A Study of Ball Bearing's Crack Using Acoustic Signal / Vibration Signal and Analysis of Fast Fourier Transformation Spectrum

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Abstract— *The field of fault diagnostic in rotating machinery is vast, including the diagnosis of items such as rotating shafts, rolling element bearings, couplings, gears and so on. Vibration analysis is the main condition monitoring technique for machinery maintenance. The different types of faults that are observed in these areas and the methods of their diagnosis are accordingly great, including vibration analysis, model-based techniques, and statistical analysis and artificial intelligence techniques. However, they have difficulties with certain applications whose behavior is non-stationary and transient nature.*

Keywords— Acoustic signal, FFT, Frequency, Signal Processing.

I. INTRODUCTION

Vibration Analysis, applied in an industrial or maintenance environment aims to reduce maintenance costs and equipment downtime by detecting equipment faults. Vibration analysis is a key component of a Condition Monitoring program, and is often referred to as Predictive Maintenance. In many cases, however, vibration is undesirable, wasting energy and creating unwanted sound. For example, the vibrational motions of engines, electric motors, or any mechanical device in operation are typically unwanted. Such vibrations could be caused by imbalances in the rotating parts, uneven friction, or the meshing of gear teeth. Careful designs usually minimize unwanted vibrations. The studies of sound and vibration are closely related. Sound, or pressure waves, are generated by vibrating structures, these pressure waves can also induce the vibration of structures. Hence, attempts to reduce noise are often related to issues of vibration.

Using vibration analysis on rotating machinery enables the early detection of faults before breakdown. This will reduce economical losses to production and equipment, saving industry millions of dollars in machine down time. The evaluations of the changes in vibration response, critical speeds and stability of a machine have become an important part of most maintenance predictive programs. This will enable the condition monitoring and diagnostic of a machine; therefore repairs can be planned and performed economically. Vibration signal analysis has been extensively used in the fault detection and condition monitoring of rotating machinery. Many schemes predictive maintenance and machinery diagnostic systems use the condition machine to identify and classify faults through the analysis of vibration signals.

II. EXPERIMENTAL WORK AND OBJECTIVES

Bearing plays a role in supporting the rotating shaft. Defects in bearing may lead to decrease in transmission efficiency, jerk and noise. We have implemented method based on acoustics and vibrations data to identify the effect of misalignment of shaft in bearing arrangement. The experiments are done on the bearing in a shaft under loading conditions. The outer shell of ball bearing is covered by housing. In the present study, a system model capable of describing the theoretical dynamic behavior resulting from wear of inner race is developed during continuous working. Depending on the characteristics of the raw acoustic signal obtained from experiment, conventional filters based on Fourier transform is applied. The Fourier transform expands the original function (signal) in terms of ortho-normal basis function of sine and cosine waves of infinite duration; however the wavelet transform can do it for finite duration as well. One of the great advantages of the wavelet filtering is that the time information is not lost. And the problem undertaken has practical importance in operation, on-line inspection, failure prediction and maintenance of rotating.

A comparison between experimental and numerical results clearly indicates that validity of the theoretical model was successfully verified for wear at inner race. The results show that the fault mechanical looseness and the effect of the evolution of wear can be monitored and detected during the machine run-up without passing by critical speed. Extensive numerical and experimental results show the ability and feasibility of the application of wavelet analysis in the diagnostic of faults inserted in the experimental set-up is very suitable to non-stationary signal analysis. Finally, results show that the sensivity and efficiency in the fault diagnostic using transient response during run-up is higher than steady state response for rotating machinery.

In this project work we tried to analyze the effect of wear of inner race on the bearing on the spectrum of acoustic signal and developed a method to identify such defect. The main objective of this project work can be used in predictive maintenance to proceed further we have to know certain things which is basically the signal processing.

III. SIGNAL

Communication happens in the form of signals. Signals are transmission of energy (mechanical, electrical or light) through appropriate media. A signal that is constant and changed once conveys single information.

Amplitude, frequency and phase are the attributes of a signal that changes with time.

1. Amplitude (A), strength of the signal over time, volts, current.
2. Frequency (f) is the rate at which the signal repeats. Hertz.

An equivalent parameter is period (T), is the amount of time for one repetition, ($T = 1/f$).

3. Phase (ϕ) is a measure of the relative position in time within a single period of a signal.

IV. VIBRATIONAL SIGNAL

Every moving body contains some vibrations in that and in our project we are dealing with wear in the bearing. When the bearing are rotated with faulty condition then there is change in vibrational signal in comparison to the ideal case. This change in the vibrational signal is shown in the form of spectrum, which is useful in our analysis purpose because in our project the acoustic signal and vibrational signal occurs with each other. If the magnitude of the acoustic signal is more then it means the system has more vibrations. Here are some common causes of vibration.

