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DYNAMICS AND FAULT DETECTION IN ROTOR BALL BEARING SYSTEM

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ABSTRACT

The dynamics of high speed rotating machinery plays an important role in the modern world. In the design of complex mechanical components and rotating machines, such as turbines, compressors, electrical machines, centrifuges or machine tool spindles, systematic analysis of dynamic behavior is needed. The dynamics of a rotor can be highly influenced by the design of support bearings, since, the critical speeds and the magnitude of vibration responses are dependent on the stiffness and damping characteristics of the bearings. To have the precise knowledge of the dynamics of rotor-bearing systems, it is very much essential to use the correct values of stiffness and damping coefficients of the support bearings. Hertzian contact theory is used to model the force- deformation relationship, also by using matlab software an attempt is made to find the solutions which will result in various plots

KEYWORDS: rotor ball bearing,stiffness and damping

INTRODUCTION

The most fundamental cause of noise and unsteady running of rolling bearings is the so-called varying compliance vibrations. These are parametrically excited vibrations that occur irrespective of the quality and accuracy of the bearing. Varying compliance of the bearing assembly can give rise to both radial and axial displacements of a shaft supported by rolling bearings. This problem was first studied by Perret in 1950, who verified the existence of such acyclic movement. Perret's approach was however incomplete in that he only studied the bearing at the instants when the rolling elements were arranged symmetrically around the load line. Further a more complete treatment was given by Meldau in 1952, in which shaft loci in a plane perpendicular to the axis of rotation were derived for both ball and roller bearings. The magnitude of shaft movements in vertical and horizontal directions were given as functions of external load, number of rolling elements, radial clearance and the local contact stiffness between rolling element and tracks as given by the Hertzian theory for elastic contacts. Tamura and Taniguchi have carried out measurements of the vertical and horizontal positions of a rotor supported by ball bearings, the angular position of the cage having been incremented in small steps for one ball passage. The loci found corresponded well with those predicted by Meldau. As Meldau also points out in his paper, his study of varying compliance (VC) vibrations is valid only for very slowly rotating bearings. Sunnersjo pointed out that in a bearing operating at normal speed, the inertia forces of the rotor have to be taken into account. The inclusion of the rotors inertia results in equations of motion for the rotor-bearing system that have non-linear and time varying coefficients, with vertical and horizontal movements being strongly coupled.

Need of the Reaserch Paper:

The dynamics of a rotor can be highly influenced by the design of support bearings. Since the critical speeds and the magnitude of vibration responses are dependent on the stiffness and damping characteristics of the bearings. To have the precise knowledge of the dynamics of rotor-bearing systems, it is very much essential to use the correct values of stiffness and damping coefficients of the support bearings. Also an effort is to find the solution using Matlab software.

Objectives:

1. Development of dynamic model of the balanced rotor supported on ball bearing to study the dynamic response of the rotor-bearing system.
2. Development of the new damping formulation and study its effect on the response.
3. To study the effect of rotor mass unbalance, speed, no. of rolling elements and internal radial clearance on the response of the system.

MATERIALS AND METHODS

By studying various literature given by different authors related to Dynamics and Fault Detection of Rolling Element Bearings an effort has been made to obtain equations of motion related to rotor bearing system. These equations that are obtained is of non-linear ordinary second order differential equations which are further solved by using Ranga-Kutta Method in Matlab Software which gives plots like time response plots, frequency- response plots, speed response plots and Poincare maps.

Figure: Bearing Selection

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Selection of Rotor (Balanced, Unbalanced)

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Create Dynamic Model of Rotor Bearing System in **Matlab**

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No. of Ball & Speed vary with Time

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Results - Poincare Map, Speed Response plot, FFT

Flowchart for Methodology

Force-Deformation Relationship for Ball Bearings

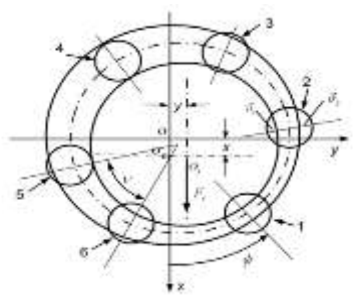

Fig 2. Loaded Bearing

Force-deformation relationship is given by Hertzian theory. The bearing has internal radial clearance of γ so that when the inner and outer rings are concentric, there is no contact between the rollers and the outer ring. Now assume that the center of the inner ring is moved from O to O' shown in Fig. 3.2. This will cause the two circles to interfere with each other over a part of the circumference. From fig. 3.2, it becomes clear that this interference will cause an elastic (for small displacement its deformation of the rollers and rings. Dowson has shown that for rings mounted firmly against solid steel shaft and bearing house, the only significant deformations are the local deformations at the contact points between rollers and rings. These deformations will give rise to the reaction force of the bearing. The zone over which the inner race and outer race circles interfere with ball will therefore be called the elastic deformation zone.

Computational Considerations

The equations of motion, are solved using the modified Runge-kutta method to obtain the radial displacement and velocity of the rolling elements. In order to eliminate the effect of the free response an artificial damping was introduced into the system. With this damping, transient vibrations are eliminated and peak steady state amplitudes of vibration can be estimated.

RESULTS AND DISCUSSION

sPoincare maps are obtained by sampling the four-dimensional flow *(x, x', y, y')*, once per forcing period $T = 1/f_{VC}$. The response of the dynamic models represented by equations (3.16) and (3.17) is compared by using the poincare maps. In modified model the response has been shifted in rpm band as seen in pp response as shown in fig 3.

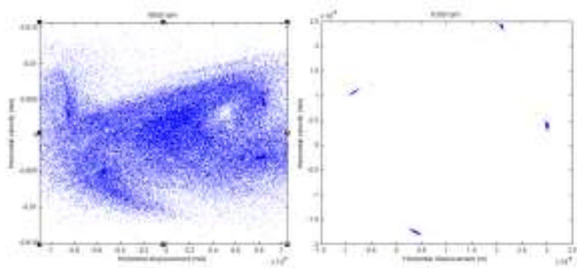

Fig 3. Poincare Map

CONCLUSION

Ball bearings are a non-negligible source of vibration in many types of rotating machine. When a bearing is subject to a radial load, a parametrically excited type of vibration appears, ball loads are function of the angular position of the cage, and the assembly stiffness continuously varies. This phenomenon generates the so-called V.C. vibrations due to the varying compliance of the bearing. Modified damping formulation gives promising results to the actual dynamics of the system response. Rotor unbalance in the system changes the system response drastically and response is in the chaotic region for most of the speed range. Also the no. of balls in the ball bearing determines the stability of the system response. Increase in no. of balls increases the bearing stiffness, thus it stabilizes the system response.

Future scope of the research paper is to study the behavior of system response by considering the cage dynamics and ball inertia into account. In the order analysis some modification is required as the ball defect frequency is buried in the noise, so implementing the new techniques to refine the order plot will also be the part of future work

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