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# CONDITION MONITORING OF ROLLING ELEMENT BEARING THROUGH SPECTRUM ANALYSIS

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**Abstract**

*Condition monitoring is the process of monitoring some parameters from the machinery, such that a significant change in the parameter can give information about the health of the machinery. Antifriction bearing failure is a major factor in failure of rotating machinery. As a fatal defect is detected, it is common to shut down the machinery as soon as possible to avoid catastrophic damages. Performing such an action, which usually occurs at inconvenient times, typically results in substantial time and economical losses. It is, therefore, important to monitor the condition of antifriction bearings and to know the details of severity of defects before they cause serious catastrophic consequences. The vibration monitoring technique is suitable to analyze various defects in bearing. This technique can provide early information about progressing malfunctions. This paper describes the suitability of vibration monitoring and analysis techniques to detect defects in antifriction bearings. Time domain analysis, frequency domain analysis have been employed to identify different defects in bearings. The results have demonstrated that each one of these techniques is useful to detect problems in antifriction bearings.*

***Keywords*** *: Antifriction bearings; Defects; Prediction; Vibration signal; Signature analysis, BPFO, BSF, BPFI, FTF .*

**NOTATION**

BD, PD : roller diameter and pitch diameter, respectively, mm
$f_o$ , $f_i$,, $f_R$ : outer race, inner race and roller malfunction frequencies, respectively, Hz
$f_r$ : rotational frequency, Hz
$n$ : number of rollers
β : angle of contact

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## 1. INTRODUCTION

Condition monitoring of antifriction bearings in rotating machinery using vibration analysis is a very well established method. It offers the advantages of reducing down time and improving maintenance efficiency. The machine need not be stopped for diagnosis. Even new or geometrically perfect bearings may generate vibration due to contact forces, which exist between the various components of bearings. Antifriction bearing defects may be categorized as localized and distributed. The localized defects include cracks, pits and spalls caused by fatigue on rolling surfaces. The other category, i.e, distributed defects include surface roughness, waviness, misaligned races and off size rolling elements. These defects may result from manufacturing error and abrasive wear. Hence, study of vibrations generated by these defects is important for quality inspection as well as for condition monitoring. Antifriction bearing failures result in serious problems, mainly in places where machines are rotating at constant and high speeds.

In order to prevent any catastrophic consequences caused by a bearing failure, bearing condition monitoring techniques, such as, temperature monitoring, wear debris analysis, oil analysis, vibration analysis and acoustic emission analysis have been developed to identify existence of flaws in running bearings. Among them vibration analysis is most commonly accepted technique due to its ease of application.

Vibration signature monitoring and analysis in one of the main techniques used to predict and diagnose various defects in antifriction bearings. Vibration signature analysis provides early information about progressing malfunctions and forms the basic reference signature or base line signature for future monitoring purpose. Defective rolling elements in antifriction bearings generate vibration frequencies at rotational speed of each bearing component and rotational frequencies are related to the motion of rolling elements, cage and races. Initiation and progression of flaws on antifriction bearing generate specific and predictable characteristic of vibration. Components flaws (inner race, outer race and rolling elements) generate a specific defect frequencies calculated from equations, Inner face malfunction frequency.

$$f_i = \frac{n}{2} f_r \left[ 1 + \left( \frac{BD}{PD} \right) \cos\beta \right] ----------(1)$$

Outer race malfunction frequency

$$f_o = \frac{n}{2} f_r \left[ 1 - \left( \frac{BD}{PD} \right) \cos\beta \right] ----------(2)$$

Roller malfunction frequency

$$f_R = \frac{PD}{BD} f_r \left[ 1 - \left( \frac{BD}{PD} \right)^2 \cos^2\beta \right] ----------(3)$$

The time domain and frequency domain analyses are widely accepted for detecting malfunctions in bearings. The frequency domain spectrum is more useful since it also identifies the exact nature of defect in the bearings.

## 2. EXPERIMENTAL PROCEDURE

An experimental test rig Machine Fault Simulator (MFS) built to predict defects in antifriction bearings are shown in Figure 1. The test rig consists of a shaft with central rotor, which is supported on two bearings. An induction motor coupled by a flexible coupling drives the shaft. A ball bearing is mounted at the ends are tested at 15Hz, 20Hz etc with different conditions.

