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Vibration analysis of Two Wheeler Gearbox Casing

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ABSTRACT

The gearbox casing protects the components of gearbox. It provides the fluid tight casing to hold the lubricants and provides support to moving components. Gearbox casing failure is the main problem for the vehicle manufacturer. Noise and vibration are the main reason for failure. So it is required to reduce the level of noise and vibration. In order to prevent failure the natural frequency and natural mode shapes should be known. In this paper, the vibration analysis of two wheeler gearbox casing was performed by finite element simulation using NASTRAN software. Gearbox casing design is a complex procedure. Design of gearbox casing was done by using CATIA, the model is imported in Hyper Mesh for meshing, modal analysis is done by using NASTRAN solver and Hyper View is used as post processor. This analysis is done for finding the natural frequency of gearbox casing in order to prevent resonance. The vibration pattern for first ten modes was studied. The analysis shows the natural frequency of vibration which varies from 878.7 Hz to 4932 Hz. The External excitation on gearbox casing must be eliminated to prevent the fracture of casing. The reason of the fracture is matching of external excitation frequency to natural frequency of gearbox casing. For validation we have used FFT analyzer to measure natural frequency of gearbox casing. From the result, this analysis shows the range of the natural frequency of two wheeler gearbox casing.

Keywords— **Gearbox, Vibration Analysis, NASTRAN, CATIA, HyperMesh, FFT analyzer.**

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I. INTRODUCTION

Gears have wide variety of applications. They form the most important component in a power transmission system. A gearbox is a combination of gears that is used to transmit energy through different parts of vehicle. It functions like to increase torque while reducing speed. Gearbox casing is the shell (metal casing) in which a train of gears is sealed. The Gearbox Housing is one of the most critical components of a power transmission system in automobile. The function of the Gearbox Housing is to provide support for the gear drive assembly that transfers power from the engine to the engine accessories and takeoff drive for the automotive accessories. The housing also functions as an oil tight container and passageway for lubrication. The complexity in predicting gearbox housing behaviour under the gear loading, engine loading and engine induced vibration is one of the main challenges of designing a new gearbox with minimum weight. A sequential manual transmission (or sequential manual gearbox) is a non-traditional type of manual transmission used on motorcycles and high-performance cars for auto racing, where gears are selected in order and direct access to specific gears is not possible. With traditional manual transmissions, the driver can move from gear to gear, by moving the shifter to the appropriate position. A clutch must be disengaged before the new gear is selected, to disengage the running engine from the transmission, thus stopping all torque transfer.

Vibration is a mechanical phenomenon whereby oscillations occur about an equilibrium point. The oscillations may be periodic such as the motion of a pendulum or random such as the movement of a tire on a gravel road. More often, vibration is undesirable, wasting energy and creating unwanted sound – noise. For example, the vibration motions of engines, electric motors, or any mechanical device in operation are typically unwanted. Such vibrations can be caused by imbalances in the rotating parts, uneven friction, the meshing of gear teeth, etc. Careful designs usually minimize unwanted vibrations. Modal oscillation of gearbox housing walls and other elastic structures is very important for the noise emitted by systems into the surroundings. Modal activity of housing walls is in direct relation with the structure and intensity of noise emitted by the gearbox into the surrounding. Therefore, research of modal activities is of general importance for modelling the process of generation of noise in mechanical systems. The noise emitted into the surroundings by the gearbox is mostly the consequence of natural oscillation of the housing.

The purpose of investigating the model of gearbox housing is to reduce the level of vibration; which causes the failure of housing. This work consists to develop a computational process to predict the vibrations of gearbox housing and its reduction. The results of Finite Element Analysis of existing gearbox housing are compared with the results to experiments. To measure the vibration experimentally we have used FFT Analyzer. A model is developed to reduce the vibration and its FEA analysis is done. The results of FEA analysis of existing gearbox housing is compared with the results of FEA analysis of modified gearbox housing to find the reduction in amplitude of vibration.

