A Review Paper on Fault Detection of a Gearbox

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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. Techniques such as wear and debris analysis, vibration monitoring and acoustic emissions require accessibility to the gearbox either to collect samples or to mount the transducers on or near the gearbox. But dusty environment, background noise, structural vibration etc. may hamper the quality and efficiency of these techniques. Hence, there is a need to monitor the gearbox away from its actual location, which can be achieved through Motor current signature analysis (MCSA). An efficient and new but non intrusive method to detect the fluctuation in gear load may be the motor current signature analysis (MCSA). Motor current signature analysis (MCSA) has been the most recent addition as a non-intrusive and easy to measure condition monitoring technique. This analysis system can be used for measuring the characteristics for a perfectly working gearbox and use the data as a standard for measuring faults and defects in other gearboxes.*

Keywords- MCSA, Transducer, Motor, Signature Analysis.

I. LITERATURE REVIEW

All machines with moving parts give rise to sound and vibration. Each machine has a specific vibration signature related to the construction and the state of the machine. If the state of the machine changes the vibration signature will also change. A change in the vibration signature can be used to detect incipient defects before they become critical. The use of vibration analysis as one of the fundamental tools for condition monitoring has been developed extensively over a period of approximately 35 years. With the parallel developments in electronic equipment, transducers, computers and software nowadays machine supervision is almost completely automated. The vibration techniques were developed with two main purposes. The first purpose is to separate the gearbox related signal from other components and to minimize the noise that may mask the gearbox signal, especially in the early stages of the fault. The second purpose is to identify the status of the gearbox, to distinguish the good and the faulty gear and to indicate the defective components.

The philosophy of machine condition monitoring is to monitor the state of a machine and to detect any deterioration in condition, to determine the cause of this deterioration and to predict when failure can be expected. Vibration analysis is the most commonly used technology used to monitor the condition of the machine. The frequency of the vibrations can also be mapped or represented, when certain frequencies will be present. The conditions then indicate about the impending defect of that system. Comparison of the vibration spectra of new equipment versus equipment that has been used will provide the information and make a decision, whether the maintenance is required or not.

Belsak et al, 2007; Isa Yesilyurt, 2004).The monitoring of a Gearbox condition is a vital activity because of its importance in power transmission in any industry. Techniques such as wear and debris analysis, and acoustic emissions require accessibility to the Gearbox either to collect samples or to mount the transducers on or near the Gearbox. Vibration analysis is one of the most important condition monitoring techniques that are applied in real life. Most of the defects encountered in the rotating machinery give rise to a distinct vibration pattern (vibration signature) and hence mostly faults can be identified using vibration signature analysis techniques. Vibration Monitoring is the ability to record and identify vibration Signatures which makes the technique so powerful for monitoring rotating machinery. Vibration analysis is normally applied by using transducers to measure acceleration, velocity or displacement.

Vibration signals collected from sensors and then processed are often contaminated by some noise and can thus be unusable for directly diagnosing machine faults. (Chia Hsuan, 2011) The main objective of this study is to identify and examine. Damage in gear teeth commonly found in the transmission system and establish fault detection method and pattern feature parameters from the vibration signatures.

Three major types of vibration analysis have been used in the early detection of machine failure, namely, frequency analysis, various techniques using the time domain analysis, and joint time-frequency analysis.

If we were to do a survey of the maintenance philosophies employed by different process plants, we would notice quite a bit of similarity despite the vast variations in the nature of their operations. These maintenance philosophies can usually be divided into four different categories:

- Breakdown or run to failure maintenance
- Preventive or time-based maintenance
- Predictive or condition-based maintenance
- Proactive or prevention maintenance.

1. Breakdown or run to failure maintenance

The basic philosophy behind breakdown maintenance is to allow the machinery to run to failure and only repair or replace damaged components just before or when the equipment comes to a complete stop. This approach works well if equipment shutdowns do not affect production and if labor and material costs do not matter.

2. Preventive or time-based maintenance

The philosophy behind preventive maintenance is to schedule maintenance activities at predetermined time intervals, based on calendar days or runtime hours of machines. Here the repair or replacement of damaged equipment is carried out before obvious problems occur. This is a good approach for equipment that does not run continuously, and where the personnel have enough skill, knowledge and time to perform the preventive maintenance work.

