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# PERFORMING FINITE ELEMENT ANALYSIS FOR IDENTIFYING INDUCED STRESSES AND NATURAL FREQUENCIES TO IMPROVE THE BEHAVIOUR UNDER SUSTAINED VIBRATIONS

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## *ABSTRACT*

*Gears are important element in a variety of industrial or commercial applications such as machine tool, vehicles, turbines, etc. Due to excessive service load, inappropriate operating conditions or simply end of life time, an unexpected failure of the gear may cause. For that reason, fault diagnosis in gears has been necessary. A possible non-destructive technique for fault detection and severity assessment can be derived from vibration signal analysis. Vibration signal analysis has been widely used in the fault detection of rotation machinery. The vibration spectrum shows the areas of stress and undue energy. Vibration measurements trend changes at different locations along the units to predict problems. The key benefits of vibration measurements include: monitoring equipment life, increasing equipment uptime, managing and scheduling maintenance work. Also the vibration analysis can determine misalignment unbalance, mechanical looseness, eccentric shafts, gear wear, broken teeth, and bearing wear. The vibration signal of a gearbox carries the signature of the fault in the gears, and early fault detection of the gearbox is possible by analyzing the vibration signal using different signal processing techniques further. CAE software like MSC Nastran or RADIOSS shall be employed for computational techniques to find the behavior of the component when subjected to excitation. For Experimentation, FFT analyzer shall record the readings to be compared for validation.*

***KEYWORDS:*** *Gear Box, Vibration, MSC Nastran, natural frequency, FFT analyzer*

## I. INTRODUCTION

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.

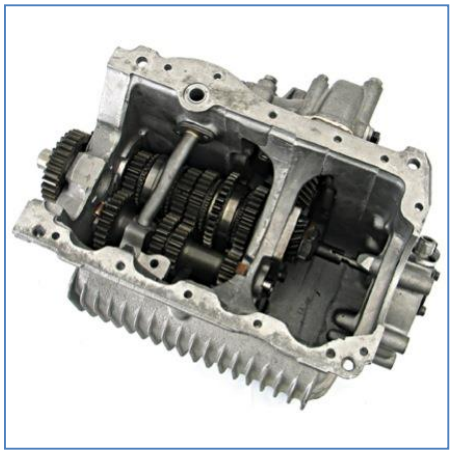


**Figure.1:**Gearbox Housing

The proposed method utilizes software in the FEA domain for analyzing the effects of the variation in the values of the design parameters influencing the modal behaviour. Also the computational approach will give the results more close to practical values through simulation. The FEM method is used to analyze the stress state of an elastic body with complicated geometry, such as gear. Also the contact and bending stresses should be calculated by using ANSYS/NASTRAN/Radioss. In this thesis the analysis of characteristics of in volume spur gears in gearbox is intended for the study by using the FEM.

Benefits CAE using software:

1. Design decisions can be made based on their impact on performance.
2. Designs can be evaluated and refined using computer simulations rather than physical prototype testing, saving money and time.
3. CAE can provide performance insights earlier in the development process, when design changes are less expensive to make.
4. CAE helps engineering teams manage risk and understand the performance implications of their designs.
5. Integrated CAE data and process management extends the ability to effectively leverage performance insights and improve designs to a broader community.
6. Warranty exposure is reduced by identifying and eliminating potential problems. When properly integrated into product and manufacturing development, CAE can enable earlier problem resolution, which can dramatically reduce the costs associated with the product lifecycle.

## II. PROBLEM DEFINITION

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.

In addition, practical gears may be mistuned by mesh stiffness variation, manufacturing imperfections and assembling errors. For some symmetric structures, such as turbine blades, space antennae, and multi-span beams, small disorders may dramatically change the vibration. It is also necessary to systematically study natural frequency and vibration mode sensitivities and their veering characters to identify the parameters critical to gear vibration.

The purpose of investigating the model of gearbox housing is to reduce the level of vibration; which causes the failure of housing. The methodology to obtain the reduction in vibration of housing will consists of providing stiffeners to the housing. This method will encompass the harmonic waves in between the frequency band formed due to the stiffeners.