II. CAD MODEL AND MESHING

Model of Gearbox casing is created in CATIA software. CATIA enables the creation of 3D parts, from 3D sketches, sheet metal, composites, molded, forged or tooling parts up to the definition of mechanical assemblies. The software provides advanced technologies for mechanical surfacing. It provides tools to complete product definition, including functional tolerance. CATIA offers a solution to shape design, styling, surfacing workflow and visualization to create, modify, and validate complex innovative shapes in industrial design.

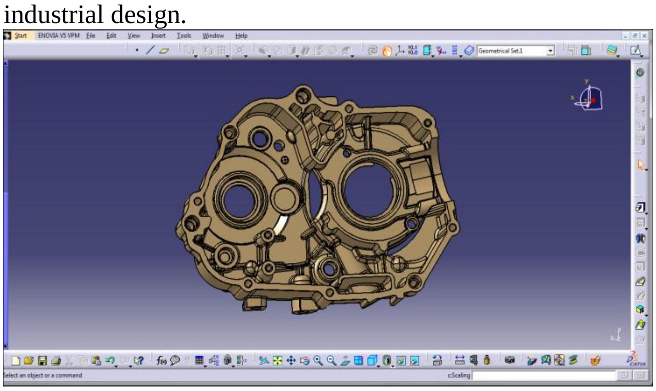

Fig.1 Gearbox casing in CATIA

For meshing the gearbox casing we have used HyperMesh software. Most FEA and CFD software do not have a great meshing algorithm; even when they have it, they do not allow good manual control on the mesh. The result is that after meshing a complicated geometry the mesh is lacking in quality, which means the analysis would either fail or give less than accurate answers. HyperMesh is the most popular software in this regard.

HyperMesh enables engineers to receive high quality meshes with maximum accuracy in the shortest time possible. A complete set of geometry editing tools helps to efficiently prepare CAD models for the meshing process. Meshing algorithms for shell and solid elements provide full level of control, or can be used in automatic mode. HyperMesh offers the biggest variety of solid meshing capabilities in the market, including domain specific methods such as SPH, NVH or CFD meshing. The meshed model consists of 23531 nodes and 80867 elements.

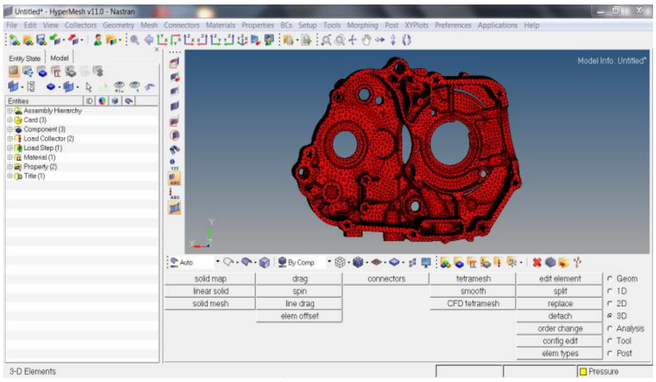

Fig.2 Meshing of Gearbox casing in HyperMesh

III. MATERIAL PROPERTIES

Mechanical properties (Elastic modulus, Poisson ratio and density) are required for free vibration analysis.

Material name for gearbox casing: Aluminium

Modulus of elasticity: 75 x 10^3N/mm^2

Poissions ratio: 0.3

Density: 2700 kg/m^3

IV. RESULTS AND DISCUSSION

A. *Vibration Analysis*

MSC Nastran is used to find the natural frequency for first 10 mode shape of two wheeler gearbox casing. MSC Nastran is commonly utilized for performing structural analysis. Although utilized in every industry, it maintains a strong following in aerospace and automotive industries for performing computational stress and strain analysis of component and system level models of structures. MSC Nastran has continued to evolve and extend capabilities to dynamics, rotor dynamics, nonlinear, thermal, high impact, NVH, fluid structural interactive and fatigue analysis.

