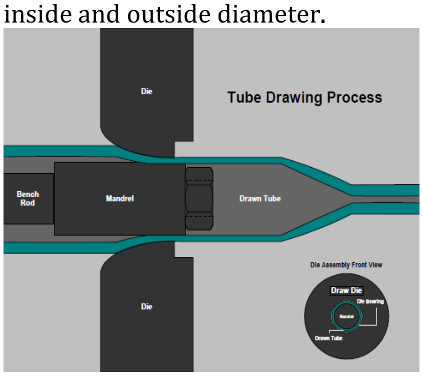


Fig. 3.Die and Mandrel Configuration

This DOM alloy is typically available by AISI/SAE steel grade 1008 up to 1026, the higher the number, the higher the carbon content and the stronger the steel. So for this study DOM steel 1026 is selected and the chemical composition and mechanical properties of 1026 steel is sufficient for our requirements. The dimensions of the tube 40mm as outer diameter (OD) & wall thickness of 3mm, which gives 34mm as inner diameter (ID). DOM offers good weldability & machinability.

3. CATIA

By using CATIA three models of roll cages are designed. It is a basic model i.e. model 1. For next model to increase stiffness additional members are added. In third model trusses are used to increase more stiffness and also bends are completely avoided in this model.

DESIGN OF ROLL CAGE MODEL 1

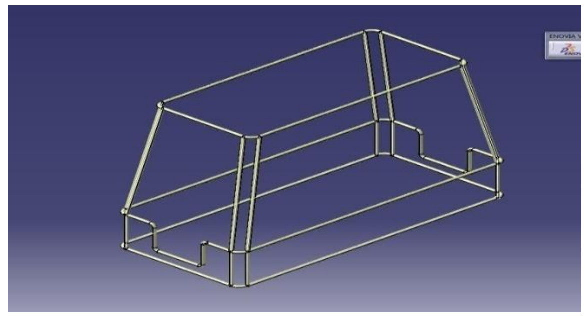


Fig. 4. Isometric view of roll cage model 1

DESIGN OF ROLL CAGE MODEL 2

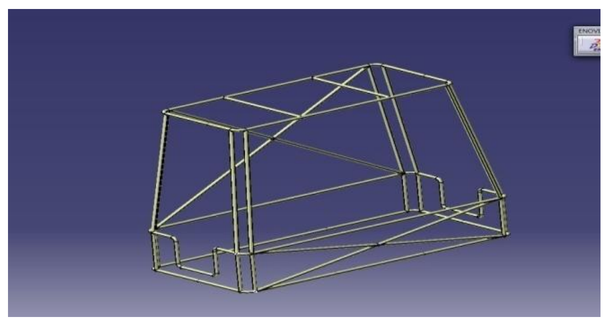


Fig. 5.Isometric view of roll cage model 2

DESIGN OF ROLL CAGE MODEL 3

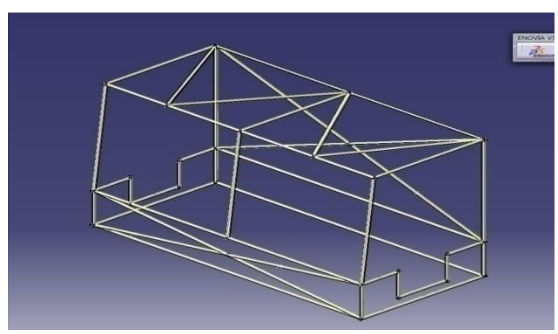


Fig. 6.Isometric view of roll cage model 3

4. ANALYSIS

Structural analysis: By using ANSYS 14.5 structural analysis is done on three models of roll cages. The base has been fixed as support and pressure of 40&60 kpa has applied on the front faces of roll cage models. Finally deformations, stresses and strains are finding out.

