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Defect Detection on Bearing by using methods of conditional monitoring & Finite element analysis.

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ABSTRACT

Rolling element bearings are frequently encountered in rotating machinery due to their sustaining capacity and low-friction characteristics. Rolling element bearings work under different conditions and frequently under heavy loadings generated in the machinery and they are subjected to time and space varying dynamic loads. The finite element analysis defect detection in rolling element bearings with single or multiple defects on different components of the bearing structure using the time and frequency domain parameters. Condition monitoring is used for increasing machinery availability and performance, reducing consequential damage, increasing machine life, reducing spare parts inventories and reducing breakdown maintenance.

Keywords— **Rolling element bearings, unbalanced force, local defects, finite element vibration analysis..**

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I. INTRODUCTION

Rolling element bearings are a common component in machinery. Therefore they have received great attention in the field of condition monitoring. Rolling element bearings are manufactured by assembling different components: The rolling elements, the outer ring and the inner ring, which are in contact under heavy dynamic loads and relatively high speeds. The Hertzian contact stresses between the rolling elements and the rings are one of the basic mechanisms that initiates a localized defect. When a rolling element strikes a localized defect an impulse occurs and this excites the resonances of the structure. The vibration signature of a damaged bearing consists of exponentially decaying ringing. These impulses will occur with a period determined by the location of the defect, the geometry of the bearing and the type of the bearing load.

II. BEARING COMPONENTS

All rolling bearings are composed of four basic parts: inner ring, outer ring, rolling elements, and cage or separator as seen in Figure 1.1. Some bearings have additional components; the guide ring and seals are used only in some special bearings.

- Inner Ring

The inner ring is mounted on the shaft of the machine and is in most cases the rotating part. The bore can be cylindrical or tapered. The raceways against which the rolling elements run have different forms such as spherical, cylindirical or tapered, depending on the type of rolling elements.

- Outer Ring

The outer ring is mounted in the housing of the machine and in most cases it does not rotate. The raceways against which the rolling elements run have different forms depending on the type of rolling elements. The forms of the raceways may be spherical, cylindirical or tapered.

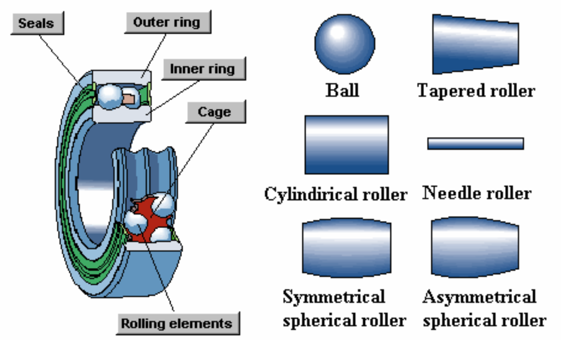


Figure 1.1 Components of the rolling bearing, Figure 1.2 Types of rolling elements

-Rolling Elements

The rolling elements may have different forms as shown in Figure 1.2. The forms of the rolling elements may be balls, cylindrical rollers, spherical rollers, tapered rollers or needle rollers. They rotate against the inner and outer ring raceways and transmit the load acting on the bearing via small surface contacts separated by a thin lubricating film. The rolling elements are made of carbon chromium steel, also called bearing steel.

III. LITERATUER REVIEW

*GuoFengWang ,Fault classification of rolling bearing based on reconstructed phase space and Gaussian mixture model., In this paper says that Rolling bearings are common and vital elements in rotating machinery and vibration signal is a kind of effective mean to characterize the status of rolling bearing fault and its severity. In this paper, a novel method is introduced to realize classification of fault signal without extracting feature vector prelim inertly. By estimating the time delay and embedding dimension of time series, vibration signal is reconstructed into phase space and Gaussian mixture model (GMM) is established for every kind of fault signal in the reconstructed phase space. After these models are built, classification of fault signal is accomplished by computing the conditional likelihoods of the signal under each learned GMM model and selecting the model with the highest likelihood. By testifying of vibration signal under different kinds of bearing status, it is proved that this method is effective for classifying not only fault types but also fault severity.