V. SIGNAL PROCESSING

New technologies and applications in various fields are now poised to take advantage of signal processing algorithms. Let us understand the concept of signal processing with a short example, as we know the signals are carrier of information, both useful and unwanted. Therefore extracting or enhancing the useful information from a mix of conflicting information is a simplest form of signal processing. More generally signal processing is an operation for extracting, enhancing, storing and transmitting useful information. Two types of signal processors are there in general which are given below.

5.1 Analog signal processor (ASP): these are used to process the analog signals. And analog signals are those signals, which vary continuously in time and amplitude. Example radio and television receivers.

5.2 Digital signal processor (DSP): These are used to process the digital signals. The digital signal, which is in the form of bits and can be represented by the binary numbers.

5.3 Signal analysis:

This task deals with the measurement of signal properties. It is generally a frequency- domain operation. Some of its applications are

1. Spectrum (frequency and / or phase analysis) analysis
2. Speech recognition
3. Speaker verification
4. Target detection

VI. FAST FOURIER TRANSFORMATION (FFT)

The Fast Fourier Transform (FFT) is a powerful tool for analyzing and measuring signals. For example, you can effectively acquire time-domain signals, measure the frequency content, and convert the results to real-world units and displays as shown on traditional spectrum. By using FFT you can build a lower cost measurement system and avoid the communication overhead of working with a stand-alone instrument. Plus, you have the flexibility of configuring your measurement processing to meet your needs.

$F(s) = \int f(t) \exp -i \omega t \, dt$

$F(s)$ is a Fourier transform of $f(t)$

VII. METHODOLOGY

7.1 Design the system for acquisition of acoustic & vibration signal. A system has to be developed to record the audio signal in the frequency range of 20 Hz to 20 KHz. Mike will act as sensor and will be interfaced with the computer. The acoustic signal will be recorded and stored in the computer for the different conditions. Specific arrangements are done over the system to make it compatible for recording the vibration data signals. Vibration data signals are recorded over the digital storage oscilloscope with the aid of accelerometer.

7.2 Processing of the acquired acoustic signal. The acoustic signal will be processed in the MATLAB environment in order to improve the signal-to-noise ratio. Low pass filters (up to 500Hz), FFT spectrum and Decomposition scalogram is used for this.

7.3 Analysis of the processed signal. The processed signal will be analyzed for fault detection in bearing. A correlation of defects in terms of frequency of operation of the shaft is our outcome.

VIII. EXPERIMENT AND RESULT

In our project we are dealing with four analyses of wear at inner race of the bearing arrangement. Arrangement is tested for different defect conditions. The bearing which is mounted over the motor shaft is our main area of concern because from here we have to record our signal and following is the list of equipment required.

Set up is shown in over here:

Fig. 8.2: Experimental set up of view bearing in front

Now firstly we took a bearing with no wear at inner race. The bearing got rotated with the help of motor shaft. The RPM is checked with the help of Tachometer and the audio signal was recorded for 0.5second with the help of mike. The signal duration of 0.5 second was sample for our diagnosis. The MIKE used was connected to the Central Processing Unit with the help single pin slot. Certain wave disturbances are clearly visible by this time on the monitor screen. The recorded readings at different speeds got analyzed. FFT is drawn for their particular speeds.