For pressure of 40kpa on model 1

Deformation

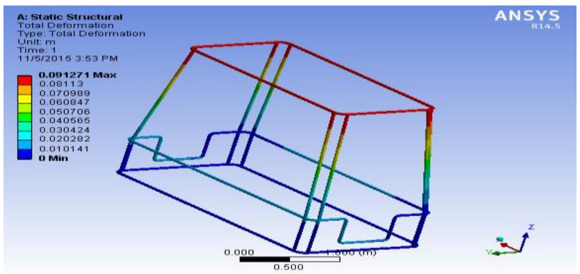
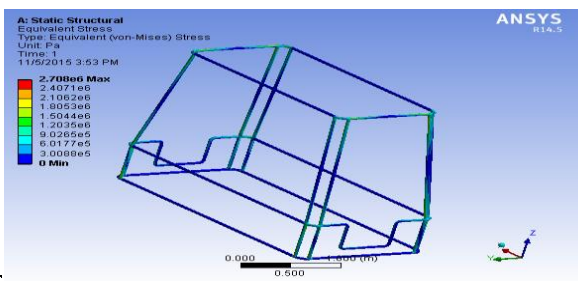
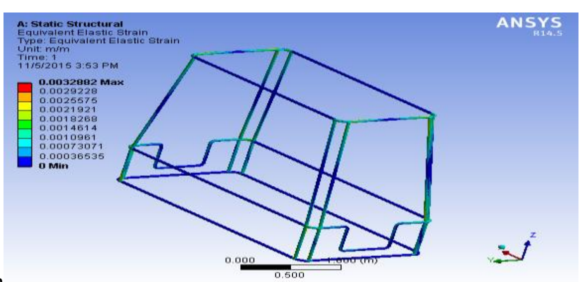


Fig. 7.Deformation result of roll cage model 1



Stress

Fig. 8.Equivalent (von-mises) stress result of roll cage model 1



Strain

Fig. 9.Equivalent elastic strain result of roll cage model 1

For pressure of 60kpa on model 1

Deformation

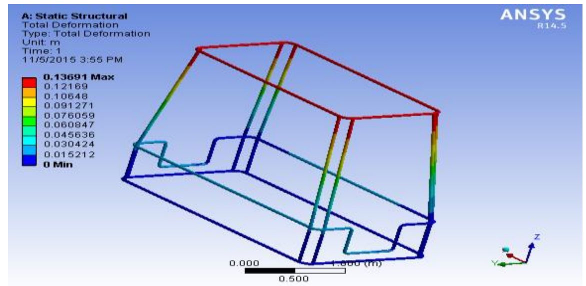
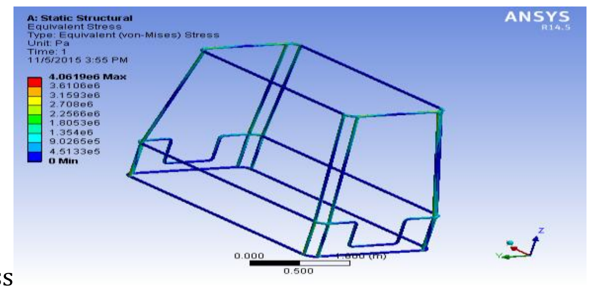
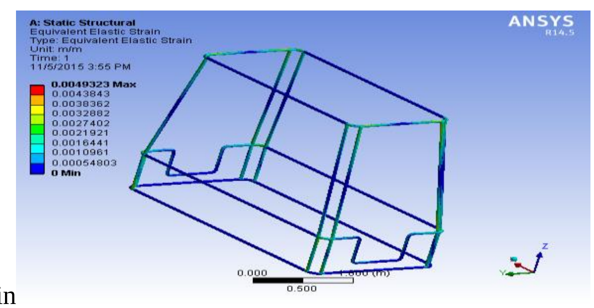


