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Modal Analysis of Spur Gear to Determine the Natural Frequencies and it's effect over the Change in Material

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Abstract: Gearing is one of the most critical components in a mechanical power transmission system and in most industrial rotating machinery. In addition, the rapid shift in the industry from heavy industries such as ship building to industries such as automobile manufacture and office automation tools will necessitate are fined application of gear technology. Using the modal models design improvement can be predicted and the structure optimized. This project is not only to review the test procedure and system identification of modal analysis but discuss the main practical problems with which engineers, performing modal analysis on industrial structures are confronted on a daily basis. FEA has been used to predict the dynamical properties of the gear. Experimental modal analysis has been carried out to determine the natural frequencies of spur gear due to change in material properties. The followed approach based on the modal analysis concept. As gears are important elements in a variety of industrial or commercial applications such as machine tool, vehicles and turbines. Objective of this investigation is to reduce weight of gear. Weight reduction has been one the critical aspects of any design. It has substantial impact on vehicle performance, fuel efficiency and in turn reduces the emissions.

Keywords: Spur gear, modal analysis, natural frequencies, weight reduction.

I. INTRODUCTION

Gear noise and vibration is a major problem in many power transmission applications. This problem becomes more significant in applications with higher operating speeds where vibratory excitation which is related to the gear transmission error. Now a days most of the mechanical systems are subjected to dynamic loading which causes & shortens of the usable time, crack, noise and fatigue, in general the total effect of work for the mechanical system is lowered. Reasons for such behavior are type of loading, construction and conditions of work where the mechanical systems operate. The spur gear is the first choice option for gears except when high speeds, loads and ratios direct towards other by using the vibration analysis and parameters such as natural frequency and vibration mode can be calculated. The noise emitted into the surroundings by the gearbox is mostly the consequence of natural oscillation of the housing Also the Finite element method is used to analyse the stress state of an elastic body with complicated geometry such as gear.

II. LITREATURE SURVEY

1) LuoYutaoa, Tan Dia[2011] the aim of this article is to developed a valid and generalized dynamic model based on the bond graph theory for planetary gear set Taking account of meshing stiffness and torsional stiffness, the dynamic model of each sub-model is established. Subsequently, free torsional vibration analysis of a planetary gear set is carried out to demonstrate the application of the bond graph model in mode analysis. The results indicate that the model can not only predict the natural frequencies and the displacement mode shapes, but also obtain the generalized deformation mode shapes simultaneously.
2) P. Guillaume Copromotor [2002] this paper presents the experimental modal analysis has become a commonly-used technique for studying the dynamical behavior of mechanical and civil structures such as for example cars, aircrafts, bridges, shore platforms and industrial machinery.
3) MatsÅkerblom[2010],this paper presents the gear noise is sometimes the dominating noise in commercial vehicles. Noise testing of complete gearboxes is very time-consuming and expensive. A test rig has been designed for testing gears under controlled conditions. The test rig is of the recirculating power type. Finite element analysis has been used to predict the dynamical properties of the gear test rig. Experimental modal analysis has been carried out on the gearbox housing to verify the theoretical predictions of natural frequencies. The test rig can be used for noise and vibration testing of gears with different manufacturing errors and different design parameters.
4) JongBoon Ooi1, Xin Wang1 [2011] presents the portal axle is a gearbox that is specially designed for off-

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road driving conditions. In this study, modal analysis of portal axle is simulated using finite element method (FEM). Modal analysis is simulated on three different combinations of gear train system commonly designed for portal axle.

