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"Early Detection of Faults in Bearing at Inner and Outer race using Condition Monitoring"

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Abstract : **Rotary machines rely heavily on the proper functioning of bearings. Bearing failure analysis often involves inducing artificial defects in various bearing components and examining them using vibration recognition tools to monitor the overall condition. As a localized bearing fault progresses and transforms into a distributed fault, it generates random signals with non-stationary components. This study focuses on investigating the effect of surface roughness on the vibration response of the outer ring of a ball bearing. The vibration spectrum resulting from a single roughness defect under purely radial loading at different locations of the outer ring is investigated. The study delves into the effects of roughness size, speed and load on vibration response. Findings are presented in both time and frequency domains. Experimental results are compared to the pass frequency of the outer ring balls, which shows an identical frequency response to the theoretical ball pass frequency and it will be validate using MATLAB software.**
IndexTerms **- Ball bearing; Distributed Defect; Surface roughness; Vibration analysis.**

I. INTRODUCTION

In rotating machinery, rolling element bearings are a must.If bearing problems arise while the machine is being serviced, it could bequite dangerous.Their motion and dynamics add to a machine's overall vibration.Even geometrically flawless rolling element b earings experience vibration when they are radially loaded.This is due tothe weight being carried by a limited number of rolling p arts.The total stiffness of the bearing assembly varies periodically as a result of changes in the number of rolling elements and the ir placement within the load zone caused by bearing rotation.Vibrations known as changing compliance vibrations are produced by this difference in stiffness.The vibration level does, however, significantly increase when a problem is present.There are two t ypes of bearing defects: spread and local .Misaligned races, waviness, uneven surfaces, and oversized rolling parts are exampl of distributed faults.

They are typically result of abrasive wear, incorrect installation, or manufacturing fault.On the rolling surfaces, local flaws inclu de spalls, pits, and fissures. The most common method of rolling element bearing failure is spalling of the races or rolling elements, which is brought on by a fatigue crack that starts below the metal's surface and spreads upward until a fragment of metal breaks off and leaves a tiny pit or spall . Abrupt variations in the contact stresses at the interface are the result of an element's interaction with its mate element when it has a local defect. This interaction produces a very brief pulse. This pulse generates noise and vibration, which can be observed to identify whether a bearing defect is present. Even when the local flaw increases, it spreads and produces a more complicated signal with significant non-stationary components. Bearing health is monitored using time and frequency domain approaches; nevertheless, correlation between the expected amplitude of spectral components and the amount of the defect is required for diagnostic purposes . It has been suggested that one geometric flaw caused by manufacturing error is surface irregularity, which can result from wear-induced vibration. It is crucial to find these flaws as a result. When a fault is encountered by the rolling element, the bearing system is excited. Because of this, the contact force varies between rolling components & raceway leading to a notable rise in vibration intensity. Numerous scholars conducted investigations on vibration analysis of local flaws in bearings. The literature review also identifies vibration studies that take into account a single fault on racial groups. Studying the vibration analysis of dispersed bearing faults is possible. Numerous researchers have worked on the identification of bearing faults; still, the extent of the defect must be correlated with the amplitude of spectral components. Analysis of the vibration amplitude prediction owing to scattered defects on the ball bearing's outer race is possible.

1.1. Typical frequencies of defects

Different frequency ranges are affected by the vibration that a bearing generates.Transient pulses occur periodically at frequencies that are set by the bearing's speed and geometry.The passing pulse frequencies rely on the bearing's distinctive frequencies.

The ball bearing vibrations that exhibit defects can be identified at several characteristc defect frequencies (FTF)

as follows:

FTF=1 /2 fr *[1+(d/D)*cos(□)]………………..i

Where d & D are the rolling element diameter and pitch diameter respectively. If there is a defect on the inner race, it strikes the balls which are revolving at the speed of fr. But the inner race itself is revolving with the shaft speed. During the time the bearing makes one complete revolution, the defect comes in to contact with certain numbers of the balls (z). Hence inner race defect frequency (BPFi)is given by

BPFi= z/2fr*(1+(d/D)*cos(□)) ……………….ii

In case of defect on the outer race, z number of balls strikes the defect with the cage speed of fc. . Hence the outer race defect frequency is z times the cage frequency which is given by

(BPFo) BPFo=fr*(1-(d/D)*cos(□))*z/2…………iii

Ball defect frequency (BSF) (BSF) =D/2d fr*[1-(d/D)*cos(□)]………iv

The previous equations present the four faults (FTF, BFPO, BFPI and BSF) in Hz. The (FTF) is the fundamental train frequency, while (BFPO) is the ball passing frequency in outer race. Also, (BFPI) is the ball passing frequency in inner race, while (BSF) is the ball spin frequency.

