Detection of the Distributed Defects on Inner & Outer Race of Ball Bearing using Vibration Analysis

Anand J. Kumbhar
Student, Mechanical Engineering Department
Rajarambapu Institute of Technology, Islampur, India

Narendra K. Chhapkhane
Associate Professor, Mechanical Engineering Department
Rajarambapu Institute of Technology, Islampur, India

Abstract— **Bearings are the very important component of rotating machinery. Bearing failure is one of the most common faults in industrial machines. Proper condition monitoring is therefore of the highest importance. The rolling bearing is a machinery component that plays a very important role, since it dominates the machine performance. Small defect in the bearing results in dangerous failure of machinery. If defect is detected on one of the bearings, not only the machine, but also the assembly line stops and the deriving costs may be extremely high. Therefore it is very important to detect defects of the bearing before they cause upcoming damage and decrease expensive downtime. The vibration analysis is the most frequently used technique for monitoring of the bearings. This technique can give early information about progressing malfunctions and can be used for future monitoring purpose. This paper describes the suitability of vibration analysis technique to detect the distributed defects in bearing. In this paper comparison of vibration spectrum of healthy and defective bearings is carried out to find defect on bearing. Results show that comparison of vibration spectrum of healthy bearing and vibration spectrum of defective bearing is helpful to recognize the defects in the bearing.**

Keywords*— *Defective Bearings, defects, Vibration analysis, Vibration spectrum, FFT analyzer.

I. INTRODUCTION

Bearings are the most significant parts in rotating machinery. When ball bearings are used, they produce vibration. Contacting forces between the bearing component are tends to produce the unwanted vibration in to the various bearing component. The types of defects induced in the bearing component will define what would be the nature of vibration and its response with respect to the time. The aim of introducing the bearing in many machine components is mainly to achieve the rotary motion between two parts and to support rotating shafts against radial or thrust loads with minimum friction. During its operational condition bearings are subjected to the heavy magnitude of fluctuating loadings whose magnitude tends to vary with respect to the time ultimately it tends to induce the severe defects on the bearing components. As bearing involves the minimum friction because of it’s less contacting surface areas so that they are more popularly used to design and manufacturing of the components like Roof Fan, Screw Jack, Automobiles components, Aero planes, Train Applications. So designing of the bearing component for minimum vibration is the key factor in the area of bearing design to expect its qualitative performance in terms of noise free and high reliable operation.

II. BEARING DEFECTS AND DEFECT FREQUENCY EQUATIONS

Rolling bearing defects may be classified as localized or distributed. A localized defect includes cracks, pits and spalls in the rolling surfaces, as well as particle contamination of the bearing lubricant. The ultimate failure mode of a correctly installed and operated bearing generates defects of this sort (i.e., fatigue spalling of the rolling surfaces). Defects of this sort recognize themselves in the bearing's vibration signal as vibratory transients which result from discontinuities in the contact forces as the defect undergoes rolling contact. Now day’s numbers of experimental investigations are available to detect these transients in the vibration signal. Bearing should operates with some inline conditions if those are not maintained or regulated properly it tends to induce distributed defects on the entire bearing structure which are listed as, misaligned races, eccentric races, off-size rolling elements and out of-round components. These defects may result from manufacturing error and abrasive wear. The major factors for causes of bearing failure are dirt, misalignment, insufficient lubrication, overloading, corrosion, foreign particle or shifted bearing cap. Malfunctioning of the bearing because of various defects mentioned above bearings is subjected to the excessive magnitude of the contacting forces, which further results in the ultimate or premature bearing failure. To ensure the proper functioning of the newly installed bearings, vibration analysis is a sort of effective tool considered for the bearing inspection to spotting such defects for the sake of safety, reliable and qualitative bearing performance. Vibration signature monitoring and analysis is an effective methodology discovered out so far to predict all possible ways of failure in the bearing as a effect of various defects found in the bearing. It basically helps to provide failure information at the earlier stages and lead to the clear picture of bearing malfunctioning. It also gives an ideal reference signature in order to monitor the bearing performance and keep it on track as well in near future. Defective rolling elements inside the bearings produce the unwanted vibration of the bearings. Defective rolling elements are the base cause of producing the Vibration Frequency at various rotary motions of the different bearing components. Components like cage, balls, inner and outer race are mainly affects on the Rotational Frequency of the bearing. Defects initiation and propagation in the ball bearing components will mainly reflects the nature of Vibration Signal and its corresponding effect on the system under consideration. Components flaws generally seems to appear on the part of the bearing component like inner race, outer race and rolling elements which generate the specific Defect Frequencies, calculated from equations mentioned by " Chaudhary and Tandon", namely;