A spherical roller bearing type MB ER 10k and MB ER 16k (with outer race, roller defects and with inner race bearings used in the present analysis are given in Table 1. Provision is made on the roller bearing housing to mount accelerometers.

Two-channel FFT analyzer was used to monitor vibration signals from good and defective bearings. To acquire and analyze data, Vibraquest data acquisition and analysis software was used. Three types of bearing defects, namely, inner race, outer race and roller defects were studied. The whole test setup is demonstrated in the picture above. The belt drive is not connected to prevent interference in spectrum. The faulted bearing is installed in the inboard bearing housing. Accelerometers are installed in vertical and horizontal directions on the motor and two bearing housings.

**Fig. 1- Experimental set up with MFS**

Experimental tests were carried out on three sets of bearings. Initially new bearing (good bearing) was fixed in the test rig and signals were recorded using FFT analyzer. The good bearing was replaced by defective bearing and signals were recorded for each one of the case separately under the same standard condition. Time domain analysis and frequency domain analysis were carried out. Time waveform indicates severity of vibrations for defective bearings and frequency spectrum identifies exact nature of defects in bearings.

**Table 1: Roller bearing details (MB and NSK)**

| Component | Size | Mfg. | Brg. No. | #of R.E. | R.E. Dia. | Pitch Dia. | FTF | BPFO | BPFI | BSF |
|---|---|---|---|---|---|---|---|---|---|---|
| Rotor Brgs | 5/8" | MB | ER- 10K | 8 | 0.3125 | 1.319 | 0.382 | 3.052 | 4.948 | 1.992 |
| Rotor Brgs | I" | MB | ER-16k | 9 | 0.3125 | 1.548 | 0.399 | 3.592 | 5.408 | 2.376 |
| Motor Brgs | ½ hp | NSK | 6203 | 8 | 0.266 | 1.142 | 0.3835 | 3.066 | 4.932 | 2.03 |

