Investigation of Bearing Failures Using Crest Factor Measurement And Experimental Vibration Analysis Using FFT

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Abstract- *The paper presents experimental vibration technique for fault detection in bearings. Bearings are subjected to lower to higher rpm's in various machines. Pitting, scratching, misalignment of shafts causes these kinds of bearing wear. Health monitoring of structures deals with maintenance of mechanical parts with help of experimental vibration analysis technique. Crest factor, also called as the "peak-to-RMS-ratio", is defined as the ratio of the peak value of a waveform to its RMS value. Comparative analysis is made between damaged and smooth working Rolling and Ball bearings. FFT analyzer and accelerometer was used to perform experimental measurements in axial and radial directions. Conclusions were drawn form readings obtained out of experiment. Bearings with damages showed higher crest values as compared to that of smooth running ones.*

Keywords- bearing elements defect, Crest factor, rolling element bearing, vibration spectrum analysis

I. INTRODUCTION

Diagnose wearing parts of machines and engines, which improve the availability, safety and help to reduce material usage. The diagnosis of bearings can be used for predictive maintenance or to prevent worse damages in mechanical systems after a defect in the bearing was detected. Hybrid ball bearing implies that a ball bearing consists of ceramic balls between metal races. The advantages are lower friction, less weight of balls, higher bearing stiffness, and reduced heat generation. During operation, the bearings are subjected to heavy and dynamic loadings generated by machines and transmitted through the components of rolling element bearings. There are different methods for the diagnosis of these defects in the bearings viz. acoustic measurement, temperature monitoring, wear debris analysis and vibration measurement. For common oil lubricated metal bearings in aircraft engines, a magnetic chip detector is mounted in the oil flow to count the metal flakes. For metal bearings, vibration based damage detection is well-known. The focus in literature is the detection of break outs above 0.5mm diameter.

II. METHODOLOGY FOR DIAGNOSIS

2.1 Distributed Defects

Distributed defects include surface roughness, waviness, misaligned races and off-size rolling elements .Causes of defects are manufacturing error, abrasive wear, and improper installation. In distributed defects, the contact force between rolling elements and raceways varies which results in vibration to recognize damages successfully the choice of features are crucial. In order to detect them, the amplitude of bearing defect frequencies and their harmonics are important.

2.2. Localized Defects

This category of defects includes pits, cracks, spalls that may develop over the rolling surfaces. Of these, spalling is the dominant mode of failure. Bentley [10] in his paper showed that 90% of the total bearing faults involves damage of the inner ring, outer ring and rolling elements due to localized defects.

2.3. Sources of Vibration

Complex vibration signatures interact through a combination of rolling and sliding (The components of rolling contact bearings – i.e. inner raceway, outer raceway, rolling elements, cage).
Variable compliance vibration can be reduced to insignificant levels by using ball bearings with an accurate level of pre-axial loads.

2.4. Geometrical Imperfection

Due to the nature of the manufacturing process, geometrical imperfections are always present in the bearing components. When an axial load is acting on the bearing and rotating with moderate speed then form and surface finish of critical rolling surface are the largest sources of vibration.

2.5. Surface Roughness

High level of surface roughness compared with lubricating film thickness generated between the rolling element raceway contacts, will cause significant vibrations because asperities break through the film and interact with the opposing surface resulting in vibration.

Defects may be present in the form of indentation, scratch, pits, abrasive particles embedded in lubricants.

LITERATURE SURVEY

Vibration based diagnostic of cracks in hybrid ball bearings [1].The paper presents a vibration based diagnostic system to detect cracks in balls of hybrid ball bearings. The diagnostic system based on a Bayesian Classifier.

Roller bearing acoustic signature extraction by wavelet packet transforms applications in fault detection and size estimation [2].

Continuous online monitoring of rotating machines is necessary to assess real-time health conditions so as to enable early detection of operation problems and thus reduce the possibility of downtime. Condition monitoring of rolling element bearings, comprises four main stages which are, statistical analysis, fault diagnostics, defect size calculation, and prognostics. An in-situ synthesized model for detection of defective roller in rolling bearings [3].

In this study a theoretical model is presented for the investigation of the damage severity on the rollers in rolling bearings using theory of dimensional analysis. The functional form of the developed model is first tested by carrying out the laboratory experiments. Experimentally it is observed that the peak vibration acceleration at the characteristic defect frequency increases considerably with increase in the spall sizes. A new time–frequency method for identification and classification of ball bearing faults [4].

