Free Vibration Mode Shape Analysis And Fabrication Of The Roll Cage For All-Terrain Vehicle Based On FEA

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Abstract: The main objective of this research work is to find the mode shapeand corresponding natural frequency of a roll cage for an ATV. Finite element analysis is used to determine the mode shapes and frequencies. We have designed a roll cage which consists of both structural base and 3-D shell which protects the user in case of impact and roll over incidents. CATIA V5 has been used for modeling the roll cage and ANSYS 14.5 for FEA analysis. The body shape of the roll cage is fixed from the front end. The frame of the roll cage consists of three main parts known as boot space, driver cabin and engine chamber. The results shows that the range of frequencies varies from(0-4.883e-004)Hz.

Keywords: Roll cage, FEA, Modal frequency, Mode Shape, ANSYS.

1. Introduction

A roll cage is a skeleton of an ATV. Selection of the roll cage material is based on cost, availability and strength. The modeling of roll cage is done in CATIA V5 software and later modal analysis is done in ANSYS 14.5 software. When the results are obtained from modal analysis we have modified the design accordingly. After successfully designing the roll cage, it is ready for fabrication.

2.0 Methodology

2.1Design and Development

Design and development of the roll cage for an ATV involves many factors which includes material selection, cross section, frame design and finite element analysis. Material selection is one of the important factors while designing the roll cage as it ensures safety, reliability and performance.

2.2 Material Selection

The frame of the roll cage will be built by using a bent tube construction using pipe bending machine and MIG welded joints. The material used for the frame of the roll cage is structural steel. Structural steel is chosen as it gives high strength, High toughness, high stiffness, etc.

2.3 Function of Roll Cage Frame

1) The main function of the roll cage frame is to provide the mechanical support to different parts of vehicle like Engine, suspension, axles, tires, transmission system, etc.
2) Provides dynamic stability and strength
3) To provide torsional stiffness and strength against vertical bending
4) Ensure the safety of passengers in accidents
5) Noise and vibration harness agent.

2.4 Cad Model of Roll Cage

CATIA V5 software has good geometric modeling capability. It has various features that are suitable for designing complex geometries. To make design and analysis simple only the frame of the roll cage has been designed without considering different types of mountings. Few parts have not been considered while designing the geometry of the roll cage as they have no impact on vibration frequency. The roll cage model is shown below:-

