STUDY OF ROTOR BEARING SYSTEM- A REVIEW

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Abstract - ***Rotating machines are extensively used in mechanical engineering applications. Rotor- disc-bearing assembly is one of the most interesting fields of study in the research area. The unbalance excitation of rotor, stability analysis of rotor or vibration control of rotor receives significant research importance over the decades. The aim of this study is to collect different research paper on the rotor-bearing system. The different improved mathematical modeling of rotor bearing system and the application of finite element model in this field improves the accuracy of the analysis of rotor bearing system. This review paper attempts to collect researchers' different contributions on this field.***

Key words: Rotor Bearing, Finite Element Method, Campbell diagram, Natural Frequency.

INTRODUCTION

Rotor dynamics is specialized branch in which study includes the lateral and torsional vibration of rotating shaft. The basic component of rotor dynamics is shaft or rotor. It also includes disc and the bearings which supports the rotor. As the rotating speed increases the amplitude of vibration also increases and it passes through a speed where it matches with the natural frequency that is called critical speed. Rotating part produce the vibration depending upon the mechanism used and if any fault is present in machine then it increases the vibration. Analysis in rotating system involves study of critical speed, unbalance loads, deflection of shaft. Bearing also plays an important role in controlling the vibration in which it acts as a damper. The stability of rotor and critical speed is mainly controlled by the stiffness properties and peak amplitude response of the bearing. Analysis of rotor dynamic is basically of three types:
Modal Analysis: In this study analysis is done for the effect of speed on frequency from zero rpm to the maximum velocity, these natural frequencies determined to avoid excitation at critical speed

Harmonic Analysis: In this analysis a range of frequencies is set to determine the response of system at different rotating speed and excitation forces.

Static and transient response: In this analysis loads on structure, joints and bearings are determined and this is done by applying fixed velocity to initial condition or transient dynamic simulation.

Many researchers studied the rotor dynamics from mid twenty century and concluded that theoretically it is difficult to find the real dynamics of rotating machine, therefore to get the natural frequencies, experiments done by making models and analyzed them through another approach like Lumped parameters models, Rayleigh-Ritz method and Finite Element Method (FEM). Then researchers founded that Finite Element Method was the best modal for finding the natural frequencies.
The present study is aiming to discuss the different types of research in the field of rotor dynamics. The introduction of different mathematical models or application of finite element technique will be discussed in this study. This review paper will try to collect different papers on the rotor dynamics.

LITERATURE REVIEW

Nelson and McVaugh [1] developed finite element model for rotor-bearing system which consist of rigid disks, rotor with distributed mass and variable cross-section and discrete bearings. In their finite element rotor model rotary inertia, gyroscopic moments and axial load are included. The detailed equations for the elements are expressed both in the fixed and rotating reference frame.

Khulief and Mohiuddin [2] presented a finite element elastodynamic model of rotor bearing system which accounted for gyroscopic moment and anisotropic bearings. Two modal truncation schemes were introduced for planar (undamped) mode and complex (damped) mode. For both modal reduction schemes modal characteristics and dynamic responses of two rotor system were evaluated. Authors concluded that both had the same level of accuracy. But it was very convenient to use planar modal transformation for gyroscopic matrices.

Taplak and Parlak [3] used Finite Method to analyze the rotor system. Rotor have complex geometries due to this it became difficult to determine its dynamic behavior by analytical modeling of the rotor. Finite Element Method also saves time and money because it solves equation very fast and easily. For determining its dynamic behavior researcher investigated the Campbell diagrams and dynamic behaviors. For this a program named dynrot was used to make analysis of critical speed. To make analysis certain mechanical properties and geometrical value was modeled and studied. Its dynamic analysis used Dynrot program and researcher concluded that rotor should provided with low imbalance value.

Miranda and Faria [4] worked on flexible rotors supported on fluid film journal bearing. For this rotor they used Finite Element method using Eigen value analysis. This model was based on Timoshenko beam theory. In this governing equation of journal bearing were obtained through Galerkin weighted residual method. After that natural frequencies were compared. Results clearly show the importance of the appropriate bearing configuration for effective damping response at critical operating condition. For high speed turbo machines finite element procedure was used. The authors concluded that the Eigen value analysis of damped gyroscopic gave good results than the technical literature result. They also concluded that finite element method can also be used for turbo machinery design and operating change at high speed.

Mutalikdesai et al [5] studied the influence of internal damping in the rotor shaft system. To do this analysis they used modal analysis method. Due to internal damping in shaft a force is generated which is tangential to the rotor orbit. As spin speed increases the force increases and it destabilize the rotor system. The authors considered three discs with simply supported ends for the study. Using Euler-Bernoulli beam theory rotor was modeled and it discretized by finite element method. The authors found that during the forward whirl, damping decreases, as the spin speed increases and in backward whirl damping increases, as the spin speed increases. In this study the authors also discussed on the stability of rotor system. If the speed of system was less than the critical speed then system was stable.