The first 10 mode shapes and their corresponding natural frequencies of two wheeler gearbox casing are shown in Fig. 3 to Fig. 12.

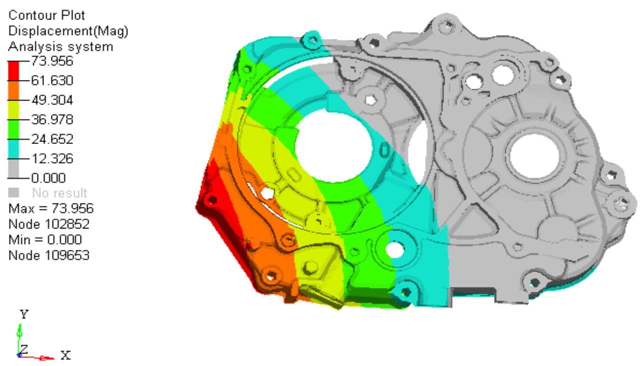

Fig.3 Mode shape 1, f_1 = 878.7 Hz

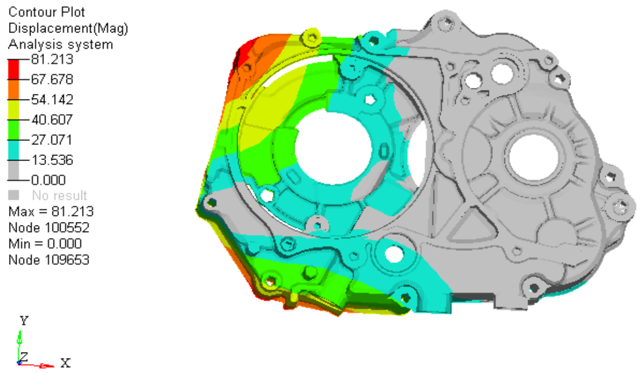

Fig.4 Mode shape 2, f_2 = 1890 Hz

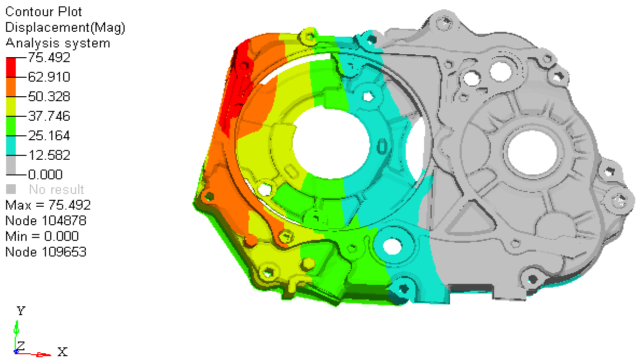

Fig.5 Mode shape 3, f_3 = 2395 Hz

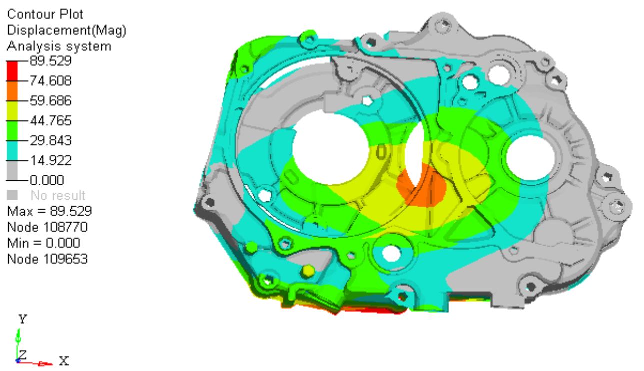

Fig.6 Mode shape 4, f_4 = 3058 Hz

