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Experimental Modal Analysis of Main Composite Shaft Used in Hydraulic Gear Pump

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ABSTRACT

In the present work an attempt is made to evaluate the suitability of composite material for the purpose of main shaft used in Hydraulic Gear Pump. For the experimentation FFT analyzer is used to calculate the natural frequencies. A composite main shaft for Gear Pump is designed in PRO-E and analyzed using ANSYS software respectively for composite. During analysis the three fundamental bending modes are extracted. Finite element models of the drive shaft will be generated and analyzed using ANSYS commercial software. Comparison of drive shaft with steel material and composite shaft shows that composite shaft gives advantages in terms of strength, weight reduction and also results are expected to show that the main shaft is not running in critical speed. The finite element model agrees well with the FFT results and can serve as a baseline model of the main shaft.

Keywords— (FFT analyzer, Finite element analysis, PRO-E, Composite Material)

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I. INTRODUCTION

Main shaft is the most important part in Hydraulic gear pump of automobile. On drive shaft different gears are mounted to transmit power from input shaft to output shaft with different speed ratio. With refer to the researcher every material system containing individual mass and stiffness distribution is susceptible to vibrate. Free vibration analysis is essential to determine the natural frequencies of material system. These are responsible for resonance phenomenon. When the load frequency is matched with one of the natural frequencies the resonance occurs. It leads to high amplitude of vibration.

Bending vibrations and critical speeds of rotating shafts is perhaps the most common problem that is discussed by a vibration engineer, as it is a vexing day-to-day problem in design and maintenance of the machinery. Some of the rotors weigh as much as 100 tons as in the case of big steam turbines and obviously they deserve utmost attention in this regard. The rotors have always some amount of residual unbalance however well they are balanced, and will get into resonance when they rotate at speeds equal to bending natural frequency. These speeds are called as critical speeds by Rankin as far as possible they should be avoided. Even while taking the rotor through a critical speed to an operational speed, special precaution should be taken. In Fault detection of bearing detection of misalignment and condition monitoring of bearing or gearing system is necessary because the system has to rotate at different speeds. If specific r.p.m. matches with critical speed which is nearer to first bending natural frequency of shaft will generate excessive vibrations due to resonance. Previous studies have used analytical and/or Experimental methods to analyze similar structures. Some studies have used extended experimental tests along with mathematical post processing of results.

The advanced composite materials such as Graphite, Carbon and Glass with suitable resins are widely used because of their high specific strength (strength/density) and high specific modulus (modulus/ density). Advanced composite materials seem ideally suited for long, power driver shaft (propeller shaft) applications. Their elastic properties can be tailored to increase the torque they can carry as well as the rotational speed at which they operate. The drive shafts are used in automotive, aircraft and aerospace applications. The automotive industry is exploiting composite material technology for structural components construction in order to obtain the reduction of the weight without decrease in vehicle quality and reliability. It is known that energy conservation is one of the most important objectives in vehicle design and reduction of weight is one of the most effective measures to obtain this result. Actually, there is almost a direct proportionality between the weight of a vehicle and its fuel consumption, particularly in city driving.

In metallic shaft design, knowing the torque and the allowable service shear stress for the material allows the size of the shaft's cross-section to be determined. In order to satisfy the design parameter of torque divided by the allowable shear stress, there is unique value for the shaft's inner radius because the outer radius is constrained by the space under the car cabin. Metallic drive shafts have limitations of weight, low critical speed and vibration characteristics. The drive shaft can be solid circular or hollow circular. Here hollow circular cross-section was chosen because the hollow circular shafts are stronger in per kg weight than solid circular. The stress distribution in case of solid shaft is zero at the center and maximum at the outer surface while in hollow shaft stress variation is smaller. In solid shafts the material close to the center are not fully utilized.

M.H. Sadeghi, S. Jafari & B. Nasseroleslami [1] studied Modal parameter extraction of high speed shafts is of critical importance in mechanical design of turbo-pumps. Due to the complex geometry and peripheral components of turbo-pumps, difficulties can arise in determination of modal parameters. Comparison of experimental and numerical results shows that there is a good conformity between the results. The results show only negligible error in longitudinal mode (1.61 %) which is an indication of undistorted natural motion.

Mr. Shekhar Dive & Prof. Prashant Karajagi [2] described Experimental and FEM methods for calculation of natural frequencies of intermediate shaft and the intermediate shaft is modelled in PRO-E and analysed in ANSYS for its natural frequency. three modes are extracted during modal analysis The difference between first frequency by FFT and by ANSYS is about 2.6%. Also the condition of resonance is avoided and intermediate shaft is not running in critical speed. S V Gopals Krishna, B V Subrahmanyam, and R Srinivasulu [3] described Almost all automobiles (at least those which correspond to design with rear wheel drive and front engine installation) have transmission shafts. The weight reduction of the drive shaft can have a certain role in the general weight reduction of the vehicle and is a highly desirable goal. Analysis done on dive shaft with different composite materials and concludes that the use of composite materials for drive shaft would induce less amount of stress which additionally reduces the weight of the vehicle. By the obtained results it can be conclude that the stresses induced in all the materials are within their allowable limits. And it can also be observed that the materials which develop less vonmises stress exhibit a little more deformation. E-glass polyster has 2.5%reduction in Von-Mises stress and 74%reduction in weight than Structural Steel.

