An Overview of Disarray in Experimental Investigation on Dynamic Analysis of Cracked Automotive Composite Drive Shaft with Nonlinear Parameters.

1Jamir A. Mullani, 2S. H. Sawant

1PG Student, Dept. of Mechanical Engineering. 2Professor, Dept. of Mechanical Engineering,
Dr J. J. Magdum college of Engineering, Jaysingpur, Shivaji University, Kolhapur, India. Email: 1mullani.jamir@gmail.com, 2sanjay.sawant2010@gmail.com

Abstract- Cracking of cylindrical composite shafts is an important area of research, since the changes observed in their vibration characteristics even during large-sized cracking are much smaller than those observed for rectangular beams; hence early identification of crack existence becomes essential to prevent sudden failures in rotating shafts. This paper tries to give an idea about the previous researches and their finding about study of some numerical and experimental studies on the dynamic behavior of composite drive shaft with effect of crack using FEM.

Index Terms- ANSYS, Cracked Composite Drive Shaft, FEM, Modal Analysis,

I. INTRODUCTION

Drive shafts for power transmission are used in many applications, including cooling towers, pumping sets, aerospace, structures, and automobiles. In metallic shaft design, knowing the torque and the allowable service stress for the material allows the size of the shaft’s cross-section to be determined. Metallic drive shafts have limitations of weight, low critical speed and vibration characteristics. When the length of a steel drive shaft is beyond 1500 mm, it is manufactured in two pieces to increase the fundamental natural frequency, which is inversely proportional to the square of the length and proportional to the square root of the specific modulus. In recent years the use of anisotropic composite structures has increased substantially due to its high strength to weight ratio and higher stiffness. The composite structures find its application in various fields like aircraft structure, high-speed machinery, military equipments and civilian products. Maintaining structural integrity is highly essential and has been the area of research of many researchers to develop various techniques for early detection of crack location, size and pattern of damage in a structure. Cracks are one of the internal damage within the structure and its early detection can prevent further degeneration of shaft. Many non-destructive techniques are in place for early detection of crack.

By considering all above facts, this paper tries to cover literature which deals with experimental investigation on dynamic analysis of cracked automotive composite drive shaft with nonlinear parameters.

II. CRACK DETECTION IN SHAFT USING LATERAL AND TORSIONAL VIBRATION MEASUREMENT AND ANALYSIS

A. Tlaisi et al. presented the Experimental and Numerical Investigations to Identify the Presence of a Crack in a Cylindrical Overhanging Shaft with a Propeller at the Free End. In the experimental study, cracks of different depths have been located at the (un-cracked) maximum bending moment position. Shaft response parameters for lateral (using an accelerometer) and torsional vibrations (using shear strain gages fixed at three different locations) have been obtained using the modal analysis software, LMS Test Lab. The experimental results have been used to validate the numerical results obtained using the three-dimensional isoperimetric elements available in the ANSYS FEM program.

The results indicated that the use of the rate of change of frequencies, modal amplitudes of displacements, velocities and accelerations as a function of crack depth ratio will indicate the presence of crack in the shaft from a crack depth ratio of 0.2. Also the use of the rate of change of torsional frequency will indicate the presence of a crack in the shaft from the initiation of the crack [1].

III. DYNAMIC ANALYSIS OF A GEARED ROTOR SYSTEM CONSIDERING A SLANT CRACK ON THE SHAFT

Qinkai Ha et al. discussed Dynamic Analysis of a Geared Rotor- Bearing System with a Breathing Slant Crack. The finite element model of a geared rotor with slant crack has been presented. Based on fracture mechanics, the flexibility matrix for the slant crack has been derived that accounts for the additional stress intensity factors. Three methods for whirling analysis, parametric instability analysis and steady-state response
analysis have been introduced. Then, by taking a widely used one-stage geared rotor-bearing system as an example, the whirling frequencies of the equivalent time-invariant system, two types of instability regions and steady-state response under the excitations of unbalance forces and tooth transmission errors, are computed numerically. The effects of crack depth, position and type (transverse or slant) on the system dynamic behaviors have been considered. The comparative study with slant cracked geared rotor has been carried out to explore distinctive features in their modal, parametric instability and frequency response behaviors [2].