Inner race defect frequency is,

$$f_i = \frac{n}{2} f_s \left(1 + \frac{BD}{PD} \cos \alpha \right) \tag{1}$$

Outer race defect frequency is,

$$f_o = \frac{n}{2} f_s \left(1 - \frac{BD}{PD} \cos \alpha \right) \tag{2}$$

Ball-rotational Frequency,

$$f_b = \frac{PD}{BD} f_s \left[1 - \left(\frac{BD}{PD} \right)^2 \left(\cos^2 \alpha \right) \right] \tag{3}$$

Fundamental train frequency,

$$f_t = \frac{1}{2} f_s \left[1 - \left(\frac{BD}{PD} \right) \cos \alpha \right] \tag{4}$$

Where, n - no. of balls, f_s - Shaft rotation frequency, BD - Ball Diameter, PD - Pitch Diameter, α - Contact angle.

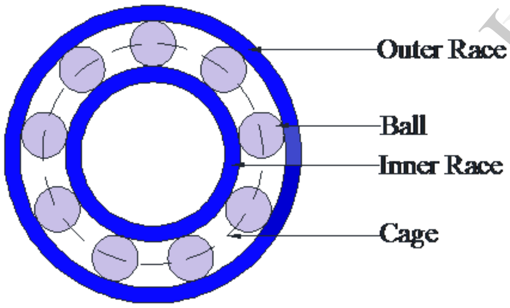

Figure 1

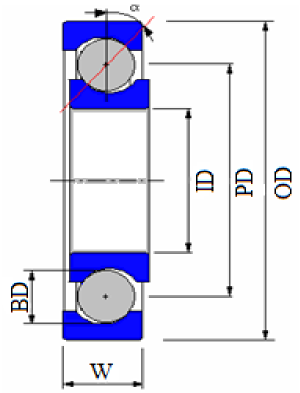

Figure 2
ID-Inner Diameter, PD- Pitch Diameter, OD- Outer Diameter, BD-Ball Diameter, W-Width, α-Contact Angle

For ball bearing with distributed defect on its inner race or outer race, it is possible to calculate characteristic defect frequency as defect detection parameter by using defect frequency equations as mentioned above. For identification of defects of ball bearings by using vibration analysis, these frequency equations have often been used. In the present work theoretically calculated rotational frequency is 24.91 Hz, inner raceway defect frequency is 135.05 Hz and outer raceway defect frequency is 89.14 Hz. Fig. (1) Shows cross of the bearing and fig. (2) Shows geometry of the bearing

III. EXPERIMENTAL SET UP

The experimental bearing test set up is designed and fabricated to identify the presence of defects on a deep groove ball bearing by vibration analysis technique is shown in Figure (3). An experimental set up consists of a circular shaft which is supported by two bearings of 6206 series. The shaft is connected to 1 HP induction motor. In this set up the bearing near to motor is used for supporting the shaft and the defective bearing to be tested is mounted on another end of the shaft. The unique feature of the set-up is that we can remove the bearing from shaft and another defective bearing can be mounted easily on the shaft for recording the vibration signatures.