3. Predictive or condition-based maintenance

This philosophy consists of scheduling maintenance activities only when a functional failure is detected. the maintenance events can be scheduled in an orderly fashion. It allows for some lead-time to purchase parts for the necessary repair work and thus reducing the need for a large inventory of spares. Since maintenance work is only performed when needed, there is also a possible increase in production capacity.

4. Proactive or prevention maintenance

This philosophy lays primary emphasis on tracing all failures to their root cause. Each failure is analyzed and proactive measures are taken to ensure that they are not repeated.

Commonly witnessed machinery faults diagnosed by vibration analysis:-

Some of the machinery defects detected using vibration analysis are listed below:

- Unbalance
- Bent shaft
- Eccentricity
- Misalignment
- Looseness
- Belt drive problems
- Gear defects
- Bearing defects
- Electrical faults
- Oil whip/whirl
- Cavitation
- Shaft cracks
- Rotor rubs
- Resonance
- Hydraulic aerodynamic forces.

In order to provide better fundamental understanding of the vibration signatures, the frequency domain, and the joint time frequency domain. Results obtained from three different signal domains are analyzed to develop possible indicative parameters that measure the integrity and the wellness of gear components.

II. VIBRATION ANALYSIS

Time Domain Analysis:

The time domain methods try to analyze the amplitude and phase information of the vibration time signal to detect the fault of gear-rotor-bearing system. The time domain is a perceptive that feels natural, and provides physical insight into the vibration. It is particularly useful in analyzing impulsive signals from bearing and gear defects with non-steady and short transient impulses

Time waveform Analysis:

Prior to the commercial availability of spectral analyzers, almost all vibration analysis was performed in the time domain. By studying the time domain waveform using equipment such as oscilloscopes, oscillographs, or 'vibrographs', it was often possible to detect changes in the vibration signature caused by faults. However, diagnosis of faults was a difficult task; relating a change to a particular component required the manual calculation of the repetition frequency based on the time difference observed between feature points. Waveform analysis can also be useful in identify vibrations that are non-synchronous with shaft speed. In machine cost down analysis waveform can indicate the occurrence of resonance.

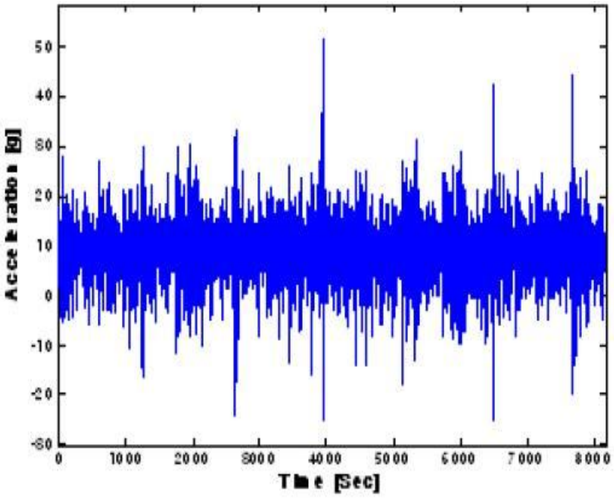

Figure 1. A typical waveform of defected gear Vibration Signal

Fast Fourier Transformation:

The Fast Fourier Transform (FFT) is simply a class of special algorithms which implement the discrete Fourier transform with considerable savings in computational time. It must be pointed out that the FFT is not a different transform from the DFT, but rather just a means of computing the DFT with a considerable reduction in the number of calculations required. The vibration characteristics of any rotating machine are to some extent unique, due to the various transfer characteristics of the machine. In the FFT plot various peaks with large and small are presented corresponding to characteristic frequencies shows the origin of defects. Or we can say FFT shows the frequencies in terms of shaft harmonics. For gear problems, special attention must be given to gear's FFT spectrum's bearing defect frequencies. The spectra of FFT may produce peaks at identified fault frequencies. These peaks may or may not represent the indicated fault. One must look for harmonics to determine if the identified frequencies were generated from the indicated fault.

If peaks appear at the fundamental fault frequency and also at frequency two times of fundamental frequency, it shows strong indication of reality of fault.

