A REVIEW ON BEARING DEFECTS ANALYSIS OF ROLLING ELEMENT BEARING USING VIBRATION ANALYSIS

Kapil Surani[1], Ronak Shah[2]
Department of Mechanical Engineering
[1] II M.E. (MACHINE DESIG), Kalol Institute of Technology and Research, Gujarat Technological University, Gujarat, India.
[2] Associate Professor, Kalol Institute of Technology and Research, Gujarat Technological University, Gujarat, India.

Abstract- *Rolling element bearings are critical components and widely used in many rotating machines such as automobiles, aerospace, weaving, machine tools that frequently fail. The defects in the rolling element bearings may come up mainly due to the following reasons; improper design of the bearing or improper manufacturing or mounting, misalignment of bearing races, unequal diameter of rolling element, improper lubrication, overloading, fatigue and uneven wear. The vibration of the bearing-rotor influences the security, performance of the rotating machines and working life of the whole plant. Although several techniques have been reported in the literature for bearing fault detection and diagnosis, it is still challenging to implement a bearing condition monitoring system for real-world industrial applications because of the complexity of bearing structures and noisy operating conditions. the purpose of the study is to investigate the vibration and noise producing characteristics of large rolling element bearings by vibration analysis, with the ultimate aim of devising means to reduce vibration and noise caused by these bearings for all audio and subsonic frequencies.*

Keywords- Rolling element bearing, condition monitoring, subsonic frequency, vibration analysis, overloading.

I. INTRODUCTION

Rolling element bearings are used in their tens of millions in rotating machinery to minimize friction between adjacent parts moving at different speeds. They are not only one of the most critical components but also one of the first to fail. The problem is a major one because, as it has been explained, fewer than 20% of bearings achieve their design life and other research has found bearing failures account for more than 50% of all motor failures. The economic loss due to bearing failure in terms of machine down time, and even human life, is huge compared to the cost of the bearing itself. Therefore, bearing condition monitoring (CM) and diagnosis has attracted substantial attention over the past four decades as economic pressure to increase machine speed has accelerated.

Rolling element bearings have been subject to extensive research over many years to improve their reliability. However, the large number of bearings associated with any given process increases the likelihood of system failure due to one of them failing, and such system failure can occur in a very short period of time. There are many reasons for early failure, including; excessive loading, inadequate lubrication, insufficient internal bearing clearance due to an excessively tight fit, etc. Bearing faults can be categorized into three sets: primary damages, secondary damage and general damage.Primary Damage includes Wear, Indentation, Smearing, Surface Distress, Corrosion (rust), etc. and Secondary Damage cover Spalling (flaking), Cracks, Bearing Cage Damage, Scoring (galling), Rollout, etc.

Detecting mechanical faults in bearings has been recognized for some time as an important aspect for preventing catastrophic failure and planning effective maintenance. There are several approaches used to diagnose faults on a bearing system including thermal analysis, oil debris analysis, and vibration analysis.

Thermal Analysis

Thermal analysis is defined as a tool used to generate warnings about the overheating of the bearing system. The thermocouples or other temperature monitoring devices usually employed at the inlet and outlet of the test chamber indicate two points of interest to study any temperature gradient of the bearing component. However, thermal analysis cannot be used to identify the type and size of the defects in a bearing system.

Oil Debris Analysis

Lubrication of a bearing may be provided in liquid, grease, or solid form and the type of lubrication is generally chosen depending on the operating conditions. Debris analysis does have a rare application on grease or solid form but generally used with oil lubricants. Bearing failures in some machines such as helicopter transmissions and aircraft turbine engines generate significant debris in their oil systems. Oil analysis program on a bearing consists of oil sampling, analytical tests and data interpretation. There are number of oil debris analysis techniques such as elementary spectroscopy, wear particle analysis, fine particulates analysis, molecular analysis, and electrochemical chemistry used to diagnose a failure on a bearing. These oil debris analyses provide information on quantity, form, and size distribution o f the debris, which can lead to damage type detection.