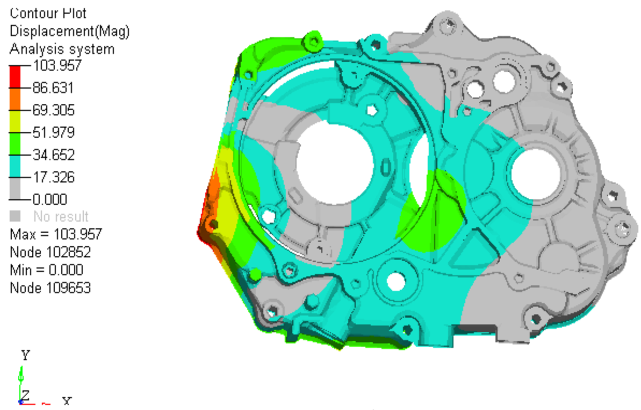

Fig.7 Mode shape 5, f_5 = 3304 Hz

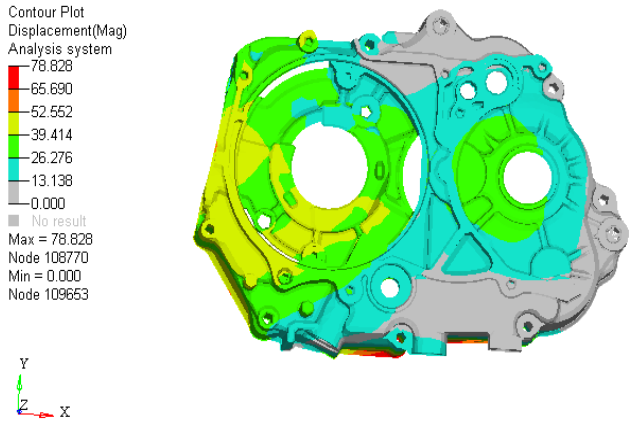

Fig.8 Mode shape 6, f_6 = 4195 Hz

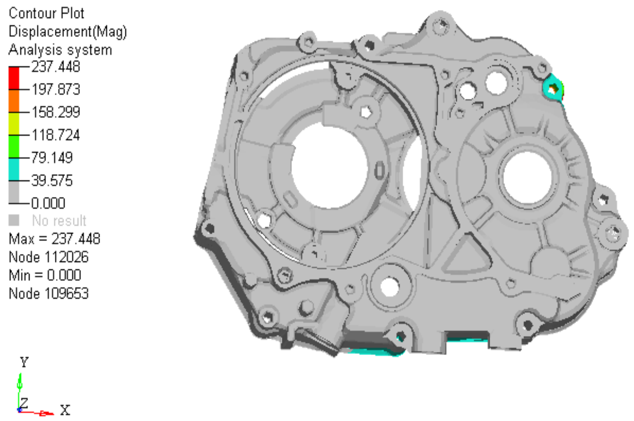

Fig.9 Mode shape 7, f_7 = 4411 Hz

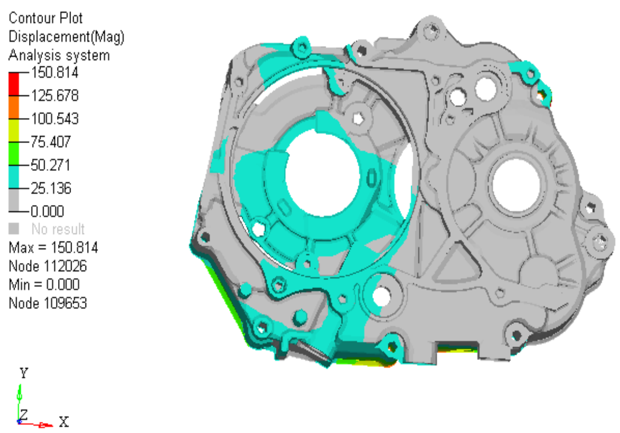

Fig.10 Mode shape 8, f_8= 4534 Hz

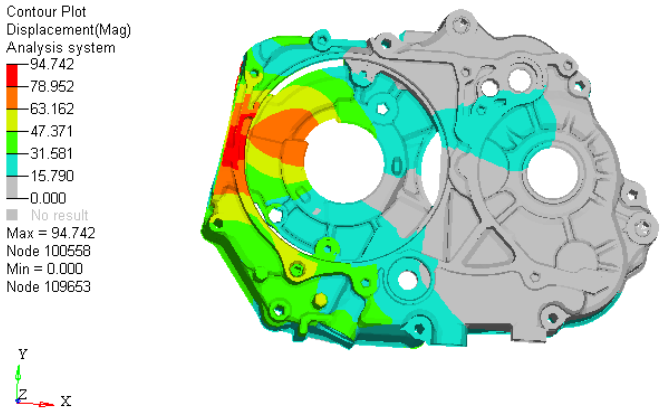

Fig.11 Mode shape 9, f_9= 4796 Hz

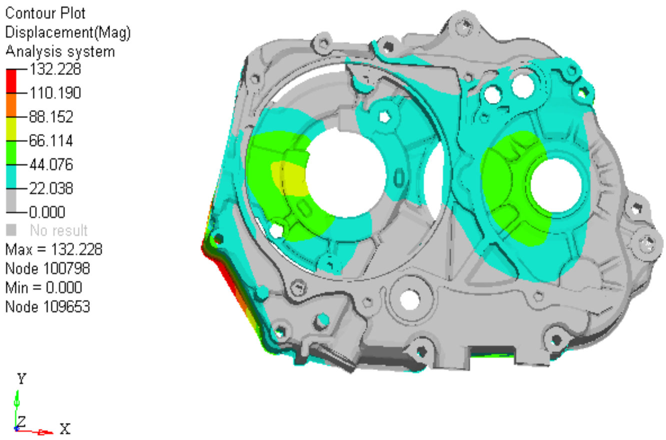

Fig.12 Mode shape 10, f10= 4932 Hz