While traveling through the load zone, the rolling element and outer race fault are subject to load variations.This has the effect of varying the cage speed or the ball pass outer race frequency to modulate the impulse train.Roughness faults have a randomly distributed phase instead of an impulsive one because the rolling parts areSpecify many points at various positions on the rough surface during each revolution.

II.Literature Review

Bearing Condition Monitoring And Diagnosis Through Vibration And Artificial Intelligence Techniques, Wasimul Haque et.al, (2019),

In this paper parameter of study for cylindrical roller bearings is rotor speed. Results have been analyzed by Fast Fourier Transform (FFT), phase plot and Poincare maps. focus on use of multi-parameters, synthesis of fault features and optimization of feature sets, in order to improve fault diagnostics accuracy, which would thus enhance machinery reliability, availability, safety, and reduce maintenance costs.

Fault Diagnosis Of High-Speed Rotating Machines Using Matlab, Mahesh B. JOSHI et.al, (2023),

In this research paper the vibration behavior of physical industrial machines is obtained, and the signals are provided to a MATLAB program to identify the fault. The information helps to suggest remedies to include in the maintenance schedule. This work offers a MATLAB-based fault diagnosis for sugar industry machines. The vibration behavior of physical industrial machines is obtained, and the signals are provided to a MATLAB program to identify the fault. The information helps to suggest remedies to include in the maintenance schedule. The ease and comprehensible nature of the method reduce time and enhance the reliability of condition monitoring for industrial machines.

Vibration Analysis Techniques for Rotating Machinery and its effect on Bearing Faults Khadersab Aa , Dr.Shivakumar , (2018)

This foundational paper explores various vibration analysis techniques applied to bearing fault diagnosis in bearing. per the bearing faults induced in rotating machinery is investigated experimentally using various vibration analysis techniques that are time, frequency and time frequency domains. The input signal obtained from the rotating machinery with rolling element bearings that is ball bearing with inner and outer race defects in comparison with health bearings are analyzed with respect to Fast Fourier FFT and Inverse fast Fourier transformation and future the spectrogram are obtained. And this experimental investigation will lead to the accurate assessment of failure of rotating machineries, with respect to bearing fault.

Bearing's Early Fault Detection Using Vibration Analysis M. A. Eissa1et.al,,2018

This paper deals with condition monitoring of machines in addition to designing machine monitoring assisting tool as software for time saving. This software is presented as fast tool affording instantaneous calculations of bearing fault frequencies for different bearing types. In addition, the presented software can instantaneously calculate the basic dynamic load rating considering bearing rating life.

Condition monitoring techniques for machine bearings in non-stationary operationFrancesco Castellania,et.al,2019

This paper focusing on several types of experimental set ups are included in the present study and the advantages and drawbacks of each are discussed. For example, on one side an ad-hoc test rig for precision measurements is developed and utilized; on the other side, real scale measurement campaigns at operating non-stationary energy conversion systems (wind turbines) are performed. A special focus on energy systems is important because often in this kind of devices fault detection becomes much more challenging due to the interplay with electromechanical couplings. The collected measurements are analyzed through the most appropriate post-processing techniques employed for non-stationary signals. In the time domain, the statistical features of the signals are addressed through novelty indexes and principal component analysis. The results support that the Mahalanobis distance is an effective index in order to monitor the level of severity of the

III Experimental Analysis:

The arrangement comprises a shaft supported by the intact bearings and propelled by a variable speed motor. Positioned between two intact bearings on the shaft, the test bearing (Single row deep groove ball bearing) was situated. The drive to the test setup was supplied by a DC motor via the coupling, as depicted in Figure 3. Various speeds were achieved utilizing the control panel of the DC motor. A tensile loading mechanism was implemented to apply radial load on the faulty bearing. The outer race of the bearing was secured with the aid of a housing. To gauge the vibrations, a piezoelectric accelerometer with a magnetic sensitivity of 10 mV per-m/s^2 was employed.