**IV. EXPERIMENTAL INVESTIGATION ON DYNAMIC ANALYSIS OF CARBON–EPoxy SHAFT**

R.B. Ingle et al. have Investigated the Dynamic Behavior of High Speed Composite Carbon Epoxy Shaft. For the analysis purpose one step composite shaft made of carbon–fibers in epoxy matrix has been manufactured with 16 layers having different stacking angles using filament winding process. The experimental set up has been designed to investigate static and dynamic analysis and performance characteristics of the carbon–epoxy shaft in aerostatic conical journal bearing at high speeds in the range of 10,000–65,000 rpm. The vibration spectrum analysis has been observed and studied for the same. Comparison of amplitude of vibration decides the maximum operational speed of the shaft with low vibration in aerostatic conical bearings. It has been observed that the static and dynamic deflection plays vital role in selection of eccentricity ratio as it changes with the radial load. The stiffness in case of aerostatic bearing rotation and no rotation rises with increase in dynamic deflection for constant supply pressure. The maximum amplitude of vibration at high speed is comparatively less in magnitude provided that the speed of shaft should be above critical speed and below natural frequency. As the carbon–epoxy shaft supported in aerostatic bearing has high damping, it has been concluded that with radial load of 6 N, the shaft runs at 65,000 rpm in more stable manner [3].

**V. AN INVESTIGATION INTO HYBRID CARBON/GLASS FIBER REINFORCED EPOXY COMPOSITE AUTOMOTIVE DRIVE SHAFT**

M.A. Badie et al. discussed the Effect of Fiber Orientation Angles and Stacking Sequence on the Torsional Stiffness, Natural Frequency, Buckling Strength, Fatigue Life and Failure Modes of Composite Tubes. In this paper Finite Element Analysis (FEA) has been used to predict the fatigue life of composite drive shaft (CDS) using linear dynamic analysis for different stacking sequence. Experimental program on scaled woven fabric composite models was carried out to investigate the torsional stiffness. FEA results showed that the natural frequency increases with decreasing fiber orientation angles. The CDS has a reduction equal to 54.3% of its frequency when the orientation angle of carbon fibers at one layer, among other three glass ones, transformed from 0° to 90°. On the other hand, the critical buckling torque has a peak value at 90° and lowest at a range of 20°–40° when the angle of one or two layers in a hybrid or all layers in non-hybrid changed similarly. Experimentally, composite tubes of fiber orientation angles of ±45° experienced higher load carrying capacity and higher torsional stiffness. Specimens of carbon/epoxy or glass/epoxy composites with fiber orientation angles of ±45° showed catastrophic failure mode. In a hybrid of both materials, [±45°] configuration influenced the failure mode [4].

**VI. ANALYSIS OF DYNAMIC CHARACTERISTICS OF THE MAIN SHAFT SYSTEM IN A HYDRO-TURBINE BASED ON ANSYS.**

Bing Bai et al. presented the study on Dynamic Characteristics of Main Shaft Used in Hydro Turbine. The parts of hydro-turbine and its stability is often damaged and affected by the vibration and this often results in great loss. The reasons for vibration are various. Based on a real machine in laboratory, this paper uses ANSYS finite element software to model the main shaft system in the hydro-turbine generating unit. The modal analysis has been carried out and the critical speed of rotation has been calculated. From the modal map it has been seen that as the order number increases, the frequency also become larger. The sixth order’s vibration is very fierce and complex. The first and the fifth order’s vibrations appear to be lateral vibrations. The others left showed that they include torsional vibration. Some of the modes don’t appear well, maybe it’s the reason that thrust bearing is not taking into consideration. As the working speed of rotation increases, due to the gyroscopic effect, the natural frequency of the positive whirl will increase while the negative whirl decrease. When the speed of the rotation equals the angular frequency, it is the critical speed of rotation, which clearly showed on the Campbell diagram [5].

**VII. SIMULATION OF DYNAMIC CHARACTERISTICS OF FAULTY MULTI-SPAN ROTOR SYSTEM THROUGH FEA**

Xiaopeng Li et al. discussed the Dynamic Simulation of Faulty Multi Span Rotor System Using FEA. In this paper, the nonlinear dynamic characteristics and responses of the rotor system and the influences of membrane coupling and gearing on the rotor system have been studied according to the change in inherent frequency due to bend-torsion coupling vibration in the single-span rotor and the whole rotor system when cracks and rubbing fault happen. The results indicated that in such a case the influence on a faulty span is greater than on rests, and the adverse influences of
bending vibration and cracks on the rotor system can be weakened or retarded by membrane coupling and gears. Results revealed are beneficial to the fault diagnosis and system maintenance and available to provide reference for designing products [6].

