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EMPLOYING COMPUTATIONAL TECHNIQUES FOR DETERMINING THE NATURE OF MODAL FREQUENCIES AND CORRESPONDING STRESSES FOR GEAR HOUSING USING MSC NASTRAN

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ABSTRACT

The gear housing protects the components of gearbox. It provides the fluid tight casing to hold the lubricants and provides support to moving components. Gear housing or gearbox failure is the main problem for the vehicle manufacturer. In order to prevent failure the natural frequency and natural mode shapes should be known. The design for Gear Housing or the Case for Transmission gears call for analysis for Structural strength and/or Vibrations occurring due to the excitation by the Engine. For this work, the Vibrations experienced by the housing would be the area of concern for study. Finite Element Modeling shall be engaged as an Analytical tool to evaluate the nature and magnitude of the vibrations. Modal Analysis in the three directions shall be assessed while Frequency Response Function analysis shall be conducted to determine the stresses induced due to vibrations. The material properties shall be assigned suitably while performing the simulation. Appropriate values shall be assigned to the design parameters for effecting the best design suitable for damping the vibrations. Parameters for Mass or stiffness or damping shall be varied for checking the effect on the performance. Experimental investigation is planned for validating the thesis. FFT analyzer shall be used for recording the direction and/or frequency or amplitude of the vibrations for the benchmark variant.

KEY WORDS: *Gear Housing, Vibration Analysis, Transmission Housing, Finite Element Modeling*

I. INTRODUCTION

The Transmission housing protects the components of gearbox. It provides the fluid tight casing to hold the lubricants and provides support to moving components. Transmission housing or 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. 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 often used interchangeably with transmission Casing or housing. Housing is a complex system to design and analysis.

It consists of various types of fixturing and inaccurate fixturing cause excessive vibration and noise production. Automobile transmissions consist of multiple gears to increase torque while slowing down the speed. Automatic, manual and continuously variable are three types of transmission used in automobiles. A manual transmission is a simple gearbox assembly. In transmission the power is transmitted in this order - engine, clutch, gearbox, and prop shaft, differential, half shafts, hubs and tyres. During power transmission if there is a slack in drive train it may cause high vibration known as transmission Shock. It is the main reason for gearbox assembly and housing failure. The casing encloses different sets of helical gears, spur gears and three bearings to support the shafts. In a power transmission gear system, the vibrations generated at the gear mesh are transmitted to the gearbox housing through the shafts and bearings. To do the analysis of entire gearbox casing it is necessary to do the analysis of casing, set of gears and effect of oil.

The study has been carried out to evaluate the analysis of the existing Gear Housing design of two wheeler. Vibration problem of the transmission housing is considered using FEA method. MSC

Nastran software has powerful analysis capabilities and CATIA software has a powerful function of solid modeling and are suited for Finite Element Analysis of complex shapes. The 3D solid model is prepared using CATIA software and imported in Hypermesh 11.0 for meshing. We will use the MSC Nastran as solver and perform the analysis of existing gear housing design.
Considering the existing design of the gear housing, in order to prevent the failure under the influence of resonance, the natural frequency and natural mode shapes should be known. This would help to take any corrective action while proposing the suitable design for gearbox. If the natural frequency, natural mode shapes, amplitude of vibration of the existing gear housing design is known then we can employ the computational techniques to determine the same for the alternative design variant for Gear Housing using MSC Nastran as a FEA solver. The results for the benchmark model (existing) would offer inputs for proposing variants over geometry or material or mass as the design parameters for improvement.

1.1 Problem Statement

Gear box is indicated when the application involves high speeds, large power transmission where noise abatement is important. Vibrations experienced by the housing would be the area of concern for study. The problems identified in existing gear housing of two wheeler are listed below.

- Lack of suitable economic methodology to identify and determine the nature and magnitude of the vibrations for existing applications.
- Inability to meet compliance or fulfillment over the increasing effect for NVH Noise, Vibration and Harshness.
- Slow speed of technical review for design as the current method needs to elaborate prototype for each variant of the design alternative.