**Specifications of gearbox housing:**
1.Material Used: Cast Iron, Cast steel, Aluminium, Fabricated Steel, Composites
2.Application for case Study: Automotive / Industrial / Machine Tool

## III. LITERATURE REVIEW

1) Ristivojevic M., et al., studied the impact of load distribution in meshed teeth, teeth geometry and manufacturing accuracy on wear of the spur gear tooth flanks. Mathematical models developed in this paper can establish the optimal correlation between loads, manufacturing accuracy and teeth geometry in order to achieve higher tooth flanks load carrying capacity. The theoretical studies show that the sign of base pitch difference and the pitch point position during contact period have strong impacts on the tooth flanks load carrying capacity.
2) M. Ognjanovic, studied gear load capacity calculation according to pitting of the teeth flank. Results of progressive wear are obtained by experiments. For these results, failure boundaries which can be used for parameters of Weibull's function definition, for different stress levels and for different stress cycles numbers (teeth mesh revolutions) have been defined.
3) P. J. L. Fernandes, et al., studied various types of contact fatigue damage and illustrated using practical examples. The causes and ways of preventing damage in each case are also discussed briefly.
4) Duzcukoglu, Imrek, studied width modification to equalize the maximum Hertz surface pressure on the single tooth meshing with that formed on the double tooth meshing of the spur gears. Experiments done by them shows that pitting appearance is delayed for the width-modified gear wheels with respect to the gears having no such modifications.
5) V.B. BHANDARI as a author in his book "Design of Machine Element" published by "Tata McGraw- Hill Publishing Company Ltd" which provides a systematic exposition of the basic concepts and techniques involved in machine design. This book follows SI units and BIS designation of materials and components used. The book is useful for study of gears.
6) V. RUDNEV, D. LOVELESS, R. COOK and M. BLACK Inductoheat Inc., USA, gives in their paper gear manufacturers have increased their technological knowledge of the production of quality gears. This knowledge has led to many improvements, including lower noise, lighter weight and lower cost, as well as increased load-carrying capacity to handle higher speeds and torque with a minimum amount of generated heat. This review concentrates on the role of induction hardening of gears and pinions in achieving these advances. Not all gears and pinions are well suited for induction hardening. External spur and helical gears, worm gears, and internal gears, racks and sprockets are among the parts that are typically induction hardened Conversely, bevel gears, hypoid gears, and noncircular gears are rarely heat treated by induction.
7) Ali Raad Hassan, gives in his paper study of Contact stress analysis between two spur gear teeth was considered in different contact positions, representing a pair of mating gears during rotation. A program has been developed to plot a pair of teeth in contact. This program was run for each 3° of pinion rotation from the first location of contact to the last location of contact to produce 10 cases. Each case was represented a sequence position of contact between these two teeth. The program gives graphic results for the profiles of these teeth in each position and location of contact during rotation.
8) M. Ristivojevic, T. Lazovic, A. Vencl gives the impact of load distribution in meshed teeth, teeth geometry and manufacturing accuracy on wear of the spur gear tooth flanks is studied in their paper.
9) Hayrettin Düzcükog˘lu, HüseyinImrek, this study gives width modification to equalize the maximum Hertz surface pressure on the single tooth meshing with that formed on the double tooth meshing of the spur gears.
10) Abdalla H El Sherif, studied careful faults diagnosis and identification can avoid unnecessary costly maintenance shutdowns. It also highlights the need to properly design and install monitoring and protection systems to optimize protection and avoid false machinery alarms and shutdowns.