Practical experiences and researches have shown that combining oil debris analysis along with vibration analysis in a bearing condition-monitoring program provides information in greater detail and more reliable information than each individual system.

Vibration Analysis

Each rotating machine has its own vibration signature as a result of the rotation of shafts, gears and bearings. Rolling bearing elements, an essential part of rotating machinery, are known to play a significant role in machine vibrations. First, structural element of the bearing acts as a spring and also adds some mass to a system. As such, bearings define, in part, the vibration response of the system to external time-varying forces. Secondly, bearings act as excitation forces, producing time-varying forces that cause system vibration. This excitation is natural in the design of rolling bearings. However, these forces can be greatly amplified as a result from imperfections or defects on the bearing components.

Detection of progressive bearing deterioration during operation by vibration measurements has been in use for a long time and this technique has become more economical and reliable in recent years. The overall level of vibration indicates the general condition of the bearing system, the cause of vibration, including such factors as unbalance, misalignment, and bearing defects. Vibration diagnostics are usually concerned with the extraction of features from a signal and associating these features with healthy or faulty components of the bearing.

A healthy bearing under constant load and speed is likely to move toward steady state dynamic equilibrium, because of the natural symmetry in a rolling bearing element. The strength of the vibration increases when a defect occurs on one of the bearing components. Due to the defect, a transient force takes place each time another bearing component contacts the defective surface, resulting in rapid acceleration of the bearing components.

II. LITERATURE REVIEW

V.V. Rao and Ch. Ratnam [1] perform an experimental analysis to find out Defect Severity in Rolling Element Bearings by the practical AE and vibration response with gradual increase of defect size in bearing outer race. They were analyzed Time waves and frequency spectrums of both methods (bearing without defect and with defects). They say some significant difference in vibration and acoustic emission spectrums. In vibration analysis, overall RMS velocity increases with the increase in RPM and load. The same trend is observed with increase in the defect size. From vibration time waves it can be concluded that there is a defect in outer race but the severity of the defect could not be ascertained. The experimental result is revealed that AE technique is superior to vibration technique and gives better analysis to diagnose the defects in bearings. Also AE technique is found useful to characterize and to find out the size of the defect.

Experimental and theoretical analysis has been done by R.G. Desavale and Asmita R. Mali [2] they developed mathematical model of the vibration amplitude of the bearing is established through experimental data based analysis (EDBA). Also they were established new mathematical model technique for rotor bearing systems. Furthermore, a model analysis on bearing system is carried out by using EDBA, the defect frequencies and vibration amplitude responses of the rotor-bearing system are obtained, and experimental result has been validated. Result shows that from mathematical modeling apart from damping factor, surface defect, load and speed have a reasonable effect on the vibration amplitude. It is obvious that as surface defect increases the vibration amplitude produced will be bigger. The increase in surface defect, speed and load causes the vibration amplitude to increases and decreases respectively.

Vana Vital Rao and Chanamala Ratnam [3] designed and developed a bearing test rig and it was setup in his workshop to study the vibration analysis of various faults in rolling element bearings. They were observed different types of seeded defects, but these defects are random in size and shape; hence the correlation between defect size and its vibration parameter is not established. They were investigate, test runs conducted with seeded defects of same type with a gradual increase of its size on outer race of radially loaded cylindrical roller bearings at different speeds and loads. Vibration data were acquired by accelerometer and processed through Fast Fouier Transform (FFT). By looking the result it is clear that the seeded defect sizes were provided in a gradual increasing manner to observe the variation in vibration RMS velocity with respective to defect size. The vibration RMS velocity increases significantly with the increase of the defect size and speed, but not in the case of load.