Fig. 10.Deformation result of roll cage model 1



Stress

Fig. 11.Equivalent (von-mises) stress result of roll cage model 1



Strain

Fig. 12.Equivalent elastic strain result of roll cage model1

For pressure of 40kpa on model 2

Deformation

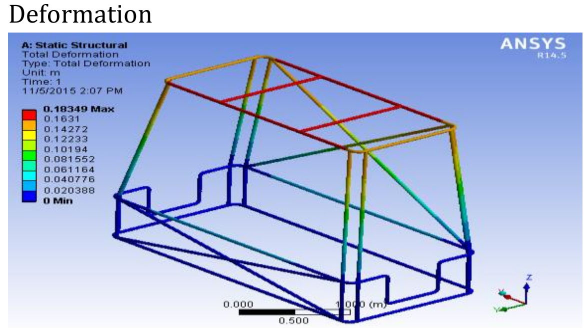
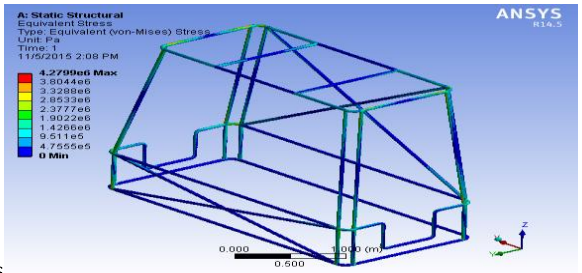
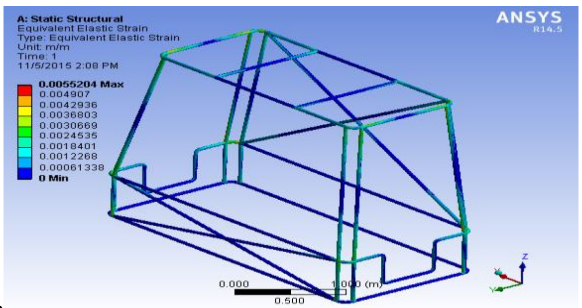


Fig. 13.Deformation result of roll cage model 2



Stress

Fig. 14. Equivalent (von-mises) stress result of roll cage model 2



Strain

Fig. 15.Equivalent elastic strain result of roll cage model2

For pressure of 60kpa on model 2

Deformation

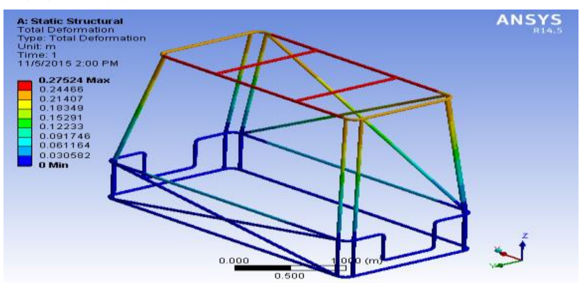
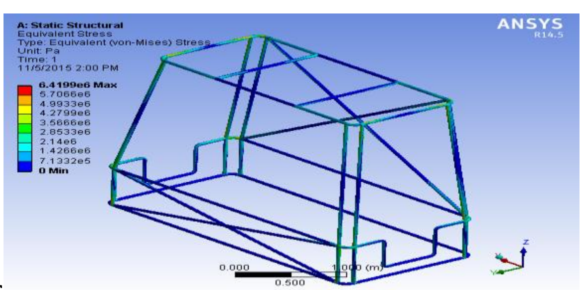
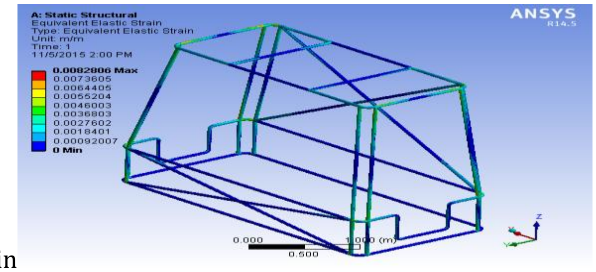