B. *Static Analysis*

Static analysis is carried out to find out the stress in gearbox casing. Load Case: 50MPa pressure or 61 KN load applied at circumferential area as shown in Fig. 13.

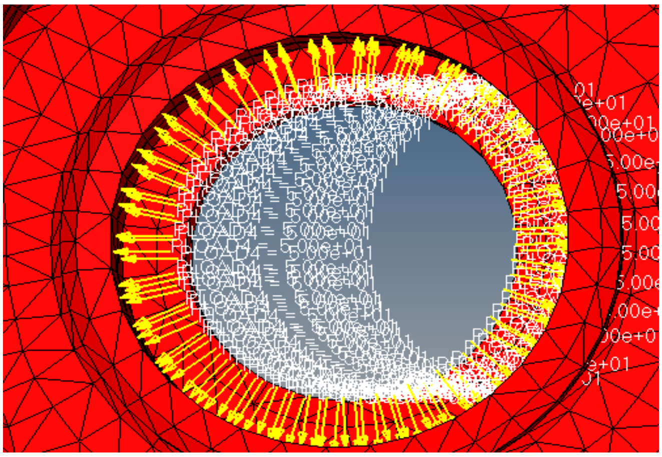

Fig. 13 Load Case

Displacement and stress plot as shown in Fig. 14 and Fig. 15 respectively. Displacement plot shows maximum displacement value 0.06mm. Whereas stress plot shows 160 N/mm^2 maximum value of von-mises stress.