Chirag B. Gandhi & Manthan Patel [4] Study covers design, analysis and development of driveshaft for automobile applications also covers dimension calculations of drive shaft based on engine power required. All design process will be performed with aid of FE analysis using ANSYS software. Optimization will be followed after performing design which includes weight reduction of drive shaft and material selection. The usage of composite materials has resulted in considerable amount of weight saving in the range of 81 – 72 % when compared to conventional drive shaft. Apart from being lightweight, the use of composites also ensures less noise and vibration. With same geometry and less weight, for composite material stress value is less compared to steel material. The present work was aimed at reducing the fuel consumption of automobiles in particular or any machine, which employs drive shaft, in general. This was achieved by reducing the weight of drive shaft with the use of composite materials. By using advanced composite materials, the weight of drive shaft assembly can be tremendously reduced. This also allows the use of a single drive shaft (instead of a two piece drive shaft) for transmission of power to the differential part of the assembly. Apart from being light weight, the use of composites also ensures less noise and vibration.

S. M. Ghoneam, A. A. Hamada, and M. I. EL-Elamy [5] studied the dynamic analysis of a rotating composite shaft. The numerical finite element technique is utilized to compute the eigen pairs of laminated composite shafts. A finite element model has been developed to formulate the stiffness matrices using lamination theory. The Campbell diagram is utilized to compute the critical speed of rotating composite shaft and instability regions to achieve accuracy and for controlling the dynamic behavior of the system in resonance state. The influence of laminate parameters: stacking sequences, fiber orientation, boundary conditions and fiber volume fractions effect on natural frequencies and instability thresholds of the shaft are studied. The results are compared to those obtained by using the finite element method and experimental measurements using frequency response function method (FRF) by applying the autogenously excitation. In the experimental part, the response of composite shaft with various types of boundary conditions and five lamina orientations were recorded and analyzed by utilizing fast Fourier transform dual channel analyzer in conjunction with the computer.

The comparison between the numerical and experimental results proves that the suggested finite element models of the composite shaft provide an efficient accurate tool for the dynamic analysis of rotating composite shaft.

II. EXPERIMENTAL MODAL ANALYSIS

Experimental modal analysis of a system, deals with determination of natural frequencies, damping ratios, and mode shapes through the vibration testing. In the case of forced vibration, the analysis includes the study of acceleration, velocity and displacement responses of the systems. The basic ideas involve in model analysis are then structure or machine or any system is excited its response exhibits a sharp peak at resonance when the forcing frequency is equal to its natural frequency, if the damping is not present large. The phase of the response changes by 180 degree as the forcing frequency crosses the natural frequency of the structure or machine and the phase will be 90 degree at response.

Procedure of Experimentation

1) Connect the accelerometer and Impact hammer to appropriate channels of FFT to cables.

2) Prepare set-up for Modal analysis and In-pulse software.

3) Mount accelerometer on shaft with the help of magnetic base.

4) Excite shaft by giving In-pulse by Impact hammer.

5) Record the response received from accelerometer in frequency domain and time domain.

6) Identify the natural frequencies and corresponding phase in FFT software and record it.

7) Repeat the procedure for different positions of accelerometer to record all vibration modes of shaft.

III. FINITE ELEMENT ANALYSIS

In this the modeling of Main shafts and finite element analysis of main shaft using by FEA. Finite Element method (FEM) simulates a physical parts behavior by dividing the geometry into a number of elements of standard shapes, applying constraints. Uses of proper boundary conditions are very important since they strongly affect the results of the finite element analysis. The main shaft is modeled in Pro-E. The step file of model is imported in ANSYS workbench. The main objective of this work is to perform the Finite Element Analysis of main composite shaft using CAE Tools, so as to determine the natural frequency in the shaft.

IV. RESULT

Comparison between Experimental and Software Results

Natural Frequency Hz	FEM
f1	728.79
f_2	2172.1

V.CONCLUSION

In this paper the Experimental and FEM methods for Calculation of natural frequencies of Main steel shaft and Main composite shaft is described. From the experimentation first natural frequency will determine for both the main shafts. These frequencies are lowest natural frequencies of main shafts. The main shafts are modelled in PRO-E and analyzed in ANSYS for its natural frequency. Modes are extracted during modal analysis. The difference between first frequency by FFT and by ANSYS and Forcing frequency of main composite shaft will be very less than natural frequency of intermediate shaft. So, result will be the condition of resonance is avoided and intermediate shaft is not running in critical speed. Also comparison of main shaft for steel and composite is carried out based on maximum deformation, maximum and minimum stresses induced in the shaft. Its design procedure is studied and along with finite element analysis some important parameter are obtained. The replacement of composite materials has resulted in considerable amount of weight reduction when compared to conventional steel shaft. Also, the results reveal that the orientation of fibers has great influence on the static characteristics of the composite shafts and offers advantages such as

Lower weight Higher strength
Progressive failure mechanism (offers warning before failure)
Lower power consumption

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