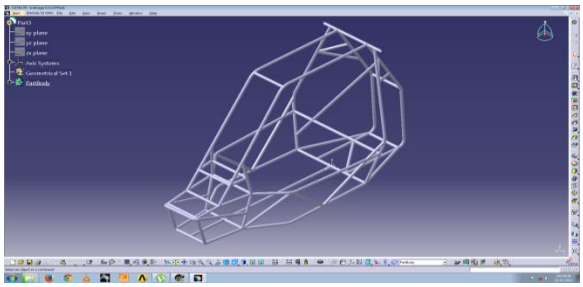

Fig 1 Isometric view of roll cage

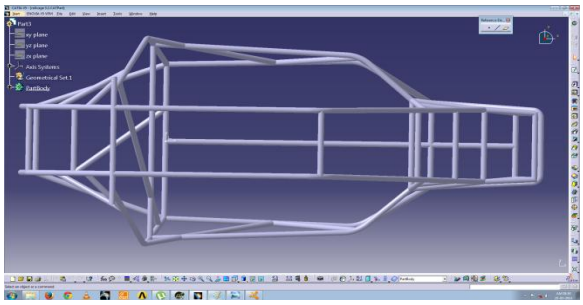

Fig 2 top view of roll cage

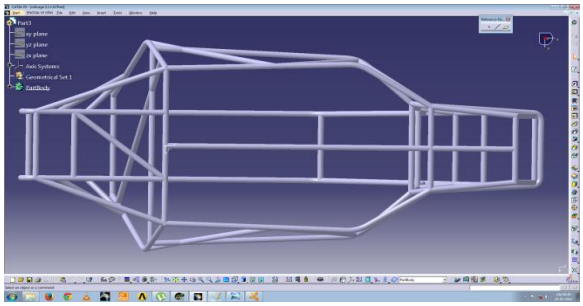

Fig 3 bottom view of roll cage

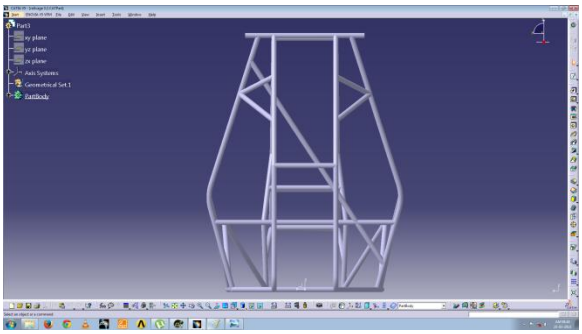

Fig 4 back view of roll cage

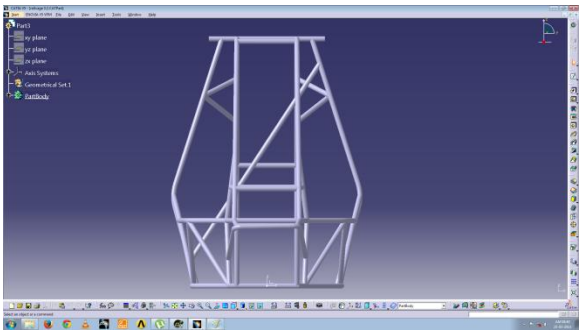

Fig5 front view of roll cage

2.5 Dimensions of Roll Cage-

SL. No.	Parameter	Actual Value
1	Max length	90 inches
2	Max width	61 inches
3	Height	54.5 inches
4	Ground clearance	11 inches
5	Trackwidth front	52.7 inches
6	Trackwidth rear	51 inches
7	Wheelbase	62 inches
8	Static stability factor	1.20
9	Weight	290 kg including driver
10	Gradability	62.84%
11	Turning circle	3.5m
12	Stopping time	3.4 sec

2.6 Modal Analysis of Roll Cage

For free vibration analysis FEA software ANSYS 14.5 has been used as analysis tool. FEA is based on discretization of object in small elements. These elements are connected from node to node. This process of discretization is known as meshing. ANSYS 14.5 provides high quality meshing facilities. The meshed model consists of 64,596 nodes and 27,103 elements. For Free vibration analysis .iges file is imported in ANSYS14.5. The front boot space part is constraint for motion. The Fixed-Free boundary condition is used for the free vibration analysis.Structural steel is used as roll cage material.Elastic modulus, Poisson ratio and material density are required for free vibration analysis. Elastic modulus- 2.0e11Pa, Poisson ratio-0.30 and density-7850kg/m3. Natural frequencies and mode shapes of roll cage is shown below:-