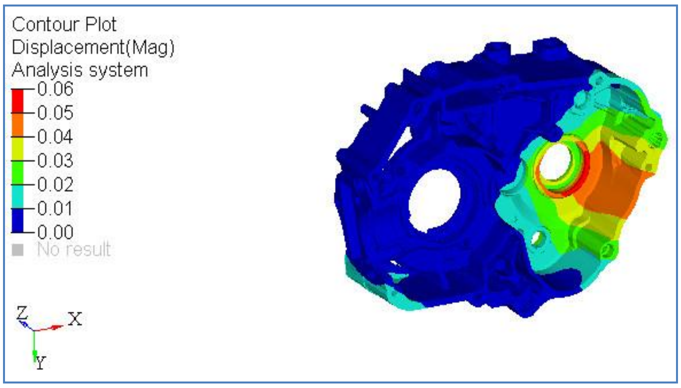

Fig. 14 Displacement plot

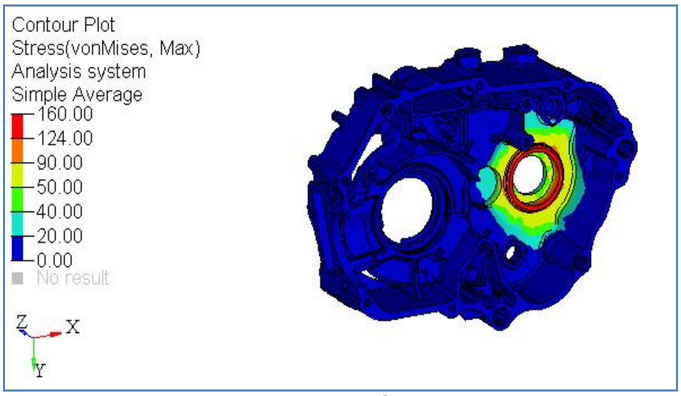

Fig. 15 Stress plot

C. *Experimentation*

In the validation process, several types of tests should be performed to obtain measured data, and then used for comparison with data predicted by the FE model. To measure the vibration experimentally we have used FFT Analyzer. Natural frequencies & mode shapes are further obtained as output.

Fig. 16 shows photograph of FFT analyzer and Fig. 17 shows photograph of two wheeler gearbox.

Fig. 16 Photograph of FFT analyzer

Fig. 17 Photograph of two wheeler gearbox

During the analysis first five natural frequencies of the gearbox casing are extracted from data. Results obtained by experimentation are in TABLE I.

TABLE I
EXPERIMENTAL RESULTS

Mode No.	Natural Frequency (Hz)
1	907.5
2	1949.9
3	2471.4
4	3154.3
5	3407.1

D. *Comparison of Natural frequency obtained by Experimentation and FEA*

The Comparison of Natural frequency obtained by Experimentation and FEA is shown in TABLE II

TABLE III
COMPARISON OF NATURAL FREQUENCY OF GEARBOX CASING OBTAINED BY EXPERIMENTATION AND FEA RESULTS

Mode No.	Natural Frequency by FEA (Hz)	Natural Frequency by Experimentation (Hz)	Percentage Variation in results (FEA Vs Expt.)
1	878.7	907.5	3.17 %
2	1890	1949.9	3.07 %
3	2395	2471.4	3.09 %
4	3058	3154.3	3.05 %
5	3304	3407.1	3.03 %

The above table shows the percentage variation in natural frequencies between the FEA and Experimentation results. The natural frequencies of the predicted modes in MSC Nastran are within 3 percent of the measured modes of experimental test data. Also, the predicted mode shapes are very similar to the experimental mode shapes. Therefore, it can be concluded that the experimental test data is in good agreement with MSC Nastran modal analysis results.

V. CONCLUSIONS

It is observed that heavy vibration excitation is the main reason for gearbox casing failure. The analysis results shows that gearbox casing is subjected to Axial bending vibration, torsional vibration and axial bending with torsional vibration. The transmission housing motion is constrained by constraining the displacement of bolt holes. MSC Nastran software has powerful analysis capabilities and CATIA software has a powerful function of solid modeling. They are suited for Finite Element Analysis of complex shapes. The 3D solid model is prepared by applying CATIA software and is transferred to MSC Nastran. In this work we have considered the vibration problem of the transmission housing using FEA method. Finite Element Analysis offers satisfactory results. First 10 Vibration mode shape has been calculated. Experimental validation results show close agreement with FEA results of the existing casing. Natural frequencies of the predicted modes are within 3 percent of the measured modes. The difference in the experimentation results and FEA results may be mainly because of difference of material properties especially density, Poisson's ratio, young's modulus etc and uneven thickness of the casing.

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