Detection of Fault in Gearbox System Using Vibration Analysis Method

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Abstract— **In gearboxes, load fluctuations on the gearbox and gear defects are two major sources of vibration. Further, at times, measurement of vibration in the gearbox is not easy because of the inaccessibility in mounting the vibration transducers. For detecting different type of gear tooth faults a experimental data is taken from single stage gearbox set up with help of FFT analyser. Vibration analysis techniques are used for detection of fault in gear system, fluctuation in gear load such as a method for detecting the evolution of gear faults based on time- frequency analysis through Matlab. The various types of defects are created on gear tooth such as one corner defect, two corner defect, three corner defect, and Missing tooth. By comparing Signals of defective condition with healthy (ok) condition through FFT analyser in which analysis is carried out with the decomposed current signal to trace the sidebands of the high frequencies of vibration. The validation is done successful by taking input signal from FFT analyser to Matlab program for calculating effective statistical parameters in defective condition for time & frequency domain analysis. The actual position in angle of rotation for one tooth missing in gearbox is also investigated by using Matlab program. It is also helpful tool for health monitoring of gears in different conditions.**

Index Terms— **Gears, defect detection, vibration, condition monitoring.**

I. INTRODUCTION

Rotating machines are extensively used in diverse engineering applications, such as power station, marine propulsion systems, aircraft engines, etc. As rotating machinery is designed to operate at higher mechanical efficiency; operating speed, power, and load are increased as weight and dimensional tolerance are decreased. As a consequence, many practical rotor dynamic systems contain rotor elements that are highly susceptible to transverse vibrations due to fatigue which can result in catastrophic failure and cause injuries and severe damage to machinery.

Mechanical equipment fault diagnosis technology uses the measurements of the monitored machinery in operation and stationary to analyze and extract important characteristics to calibrate the states of the key components. By combining the history data, it can recognize the current conditions of the key components quantitatively, predicts the impending abnormalities and faults, and prognoses their future condition trends.

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By doing so, the optimized maintenance strategies can be settled, and thus the industrials can benefit from the condition maintenance significantly.

The contents of mechanical fault diagnosis contain four aspects, including fault mechanism research, signal processing and feature extraction, fault reasoning research and equipment development for condition monitoring and fault diagnosis. In the past decades, there has been considerable work done in this general area by many researchers. A concise review of the research in this area has been presented by landmarks are discussed in this paper. The novel signal processing techniques are presented. The advantages and disadvantages of these new signal processing and feature extraction methods are discussed in this work. Then the fault reasoning research and the diagnostic equipments are briefly reviewed. Finally, the future research topics are described in the point of future generation intelligent fault diagnosis and prognosis system.

There are different types of defect in gears such as bending failure, wear failure etc. which can lead to catastrophic failure if undetected. Vibration behavior of cracked structures, in particular cracked rotors has received considerable attention in the last three decades.

With the development of modern science and technology, machinery and equipment functions are becoming more and more perfect, and the machinery structure becomes more large scale, integrated intelligent and complicated. As result, the component number increases significantly and precision required for the part mating stricter. The possibility and category of related component failures world, and even a small mechanical fault may lead to serious consequences. Hence it is necessary to efficient fault detection and diagnosis is critical to machinery normal running. Although optimization techniques has been carried out in the machine design procedure and the manufacturing procedure to improve quality of mechanical components.

This paper deals with gear condition monitoring based on vibration analysis techniques. Gears are important element in a variety of industrial applications such as machine tool and gearboxes. An unexpected failure of the gear may cause significant economic losses. For that reason, fault diagnosis in gears has been the subject of intensive research. Vibration signal analysis has been widely used in the fault detection of rotation machinery. A possible damage in gear units can be identified by monitoring vibrations. In relation to that, different methods of time signals analyses are presented. Time-frequency methods are effective tools for analyzing diagnostics signals and have been widely used to describe machine condition. Signals have been obtained by experiments. Healthy and faulty vibration signals monitored from a gear test rig are analyzed.

II. CONDITION MONITORING

Vibration Analysis

The most commonly used method for rotating machine is vibration analysis Measurements can be taken on machine bearing casings with seismic or piezo-electric transducers to measure the casing vibrations and on the critical machines to measure the radial and axial vibration of the shaft. The level of vibration can be compared with historical baseline values to detect severity.