1.2 Scope and Objective

1.2.1 Scope

- With the review of the existing design, this scope shall encompass activities for Analysis to evaluate the design aspects.
- Analytical methodology shall be deployed for the work.
- Preliminary investigation shall be based on the mathematical treatment to the problem case.
- The validation shall be effected by conducting experimentation over the existing gearbox.
- FFT analyzer shall be deployed to measure the natural frequencies of the subject part
- Recommendation for design change (over the parameter identified) shall be made upon investigating the results.

1.2.2 Objective

- Capture the data and define statement
- Deploy analytical methodology for finding solution
- Evolve design alternatives for the problem
- Conduct analysis for security results
- Validation with existing problem case

1.3 Methodology

Following methodology will be used for the execution of the present research work as described in Fig 1.1

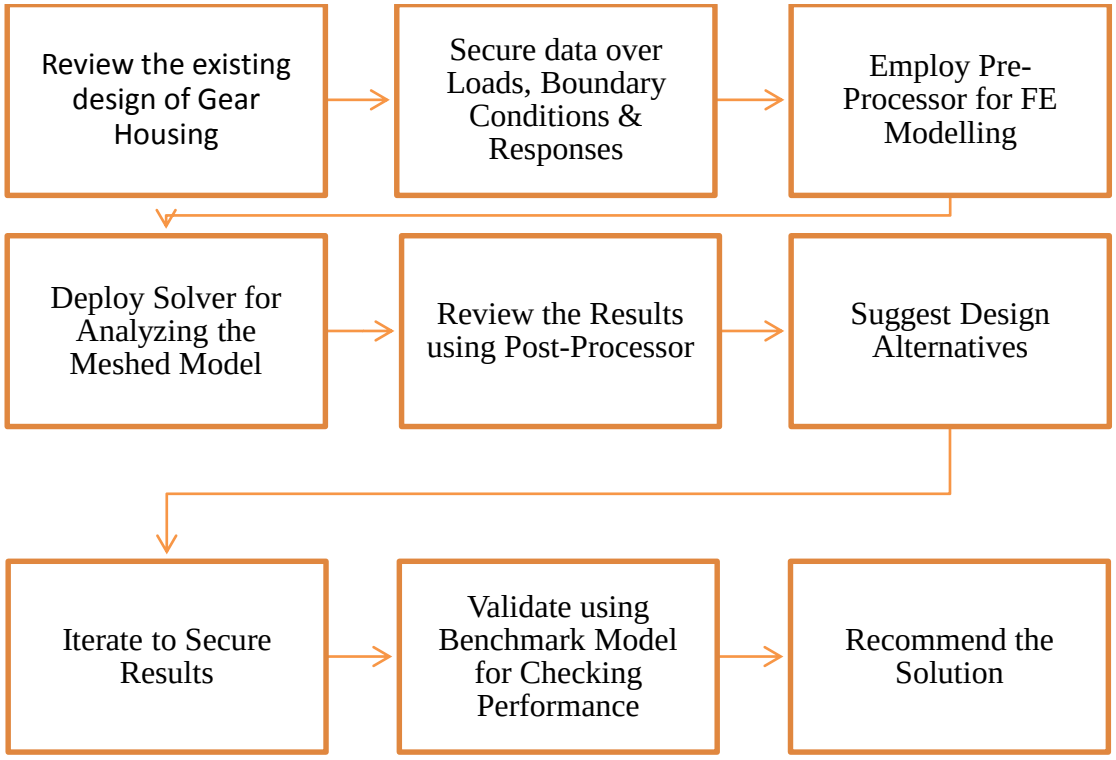

Fig. 1.1 : Methodology

II. LITERATURE REVIEW

There has been a great deal of research on gear housing analysis, and a large body of literature on gear housing modeling has been published in the earlier research papers. The gear housing stress analysis, the transmission errors, and the prediction of gear housing dynamic loads, noise and vibrations in the transmission housing. The Transmission housing protects the components of gearbox. It provides the fluid tight casing to hold the lubricants and provides support to moving components.