In the proposed procedure, firstly, as a pre-processing step, the most impulsive frequency bands are selected at different bearing conditions using a combination between Fast-Fourier-Transform FFT and Short-Frequency Energy SFE algorithms. The conclusion resulting from this paper is highlighted by experimental results which prove that the proposed method can serve as an intelligent bearing fault diagnosis system. Bearing performance degradation assessment based on a combination of empirical mode decomposition and k-medoids clustering [5]

Bearing is the most critical component in rotating machinery since it is more susceptible to failure. The extracted features are then subjected to K-medoids based clustering for obtaining the normal state and failure state cluster centers. The results demonstrate that the recommended method outperforms the time-domain features, SOM and FCM based PDA in detecting the early stage degradation more precisely. Stability-Based System for Bearing Fault Early Detection [6]

This paper presents a new and straightforward system for bearing fault detection. The system computes the stability of two vibration signals by using the direct matching points (DMP) of an elastic and non-linear align function. It is able to find discriminate properties in the stability of fault-free and faulty bearing vibration signals from the early and late stages of the fault in critical bearing parts. Experimental results validate the use of the proposed stability-based system for predictive maintenance in bearings. Automatic damage identification of roller bearings and effects of sifting stop criterion of IMFs[7]

Damage identification of roller bearings has been deeply developed to detect faults using vibration-based signal processing. Empirical mode decomposition (EMD) is one of the recent techniques adapted to this purpose; it decomposes a multi-component signal into some elementary Intrinsic Mode Functions (IMFs). One of the most relevant drawbacks in fault diagnosis is the sifting stop criterion. By extracting feature vectors for each decomposing algorithms, the accuracy of defect detection is examined by labeling the samples whether they are healthy or faulty using support vector machine (SVM).A Novel Approach Integrating Dimensional Analysis and Neural Networks for the Detection of Localized Faults in Roller Bearings [8]

The detection of the defective/worn out bearing components used in rotating machines is one of the main concerns in various applications. To improve the computational efficiency in the nonlinear dynamic analysis for the rolling contact bearings, a new methodology based on dimensional analysis (DA) theory is proposed in this paper. A comparison between the responses predicted by proposed DA method and the BPNN showed a fair amount of the agreement between the two approaches and validated the proposed model and proved outstanding tool for identification of spalled/damaged bearing components. Classification of ball bearing faults using a hybrid intelligent model[9]

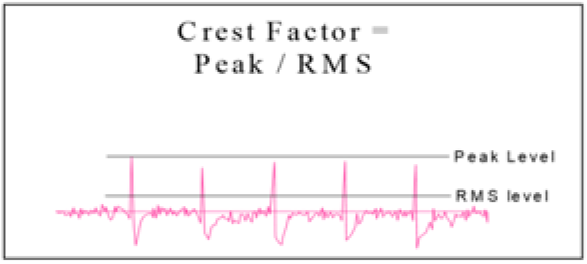
In this paper, classification of ball bearing faults using vibration signals is presented. A review of condition monitoring using vibration signals with various intelligent systems is first presented. A hybrid intelligent model, FMM-RF, consisting of the Fuzzy Min-Max (FMM) neural network and the Random Forest (RF) model, is proposed. A benchmark problem is tested to evaluate the practicality of the FMM-RF model. Fault detection analysis in rolling element bearing: A review[10] failure of machines. Hence, early identification of such defects along with the severity of damage under operating condition of the bearing may avoid malfunctioning and breakdown of machines. Defective bearings are source of vibration and these vibration signals can be used to assess the faulty bearings.

III. EXPERIMENTAL VIBRATION ANALYSIS

3.1 Crest Factor

The Crest factor, also sometimes called the "peak-to-RMS-ratio", is defined as the ratio of the peak value of a waveform to its RMS value. It is a pure number, without units. The crest factor of a sine wave is Ö2, or1.414; i.e. the peak value is 1.414 times the RMS value. A typical vibration signal from a machine with a large imbalance and no other problems will have a crest factor of about 1.5, but as the bearings begin to wear, and impacting begins to happen, the crest factor will become much greater than this. The reason that the crest factor is so sensitive to the existence of sharp peaks in the waveform is that the peaks do not last very long in time, and therefore do not contain very much energy. The RMS value is proportional to the amount of energy in the vibration signal.

Relation between crest factor and amplitude



The Crest Factor is equal to the peak amplitude of a waveform divided by the RMS value.

Crest factor in fault Detection

1. Purpose of the crest factor calculation is to give an analyst a quick idea of how much impacting is occurring in a waveform. Impacting is often associated with roller bearing wear, cavitations, gear tooth wear.
2. Higher value of crest factor indicates less life bearing; need to replace with new one.