Fig. 16.Deformation result of roll cage model 2



Stress

Fig. 17.Equivalent (von-mises) stress result of roll cage model 2



Strain

Fig. 18.Equivalent elastic strain result of roll cage model 2

For pressure of 40kpa on model 3

Deformation

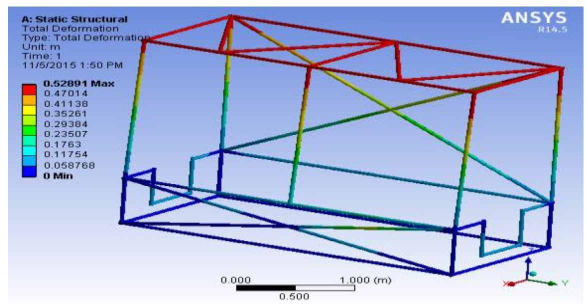
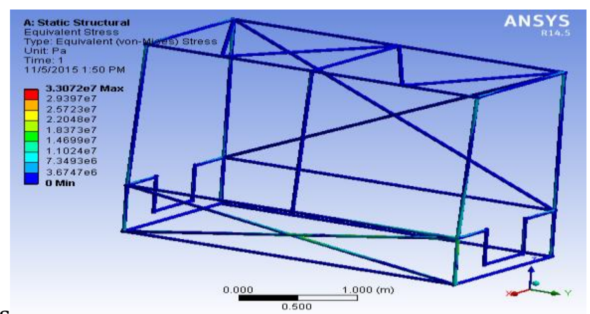
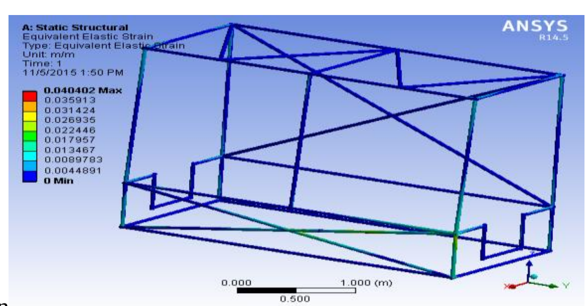


Fig. 19.Deformation result of roll cage model 3



Stress

Fig. 20. Equivalent (von-mises) stress result of roll cage model 3



Strain

Fig. 21.Equivalent elastic strain result of roll cage model 3

For pressure of 60kpa on model 3

Deformation

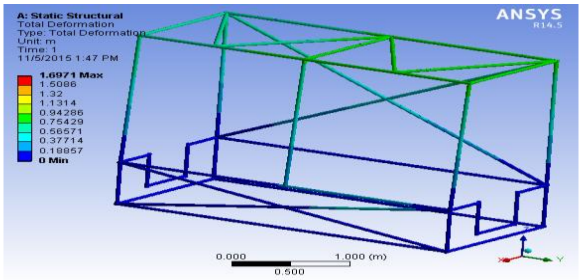
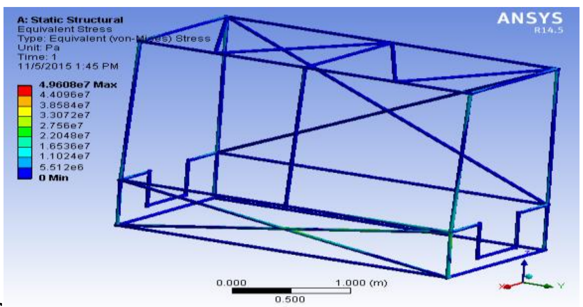
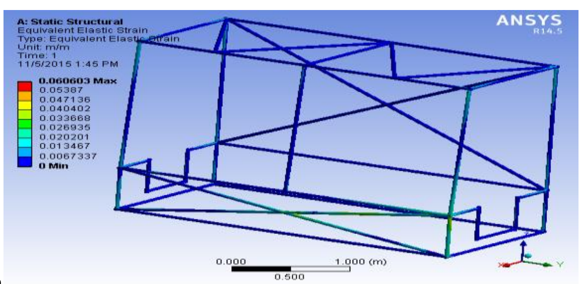


Fig. 22.Deformation result of roll cage model 3



Stress

Fig. 23. Equivalent (von-mises) stress result of roll cage model 2



Strain

Fig. 24.Equivalent elastic strain result of roll cage model 3

Structural analysis is used to assess the behavior of engineering structures under the application of various loads.

Modal analysis: Any complex body can vibrate in many different ways. I.e., there is no one "simple harmonic oscillator". These different ways of vibrating will each have their own frequency, that frequency determined by moving mass in that mode.Finding out Different mode shapes, corresponding frequencies and deformations for roll cage model 1.

Frequencies and Deformations for 7 different mode shapes have been calculated. All the resulted values are tabulated in the results table.