*R B Sharma, Yogesh Sharma compared experimental results and CAE results of defective and defect free bearings. The experimental investigation for the mode shapes and the critical frequencies of the cracked bearing have been obtained from the experimental test rig setup and the mode shapes experimental step up. Experimental set up consisted of motor driven shaft o which test bearing was mounted. The bearing is mounted in between the DC motor and Eddy Current Dynamometer. DAQ card was provided for further signal analysis and Lab- View software was used to interpret signal in time domain analysis. A numerical simulation of the bearing is performed using ANSYS, and practical investigations were carried out to verify the proposed measurement approach. First mode shape and second mode shape were plotted and their behavior was observed. Defect type was triangular notch of 12mm each side and 14mm base side, depth of crack was 27mm approximately. The model is evaluated for the FEM analysis under the modal analysis head, to know the resulting fundamental frequency of the cracked crankshaft using ANSYS 14.0. The comparison is drawn in between the experimental investigation and the modal analysis using CAE methodology of the bearing with & without crack. The results obtained from the simulation are approximately validates by the experimental ones.

*Defect detection in deep groove polymer ball bearing using vibration analysis ,AttelManjunath and D V Girish,The vibration analysis or condition monitoring is based on the principle that all systems produce vibration. When a bearing is running properly, the vibrations generated are very small and generally constant. But, due to some of the dynamic processes that act in the machine, defects develop causing the changes in the vibration spectrum.Firstly, Vibration signals collected in the form of time domain are converted into frequency domain by processing Fast Fourier Transform (FFT) on each of the four bearings. Vibration signals of a new bearing and defective bearings for a radial load of 30N and 60N at 1000 rpm are shown in Figure 3 and 4. The fundamental frequency theoretically calculated for the inner race defect bearing from equation (1) is found to be 79.38 Hz.

*Time- Frequency Domain Analysis

Time-frequency domain techniques have capability to handle both, stationary and non- stationary vibration signals. This is the main advantage over frequency domain techniques. Time–frequency analysis can show the signal frequency components, reveals their time variant features. A number of time-frequency analysis methods, such as the Short-Time Fourier Transform (STFT), Wigner-Ville Distribution (WVD), and Wavelet Transform (WT), have been introduced. STFT method is used to diagnosis of rolling element bearing faults.

Envelop analysis-based indexes in frequency domain Frequency domain is another description of a signal. It can reveal some information that cannot be found in time domain. Envelope detection or amplitude demodulation is the technique of extracting the modulating signal from an amplitude-modulated signal. The effects of interfering signals can be minimized by demodulation. In this work, Hilbert transform is used to calculate the envelope of a resonance component Envelope analysis is the FFT (Fast Fourier Transform) frequency spectrum of the modulating signal or envelope spectrum in other words. It is considered an excellent tool for diagnostics of local faults like cracks and spallings in rolling element bearings where faults have an amplitude modulating effect on the characteristic frequencies of the machinery. Rollers or balls rolling over a local fault in the bearing produce a series of force impacts. If the rotational speed of the races is constant, the repetition rate of the impacts is determined solely by the geometry of the bearing. The repetition rates are denoted bearing frequencies, for example, BPFO (Ball Passing Frequency Outer Race), BPFI (Ball Passing Frequency Inner Race), and BFF (Ball Fault Frequency) are frequently used. They are as follows ,

$$BPFO(Hz) = \frac{z}{2} fr \left(1 - \frac{d}{D} Cos\theta\right) \ldots\ldots\ldots\ldots\ldots(1)$$

$$BPFI(Hz) = \frac{z}{2} fr \left(1 + \frac{d}{D} Cos\theta\right) \ldots\ldots\ldots\ldots\ldots(2)$$

$$\mathrm{BFF(Hz)} = \frac{D}{2d} fr\left[1 - \left(\frac{d}{D}\right)^2 \mathrm{Cos}^2\theta\right] \quad \text{(3)}$$

Where, Z is the number of balls or rollers, d is the ball diameter, D is the pitch diameter, a is the contact angle, and fr is the rotating frequency. When a envelop spectrum is obtained, we usually examine the values of axis y according to the characteristic defect frequencies in axis x. By the background knowledge and experiences, the decision can be made where the defect locates. In intelligent ways, we learn from the experts' identification process. However, the BPFO, BPFI and BFF are not only affected by the geometries of bearings but also the rotating speed of the shaft, so it makes the tasks under different rotating speeds difficult to accomplish. Therefore, FO, FI, and FB are presented below:

