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Free Vibration Mode Shape Analysis of Space Frame Chassis of a Sports Car based on FEA

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***Abstract*— The main objective of this research work is to find the mode shape and corresponding natural frequency of a space frame chassis. Finite element analysis is used to find the mode shape and frequency. In order to simplify the analysis process only chassis frame of a sports car has been considered and complex assemblies has been avoided. CATIA V5 has good modeling features with lots of facilities for design. The model of space frame chassis has been prepared in CATIA V5. For analysis FEA based software ANSYS 14.5 has been used. The body shape is fixed and it is not subjected to any change in design parameters for the present study. The frame consist of 95 body parts and it is divided in three major parts known as boot space, driver cabin and engine chamber. The engine chamber can accommodate variety of engines without major change. The results shows that the frequency range varies from (130.49-228.48) Hz.**

Keywords*— Chassis, FEA, Modal frequency, Mode Shape, ANSYS.

I. Introduction

A. *Sports Car Chassis*

Chassis frames are intended to support the loads and torsional forces. There is a great significance of torsional forces in stability and comfort of a vehicle. Automotive chassis space frame is used to support the all types of mechanical parts like engines, brakes system, handle, tires, transmission, suspension, drive shaft on frame. The material used for space frame is steel tubes or Al alloy tubes. Due to less weight consideration Al alloys is used for various frame works. We have used steel tubes.

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B. *Types of Chassis frames*

- Ladder chassis.

This is the oldest kind of chassis used in automotive industry. As its name, it looks like a ladder, so it is called a ladder chassis. Most SUV and modern vehicle are based on this chassis. It is constructed by two longitudinal members interconnected by lateral members. Few cross members are also used to provide the rigidity against torsional and vertical bending.

- Back bone chassis

In backbone chassis the front and rear axle is connected by a tubular backbone. This tubular backbone provides the required mechanical strength. The torsional stiffness of the backbone chassis is derived from one large cross section central tube running the length of the car, the resistance to twist depends mostly on the cross sectional area of that tube.

- Monocoque chassis

Monocoque chassis is used for the modern vehicles. It is a single piece frame with combination of shape structure of vehicle. There is very less joints in this type of chassis which provides more strength and rigidity.

C. *Function of Chassis Frame*

- The main function of the chassis frame is to provide the mechanical support to different parts of vehicle like Engine, transmission, axle, tires, suspension system etc.
- Provide dynamic stability and strength.
- To provide torsional stiffness and strength against vertical bending.
- Noise and vibration harness agent.
- Ensure the safety of passengers in accidents.
- Improve crash worthiness.

II. Cad Model of Space Frame Chassis

CATIA [2] software has good geometric modeling capability. It has various features suited for complex geometry like chassis modeling. To simplify the design and analysis procedure only space frame chassis has been considered without different types of mountings. Few parts have not been considered for designing to simplify the geometry and it has no impact on vibration frequency. The CAD model is shown as figure 1. For free vibration analysis FEA software ANSYS 14.5 [1] has been used as an 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. Figure 2 shows the meshed model of steel material chassis. ANSYS 14.5 have high quality meshing facility. The meshed model consists of 2,50,507 nodes and 1,20,353 elements, linear tetrahedral elements are used for meshing.

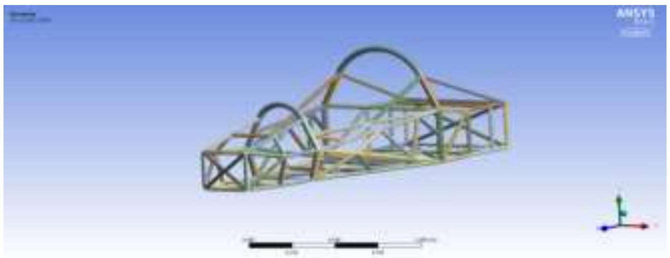

Figure 1 Cad Model of space frame chassis for Analysis.

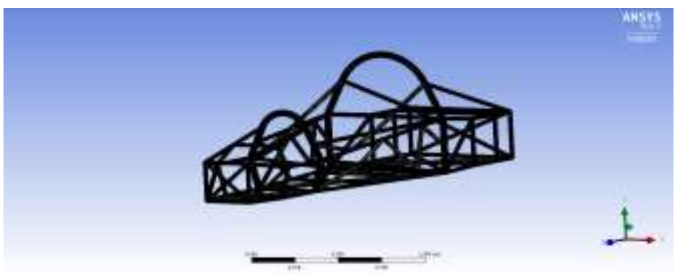

Figure 2 Meshed Model of space frame chassis.