Deformation1

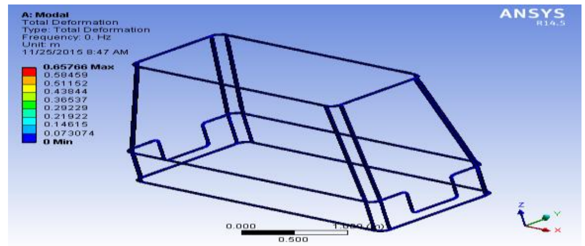


Fig. 25.Mode shape 1 for roll cage model 1

Deformation

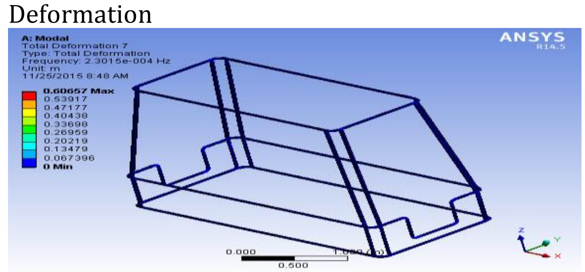


Fig. 26.Mode shape 7 for roll cage model 1

Finding out Different mode shape frequencies and deformations for roll cage model 2

Deformation1

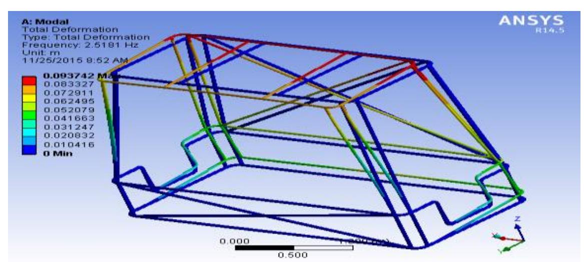


Fig. 27.Mode shape 1 for roll cage model 2

Deformation

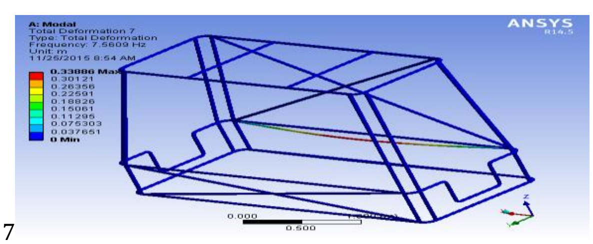


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Fig. 28.Mode shape 7 for roll cage model 2

Finally, finding out mode shape frequencies and deformations for roll cage model 3

Deformation

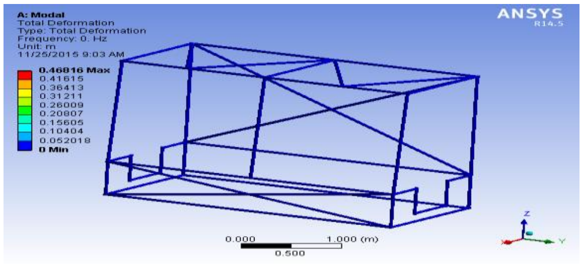

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Fig. 29.Mode shape 1 for roll cage model 3

Deformation

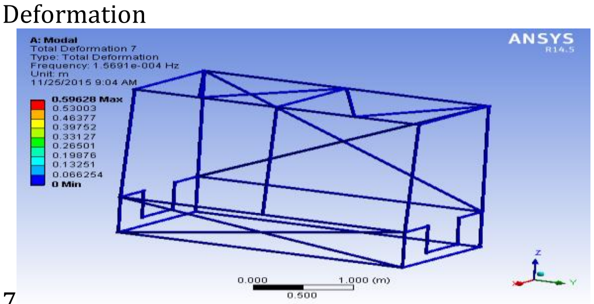

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Fig. 30.Mode shape 7 for roll cage model 3

5. RESULT

Structural analysis: The values of three roll cage models for pressures of 40&60kpa from ANSYS pictures tabulated below.

	Pressure	Deformation	Stress	Strain
Model 1	40kpa	0.09127	2.708e6	0.00328
	60kpa	0.13691	4.061e6	0.00493
Model 2	40kpa	0.18349	4.279e6	0.00552
	60kpa	0.27524	6.419e6	0.00828
Model 3	40kpa	0.52891	3.307e7	0.04040
	60kpa	1.69710	4.960e7	0.06060

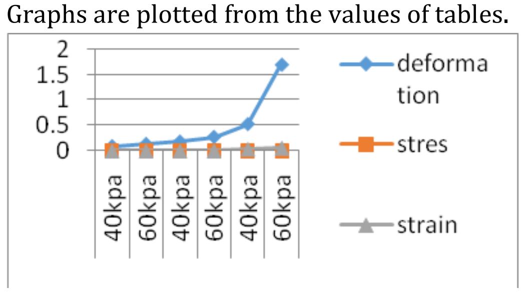
Table 1.results from structural analysis

Modal Analysis: The values of deformations and frequencies at different mode shapes from ANSYS pictures of three roll cage models are tabulated below.