Wang et al [6] studied on rotary compressor. In this system two main moving components present are rolling piston and contracted rotor-journal bearing. Inertia force, the contact force and the gas force act periodically and these forces changes rapidly with the variation of speed. This leads to vibration in the system. The authors solved the 3-dimensional numerical modal using Finite Element Method. The authors concluded that in rotor journal bearing system longitudinal, flexural and torsional vibration occurs. When speed was increased then the torsional and flexural vibration also increases, but no change in longitudinal vibration. The authors founded that max Von-misses stress exists at the wall and it require special attention at the time of design. They also found that lubrication performance of main bearing is better than the sub-bearing. The deformation was greater as the eccentric was farther from the main bearing.

Rosyid et al [7] used Substructuring method for the analysis of rotor bearing system using model reduction technique. The effectiveness of reduced model was evaluated by comparing critical speeds, damping ratio, first natural frequencies and the response of both the full system and reduced system. The efficiency of the reduced model depends upon the determination of the number and location of master node. But the disadvantage was that the reduction was less accurate in unstable or nearly unstable system.

Different authors tried to analyze the rotor bearing assembly using Ansys software. Fegade et al [8] used alternative method named harmonic analysis to find frequency of rotor bearing assembly using ANSYS. The rotary inertia and the internal damping in rotor were included in their analysis. The authors considered three different sets of bearing support to study the natural frequency of the assembly. In 1st case two undamped isotropic bearings were used whereas in 2nd case symmetric orthotropic bearings and in 3rd case two identical journal bearings were kept for the analysis. They concluded that isotropic bearings (combi14 element) and symmetric orthotropic bearings (matrix27 element) bearings gives the more critical speed than the identical journal bearings (combi214 element).

Jalali et al [9] studied the high speed rotor under both static and dynamic conditions. To avoid resonant condition modal analysis is very important. The authors studied the full rotor dynamic analysis with certain geometrical and mechanical properties of high speed rotor. They found a good result between the theoretical and experimental result which gave the accuracy of Finite Element Model. The authors studied the behavior of Campbell diagram, critical speed and unbalance response of rotor. Campbell diagram and critical speed was used to investigate dynamic behavior of rotating system. This was done by both 1d-beam model and 3-dimensional finite element model. The authors concluded that one-dimensional finite element method can be used for rotor dynamic analysis with good accuracy.

Rotors are modeled as one dimensional beam like structure in many literatures. Jalali et al [10] used finite element model of rotor based on Timoshenko beam element. They had shown the bending critical speed, the Campbell diagram, the operational deflection shapes at the critical speeds, the mode shapes of the rotor in rotating condition and the unbalance response of the rotor. Natural frequencies of the shaft were depicted from the Campbell diagram. The authors proved that real critical speed was the speed corresponding to the intersection line of W (natural frequency of rotor) =Ω (spin speed of rotor) with the forward whirl curve not the backward whirl curve. This was achieved by using the operational deflection shape and unbalance response.

Using Rayleigh's theory and assumed mode method Norouzi et al [11] modeled the rotor bearing system. This method can solve the complicated rotor bearing system with any number of disks and bearing with arbitrary number of mass unbalance. The authors also concluded that this method was most efficient for calculating the natural frequencies, studying the gyroscopic effect and forced response of complex rotors. The authors concluded that this method was less time taken and easy to use. Therefore this model can be used in complicated rotor models.

Mat lab program was developed by Muminovic et al [12] to simulate the rotor bearing model to calculate the natural frequency. The authors have drawn the diagram of natural frequency with respect to length, diameter of rotor and density of material. The authors tested the model using the solid works software. Using this model the authors analyzed the change in natural frequency because of change in length, diameter and modulus of elasticity.

Nareena and Suresh [13] used Ansys for the analysis of the centrifugal pump. At higher speed pump shaft subjected to higher lateral and torsional vibration. This was because of gyroscopic effect and centrifugal force of element mounted on the shaft. Deflection of rotor occurred maximum at resonance point. So, to avoid resonance it was necessary to calculate all stiffness and damping coefficient. The authors used ANSYS to predict the lateral critical speed of the rotor by plotting the Campbell diagram and compared it with the theoretical calculation.

CONCLUTION

Analysis of rotating parts was very important topic because if any failure occurs then whole system shuts down. Therefore analyzing the critical speed of rotor was very important topic from many decades. Many authors studied on this topic and they found that theoretically it was difficult to find real dynamics of rotating machine. Therefore to get the natural frequencies they adopted an approach for modeling and analysis like Lumped parameters models, Rayleigh-Ritz method and Finite Element Method (FEM). Then they concluded that Finite Element Method was the best modal for finding the natural frequencies. It was easy to use, less time taking and cheap. In this paper an attempt has been taken to collect different research papers on the vibration analysis of the rotor bearing assembly. From this review paper a new scholar will get an idea of different types of analysis in this field and can collect the source of the papers at a single glance.

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