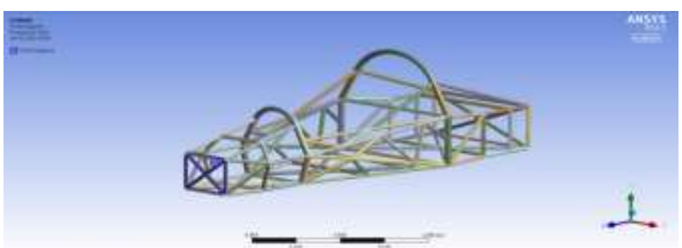

Figure 3 Constraint positions of space frame chassis.

The overall length of the chassis is 2650mm, the wheelbase is 2000mm and its weight is 35 kilograms. For free vibration analysis the .iges file is imported in ANSYS 14.5. The front boot space part and the engine rear part is constraint for motion. The horizontal supporting members are also fixed. The Fixed- fixed boundary condition is used for the free vibration analysis.

III. Material Properties

Al alloys and steel bars are used for the chassis material. Different parts of vehicle are mounted on space frame chassis using fixtures. Loosing of fixtures may cause serious vibration and noise problem. Elastic modulus, Poisson ratio and material density are required for free vibration analysis. The steel bar material properties selected for the space frame chassis are Elastic modulus – $2.0e^{11}$ Pa, Poisson ratio- 0.30 and density- 7850 kg/m3.

IV. Free Vibration Analysis

ANSYS 14.5 workbench is selected for modal analysis and the load is selected by program automatically. The first 10 order vibration mode of chassis is shown in figure 4.

To determine the modal response, modal analysis using FE is performed using implicit FE code-ANSYS 14.5. The governing dynamic response equation is given by:

$$[M]\{\ddot{x}(t)\} + [C]\{\dot{x}(t)\}+[K]\{x(t)\}= \{F(t)\} \qquad (1)$$

Where-[M], [C], [K] are the global mass, Damping and Stiffness Matrix of the model; $\{\ddot{x}(t)\}$- Acceleration Vector, $\{\dot{x}(t)\}$-Velocity Vector, $\{x(t)\}$-Displacement vector.

For undamped free vibration analysis the damping and external excitation force is zero ([c]=0, [F]=0).Equation (2) can be represented as undamped free vibration

$$[M]\{\ddot{x}(t)\} +[K]\{x(t)\}= 0 \qquad (2)$$

the solution of the above equation can be written as

$$\{x\}=\{X\}\ e^{i\omega t} \qquad (3)$$

where {X} represents the amplitudes of vibration of all the masses (mode shape or eigenvector's), ω eigen frequency (rads-1), so the (2) reduces in-

$$([K]- \omega^2[M])\{X\}= 0 \qquad (4)$$

If we replace ω^2 by λ the (4) become a linear problem in matrix algebra.{Xi} has nonzero solution, then coefficient matrix must be equal zero. Each eigenvector{X} and corresponding eigenvalues is solved using ANSYS.

V. Results and Discussion

There are two motion supported boundary conditions for which simulations can be performed. In free-free boundary conditions all DOF of boundaries are subjected to variations. In fixed-fixed boundary conditions guarantee that all degrees of freedom are constrained in boundaries. The FEM based software Ansys.14.5 version solved the space frame chassis modal analysis and we find the natural frequency and mode shape. In dynamic simulation problems modeling of boundary conditions is very challenging problems and they might have no unique results. Through in our study we have

