Investigation on Difference process parameters and Technique used for Detecting Defect of Ball Bearing: A Review

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***Abstract*: Since spherical roller bearings (SRBs) can carry high load in both axial and radial direction, they are increasingly used in industrial machineries and it is becoming important to understand the dynamic behavior of SRBs, especially when they are affected by internal imperfections. A dynamic model is reported herein for the study of vibrations of deep groove ball bearings having single and multiple defects on surfaces of inner and outer races. Masses of shaft, housing, races, and balls are considered in the modeling. The model provides the vibrations of shaft, balls, and housing in time and frequency domains. Rolling element bearings find widespread domestic and industrial application; Defects in bearing unless detected in time may lead to malfunctioning of the machinery. Different methods are used for detection and diagnosis of the bearing defects. This paper presents the literature review of ball bearing. It is essential to study the performance characteristics under different loading and operating conditions. Here in this paper different parameters and defect which are responsible for the performance of ball bearing where investigated.**

***Keywords*: ball bearing, dynamic analysis, friction, surface modeling, defects**

1. Introduction

Rolling bearing includes all forms of roller and ball bearing which are mainly used for providing the rotary motion of a shaft. Normally a complete assembly of bearing is sold in the market having different geometric specification, which includes inner ring, outer ring, rolling element (balls or rollers) and the cage which separates the rolling element from each other. The geometric parameters and tolerance of rolling bearings are high precision, low cost but commonly used in all kinds of rotary machine. Several decades have been taken to develop the bearing from the initial idea to the modern rolling bearing.

These bearings are mostly used in rotating machineries and consider as a most critical component. Proper functioning of bearings is most important in thermal power stations, chemical plants, aviation industries and also process industries. A large survey on faults in the electric motor was carried out by Electric Power Research Institute (EPRI) in 1985 and found that 41% of faults related to worn motor bearings. Well performance and reliability of rolling element bearings is essential for proper functioning of machines and to prevent catastrophic failure of the machinery. Bearing health and performance can be easily identified by using health monitoring techniques. Many condition monitoring techniques is available to monitor the health of bearing; these are wear debris analysis, motor current analysis, noise monitoring, temperature monitoring, vibration monitoring etc.

Fig.1 showing ball bearings

2. Vibration analysis of rolling element of ball bearing

The vibration monitoring is the most useful technique use for monitoring the vibration generated in bearings, because it is reliable and very sensitive to fault severity. Bearings act as a source of vibration and noise because of either varying compliance or the defects presence in parts of bearing. These vibration signals will give us information about the health of bearing. Vibration monitoring is the most popular technique to diagnosis of rolling element bearing faults. Many researchers have been worked on vibration signal analysis techniques and numbers of research papers have been published by them. They reviewed the vibration monitoring of rolling element bearing by High-Frequency Resonance Technique. Some of the research wok is shown here in below section.

Tandon et.al [1] presented a review on vibration and acoustic measurement methods for the detection of defects in rolling element bearings; they covered vibration measurement in both time and frequency domains along with high-frequency resonance technique and for acoustic measurements sound pressure, sound intensity and acoustic emission techniques other than this they also included wavelet transform method and automated data processing technique.

Mathew et.al [2] A brief review of vibration monitoring techniques in time and frequency domains and their results on rolling element bearings have been presented. The faults due to surface roughness, waviness, misaligned races, manufacturing error, and off-size rolling elements are categorized under distributed defect while bearing faults like spalls, pits, dirt, dent, and crack on the rolling surfaces, brinelling and contaminations in lubricant are considered as localized defect in a rolling element bearing.

Patel et al. [3] formulated a dynamic model for the study of vibrations of deep groove ball bearings having single and multiple defects on surfaces of inner and outer races. The solution was obtained using Runge-Kutta method. And showed the good correlations between the numerically simulated and experimental results, and demonstrated that this dynamic model can be used with confidence for the study and prediction of vibrations of healthy and defective deep groove ball bearings.