Transmission housing or gearbox 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. The current literature reviews also attempt to classify gear housing model into groupings with particular relevance to the research.

Vasim Bashir[8] reported that in the design analysis and optimization of gearbox foot casing of gearbox, it provides support to the shaft, bearings and hence the gear loadings. Thus the gear box casing is an important component to be taken into account while designing. To solve this problem it is essential to carry out the analysis of foot casing and redesign the existing foot casing in order to save material as well as cost. 3D model is generated in PRO-E software, while static analysis is done in ANSYS software. Optimization is based on ANSYS results, which can be used to enhance the efficiency of the design process. The process is repeated until all specified criteria are met. Final results are more optimize than existing design

The main objective of this work is to optimize foot casing and finding out the effective design of gearbox with respect to cost. Gearbox foot casing is analyzed under certain load conditions including static and dead weight conditions. This mesh is applied to entire body. Tetrahedron Element Method is selected to solve foot casing model.

Benefits of this research work are as follow:

- The implementation of static analysis has helped in developing an optimum design.
- It has helped in selection of appropriate material for cost effective design.
- Reduced prototype development and testing time.

In this study has been carried out to evaluate static analysis of the gearbox foot casing using commercial software ANSYS. Analysis is to find out the total amount of stresses and deformation of any structural component by load. The gearbox casing is manufactured from cast iron FG260 material.

Mitchell Lebold[6]reported that in vibration analysis for condition assessment and fault diagnostics has a long history of application to power and mechanical equipment. The interpretation and correlation of this data is often cumbersome, even for the most experienced personnel, and thus automated processing and analysis methods are sometimes sought. As such, statistical features are commonly used to provide a measure of the vibration level that can be compared to a threshold value indicative of a failed condition.

Many feature vectors have been developed over the years and are well documented in the literature. What is not clear from the literature is the details associated with each feature so that the results are consistent among users. Preprocessing is vaguely stated and terms, such as "residual signal", are commonly used yet can mean different techniques. An attempt has been made to define the terms, establish the preprocessing needed for each feature, and provide the details needed to produce consistent results.

Jeff Mendoza[3]presented a time-domain dynamic analysis of a helical gear box with different housing models using a unique finite element-contact mechanics solver. The analysis includes detail contact modeling between gear pairs along with the dynamics of gear bodies, shafts, bearings, etc. Inclusion of the housing in the dynamic analysis not only increases the fidelity of the model but also helps estimate important NVH metrics, such as dynamic load and vibration transmission to the base, sound radiation by the gearbox, etc. Two different housing models are considered.

In the first, the housing is represented by a full FE mesh, and in the second, the housing is replaced by a reduced model of condensed stiffness and mass matrices. An end-to-end solution to predict radiated noise from a gear box is presented. Unique finite element contact mechanics solver is used to model the gear dynamics. Reduced housing model is used to speed up the analysis. Results from the analysis with reduced housing model match well with the analysis with full FE housing to commend their use for future analysis. Housing FRF is computed from the steady state response and is used to solve the acoustic radiation problem using a boundary element solver. Two different methods used to compute housing FRF give different levels of accuracy for the sound radiated by the housing.

JiraTuma[9]reviewed practical techniques and procedures employed to quiet gearboxes and transmission units. The author prefers solving the gear noise problem at the very source to introduce an enclosure as a means to reduce radiated noise, which seems to be easy but its effect on the sound pressure level is small. The gearbox noise problem solution is focused on the improvement of gear design; on the verification of its effect on the radiated noise and the determination of the gears' contribution to the truck's or car's overall noise levels and on the analytical and/or numerical computer-based tools needed to perform the signal processing and diagnostics of geared axis systems. All of the analytical methods are based on the time and frequency domain approach. Special care is addressed to the smoothness of the drive resulting from the transmission error variation during a mesh cycle.

Mr.Vijaykumar[4]reported about vibration analysis for gearbox casing using Finite Element Analysis (FEA). ANSYS software used to determine the natural vibration modes and forced harmonic frequency response for gearbox casing. The important elements in vibration analysis are the modeling of the bolted connections between the upper and lower casing and the modeling of the fixture to the support. This analysis is to find the natural frequency and harmonic frequency response of gearbox casing in order to prevent resonance for gearbox casing. From the result, this analysis can show the range of the frequency that is suitable for gearbox casing which can prevent maximum amplitude.