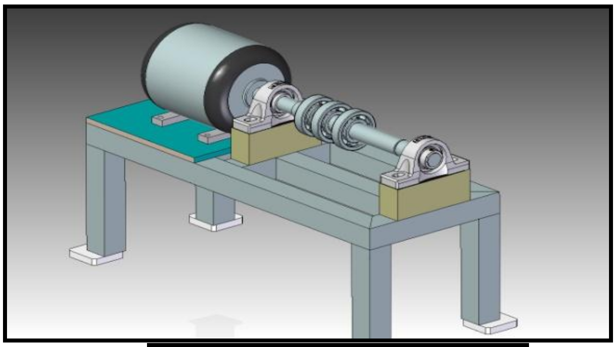
$$FO = \frac{BPFO}{fr} \quad \text{(4)}$$

$$FI = \frac{BPFI}{fr} \quad \text{(5)}$$

$$FB = \frac{BFF}{fr} \quad \text{(6)}$$

IV. EXPERIMENTAL SETUP

Experimental set up consists of motor driven spindle on which two support bearings plumber block and three test bearing are mounted. Defects on bearing are created by WEDM. Fig. 1 shows experimental setup. Most of researchers used belt and pulley arrangement for driving spindle on which test bearing is mounted. But it was found that belt and pulley arrangement will act as another source of vibration due to slight misalignment and this will corrupt vibration signal. Hence in this set up, directly shaft is connect to motor shaft and spindle carrying test bearing. Load is applied with the help of wire-rope arrangement it shows in setup. 0.5 Kg load is appliedgradually; speed regulator is use for regulating a speed.



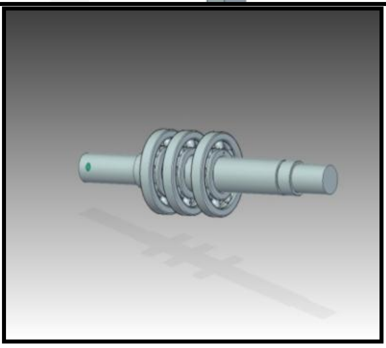


Fig.1.3 Experimental setup

A set up consists of 1/6 HP at 6000rpm single-phase motor and output shaft which is mounted on table. Radial load is applied on test bearing by wire-rope pendant. Test bearing is mounted in between two Plummer Block support bearing. The support bearings are defect free bearings and the test bearings are defective. An accelerometer with magnetic base is mounted on the test bearing. The accelerometer is connected to FFT Analyzer which processes the time signals. The output of analyzer is connected to computer which has the relevant hardware and the Lab-View Deosoft software to acquire the data. Cylindrical defect created by WEDM from 1.5mm to 2mm diameter sized defect is analyzed. Deep groove single row ball bearing is preferred. Load is varied from 5N to 20N while speed is varied from 300, 500 up-to 1000 rpm.

VI. EXPERIMENTAL RESULT

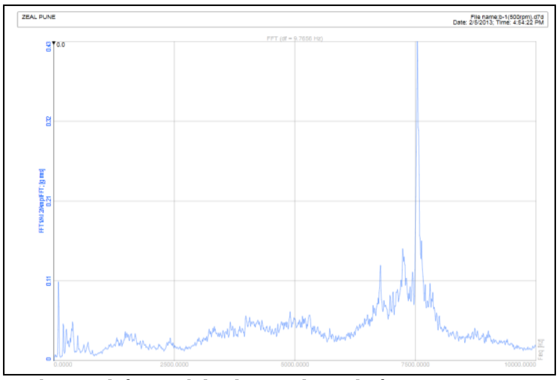
The numerical and experimental results at different speeds, loads and defect sizes are plotted and comparison has been made. It is observed that, numerical results obtained by mathematical formulas and both are validated successfully by experimental results. The peak amplitudes are obtained at inner ring defect frequency.