Tomovic et al. [4] they have proposed a vibration model of a rotor- rolling bearings system to find the effect for internal radial clearance value and number of rolling elements influence on rigid rotor vibrations in unloaded rolling element bearing.

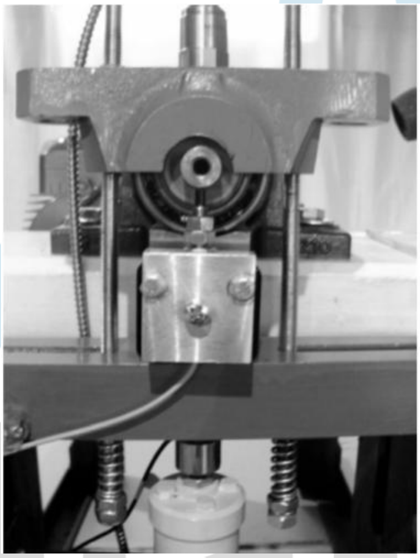

Fig.2 Experimental analysis perform during experimental work on bearing in unloaded state [4]

3. Local defect on bearing element

The time domain vibration analysis is depend on the estimation of statistical parameters like crest factor, skewness, kurtosis, probability density curve, etc. Among this kurtosis is the most effective parameter in a time domain which is calculated using following expression

$$\text{Kurtosis} = \frac{(N-1)\sum_{i=1}^{N}(x_i-x)^4}{\sum_{i=1}^{N}(x_i-x)^2} \quad \textbf{......................... (1)}$$

Where xi = instantaneous amplitude, x = mean, N= speed in rpm.

In the frequency domain analysis the fault signal can be identified based on bearing fundamental frequencies which depend on the bearing geometry and rotor speed which have been calculated using following eq.

- Inner race ball pass frequency

$$\text{BPFI} = \frac{n}{2}\,\text{fr}\left(1 + \frac{d^2{}_b}{d_p \cos\emptyset}\right) \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

- Outer race ball pass frequency

$$\text{BPFO} = \frac{n}{2}\,\text{fr}\left(1 - \frac{d^2{}_b}{d_p \cos\emptyset}\right) \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

McFadden et.al [5] in their theoretical and experimental studies they have considered single point defect and multiple point defects on the inner race.

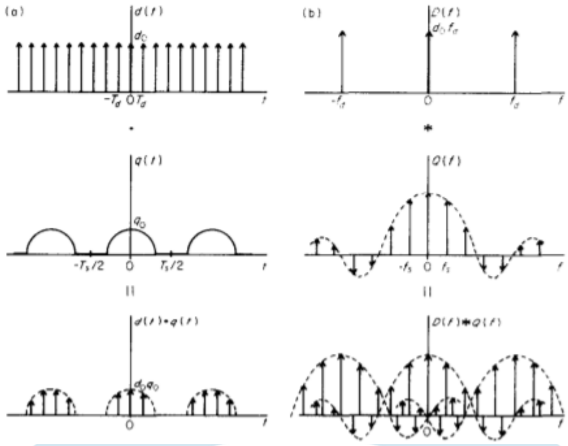

Fig.3 The impulses produced by an inner race defect under a radial load. (a)Time histories, (b) spectra [5]

The impulses generated by interaction of defect with inner race has been generated by delta function while, variations in the load around the bearing has been computed by Stribeck equation under radial load.

Su et al. [6] have obtained a reliable model to predict the possible bearing frequencies, harmonics and sidebands for the various types of localized fatigue damage, the pattern of expected frequencies can be searched for as part of routine bearing condition monitoring.

4. Use of ball bearing as an integral shaft bearing

Integral Shaft bearing provides two internal designs viz. two rows of widely spaced balls and each row of ball and roller which gives broad range of load carrying capacities. The end of shaft normally extends beyond the outer ring on both sides. Many of the researchers have done some work in this area and they optimized the different parameters on which the performance was dependent, some of the work is mention here.

