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Review of Fault Diagnosis of Cylindrical Bearing with Defects

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ABSTRACT: Rolling element bearings are crucial to the efficient operation of rotating machinery. One of the main causes of nonlinearity in rotating machinery that significantly affects the system's behaviour is bearing. Radial internal clearance, unbalanced force, bearing preload, stiffness, damping, number of rolling elements, defects, and other factors are the main causes of nonlinearity. Surface flaws like localized and distributed flaws are partly to blame for the system's nonlinear behaviour. In the past two decades, numerous studies and techniques have been put forth to comprehend the nonlinear dynamic behaviour of rolling element bearings while taking into account various bearing parameters and surface flaws. This article reviews many theoretical frameworks and experimental studies that have been put forth for the investigation of rotational systems' nonlinear behaviour.

KEYWORDS: Rotating Machinery, Bearing, Condition Monitoring, Localized Defects, Distributed Defects

I. INTRODUCTION

Rotating machinery is widely used in industrial applications. As a crucial component of the majority of industrial rotary machines, rolling element bearings need to be continuously inspected for damage in order to avoid system failure, unneeded machine stops, production delays, and the resulting financial losses. If the bearings failed during operation, the machine could be dangerous. Pitting, spalling, surface damage, electro erosion, and wear are the primary causes of such failures. Surface damage on the raceways or rolling elements of bearings is the most common cause of defects. Such surface defects can be classified into two forms: localized faults or distributed faults.[1] Cracks, pits and spalls, dents, scratches, bump flanking, and fault size prediction are examples of localized flaws. Surface roughness, waviness, misaligned races, and off-sized rolling components are examples of distributed problems.[2]–[5] During operation, defective bearings may generate noise and vibration, which eventually lead to rotor-bearing system failure and serious economic and personal losses. Any rotating machine's efficiency is strongly influenced by the way rolling bearings behave dynamically. Due to the critical role that rolling element bearings play in rotating machines, it is necessary to keep an eye on their condition in order to prevent failure and unintentional losses. Thus, analysis of defective bearings is a research area from a condition monitoring point of view.[6]

II. LITERATURE SURVEY

Several researchers have worked on the analysis of vibration generation by bearings with and without defects. McFadden et al.[7], [8] proposed mathematical models to investigate vibration response and the effects of various characteristics such as transmission path and loading, as well as single and multiple localized faults. Tandon et al.[9] offered an extension of McFadden and Smith's work for studying the behaviour of REBs with localized flaws on various components of bearings under radial and axial load. Harsha [10] studies the nonlinear dynamic behaviour brought on by the number of balls and cage run-out in a rotating system supported by rolling element bearings. Kiral et al. [11], [12]employed a FE approach to forecast the effects of rotational speed, housing structure geometry, and fault number and location for analysis of vibrations of REBs with a single defect and multiple faults on the races and rolling elements. Patel et al. [6]proposed a dynamic model for predicting ball bearing vibrations with single and multiple localized faults on the races. This model took into account the masses of the rolling parts, races, and shaft. The localized fault was also formulated using the rectangular displacement excitation model. Patel et al.[13]examine the experimental investigation of ball bearings with different sizes of the circular defects on bearing races with different radial loads. The vibration peaks at BPFI and BPFO are becoming noticeable as the circular flaw size increases, according to the author. Local faults on the outer race have better visibility than those on the inner race. Saruhan et al.[14] showed estimated findings for four separate defects on both races and balls, as well as combinations of all element faults, in an amplitude spectrum.

The experimental vibration response of a ball bearing with a localized flaw and an imbalanced rotor was studied by Nagane et al.[15] At various speeds and other parameters, the statistical parameters RMS value and Peak value are seen for both healthy and defective bearings. A ball bearing with a dispersed flaw on the outer race was the subject of a study by Kulkarni et al. [16] in his experimental analysis. At various radial loads and speeds, experiments are conducted at various fault locations. The author plotted results in the time domain and frequency domain, which found that the experimental characteristic frequency values nearly match the theoretical computed. Wen et al.'s [17] experimental investigation of the dynamic motions of the cage for different speeds and weights of ball bearings. Through FEM with Ansys, Utpat et al. [18] analyse the ball bearing with various sizes of flaws operating at various speeds. Patel et al. [19] discuss the results of an experimental investigation of an inner race defect on a cylindrical roller bearing under varying speeds and radial loads. Different statistical characteristics, including RMS, crest factor, skewness, kurtosis, and frequency domain techniques, including FFT and envelope spectrum, were retrieved and compared for healthy and unhealthy bearings at various speeds and radial loads in order to analyse bearing performance. The experimental investigation of a ball bearing with various loads, flaws, and constant speed was provided by Kondhalka et al [20]. Both the time domain and the frequency domain results are displayed. The experiments' results are contrasted with those of MATLAB. Sesana et al.[21] investigate the effect of different kinds of defects on the balls with axial loading and constant speed. For DOE, the author used ANOVA with four factors and three levels. The author utilised an ANOVA for DOE that had four components and three levels. The author came to the conclusion that the factors that had the most influence on noise and vibration phenomena were scratches, geometry, and plastic deformation. Dimension scatters had less of an effect.

Kankar et al.[22] revealed the nonlinear behaviour of a ball bearing with spall as a localized fault on all of the bearing's elements, including the inner race, outer race, and ball. The radial clearance and the quantity of balls were also evaluated as non-linearity sources by the author. Pandya et al. [23] presented the analysis of a high-speed rotating shaft with localized faults on the outer race, inner race, and rolling element. Patel et al. [24] studied the theoretical model to anticipate the impact of a localized defect on the dynamic behaviour of a cylindrical roller bearing at both the inner and outer races. Patra et al.[25], [26] examine the behaviour of cylindrical roller bearings in balanced and unbalanced conditions for different sets of speeds. Author extended his work with an investigation of the behaviour of bearings with unbalanced rotors and localized defects on races and rolling elements. Rafsanjani et al. [27] analysed the nonlinear dynamic model considering the internal radial clearance with local defects bearing elements. For each scenario, the system's peak-to-peak frequency response is computed, and the fundamental paths leading to periodic, quasi-periodic, and chaotic motions for various internal radial clearances are identified. Patel et al.[3] presented the mathematical model of a cylindrical roller bearing with the couple effect of inner race and outer race defect as well as the couple effect of inner race, outer race, and roller defect with radial and axial loading. The understanding of system behaviour such as periodic to chaotic under varied speed settings is a major finding of this research. Liu et al. [28] presented the theoretical investigation of the combined defect's impact on radial vibrations in a ball bearing. Ahmadi et al. [29] contribution is to show how the angular extents between low-frequency entry events and high-frequency exit events on the vibration signal change on speed. Shah et al. [30]study the vibration produced by healthy and faulty bearings, taking into account the lubricating film and non-linear Hertzian contact. The goal of this study is to see how radial load, lubricant, defect size, and location affect vibration amplitude at bearing defect frequency. The experimental vibration of a deep groove ball bearing with coupled flaws on raceways was studied by Shah et al.[31]In the presence of combined flaws, the author examined the effects of variation in local defect width, waviness order, load, shaft speed, and lubricant role on vibration level.

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