3.2 FFT ANALYSER

The FFT or Fast Fourier Transform spectrum analyzer uses digital signal processing techniques to analyzer a waveform with Fourier transforms to provide in depth analysis of signal waveform spectra.With the FFT analyzer able to provide facilities that cannot be provided by swept frequency analyzers, enabling fast capture and forms of analysis that are not possible with sweep / superheterodyne techniques alone.As with any form of technology, FFT analysers have their advantages and disadvantages:

Advantages of FFT spectrum analyzer technology

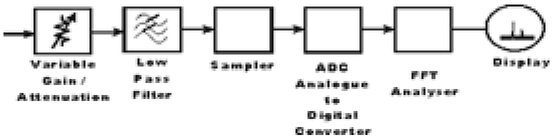
- Fast capture of waveform
- Able to capture non-repetitive events
- Able to analyze signal phase
- Waveforms can be stored

Disadvantages of the FFT spectrum analyzer technology

- Frequency limitations
- Cost

FFT spectrum analyzer

The block diagram and topology of an FFT analyzer are different to that of the more usual super heterodyne or sweep spectrum analyzer. In particular circuitry is required to enable the digital to analogue conversion to be made, and then for processing the signal as a Fast Fourier Transform.



Experimental Setup

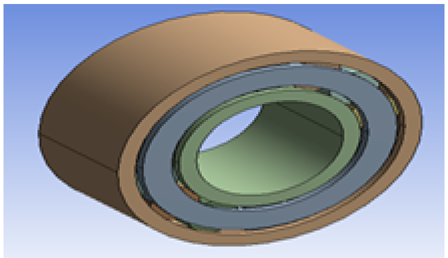


Fig. 1 Cad model for Roller bearing

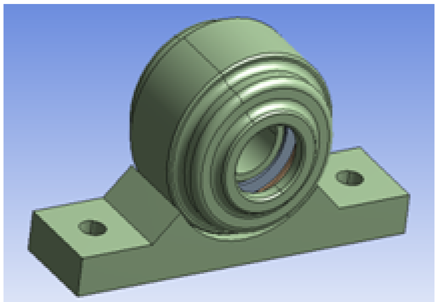


Fig. 2 Cad model for Roller bearing (with Housing)

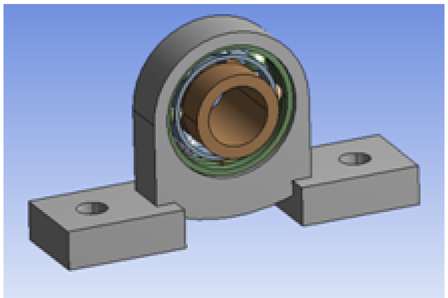


Fig.3 Cad model for Ball bearing (with Housing)

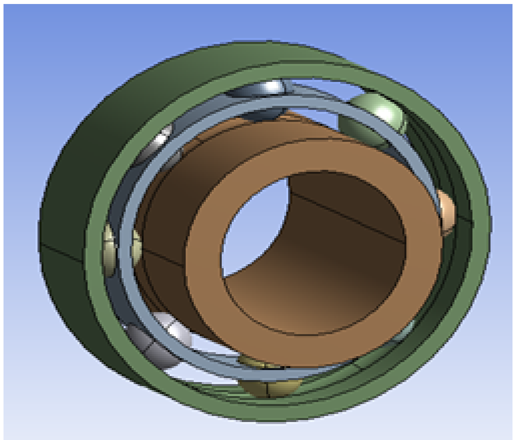


Fig.4 Cad model for Ball bearing

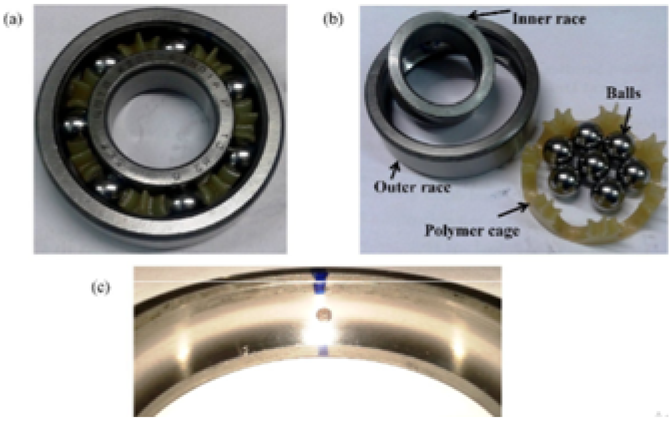


Fig.5 Image of the test bearing and the defect (a) test bearing (b) components of the test bearing (c) circular defection outer race