## 3. RESULTS AND DISCUSSIONS

### 1) Analysis of FFT data for Good bearing at 15Hz

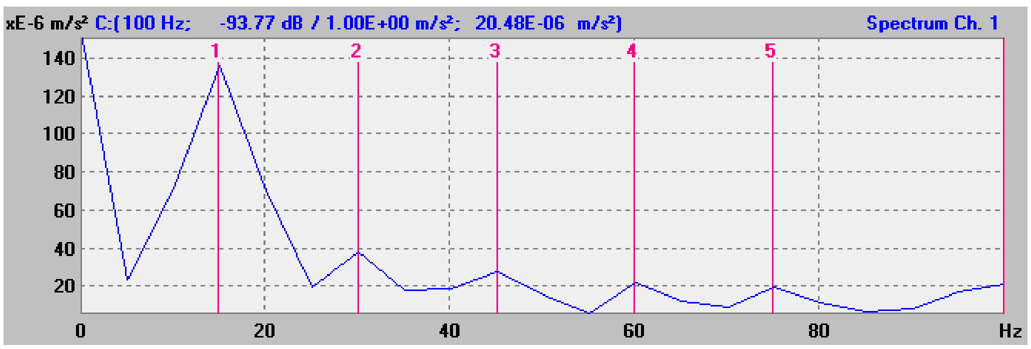


**Fig. 2- Trace at 15 Hz**

**<u>For 15 Hz</u>** FTF: 5.73 BPFO : 45.78 BPFI : 74.22 BSF: 29.88

### 2) Analysis of FFT data for Inner Race Faulty at 15 Hz

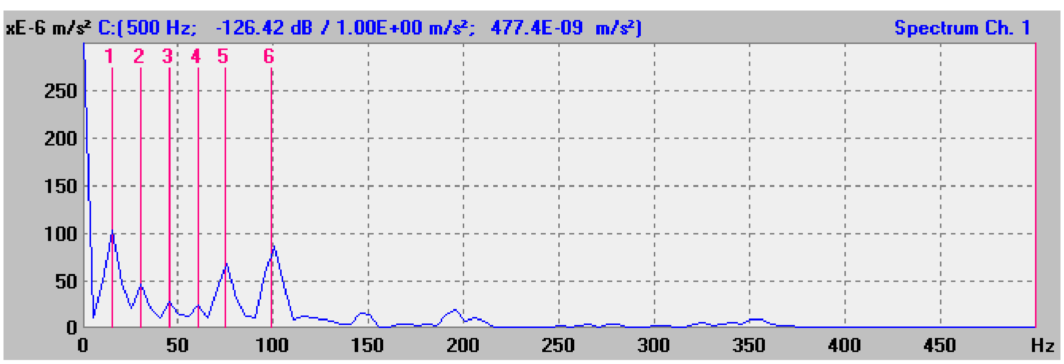


**Fig. 3- Trace at 15 Hz**

**<u>For 15 Hz</u>** FTF: 5.73 BPFO: 45.78 BPFI : 74.22 BSF: 29.88

**3) Analysis of FFT data for Outer Race Faulty at 12 Hz**

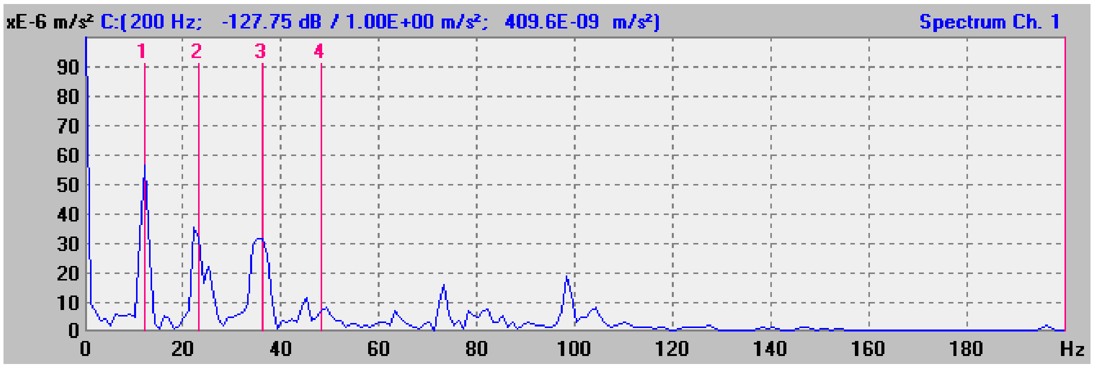


**Fig. 4- Trace at 12 Hz**

**For 12 Hz** FTF: 4.584 BPFO: 36.624 BPFI: 59.376 BSF : 23.904

**4) Analysis of FFT data for 1 inch shaft and Ball Fault at 13.5 Hz**

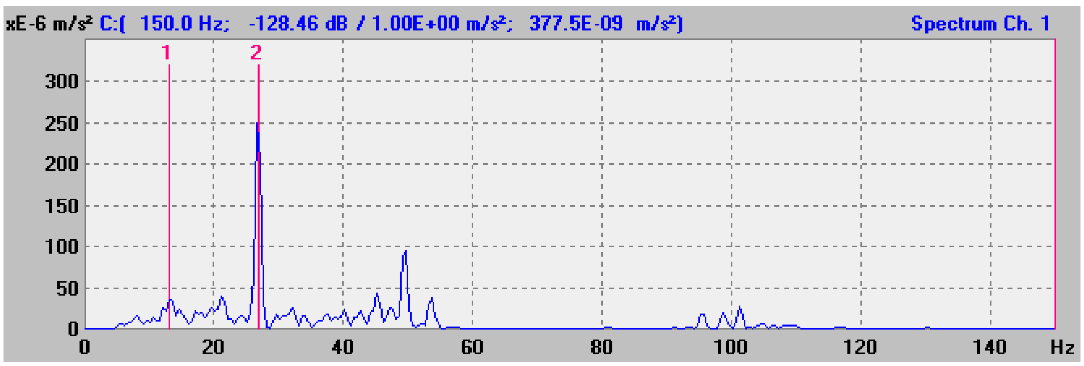


**Fig. 5- Trace at 13.5 Hz**

- **For 13.5 Hz** FTF: 5.3865 BPFO: 48.492 BPFI : 73.008 BSF: 32.076

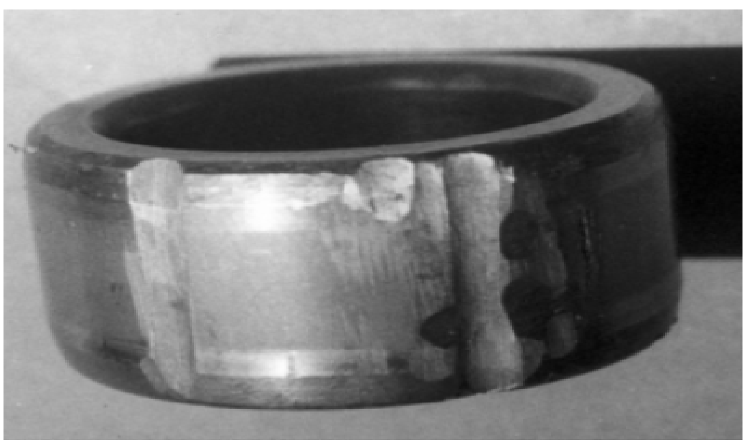

**Fig. 6- Bearing with inner race defect**

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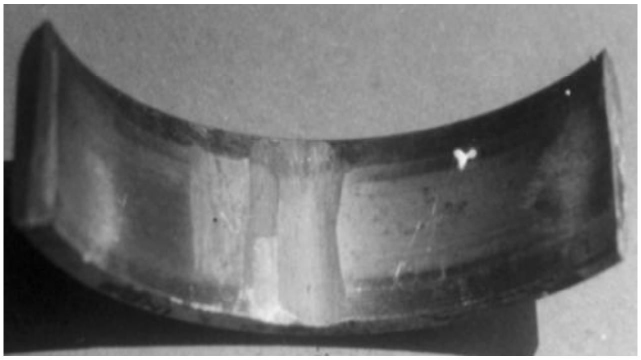

**Fig. 7- Bearing with outer race defect**

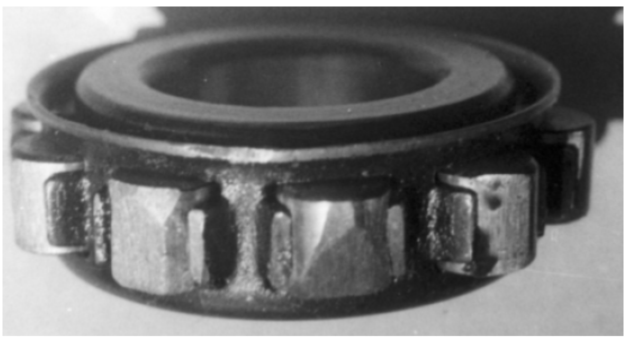

**Fig. 8- Bearing with rolling element defect**

The vibration signals of good bearing and defective bearing is shown in figures 2 to 5, respectively. The magnitude of peak to peak time response of good bearing is found. In order to assess the clarity in different defects in bearings the spectrum analysis is shown in figures 2 to 5 for good bearing, bearing with inner race defect, bearing with outer race defect and bearing with roller defect, respectively. The details of inner race defect, outer race defect and roller defect are shown in figures 6-8, respectively. The magnitude of spectrum at various harmonic frequencies for defective bearing is found to be quite distinct in comparison to good bearings. The fundamental frequency estimated for the inner race defect from the equation (1) is found to be 74.4 Hz (approx. 5X). The fundamental frequency for the outer race defect bearing from equation (2) is found to be 36 Hz (approx. 3X). The fundamental frequency for the roller defect bearing from the equation (3) is found to be 27Hz (approx. 2X). The results correlate very well.

## 4. CONCLUSIONS

Time waveform and frequency spectrum provide useful information to analyze defects in antifriction bearings. Time waveform indicates severity of vibration in defective bearings. Frequency domain spectrum identifies amplitudes corresponding to defect frequencies and enables to predict presence of defects on inner race, outer race and rollers of antifriction bearings. The distinct and different behavior of vibration signals from bearings with inner race defect, outer race defect and roller defect helps in identifying the defects in roller bearings.

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