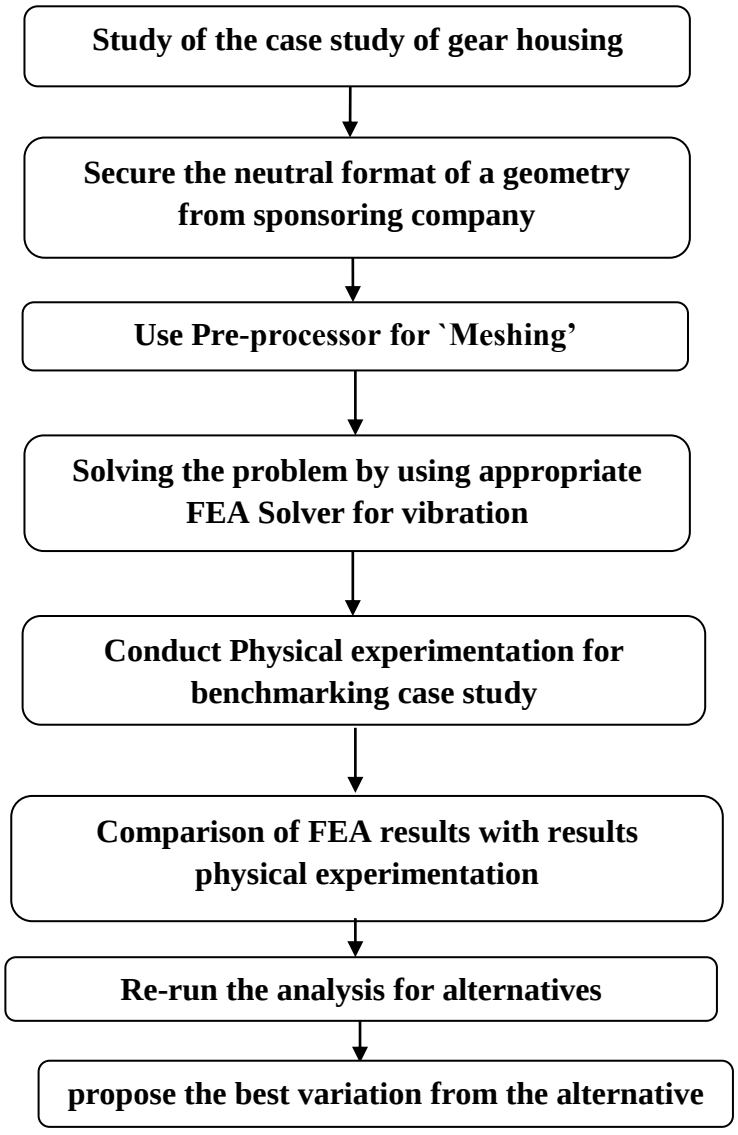
## IV. SCOPE OF THE WORK

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 will be compared with the results to experiments. To measure the vibration experimentally we may use FFT Analyser or equivalent vibration measuring device. A model will be developed to reduce the vibration and its FEA analysis will be done. The results of FEA analysis of existing gearbox housing will be compared with the results of FEA analysis of modified gearbox housing to find the reduction in amplitude of vibration.

## V. OBJECTIVES OF THE STUDY

The following are the objectives of the study:
1) Define problem case study for work.
2) F E modeling (Meshing)of the component.
3) Conduct modal analysis upon securing meshed model.
4) Conduct frequency and response analysis with specified frequency for excitation.
5) Identify the design parameters for the improvement
6) Validation through physical experimentation

## VI. PROPOSED FLOW CHART AND METHODOLOGY



### Test Setup for Physical Experimentation

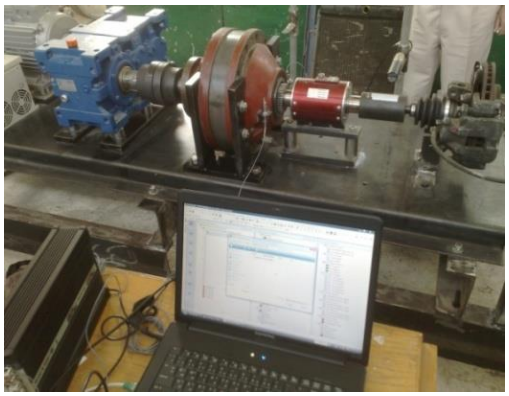


**Figure.2**Typical Test setup for Physical Experimentation

Figure shows the typical test setup for measuring the vibrations of the gearbox housing. The natural frequencies for the component by using the resonance will be measured. We can use either accelerometer or FFT analyzer for determining the natural frequencies by using the principle of resonance.

## VII. VALIDATION

The natural frequencies for existing housing obtained using Finite Element Method will be validated by comparing results obtained from experimentation. The variation in FEA and experimental results could be in the range of 10-20 %.

## VIII. CONCLUSION

The compliance for the Gear Box includes the response of the Case designed towards Vibration and Structural integrity. The design arrived through the deployment of methodology used for this work shall be validated using alternative means. The significance of design parameter for the particular case study applicable for this work shall be studied and the results shall help further studies in similar domain.

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