In this analysis, pressure is applied to surface as a normal to that surface. This is meaning that force is mainly applied analysis. For the Y-axis and X-axis, the first maximum amplitude for normal stress and directional deformation are happen at some frequency. At this frequency, the resonance is occurred. In this analysis, first resonance is happen when the ratio of harmonic forced frequency over natural frequency is the first resonance in harmonic forced frequency/first modal natural frequency.

Ashwani Kumar[1]has presented the research on Free Vibration Analysis of Truck Transmission Housing Based on FEA Material-Based Vibration Characteristic Analysis of Heavy Vehicle

Transmission Gearbox Casing Using Finite Element Analysis and reported that heavy vibration excitation is the main reason for transmission housing failure. The analysis results shows that transmission housing 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. ANSYS software has powerful analysis capabilities and SOLIDEDGE 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 SOLIDEDGE software and is transferred to ANSYS. In this research work we have considered the vibration problem of the transmission housing using FEA method. Finite Element Analysis offers satisfactory results. First 20 Vibration mode shape has been calculated. The experimental and analytical analysis is not available in literature for the transmission housing. So it is a new simulation analysis for transmission housing.
ArpitDwivedi[5]Analysis results show that transmission housing is subjected to torsional vibration, axial bending vibration, and axial bending with torsional vibration. The first 20 vibration mode shapes and corresponding natural frequencies have been calculated using ANSYS 14.5 FEA-based simulation software. The transmission housing motion is constrained by considering the fixed–fixed boundary conditions. The 3D solid model is generated using SOLIDEDGE software and is transferred to ANSYS 14.5.
In this research work, we have considered the problem of influence of transmission casing material on mode shapes and natural frequency. The FEA result shows that on design and vibration index, all four materials can be used as a truck transmission casing without considering the manufacturing prospects. FEA offers satisfactory results.
The review of the recent research papers on the analysis of gear housing vibration has been carried out. Systematic study is performed on the existing design of Gear housing of two-wheeler. Prepared the Project schedule for year 2014-15, experimentation plan and validation plan is ready. Received CAD model of existing Gear Housing from design department. Collected material properties of existing Gear Housing model. Identified the boundary conditions and employed pre-processor for FE modeling.

III. CONCLUSION

The study has been carried out to evaluate the analysis of the existing Gear Housing design of two wheeler. Vibration problem is considered of the transmission housing using FEA method. It is observed that Noise and vibration are the main reason for failure. 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 prepared using CATIA software is imported in Hypermesh 11.0 for meshing. Analysis of existing gear housing design will be performed using the MSC Nastran as solver. Recommendation for design change over the key design parameter identified shall be made upon investigating the results.

IV. FUTURE WORK

If the natural frequency, natural mode shapes, amplitude of vibration of the existing gear housing design is known then we can employ the computational techniques to determine the same for the alternative design variant for Gear Housing using MSC Nastran as a FEA solver. The results for the benchmark model (existing) would offer inputs for proposing variants over geometry or material or mass as the Design parameters for improvement. Experimental investigation is planned for validating the thesis. FFT analyzer shall be used for recording the direction and/or frequency or amplitude of the vibrations for the benchmark variant.
1. Obtain natural frequency and mode shapes of existing gear housing using Nastran.
2. Validate the Natural Frequency and Mode Shapes of existing gear housing using FFT Analyzer as a experimental method.
3. % Variation in Computational Versus Experimentation will be calculated
4. Key design parameter(Geometry, material or mass) will be identified and obtained the natural frequency and mode shapes by changing the value of key design parameter using Nastran.

5. Natural frequency of the model without changing the key design key parameter will be compared with the natural frequency of model with change in key design parameter and with operating frequency.
6. The % variation in the natural frequency and mode shapes will be calculated and model safe from resonance point of view will be proposed.

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