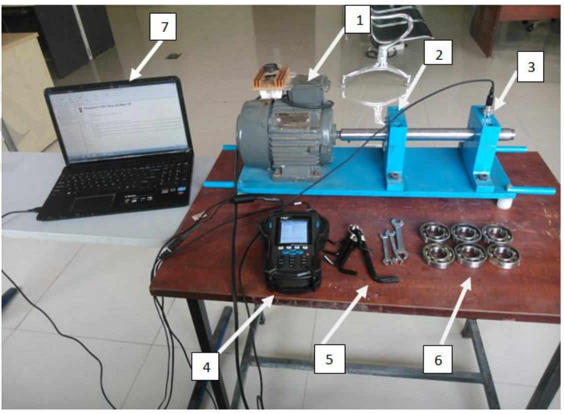

Figure 3. Photograph of Experimental Setup

1 – Motor, 2 – Housing (Plummer Block), 3 – Accelerometer, 4 – FFT Analyser (SKF Microlog Analyser), 5 – LN Keys & Spanner, 6 – Bearings, 7 – Monitor.

In the present work for recording vibration signatures 6206 type of deep groove ball bearing is used.

TABLE1. BALL BEARING DETAILS (6206)

Parameter	value
Number of balls	9
Outer diameter, mm	62
Inner diameter, mm	30
Ball diameter, mm	9.52
Pitch diameter, mm	46.482
Contact angle, α	0^0

In this paper distributed defect on outer and inner race of the bearing is studied for the constant speed of 1495 RPM.

TABLE 2 PEAK VALUES (AMPLITUDES) OF GOOD AND DEFECTIVE BEARINGS

Bearing Condition	**Frequency in Hz**	**Peak Values in G RMS**				
		1st Reading	**2nd Reading**	**3rd Reading**	**4th Reading**	**5th Reading**
Good (Healthy) bearing for Inner Race	135	0.0012	0.0014	0.0031	0.0035	0.0044
Bearing with inner race defect	135	0.0641	0.0679	0.0853	0.088	0.0943
Good (Healthy) bearing for Outer Race	90	0.0026	0.0029	0.0035	0.0036	0.004
bearing with outer race defect	90	0.043	0.052	0.054	0.062	0.067

Experimental tests were carried out for two sets of bearings. Initially good (healthy) bearing is mounted on the shaft and signatures are recorded for it by using FFT analyzer. Then defective bearings of the same configuration are mounted on the shaft and signatures are recorded by using FFT analyzer. Bearing signatures shows number of peaks. The peaks at interested frequencies are used for comparison.

IV. RESULTS AND DISCUSSION

A. *Analysis of Bearing with Inner Race Defect*

The experimental vibration signatures of good (healthy) bearing and defective bearings taken by using FFT analyser for inner race are shown in figure below.

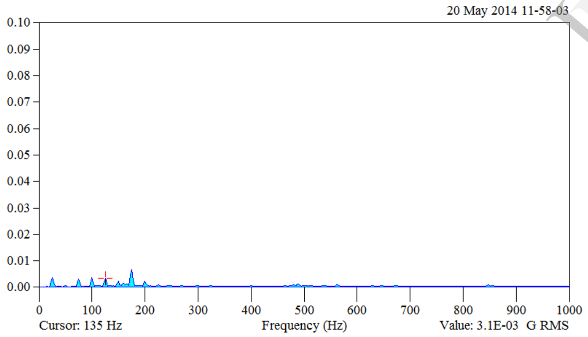

Figure 4 Vibration Signals of Good Bearing (Frequency in Hz vs. Amplitude in G RMS)

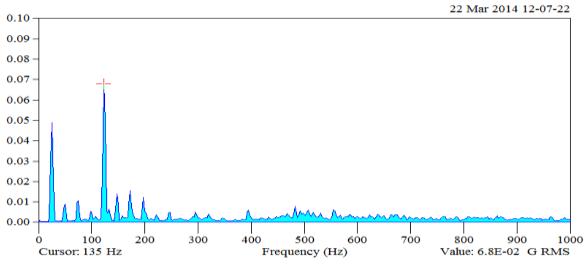

Figure 5 Vibration Signals of Bearing with Inner Race Defect (Frequency in Hz vs. Amplitude in G RMS)

Figure 4 shows that for good bearing the experimental amplitude value shown by cursor is 0.0031G RMS at frequency 135 Hz.