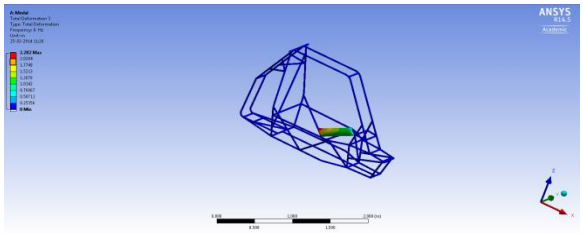

Fig6 Mode Shape 2 f=O Hz

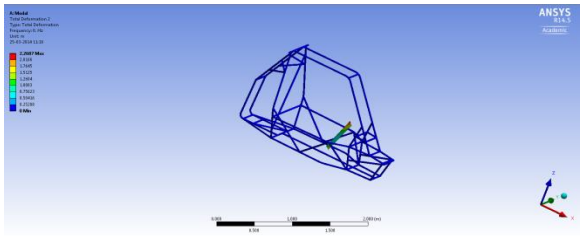

Fig7 Mode Shape 3 f=O Hz

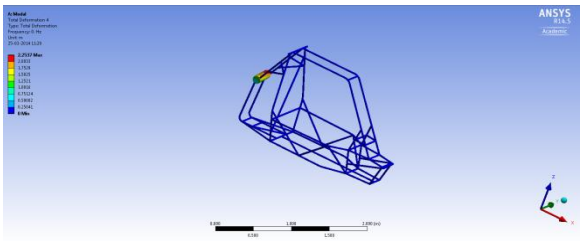

Fig8 Mode Shape 4 f=O Hz

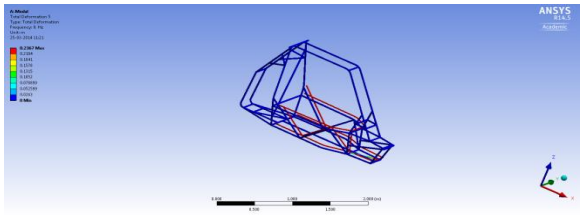

Fig9 Mode Shape 5 f=O Hz

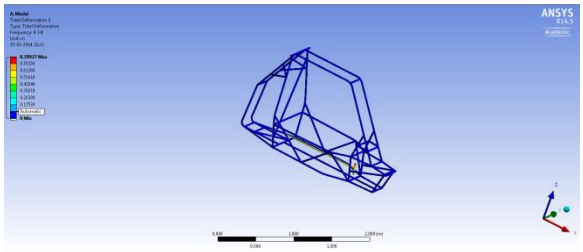

Fig10 Mode Shape 6 f=O Hz

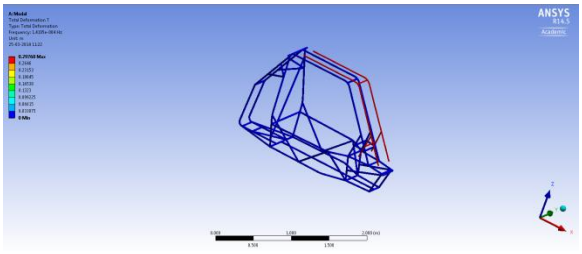

Fig11 Mode Shape 7 f= 1.4195e-004 Hz

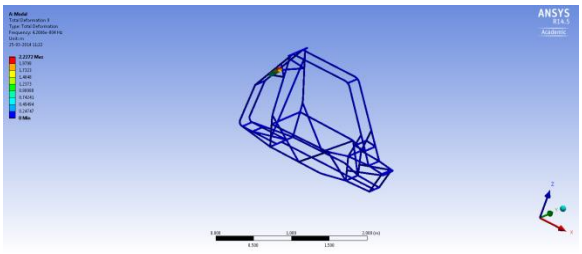

Fig12 Mode Shape 9 f= 4.2666e-004 Hz

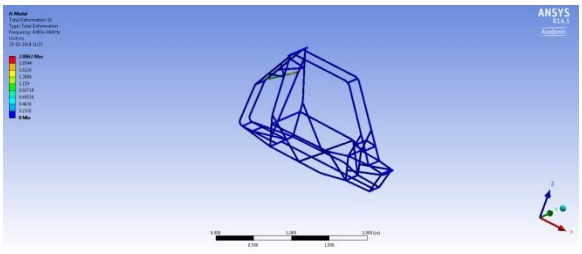

Fig13 Mode Shape 10 f= 4.883e-004 Hz

3.0 Results and Discussion

The FEM based software Ansys 14.5 is used to solve the modal analysis of roll cage and we find the natural frequency and different mode shapes. Fixing the boundary conditions in dynamic simulation problems is very challenging and might have no unique results. In our study we have different mode shapes and their corresponding natural frequencies. A graph is plotted when solution is done.

Object Name	*Total Deformation*	*Total Deformation 2*	*Total Deformation 3*	*Total Deformation 4*	*Total Deformation 5*
State	Solved				
Scope					
Scoping Method	Geometry Selection				
Geometry	All Bodies				
Definition					
Type	Total Deformation				
Mode	1.	2.	3.	4.	5.
Identifier					
Suppressed	No				
Results					
Minimum	0. m				
Maximum	3.2485 m	2.2687 m	2.282 m	2.2537 m	0.2367 m
Minimum Occurs On	PartBody				
Maximum Occurs On	PartBody				
Information					
Frequency	0. Hz				

Fig14 Results of first five mode shapes

Object Name	*Total Deformation 6*	*Total Deformation 7*	*Total Deformation 8*	*Total Deformation 9*	*Total Deformation 10*
State	Solved				
Scope					
Scoping Method	Geometry Selection				
Geometry	All Bodies				
Definition					
Type	Total Deformation				
Mode	6.	7.	8.	9.	10.
Identifier					
Suppressed	No				
Results					
Minimum	0. m				
Maximum	0.78927 m	0.29768 m	1.3399 m	2.2272 m	2.0862 m
Minimum Occurs On	PartBody				
Maximum Occurs On	PartBody				
Information					
Frequency	0. Hz	1.4195e-004 Hz	3.7396e-004 Hz	4.2666e-004 Hz	4.883e-004 Hz

Fig 15 Results of last five mode shapes

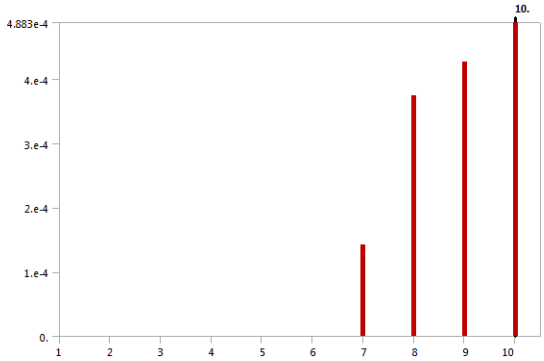

Fig16 Graph obtained when solution is done in ANSYS 14.5 software.

Mode	Frequency [Hz]
1.	0.
2.	
3.	
4.	
5.	
6.	
7.	1.4195e-004
8.	3.7396e-004
9.	4.2666e-004
10.	4.883e-004

Fig17 Natural Frequencies of roll cage

4.0 Fabrication

After analysis it is concluded that the roll cage is safe and can be fabricated. The material was cut according to the dimensions and than machined. In the college workshop the material was joined by metal arc welding process. All the members of the roll cage are joined by this technique.

Fig18 Photograph of fabricated roll cage

5.0 Conclusion

This paper presents design and modal analysis of roll cage. In this paper first 10 mode shapes and their corresponding natural frequencies have been determined. CATIA V5 is used for modeling the roll cage and ANSYS 14.5 is used for analysis. The roll cage motion is constrained by the fixed-free boundary conditions. In this research work we have considered the problem of roll cage mode shapes and natural frequency. Analysisresults shows that the natural frequency range varies from (0-4.883e-004) Hz. Bending and torsional vibration modes has been identified. FEA offers satisfactory results.

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