Inner Bore diameter (D_i)	30 mm
Outer Diameter (D)	84 mm
Raceway width (b)	23 mm
Pitch Diameter (D)	61 mm
Ball diameter (d)	17.463 mm
Number of balls (*n*)	7

Table 1 Bearing Properties

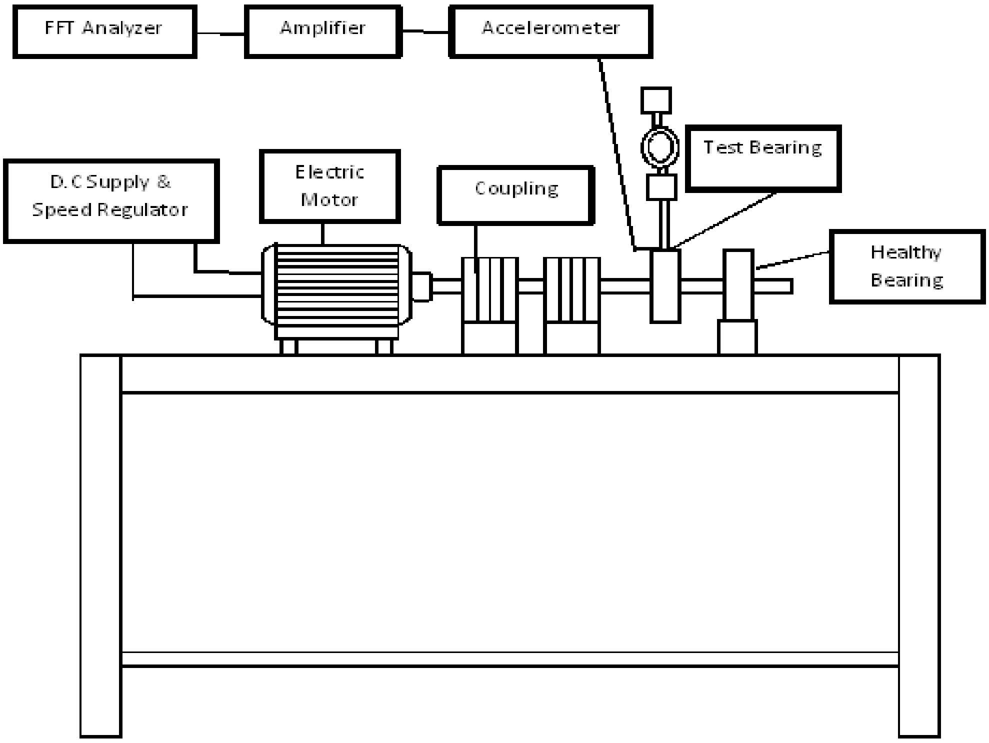

Fig.1 Experimental Test Rig

N = 4866 rpm	$(F_R)_2$=81.10 Hz	$(FTF)_2$ = 28.94 Hz
		$(BPFi)_2$ = 365.13 Hz
		$(BPFo)_2$ = 202.59 Hz
		$(BSF)_2$ = 260.07 Hz

Table 2.Theoretical Fault Frequencies

IV. Test Rig Specifications:

1.Induction Motor:

Make : Crompton Greaves
Power Supply : 3 – phase A.C. 415 V
Power : 3 H. P.

2.FFT Analyser:

Type : OR34

Manufacturer : OROS

No.of Channels: 4

V. RESULTS AND DISCUSSIONS:

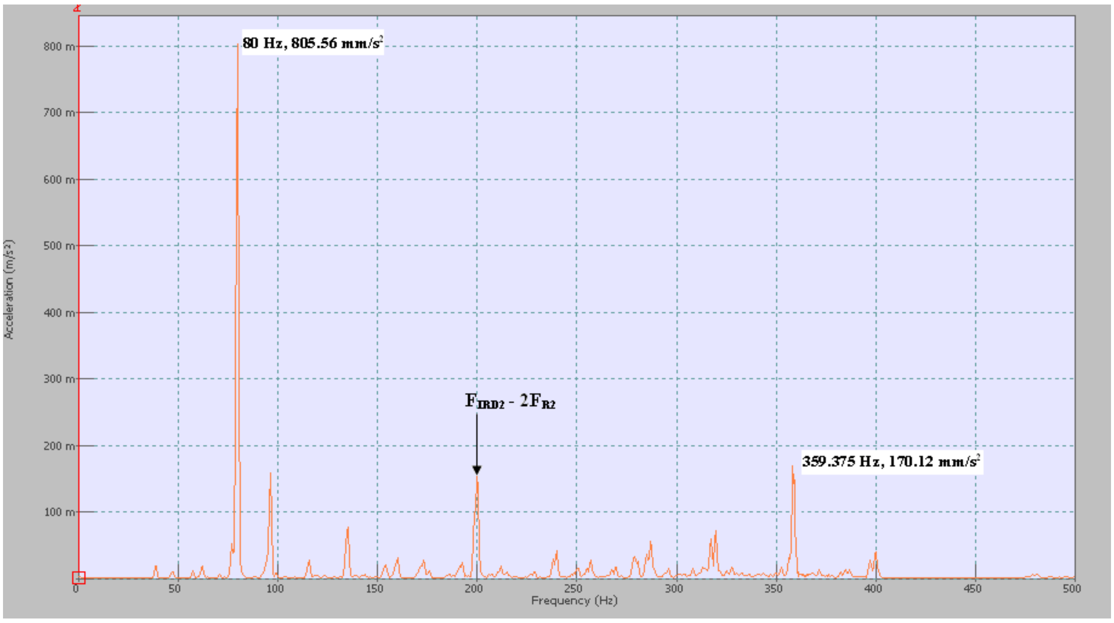

Fig 2. Spectrum of bearing with inner race defect with 20 kg load at 4866 rpm)