Interpreting the vibration signal obtained is a complex process that requires specialized training and experience. The most common method is to examine the individual frequencies present in the signal. These frequencies correspond to certain mechanical components (for example, the various pieces that make up a rolling-element bearing) or certain malfunctions (such as shaft unbalance or misalignment). By examining these frequencies and their harmonics, the analyst can often identify the location and type of problem and sometimes the root cause as well. For example, high vibration at the frequency corresponding to the speed of rotation is most often due to residual imbalance and is corrected by balancing the machine. As another example, a degrading rolling-element bearing will usually exhibit increasing vibration signals at specific frequencies as it wears. Special analysis instruments can detect this wear weeks or even months before failure, giving ample warning to schedule replacement before a failure which could cause a much longer down-time. Beside all sensors and data analysis it is important to keep in mind that more than 80% of all complex mechanical equipment fails accidentally and without any relation to their life-cycle period.

III. EXPERIMENTAL TEST RIG

Test Setup

Test performed on the single stager spur gear box (no of teeth on pinion is 26 and no. of teeth on gear is 46) which is running at 950 rpm. Module of gear is 2.5mm. The power is transferred from motor to gearbox by means o belt drive. The different types of defects are to be created on spur gear teeth like **1 tooth missing and cracked tooth**.

Rope brake dynamometer having diameter of pulley of motor 125mm is used. 3 Phase, 0.5 HP, 1440 rpm induction motor used to transfer

Figure1. Experimental Test Rig

FFT Analyser

For diagnostic of all mention defects a 4 channel fast furrier transform (FFT) analyzer and piezoelectric accelerometer is used. The readings obtained from FFT analyzer is processed with spectrum analysis & time domain analysis with its statistical parameters. Multichannel spectrum analyzer, data collector and balancer with software are used.

IV. EXPERIMENTATION

Experimental Methodology

In an experimental procedure gearbox is allowed to run at its rated power and speed by applying different load conditions on rope brake dynamometer is used. For vibration measurements magnetic base accelerometer is place on the top just below the location of bearing in axial & radial direction of gearbox.

By making all above arrangements, readings are taken for healthy gear and good lubrication condition. This data is stored in FFT analyzer for further analysis.

Vibration spectrums are taken for gears having various faults & the data is stored in computer for further analysis. For different condition of faults & different load conditions data is collected.

Formation of Fault On Gear Tooth

The one corner defect, two corner defect, one tooth missing, cracked tooth defects are the common faults in gears. The gear tooth fault generated manually on gear tooth. The crack on gear tooth generated by cutting the single tooth using hack saw. After taking reading on of cracked tooth gear then the gear tooth is cut completely and original non defective gear is replaced with this gear.

V. RESULTS

The basic aim of this project work is to design a test rig and to carry out experimentation to detect different types of faults namely broken tooth and missing tooth in a gear box. In the experimentation, vibration response measured from the gear box is analyzed to detect different faults. For this analysis gearbox rotates at loading condition and at constant speed of induction motor. Varying load is applied on the output shaft of the gear box by means of a Rope – Brake Dynamometer. The motor speed is maintained at a constant speed of 950 rpm by the Variable Frequency Drive (VFD). The vibration response from the gear box is recorded by a FFT analyzer. The response is recorded against frequency scales (FFT).

Reading are taken at diffrent load condition such as 0 kg, 1.5 kg, 2.5 kg, 3.5 kg. Accelerometer is placed on the bearings in horizontal and vertical positions.

Following figure shows the different Vibration analysis Graphs of Gearbox for Amplitude Responce and Frequency Responce at diffrent positions of the accelerometer in horizontal and vertical alignment.

Comparison of Frequency-Amplitude responses at various Loads

For Horizontal Position of Accelerometer

1. No Load condition (Graph 1)

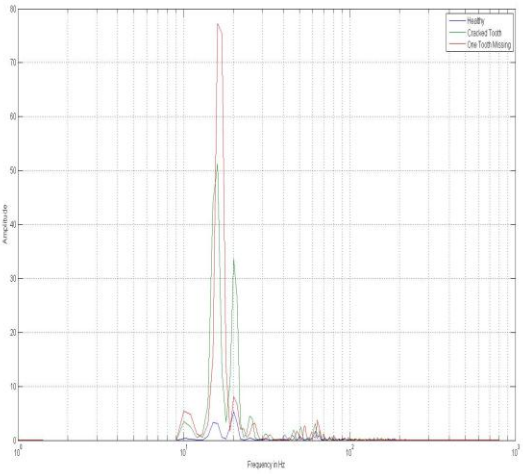

Figure 2. Amplitude vs Frequncy (No load Horizontal)