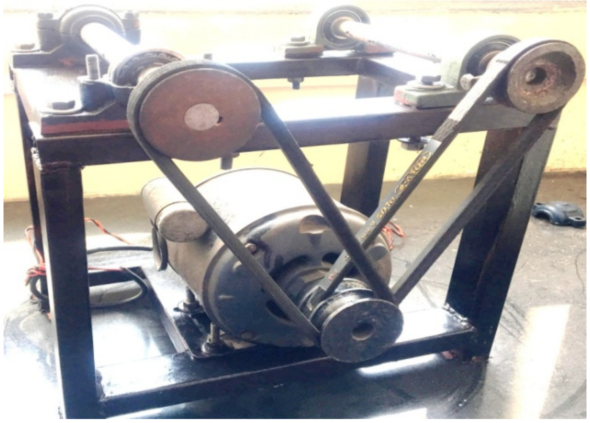


Fig.6.1 Photographic view of Experimental Setup

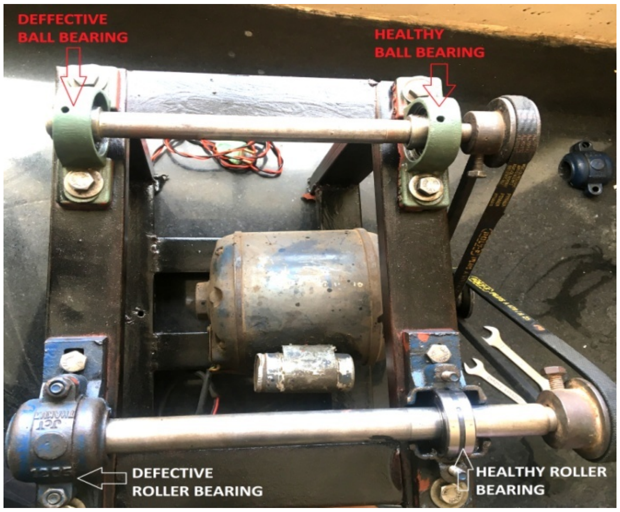


Fig.6.2 Photographic view of Experimental Setup (TOP VIEW)

OUTPUT GRAPGHS:-

- **BEARING 1 A**

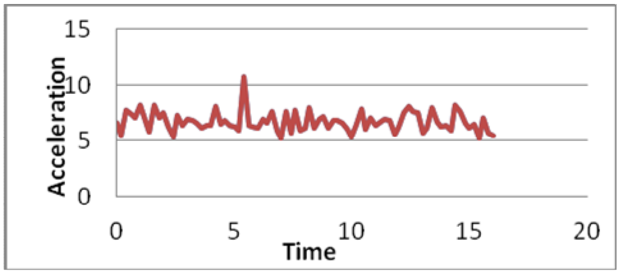


Fig 7.1 Acceleration (Y-axis) V/s Time (X-axis) for Healthy Roller Bearing in Axial direction

- **BEARING 1 R**

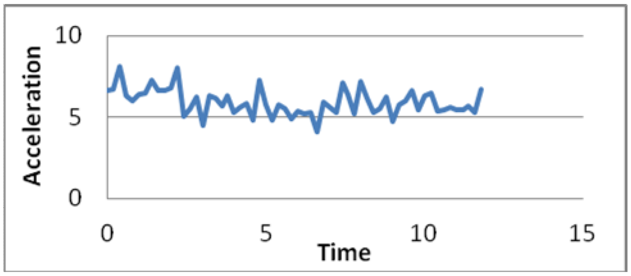


Fig 7.2 Acceleration (Y-axis) V/s Time (X-axis) for Healthy Roller Bearing in Radial direction

- **BEARING 2 A**

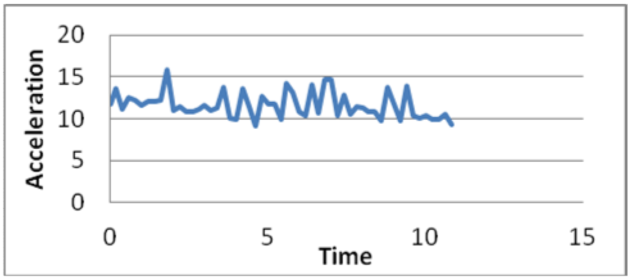


Fig 7.3 Acceleration (Y-axis) V/s Time (X-axis) for Defective Roller Bearing in Axial direction