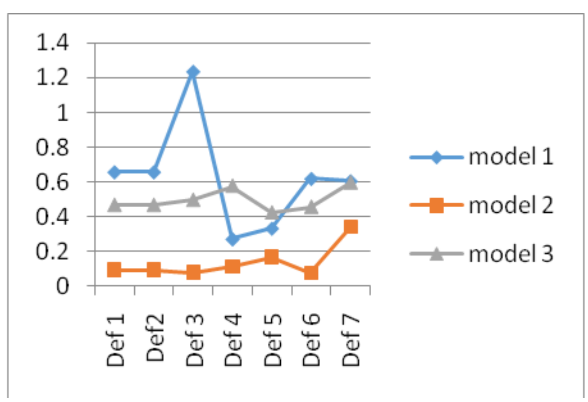
Mode Shapes	Model 1	Model 2	Model 3
	Deformation m	Deformation m	Deformation m
	Frequency HZ	Frequency HZ	Frequency HZ
1	0.6576	0.0937	0.4681
	0	2.5181	0
2	0.6576	0.0937	0.4681
	0	2.5181	0
3	1.2342	0.0810	0.4966
	0	3.3508	0
4	0.2731	0.1127	0.5768
	0	5.0116	5.1852e-005
5	0.3345	0.1692	0.4245
	7.9922e-005	6.2314	1.1792e-004
6	0.6198	0.0776	0.4569
	1.8365e-004	6.5668	1.3414e-004
7	0.6065	0.3388	0.5963
	2.3015e004	7.5609	1.5691e-004

Table 2.results from modal analysis

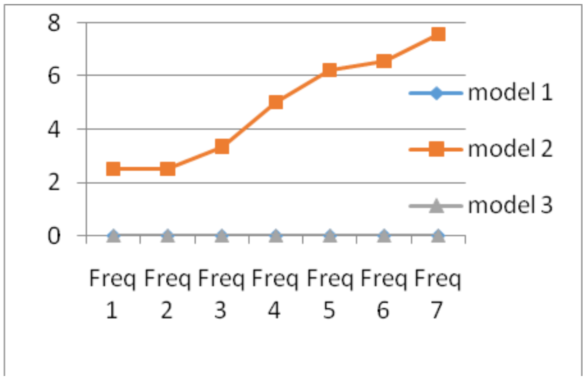
Graphs are plotted from the values of tables.



Graph 1.structural analysis graph



Graph 2.deformations in modal analysis



Graph 3.frequencies in modal analysis

6. CONCLUSION

In this study 3 types of roll cages are designed for on road transport vehicles which can be easily fixed it to the vehicle chassis and by using ANSYS structural and modal analyses are done to find out the stress and deformation factors of the models.

In Structural analysis a pressure of 40kpa and 60kpa are applied on the roll cage for evaluating the deformations, von-mises stresses and strains for each model and the results obtained from ANSYS are displayed in the form of tables and graphs.

From the results of structural analysis, it is clear that the lowest deformations and lowest strains are observed in model 1 for both 40kpa and 60kpa cases, when comparing it with other models.

But the results of stresses in structural analysis for both the cases of 40Kpa and 60Kpa the model 3 gives better results, but all the stress values of 3 models obtained are within limits.

Modal analysis is used to find mode shapes and corresponding frequencies of roll cage models so designed. The range of frequencies for model 1 is (0-2.30e-004) HZ, for model 2 is (2.51-7.56) HZ, for model 3 is (0-1.56e-004) HZ. It clearly shows the values are lower in model 1 and much higher in model 2.

So, finally based on structural analysis results and modal analysis results Model 1 gives better results comparing with other models. So it is concluded that model 1 is better suitable for this design requirements.

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