2. 1.5 kg Load (Graph 2)

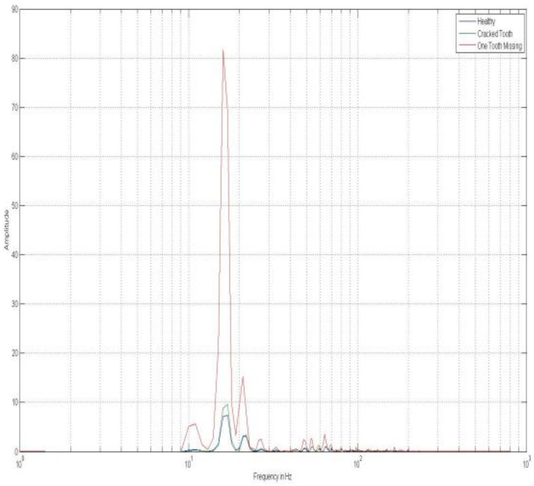

Figure 3. Amplitude s Frequency (1.5 kg load Horizontal)

3. 2.5 kg Load (Graph 3)

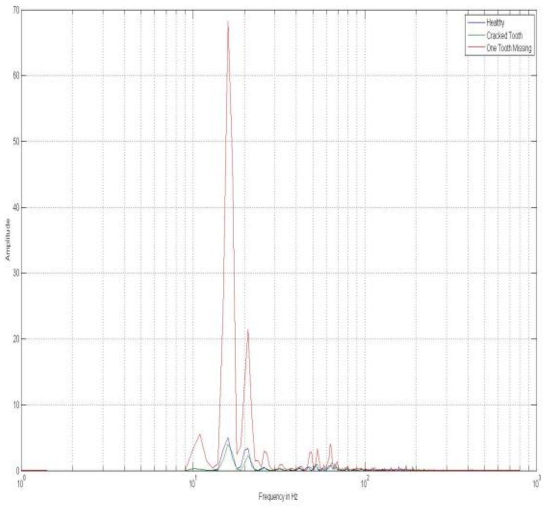

Figure 4. Amplitude s Frequency (2.5 kg load Horizontal)

4. 3.5 kg Load (Graph 4)

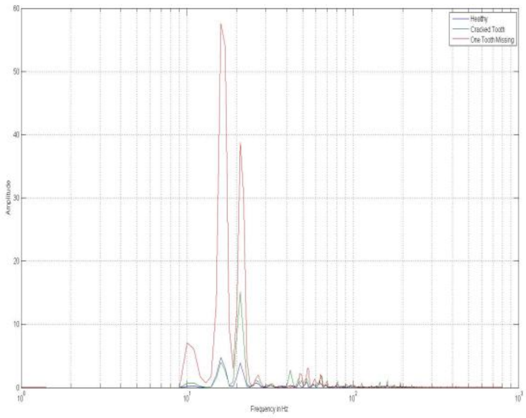

Figure 5. Amplitude vs Frequncy (3.5 kg load Horizontal)

For Vertical Position of Accelerometer

1. No Load Condition (Graph 5)

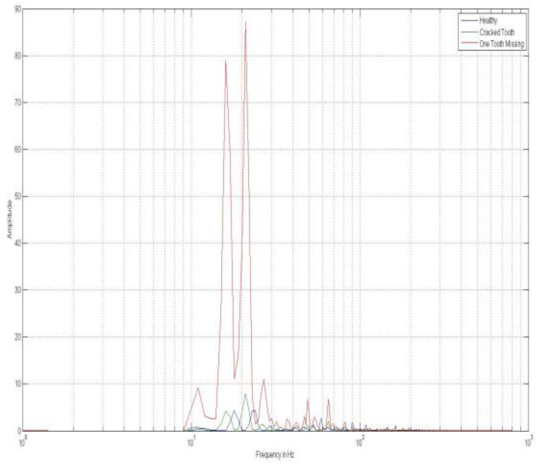

Figure 6. Amplitude vs Frequncy (No load Vertical)

2. 1.5 kg Load (Graph 6)