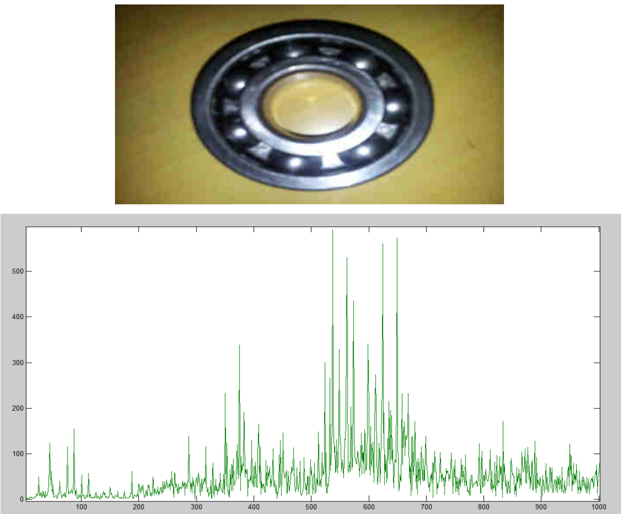

Fig.8.3: Bearing with no wear with corresponding FFT Spectrum

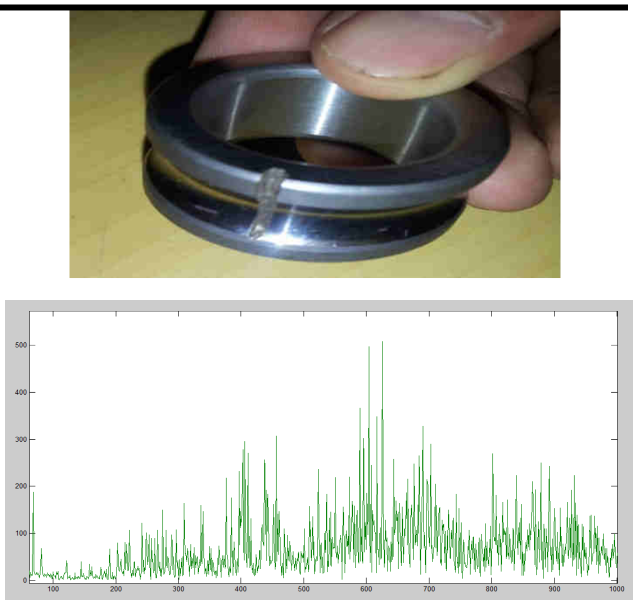

Fig.8.4: Bearing with wear of 1.5mm by width and thickness at inner race with corresponding FFT Spectrum

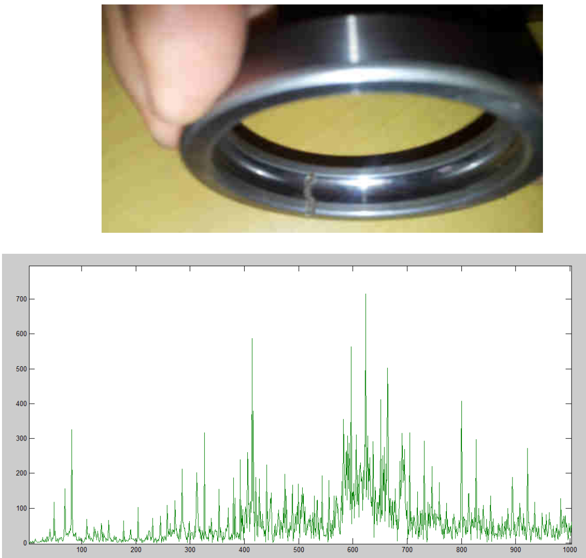

Fig. 8.5: Bearing with wear of 1.5mm by width and thickness at outer race with corresponding FFT Spectrum

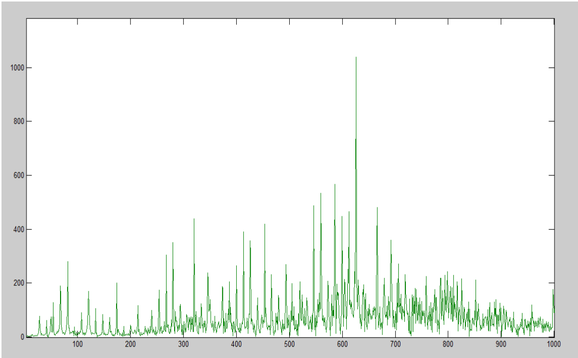

Fig.8.6:Bearing with wear of 2mm by width and thickness at outer race with corresponding FFT Spectrum

IX. CONCLUSION AND FUTURE SCOPE

Results can also be summarized in the form of FFT graph values which are same as of earlier shown in the chapter 3 but here just an expansion for the particular value is done. The significance of these plots is that we can obtain the rotational speed at any desired point and also at any instant.

These are basically FFT plots for the minimum speeds of all the four signals. Here also the value of the first peak and last peak is given in the graph itself, through which the value of the speed may be calculated.

As the speed over which frequency peaks is obtained is 1460 r.p.m. which can be converted in frequency as:

1460/60 = 24.333 r.p.s

And it defines the frequency as:

24.333*7 = 208 Hz (as number of balls are 7)

9.1 FUTURE SCOPE

This process can be used for live analysis of other machines, example internal combustion engines, Compressors, Turbines etc. we will use our this topic of vibration and acoustics for fault diagnosis in the higher studies as here a very vast scope is available.

9.2 APPLICATIONS

Applications of the method prescribe above includes:

- Condition monitoring of equipment It includes
- Railway tracks
- Machine having rotary components e.g lathe
- Fault diagnosis of rotary components like impeller, pumps etc
- Critical equipment where access is not feasible like control rod evaluation mechanism in nuclear power plant
- Also used for fault diagnosis of hard disk of computer
- Quality inspection of biscuits (like crispness testing)

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