VIII. PREDICTION OF THE TORSIONAL STRENGTH OF THE HYBRID ALUMINUM/COMPOSITE DRIVE SHAFT

S.A. Mutasher presented paper on the Evaluation of the Torsional Strength of Hybrid Aluminum/Composite Drive Shaft. A hybrid aluminum/composite is an advanced composite material that consists of aluminum tube wound onto outside by layers of composite material. The result from this combination is a hybrid shaft that has a higher torque transmission capability, a higher fundamental natural bending frequency and less noise and vibration. This paper has investigated the maximum torsion capacity of the hybrid aluminum/composite shaft for different winding angle, number of layers and stacking sequences. The finite element method has been used to analyze the hybrid shaft under static torsion. ANSYS finite element software was used to perform the numerical analysis for the hybrid shaft. Full scale hybrid specimen was analyzed. Elasto-plastic properties were used for aluminum tube and linear elastic for composite materials. The results showed that the static torque capacity was significantly affected by changing the winding angle, stacking sequences and number of layers. The maximum static torsion capacity of aluminum tube wound outside by six layers of carbon fiber/epoxy composite at winding angle of 45° was 295 Nm. Good agreement was obtained between the finite element predictions and experimental results [7].

IX. DYNAMIC ANALYSIS OF A ROTATING COMPOSITE SHAFT

S. M. Ghoneam et al. discussed the Dynamic Analysis of a Rotating Composite Shaft. The numerical finite element technique has been 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. These matrices take into account the effects of axial, flexural and shear deformation on the Eigen-nature of rotating composite shaft. The Campbell diagram has been 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 have been studied. The results were 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 [8].

X. NONLINEAR NORMAL MODES OF A ROTATING SHAFT BASED ON THE INVARIANT MANIFOLD METHOD

Mathias Legrand et al. discussed the nonlinear normal mode methodology is generalized to the study of a rotating shaft supported by two short journal bearings. For rotating shafts, the forces arising from the supporting hydraulic bearings are nonlinear, even when the shaft deformation is in the linear range. In this study, the rotating shaft is represented by a linear beam, while a simplified bearing model is employed so that the nonlinear supporting forces can be expressed analytically. The equations of motion of the coupled shaft-bearings system are constructed using the Craig-Bampton method of component mode synthesis, producing a model with as few as six degrees of freedom (DOF). Using an invariant manifold approach, the individual nonlinear normal modes of the shaft-bearings system are then constructed, yielding a single-DOF reduced order model for each nonlinear mode. A generalized formulation for the manifolds is required, since the system features damping as well as gyroscopic and nonconservative circulatory terms. The nonlinear modes are calculated numerically using a nonlinear Galerkin method that is able to capture large amplitude motions. The shaft response from the nonlinear mode model is shown to match extremely well simulations from the reference Craig-Bampton model.

XI. VIBRATION ANALYSIS OF CRACKED CANTILEVER BEAM WITH NON-LINEAR PARAMETERS AND HARMONIC EXCITATIONS

R.S. Pawar, S.H. Sawant presented paper on beams undergoing small displacements, linear beam theory can be used to calculate the natural frequencies, mode shapes, and the response for a given excitation but when the displacements are large, linear beam theory fails to accurately describe the dynamic characteristics of the system. Highly flexible beams, typically found in aerospace applications, may experience large displacements. These large displacements cause geometric and other nonlinearities to be significant. The nonlinearities couple the (linearly uncoupled) modes of vibration and can lead to modal interactions where energy is transferred between modes. This investigation focuses in the study of the vibration analysis of cracked cantilever beam subjected to free and harmonic excitation at the base. The objective of the study is to identify the effect of non-linearity’s namely Material,
Geometric, and Damping on the natural frequency and mode shapes of cracked cantilever beam by theoretical, numerical and experimental methods.

XII. CONCLUSION

By the literature review it is seen that a metal shaft can be replaced by composite drive shaft with nonlinear parameter and presence of crack on composite drive shaft affect its vibrational characteristic. So some numerical and experimental studies on the dynamic behaviour of composite drive shaft with effect of crack is helpful to detect the presence of crack on composite drive shaft.

REFERENCES