Peng et.al [7] Presented paper on Static Analysis of Rolling Bearings Using Finite Element Method. In this he did Static Analysis of Angular Contact Ball Bearing, Contact Analysis and Simulation of Angular Contact Ball Bearing with Simplified Model Using Beam Element. He fined the reasonable reference reaction force from the outer ring to the inner ring by means of FEM simulation. Also, instead of using ball, to simplify the rolling bearing with some other elements between the inner and outer ring. The model mainly used to be discussed is angular contact ball bearing. To do the simulation with the part model of bearing, flexible model has to be used for the rings and ball.

Takabi et.al [8] presented paper on Experimental testing and thermal analysis of ball bearings. This paper present a comprehensive mathematical model to analyze the thermal behavior of a ball bearing is presented. Considered in conjunction with the transient heat transfer model is the dimensional change of the bearing components due to unequal temperature rise of the bearing components. The model provides a practical tool for evaluation of the transient and steady state characteristics of rolling element bearings owing to the lumped assumption of the bearing components and the finite number of thermal nodes in the heat transfer model of the entire system.

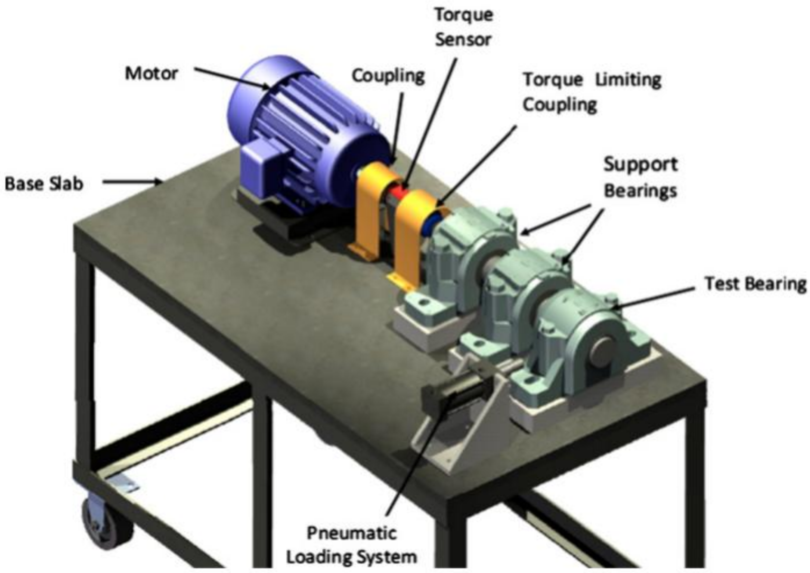

Fig.4 showing the experimental setup used for the work [8]

Edwin et.al [9] presented paper on Numerical Model to Study of Contact Force in A Cylindrical Roller Bearing with Technical Mechanical Event Simulation**.** This paper focused on the employed modeling technique makes it applicable for a wide range of ball bearing assemblies using the appropriate presented methods to estimate the critical parameters, such as convection coefficients and contact resistances. However, for a given bearing system in practice one needs to consider the appropriate material properties, boundary conditions etc. nevertheless, the approach remains valid.

Bhamidipati et.al [10] Presented paper on FEA Analysis of Novel Design of Cylindrical Roller Bearing**.** This paper focused on studying a roller design which can develop uniform contact-stress distributions by eliminating any edge stress and also recommend a roller bearing design which is easier to fabricate. The roller is relaxed to deflect due to the hollow cavity at the ends of the roller when subject to a compressive contact load, which in turn results in the reduction in contact stress distribution at both ends of the roller.

5. Existing Research work

Many of the researchers perform different analysis to identify the different process parameters of bearing performance. Some of the researcher work are mention in the below section.

Singh et.al [11] in this paper focused on a review of literature concerned with the vibration modeling of rolling element bearings that have localized and extended defects. An overview is provided of contact fatigue, which initiates subsurface and surface fatigue spalling, and subsequently leads to reducing the useful life of rolling element bearings. To investigate the effects on the vibration characteristics of defective rolling element bearings, a full parametric study could be conducted that could include a matrix of parameters, which can be varied. These parameters may include load (both radial and axial) on a bearing, rotational speed, clearance within a bearing, and various defect types. The types of bearing defects may range from line, to area, to extended area spalls having different profiles of surface roughness, which can be made similar to operational defects observed in real-world applications.