5) V. Palanisamy and Sidharth Das [2013], this paper presents a friction wheel with teeth cut is known as a tooth wheel or gear. The need for this project is that in earlier time's design of any machine element were carried out manually. This was tedious and time consuming. In this emerging world of technology new software's are introduced. Mechanical software's for modeling and analyzing are also available.
6) Biserka Isailovic,VesnaMarjanovic[2012],this paper presents the characteristics and problems of optimization of gear trains with spur gears.It provides a description for selection of the optimal concept based on selection matrix selection of optimal materials optimal gear ratio and optimal positions of shaft axes. The paper will further present the definition of mathematical model with an example of optimization of gear trains with spur gears using original software.
7) Hamed Moradi, Hassan Salarieh[2012],this paper presents the nonlinear oscillations of spur gear pairs including the backlash nonlinearity is studied. Using multiple scale method forced vibration responses of the gear system including primary super-harmonic and sub-harmonic resonances are investigated. Unlike the previous works where the nonlinearity of a gear backlash was modeled by a discontinuous and non-differentiable function, the proposed third-order polynomial function for backlash nonlinearity is capable of predicting more convenient and refined dynamic responses.
8) Cai-Wan Chang-Jian, Shiuh-Ming Chang [2011], this paper presents the dynamic orbits of the system are observed using bifurcation diagrams plotted using the dimensionless damping coefficient and the dimensionless rotational speed ratio as control parameters. The numerical results reveal that the system exhibits a diverse range of periodic, sub-harmonic and chaotic behaviors. This study has presented a numerical analysis of the nonlinear dynamic response of a spur gear system subject to linear and nonlinear suspension effects respectively.
9) Shuting Li[2013] This paper presents that a greater tooth root tensile stresses are resulted by the centrifugal load when the gears run at high speed. So it is necessary to take the effect of the centrifugal load on tooth root bending strength into account when to perform bending strength calculations of the thin-rimmed inclined web gears used at high speeds.

III. PROBLEM DEFINITION

By using the free vibration analysis critical parameters, such as natural frequencies and vibration modes that are identified.It is also observed that how material and material properties affect the natural frequencies and mode. During the design process, modal parameters are often altered to evaluate alternative design choices, reduce weight and tune the system frequencies to avoid resonance.

IV. NEED FOR MODAL ANALYSIS

The noise emitted into the surroundings by the gearbox is mostly the consequence of natural oscillation of the housing. 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. 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.

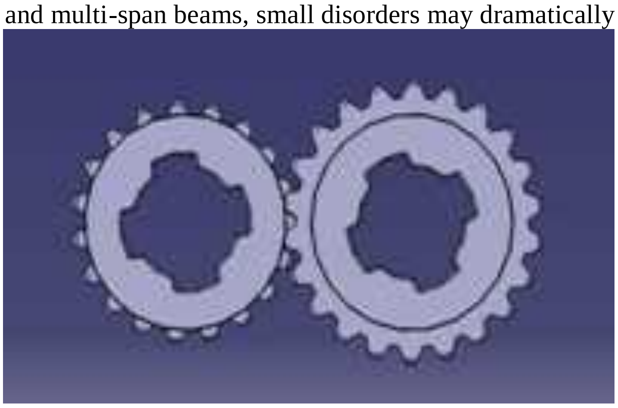

Fig 1.3D model of Spur Gear

Specifications of gears:
1. Material Used:EN8/ EN24/AISI1040/AISI4340
2. Type: Spur Gear
3. Application for case Study: Automotive Gear Pair.

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TABLE I. Dimensions of gear pair

Parameter	Pinion	Gear
Addendum	2 mm	2mm
Dedendum	2.5 mm	2.5 mm
Addendum circle diameter	42 mm	48 mm
Dedendum circle diameter	33 mm	39 mm
Face width	20 mm	20 mm
No of tooth	19	22
Pitch circle diameter	38 mm	44 mm
Tooth thickness	3 mm	3 mm
Clearance	0.5 mm	0.5 mm
Circular pitch	6 mm	6 mm
Pressure angle	250	250

V. OBJECTIVES

1. Identify and study using software tools (for simulation/analysis),the nature and characteristics of mode shapes.
2. Evaluate the influence of the mass/geometry over the modes and in turn over the design of the gear.
3. To improve the performance of exiting gear without compromising on the performance.
4. To increase the fundamental frequencies of gear & pinion at optimum weight.
5. Carry out physical experimentation to validate the model.

VI. METHODOLOGY

1) Computational approach

This presents a computational approach for the assessment of structures. One of the main features of the work is the search for simplicity and robustness in all steps of the modelling, in order to match the proposed method with industrial practices and constraints. The proposed method utilizes software in the FEA domain for analysing the effects of the variation in the values of the design parameters influencing the modal behaviour.

Benefits of using CAE software:-

It has intuitive graphical interface with direct access to CAD geometry, advanced meshing, integration with other compatible software for solving. It is optimized for large scale systems, assemblies, dynamics and NVH simulations.Typically the CAE interface design to handle NVH cases has graphical interface with direct access to CAD geometry which is most suitable for performing modal analysis.

2) Experimental set up

With the use of experimental set-up we can identify the natural frequencies for the component using the principle of resonance. Typically, FFT analyser is used for determining the same. The software analysis can yield the modes of the nth order, which in turn can be verified further using the testing equipments for this purpose (future scope).