In figure 5 the experimental amplitude value shown by cursor for bearing with inner race defect is 0.068 G RMS at same frequency 135 Hz which is more than that of good bearing and thus indicates that it is defective bearing.

If we compare this experimental frequency with the inner race defect frequency which is calculated theoretically by using equation (1) is at 135.05 Hz. It indicates that experimental frequency (135 Hz) is very near to theoretical inner race defect frequency (135.05 Hz).

Hence we can conclude that there is defect on inner race.

B. *Analysis of Bearing with Outer Race Defect*

The experimental vibration signatures of good (healthy) bearing and defective bearings taken by using FFT analyser for outer race are shown in figure 6.

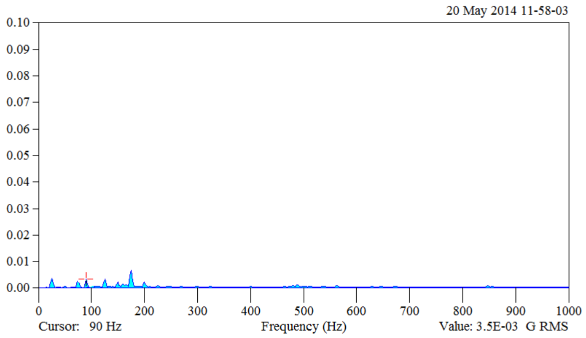

Figure 6 Vibration Signals of Good Bearing (Frequency in Hz vs. Amplitude in G RMS)

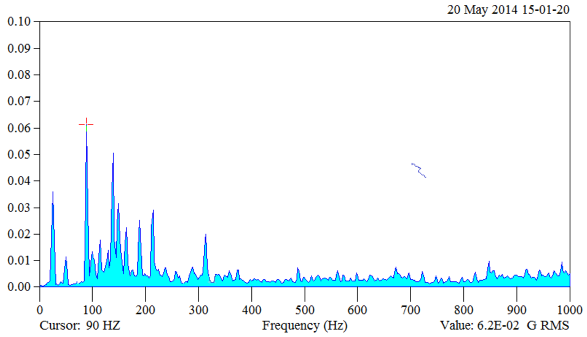

Figure 7 Vibration Signals of Bearing with Outer Race Defect (Frequency in Hz vs. Amplitude in G RMS)

Figure 6 shows that for good bearing the experimental amplitude value shown by cursor is 0.0035G RMS at frequency 90 Hz.

In figure 7 the experimental amplitude value shown by cursor for bearing with outer race defect is 0.062 G RMS at same frequency 90 Hz which is more than that of good bearing and thus indicates that it is defective bearing.

If we compare this experimental frequency with the outer race defect frequency which is calculated theoretically by using equation (2) is at 89.14 Hz. It indicates that experimental frequency (90 Hz) is very near to theoretical outer race defect frequency (89.14).

Hence we can conclude that there is defect on outer race.

The peak values (Amplitudes) of good bearing and defective bearing at its defect frequencies are shown in the table 2. The experimental frequencies (135 Hz & 90 Hz) of good and defective bearings mentioned in the table are very near to the theoretical defective frequencies (135.04 & 89.14 Hz) of bearings.

The amplitude values for inner and outer race of good bearing varies with respect to time even there is no defect on bearing. The amplitude values for inner race defective bearing and outer race defective bearing increases with respect to time because of increase in severity of defect.

V. CONCLUSION

Vibration analysis by using FFT analyzer is very useful and effective technique for detection of distributed defects on bearings especially at their early stages. Defects can be detected without interrupting manufacturing or production process of rotating machinery. Vibration spectra of good bearing and defective bearings are compared to find out the defect. Because of defect frequency equations it is possible to find out the location of the defect whether it is on outer race, inner race, ball or cage.

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