EXPERIMENTAL RESULT TABLE-

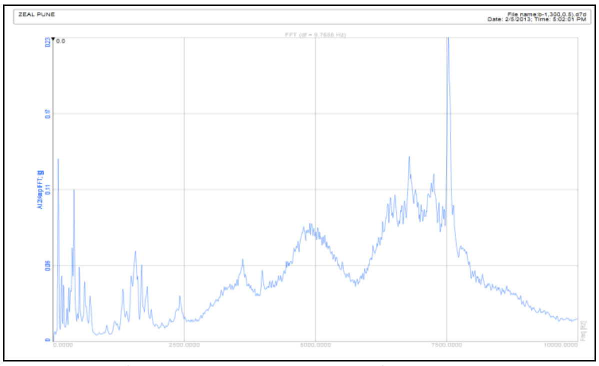
Sr.no	Bearing type	R.P.M.	Radial Load N	Theoretical Hz	Experimental " g" (Peak) value
1	B1	300	0	25Hz	0.01087 g @25Hz
	B1	300	5	25Hz	0.00713 g @25Hz
	B1	300	10	25Hz	0.00651 g @25Hz
	B2	300	0	65Hz	0.01050 g @65Hz
	B2	300	5	65Hz	0.01248 g@65Hz
	B2	300	10	65 Hz	0.01856 g @65Hz
	B3	300	0	80Hz	0.01211 g @80Hz
	B3	300	5	80Hz	0.00955 g @80Hz
	B3	300	10	80Hz	0.00622 g @80Hz
2	B1	1000	0	25Hz	0.0081032 g @25Hz
	B1	1000	5	25Hz	0.0179279 g @25Hz
	B1	1000	10	25Hz	0.0345698 g @25Hz
	B2	1000	0	65Hz	0.0150742 g @65Hz
	B2	1000	5	65Hz	0.0157572 g @65Hz
	B2	1000	10	65Hz	0.0175685 g @65Hz
	B3	1000	0	80Hz	0.0170717 g @80Hz

	B3	1000	5	80Hz	0.0086939 g @80Hz
	B3	1000	0	80Hz	0.0056236 g @80Hz

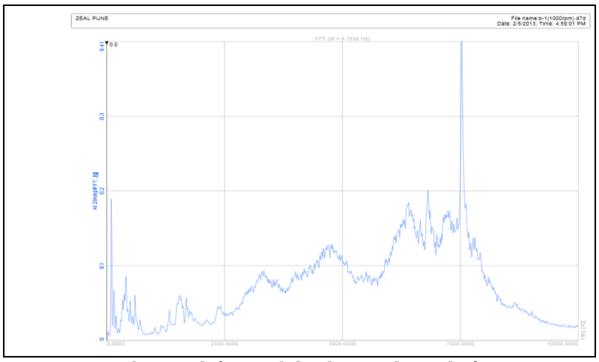
EXPERIMENTAL RESULT DIAGRAMS



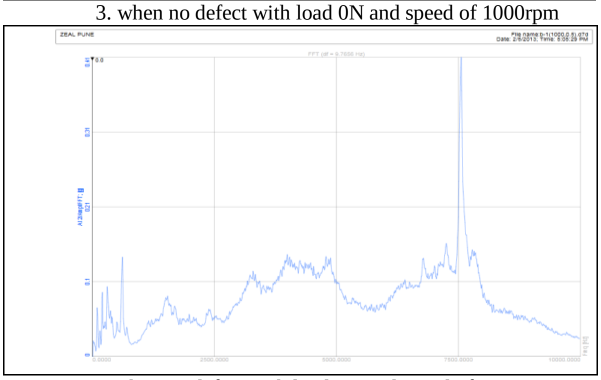
1. when no defect with load 0N and speed of 300rpm



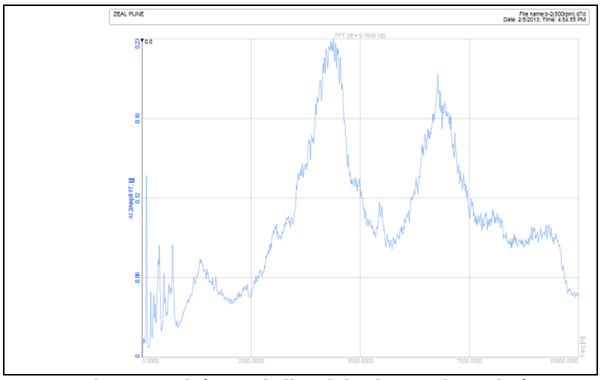
2. when no defect with load 5N and speed of 300rpm



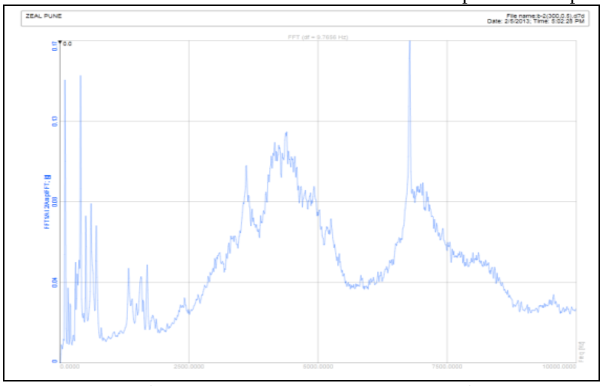
3. when no defect with load 0N and speed of 1000rpm