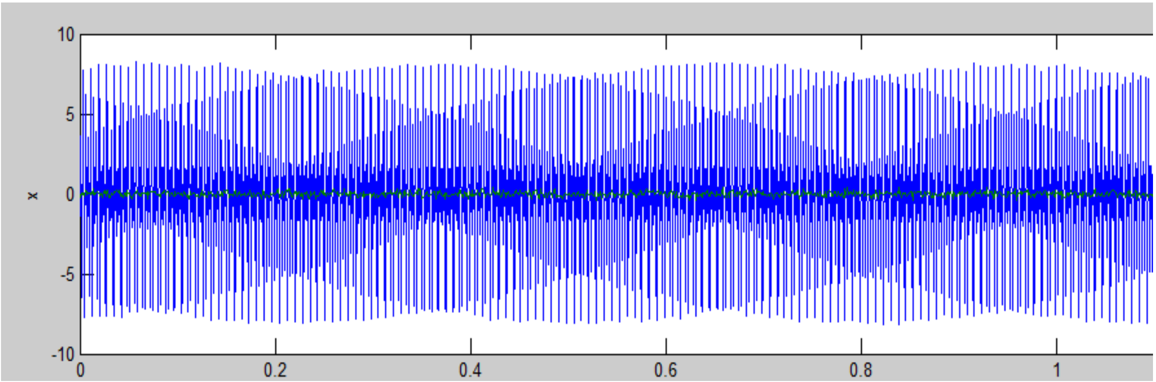

Fig 3 Time domain MATLAB output of bearing with inner race defect with 20 kg load at 4866 rpm

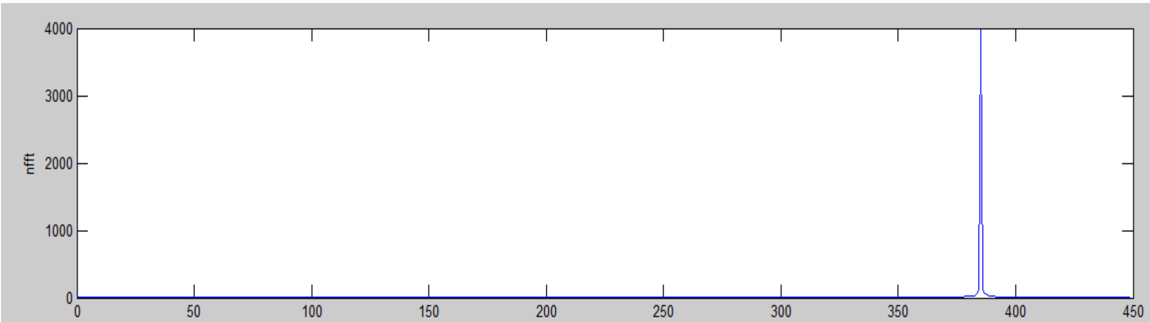

Fig 4 Spectrum of MATLAB output of bearing with inner race defect with 20 kg load at 4866 rpm

The frequency spectrum of the vibration signals from the bearing with inner race defect at speed 4866 rpm is shown in Fig.2. It shows peaks, the peak at 80 Hz is of shaft rotational frequency (F_{R2}) with difference of 1.10 Hz only and also peak at 359.375 Hz is of inner race defect frequency (BPFi) with difference of 5.755 Hz only with estimated one .The MATLAB output of same defect shows this defect frequency (BPFi) at 385.225 Hz, which varies by 20.95 Hz from theoretical and by only 25.85 Hz from measured one. This output in time domain is shown in fig. 3 and its respective spectrum in fig. 4.

VI. Conclusion :

In conclusion, the project underscores the critical importance of early detection and monitoring of defects in rolling element bearings, given their pivotal role in both domestic and industrial applications. Failure to address such defects in a timely manner can lead to significant operational disruptions and economic losses.Considering all the results and analysis, the thesis reveals that the defect in ball bearing exists at the inner race and outer race of a faulty bearing. Also it was proved that faulty frequencies obtained through the vibration analysis are similar to faulty frequencies obtained through MATLAB programming.

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