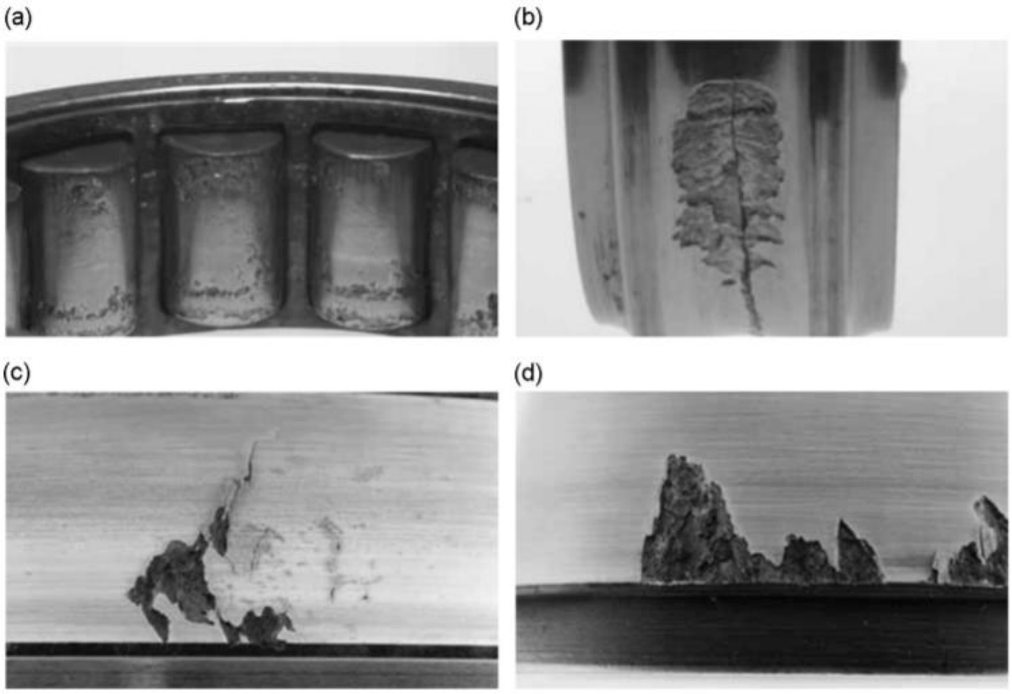

Fig.5 Fatigue spalls on various elements of rolling element bearings [11]

Viramgama et.al [12] focused on increased usage and the increased sophistication mechanical design came to necessity to predict their endurance capability. In this project an effort has been put to analyze the ball bearing using finite element analysis the stress level or displacement behavior of ball bearing. The main target is to find the most influencing parameters for radial stiffness of the bearing under an axial load. The life of bearing we get is in the multiple. So we can conclude that our bearing is safe against the radial and axial load which is applied at static and dynamic condition

Patel et al. [13] this paper focused on theoretical and experimental vibration of dynamically loaded deep groove ball bearings having local circular shape defects on either race are reported in this paper. The shaft, housing, raceways and ball masses are incorporated in the proposed mathematical model. Simulated and experimental results pertaining to vibration of bearing housings are compared and discussed. When a ball approaches to the inner race defect, the additional displacement of the ball changes from zero to maximum, while, it reaches to zero from its maximum value when ball reaches from the center of the defect to the other end of the defect.

Fig.6 Photographic view of experimental set up.