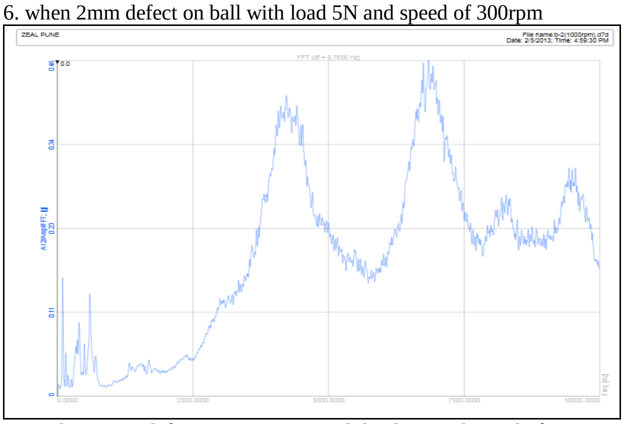
4.when no defect with load 5N and speed of 1000rpm



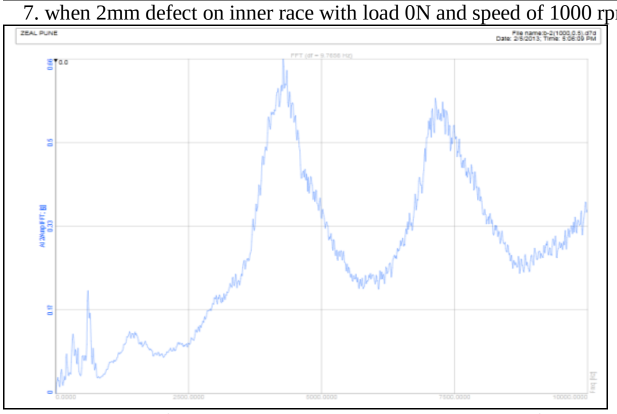
5. when 2mm defect on ball with load 0N and speed of 300rpm



6. when 2mm defect on ball with load 5N and speed of 300rpm

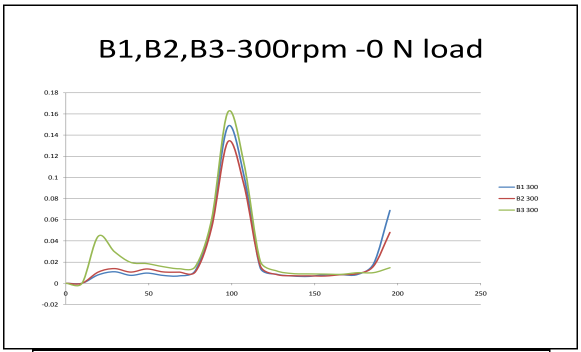


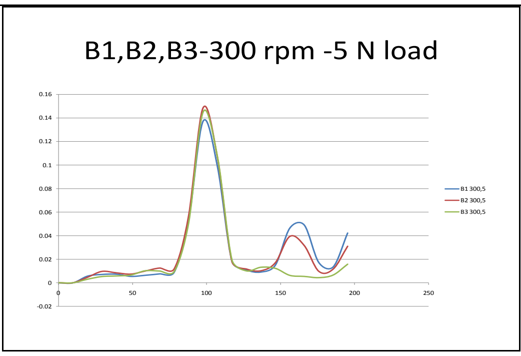
7. when 2mm defect on inner race with load 0N and speed of 1000 rpm



8.when 2mm defect on inner race with load 5N and speed of 1000 rpm

VII. ANALYTICAL RESULT BY ANSIS





VIII. CONCLUSIONS

When defect is present on inner race at constant force 5N and 300 rpm vibration level varies with increase indefect size. It is observed that, vibration amplitude increases with increase in size of defect. When defect is present onball at constant speed 300 rpm and defect size 2mm vibration level varies with change in load. . It is observedthat, vibration amplitude decreases with increase in load. When at constant speed and constant load but defect positionsare compared that is vibration amplitudes of defect present on inner race and outer race is compared, it is found thatvibration amplitude at ball is slightly less than that of inner race Hence, inner race defect is more severe. Conditionmonitoring can be done by time domain and frequency domain technique. Time data graphs are acquired andobserved. It was found that, data extraction from time domain signals is very difficult because it can detect presence of faultbut unable to detect exact location. In frequency domain analysis vibration amplitudes can be compared at bearingrace pass frequency. It was observed that, frequency domain analysis can be effectively used to detect the various sourcesof fault.

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