If no peak appears at the fundamental fault frequency but peaks are present at two, three, and maybe four times of fundamental fault frequency, then this also represents a strong indication that the indicated fault is valid.

FFT for Determination of the Severity of the Fault:

One way to determine the fault's severity is to compare its amplitude with the past readings taken under consistent conditions.

Another way is to compare the amplitude to the other readings obtained by similar machines running under same conditions. A higher than normal reading indicates a problem.

III. METHODOLOGY

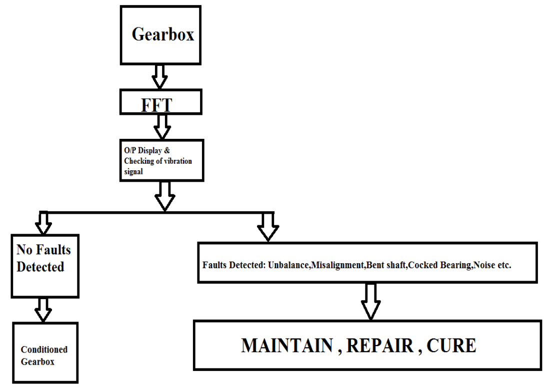

Figure 2.

IV. CONCLUSION

After the review of literature on gear fault analysis, the following points are concluded:

1. Gearbox vibration signals are usually periodic and noisy. Time-frequency domain average technique successfully removes the noise from the signal and captures the dynamics of one period of the signals.
2. Time domain techniques for vibration signal analysis as waveform generation, Indices (RMS value, Peak Level value, and crest factor) and overall vibration level do not provide any diagnostic information but may have limited application in fault detection in simple safety critical accessory components. The statistical moment as kurtosis is capable to identify the fault condition but skewness trend has not shown any effective fault categorization ability in this present gear fault condition.
3. Spectral analysis may be useful in the detection and diagnosis of shaft faults.
4. In frequency domain analysis, it is concluded that FFT is not a suitable technique for fault diagnosis if multiple defects are presents on gearbox. The envelope analysis and Power Spectrum Density techniques have shown a better representation for fault identification. The Hilbert Transform and PSD

techniques are suitable for multiple point defect diagnostics for condition monitoring.

5. Synchronous signal averaging has the potential of greatly simplifying the diagnosis of shaft and gear faults (i.e., the safety critical failures) by providing significant attenuation of non-synchronous vibrations and signals on which ideal filtering can be used. Further development needs to done on the implementation of synchronous averaging techniques and the analysis of results.
6. Expert system based on ANN and fuzzy logic can be developed for robust fault categorization with the use of extracted features from vibration signal.
7. The results further show that the waveform generation in case of multiple faults at gear contact surfaces is only useful to find the healthy or faulty condition but not capable to identify the categories of fault.

These conclusions motivate further research to incorporate other parameters and symptoms with vibration features to develop more robust expert systems for diagnose the problem of gear faults signature analysis. It has been shown that using these ways of vibration signal analysis there are possibilities to detect signal faults and distributed faults in gearboxes. A signal fault is caused by a tooth crack/fracture and breakage, a spall in a gearing or in an inner or outer race of a bearing, a spall on a rolling element of a bearing; distributed faults are caused by uneven wear (pitting, scuffing, abrasion, erosion).

The aim of this research is to advance the field of condition monitoring and fault diagnosis in gearbox operating under different load conditions. The common types of faults in gearbox are studied in the project. The various types of current based condition monitoring and fault diagnosis techniques are reviewed. The main aim of the research work is to diagnose the common mechanical faults experimentally with help of suitable signal processing techniques.

This research work investigates the feasibility of detecting mechanical faults such as bearing failure and wear gear failure, gear tooth broken failure using the spectrum of current of a motor. Defective bearings, wear gear failure, gear tooth broken failure generate eccentricity in the air gap with mechanical vibrations. The air gap eccentricities cause vibrations in the air gap flux density that produces visible changes in the current spectrum. The signal processing techniques FFT are applied to detect the bearing fault and gear faults of gearbox. Experimental results show that the characteristic frequencies could not see in the power spectrum if bearing fault and gear fault are small in size. As severity of fault increases, the characteristic frequencies become visible. In the research work, an experiment has also been conducted to detect the gear box fault.

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