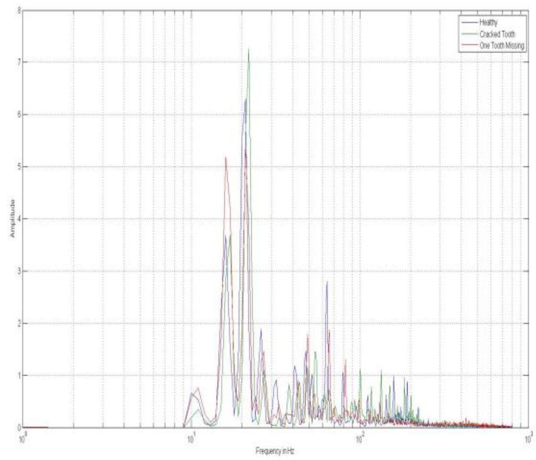

Figure 7. Amplitude s Frequency (1.5 kg load Vertical)

3. 2.5 kg Load (Graph 7)

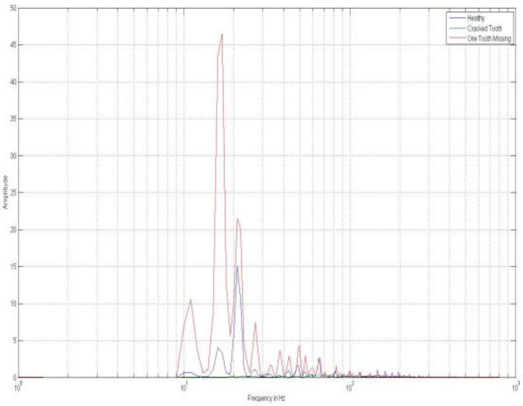

Figure.8 Amplitude s Frequency (2.5 kg load Vertical)

4. 3.5 kg Load (Graph 8)
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Figure.9 Amplitude s Frequency (3.5 kg load Vertical)

Graph obtained from MATLAB Software.

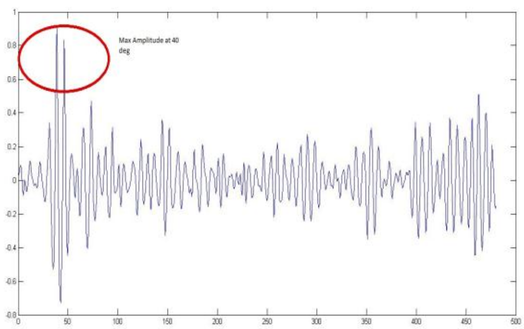

Figure 10 Amlitude vs Degrees of revolution

VI. DISCUSSIONS

After visualized these graphs, simply we can see the effect of dynamic vibration by the frequency response and amplitude response. In graphs 1 to graph 8 we can see amplitude response increasing according to gear defect. The 1st condition at which gear has no fault (healthy) amplitude response is minimum. The 2nd condition corresponds to the crack in gear tooth amplitude response is more than that for the healthy gears. The 3rd condition corresponds to the missing tooth of gear amplitude of vibration is highest and is above 50mm.

Graph 1 to graph 8 shows the comparison of the amplitude and frequency responses for various positions of accelerometers at various loads. In these graphs we can observe that the amplitude of vibrations if different for various conditions and is in the specified range, also the vertical amplitude responses are higher than the horizontal amplitude responses. The amplitude of vibrations goes on decreasing as the load on the gearbox increases.

Fig.10 shows the graph of Amplitude vs Degrees of Revolution of gearbox shaft. This shows us that at approximately 40^0 there is maximum amplitude. This shows us that there is fault in gear at approximately 40^0.

VII. CONCLUSION

After analyzing these all graphs we got dynamic vibration amplitude values for different faults. So after these result we conclude that this whole system was a modern phenomena to get defect in a gearbox. Now days this kind of modern system is used by industrial purpose. If we match vibration response of a new faulty gearbox to the response of a gearbox with known fault so we can conclude what kind of fault this gearbox has before disassembling the whole system. Big advantages of this kind of system are that we reach directly at the fault after opening the whole system. So this becomes a less time consuming process to repair a faulty sy1stem. But there is lot of study possible in this field. Because fault can be any kind like misalignment of shaft, crack in gear, and bearing crack, but here we considered only 2 kinds of faults of a gear. So for further future study we can include these defects also. So in our opinion these aspects can be taken as future work of this project.

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