Fig.2. Actual Experimental setup of gear pair on FFT

The computational approach will give results moreclose to practical values through simulation/ analyses.The technique would deploy any of the following software tools: Patran/Nastran, ANSYS, Abaqus or any compatible CAE software in the Structural/ NVH domain.It is proposed to induce a defect on a particular tooth of a chosen gear in the gear box & generate the vibrations. To sense the vibrationsignal generated by the gearbox an accelerometer has been used. In order to process the vibration signal sensed by the accelerometer on FFT Analyzer has been selected. With the use of experimental set up we can identify the natural frequencies for the component using the principle of resonance. Typically FFT Analyzer is used for determining the same.The computational approach given results more close to practical values through analyses.[7]

VII. EXPERIMENTAL RESULTS

Type of test: Vibration test
Aim of test: To record natural frequency through physical experimentation whilecomparing results with finite element modelling
Name of the Port: Automotive gear.
Machine Type: FFT Analyzer[8]
Instrument used: Accelerometer, RT Pro Photon software.

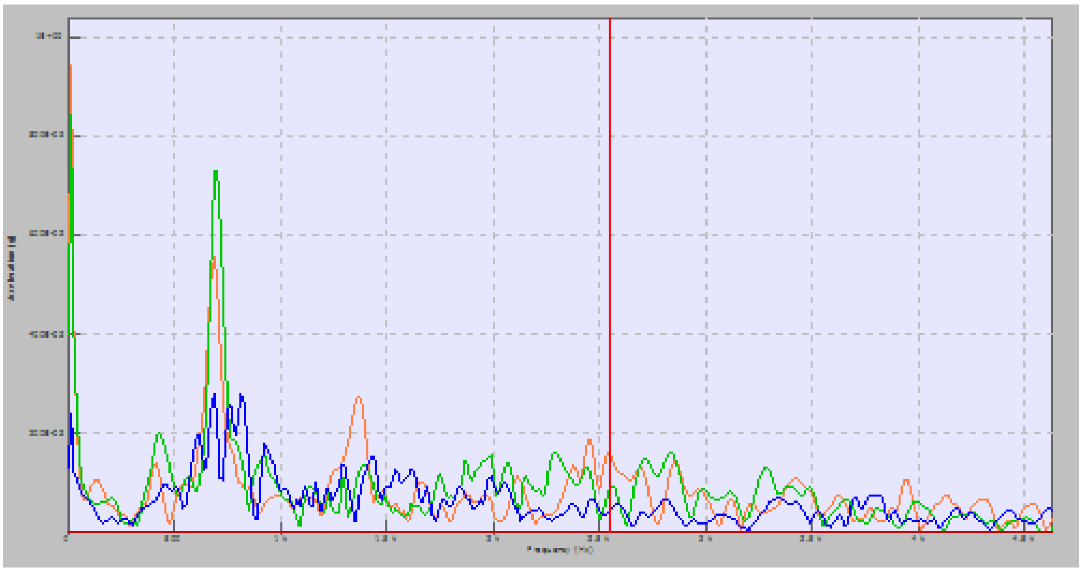

Fig 3.Test graph for actual experimental setup of gear pair on FFT

TABLE II: Result of Physical Validation

Sr. No.	Material	Readings determined by FEA Method	Reading recorded during physical experimentation	% Variation results analysis Vs Experiment
1	EN8	6.50 x E+04	6.92 x E+04	6.06 %
2	EN24	6.80 x E+04	7.20 x E+04	5.5 %
3	EN8(1st Iteration)	7.40 x E+04	7.79 x E+04	5.0 %
4	EN24(1st Iteration)	7.65 x E+04	8.01 x E+04	4.49 %
5	EN8(2nd Iteration)	7.33 x E+04	7.68 x E+04	4.55 %
6	EN24(2nd Iteration)	7.68 x E+04	8.03 x E+04	4.43 %

The natural frequency of gear obtained through FFT Test concurs fairly with the results obtained by FEA Method. Considering variation in the material properties and specification in the test specimen, the results are acceptable.

VIII. CONCLUSION

We have increased performance of modified gear and determined fundamental natural frequencies to avoid resonance at optimum weight. After modal analysis of modified gears, frequencies and mode shapes for EN8 and EN24 were found. It observed that if mass of gear is changed then frequencies and mode shapes also changes. We have saved material and cost by weight reduction for material EN8 by 2.8% and for material EN24 by 4.1% of gear.

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