Tandon et al. [14] in this paper the experiments has been carried out using a test rig for capturing the vibration signals of test bearing. The external vibration has been imparted to the housing of the test bearing through electromechanical shaker. In envelope analysis the center frequency has been selected using the spectral kurtosis for the filters length of 32 and 64 for different bandwidths. Through this study, it has been revisited and confirmed that the defect detection in envelope analysis mainly depends on the selection of center frequency and bandwidth. The spectra of selected center frequency with several bandwidths have been studied and compared for identification of defective frequency.

xin et al. [15] this paper analyzed of the bearing joint has been modeled by introducing a nonlinear constraint force system, which takes into account the contact stiffness interaction between the rolling elements and the raceways. The proposed model has been applied in the dynamic simulations of a planar slider–crank mechanism with a deep groove ball bearing joint. A general methodology for dynamic modeling and simulation of planar multimode systems containing the deep groove ball bearings with clearance was presented and discussed throughout this work. The bearing joint used is modeled by introducing a nonlinear constraint force system, which takes into account the contact stiffness interaction between the rolling elements and the raceways.

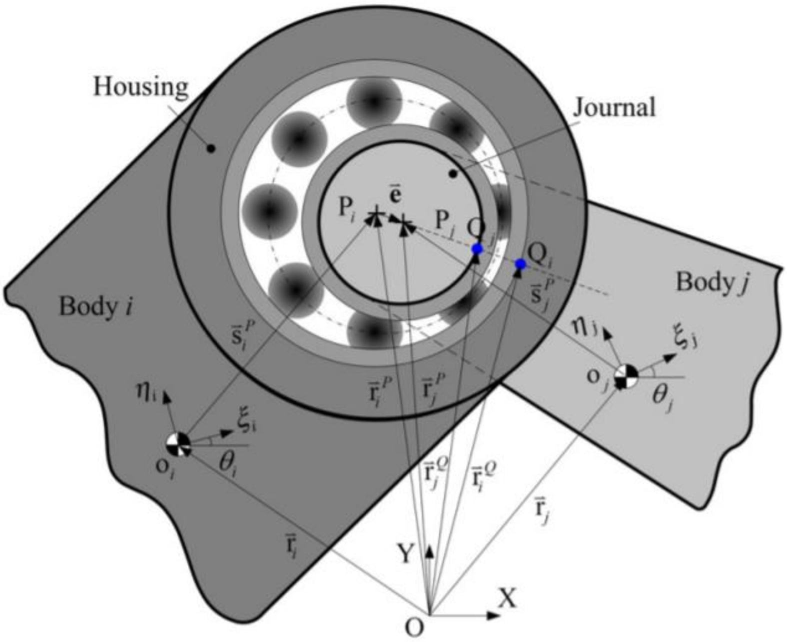

Fig.7 Modeling of a deep groove ball bearing in a multi-body system.

Patel et al. [16] Focused on a dynamic model is reported herein for the study of vibrations of deep groove ball bearing having the single and multiple defects on the surface of the inner and the outer race. The mass of housing, shaft, races and balls are considered in the dynamic model. Characteristics defects frequencies and its harmonic are broadly investigated using both theoretical and experimental results are observed.

Xiao et.al [17] have extended existing 3 DOF model of single raw deep groove ball bearing (DGB) into a 5 DOF comprehensive dynamic model of double-row spherical roller bearing (SRB) with the consideration of races and ball surface waviness, radial clearance, surface defects, point defects and loading conditions.

Babu et al. [18] have noticed that inner race radial waviness produce high amplitude of vibration as compared to outer race waviness. In their 6-DOF dynamic model of rigid rotor angular contact ball bearings system the effect of frictional moments have been incorporated.

6. Conclusion

Here In this paper, an effort were done to review different parameters that were responsible for the performance of heat exchanger. Here in this work an attempt has been done to summarize the recent research and developments in field of vibration analysis techniques for diagnosis of ball bearing faults has been made. Different methods were used to measure vibration peaks generate in spectrum at the bearing characteristics frequencies, from that we can easily understand which bearing component was defected. It has been observed that using different method it can measure vibration amplitude of the defective bearing which is showing more amplitube compare to the healthy bearing. Moreover, the presence of bearing fault (local or distributed) and its location can be identified through life cycle time and different process parameters. The accuracy of the dynamic model depends on the considerations like mass of shaft, bearing elements, housing, linear or nonlinear bearing stiffness, lubrication, speed, damping, defect, friction and presence of noise.

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