- **BEARING 2 R**

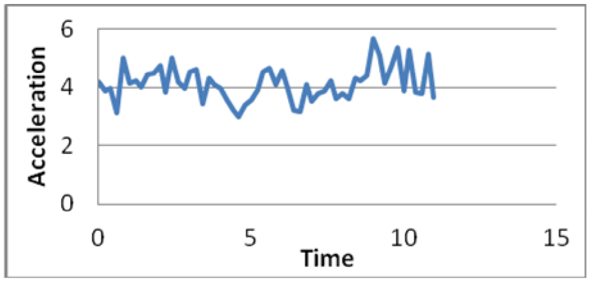


Fig 7.4 Acceleration (Y-axis) V/s Time (X-axis) for Defective Roller Bearing in Radial direction

- **BEARING 3 A**

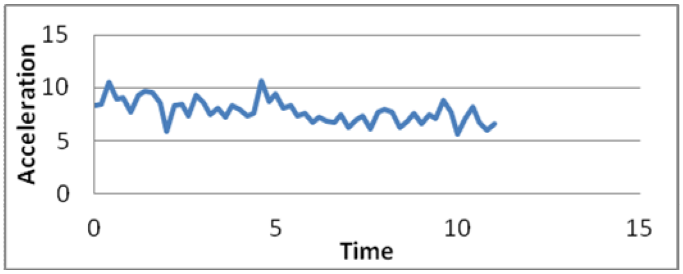


Fig 7.5 Acceleration (Y-axis) V/s Time (X-axis) for Healthy Ball Bearing in Axial direction

- **BEARING 3 R**

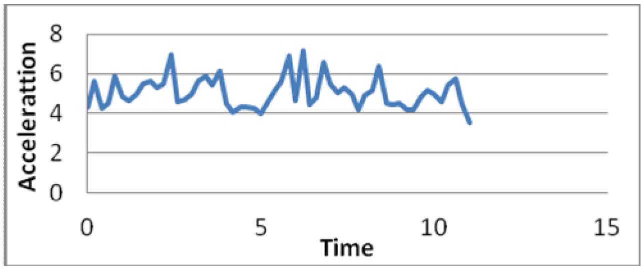


Fig 7.6 Acceleration (Y-axis) V/s Time (X-axis) for Healthy Ball Bearing in Radial direction

- **BEARING 4 A**

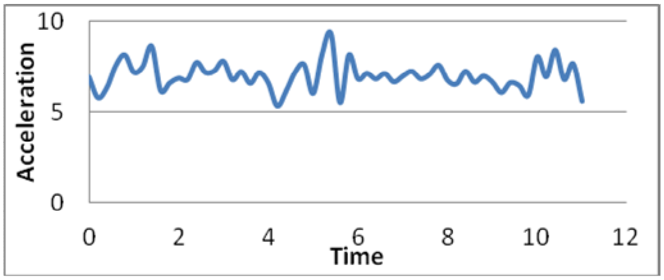


Fig 7.6 Acceleration (Y-axis) V/s Time (X-axis) for Defective Ball Bearing in Axial direction

- **BEARING 4 R**

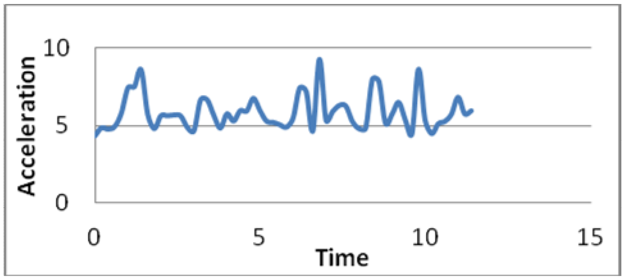


Fig 7.8 Acceleration (Y-axis) V/s Time (X-axis) for Defective Ball Bearing in Radial direction

CREST FACTORS COMPARISON

Sr. No.	Bearing No.	Crest Factor	
		Radial	Axial
1	Bearing No. 1	4.53	5.54
2	Bearing No. 2	6.63	5.093
3	Bearing No. 3	4.55	4.23
4	Bearing No. 4	5.76	4.64

IV. CONCLUSION

Value of Crest factor is more for defective bearings than Healthy bearings. With Increase in level of defect on

Rollers and Balls, vibration acceleration values shows increase in amplitude. The increased in amplitude is strong indication for damage in Roller and Ball bearings. Hence FFT analyzers can be used to analyze health monitoring for structural components

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