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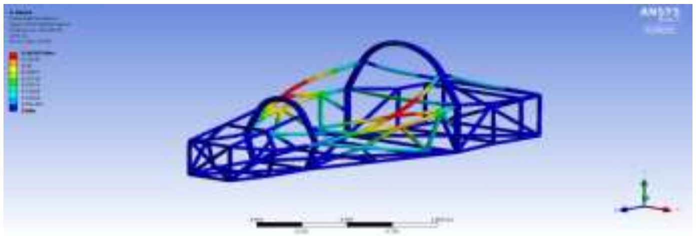
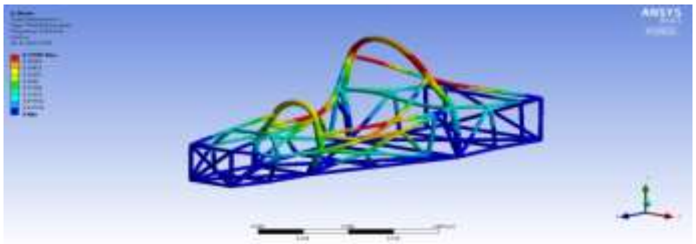
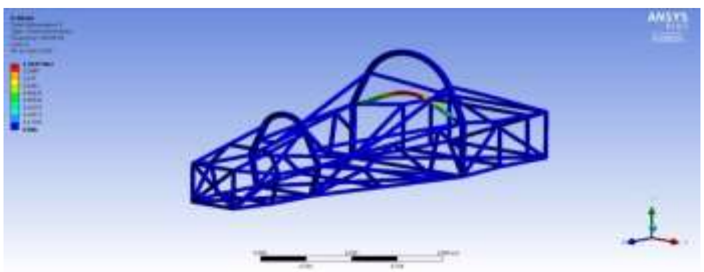
find the natural frequencies and first ten modes shape of chassis as shown in figure 4.



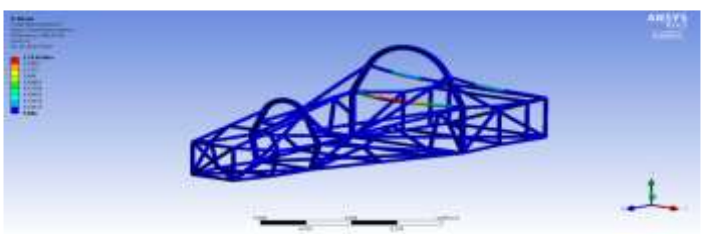
Mode Shape 2 f_2=130.49 Hz



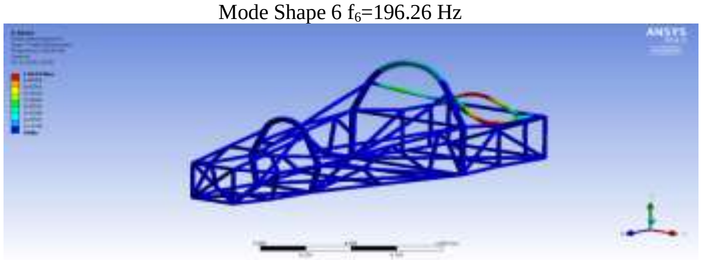
Mode Shape 3 f_3=135.91 Hz



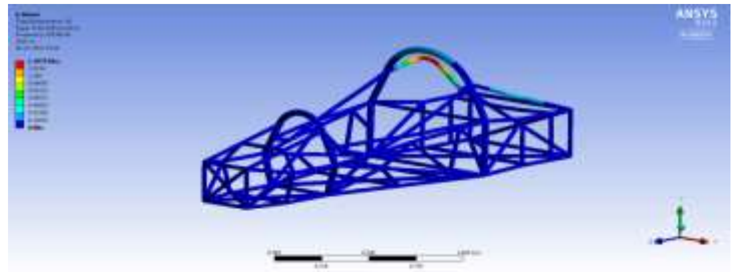
Mode Shape 5 f_5=192.68 Hz



Mode Shape 6 f_6=196.26 Hz



Mode Shape 8 f_8=224.15 Hz



Mode Shape 10 f_{10}=228.48 Hz

Figure 4 Different mode shapes (2,3 5,6,8 & 10) of space frame chassis.

Figure 4 shows the mode shapes and corresponding natural frequency of space frame chassis. The frequency range varies from (130.49- 228.48) Hz. Mode 2 and 3 is torsional vibration mode. This torsional vibration is performed at single mid side on space frame chassis. The mode 5, 6 and 8 is bending vibration mode. The mode 10 is torsional vibration mode.

VI. Conclusion

This paper present the design and free vibration analysis of a chassis space frame. The first 10 mode shapes and corresponding natural frequencies have been determined. CATIA V 5 has good modeling capability and ANSYS 14.5 is used for analysis. The chassis motion is constrained by considering the fixed-fixed boundary conditions. In this research work we have considered the problem of chassis mode shapes and natural frequency. The analysis results shows that the frequency range varies from 130.49 to 228.48 Hz, different vibration modes like torsional and bending has been identified. Finite Element Analysis offers satisfactory results.

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