Theoretical modeling for vibration response of ball bearing with defect on the races of ball bearing was prepared by Samir Shaikh and S.S. Kulkarni [4]. They analyzed vibration response due to defect is necessary for condition monitoring of rolling element bearing to improve bearing performance. In the analytical formulation, the contacts between the ball and the races are considered as non-linear springs. They calculate the contact force using the Hertzian contact deformation theory. From result it is seen that in pure radial loaded bearing, the effect of surface defect is more at lower speed than the higher speed of ball bearing. As the size of defect increases in ball bearing increases the amplitude response of bearing. The comparison of characteristic response of healthy and defective bearing is useful to identify the defective bearing at an early stage, using vibration response.

H. Saruhan and S. Sardemir [5] have been introduced new experimental setup for vibration generation in the rolling element bearings. This model clearly explains high frequency vibration in acceleration spectrum. When the defect grows in the bearing, stochastic excitation becomes stronger in the defective area. In defective area vibration level increases is a good indicator of bearing faults. A numerical simulation of the proposed model was validated with experimental results.

V. N. Patel, N. Tandon and R. K. Pandey [6] present a dynamic model for the study of vibrations having single and multiple defects on surfaces of inner and outer races of deep groove ball bearings. The masses of shaft, housing, races, and balls are considered in the modeling of defective ball bearing. The solution of governing equations of motions is obtained using Runge–Kutta method. The dynamic model provides the vibrations of shaft, balls, and housing in time domain and frequency domain. Results from the model are validated with experimental results, which are generated with healthy and defective deep groove ball bearings. The characteristic defect frequencies and its harmonics are investigated using both theoretical and experimental results.

Experimental investigation carried out by Sham Kulkarni an Anand Bewoor [7] to analysis the detection of bearing fault. They emphasize the comparison of some vibration parameters to characterize the distributed defects in the bearing, RMS, Peak and peak to peak which are used in the detection defects in the bearing. They have been shown that vibration based monitoring is an effective method for detecting the faults in the bearing. Authors conclude that defect detectability with outer and inner race defect is successfully obtained using statistical analysis. They say the Inner race defect gives better response to speed variation. However, outer race defect gives better response at high load.

V. M. Nistane and S. P. Harsha [8] reported Bearing Prognostic Simulator (BPS) as test rig which is used to examine vibration signature of bearing throughout the lifespan. They evaluate the bearing failure which is assessing to investigate variation of defect in bearing under radial load and constant speed. They acquired vibration signatures are scrutinized to extract statistical feature for proper representation of failure evaluation.

A Theoretical Model has been prepared by N. Tandon and A. Choudhury [9] to predict the amplitudes of the spectral components due to outer race waviness to be much higher as compared to those due to inner race waviness. In the case of an off-size rolling element, the model predicts discrete spectra having significant components at multiples of cage frequency. Result of model is, for outer race waviness, the spectrum has components at outer race defect frequency and its harmonics. In case of inner race waviness, the waviness orders equal to number of rolling elements and its multiples give rise to spectral components at inner race defect frequency and its multiples.

Ankur Gill [10] used novel sensors such as an Air-coupled ultrasonic transducer; Eddy current Piezo electric ultrasonic transducer as diagnostic tools for detection of bearing faults has been investigated. He did series of experiments in a laboratory environment. He created localized defects with different sizes intentionally on the test bearing components simulating evolving cracks or other related faults. He applied four different signal processing techniques to extract the signal features. Also resulting data for different bearing speed and load showed that the sensors are capable of detecting different types of defects located on the bearing components. The result showed that techniques based on time - frequency (especially wavelet analysis) and frequency analysis are the most appropriate diagnosis techniques for faulty bearings, respectively. PUT was the only sensor, which could detect the defect as small as 0.2mm on the outer race with the Fourier series bases Spectrum.

III. CONCLUSIONS

In this paper, an attempt to summarize the recent research and developments in the vibration analysis techniques for diagnosis of rolling element bearing faults has been made. This study found that the time domain techniques only can indicate the fault(s) present in the bearing but it can’t identify the location. Frequency domain techniques have ability to identify the location of fault(s) in bearing. Vibration peaks generates in spectrum at the bearing characteristics frequencies, from that we can easily understand which bearing element is defected.

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