Review on Condition Monitoring of Bearings using vibration analysis techniques.

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ABSTRACT – A Bearing is one of the important components in the Rotary machines and has been widely used in various industries in many of the applications such as shaft mountings, to reduce friction as well as facilitate relative motion between the two components etc. It is therefore very essential to determine the early faults conditions from bearings. There are various methods to detect faults in the bearings, such as vibration monitoring, wear debris monitoring, temperature monitoring, soap techniques, non destructive test etc. Vibration signal analysis may be one of the commonly used techniques for checking the condition and finding faults in bearings. Vibration analysis has been used as a predictive maintenance procedure in the machine maintenance. By adopting appropriate signal processing techniques, changes in vibration signals due to faults can be detected to aid in maintaining the bearings health condition. By detecting and analyzing the machine vibration, it is possible to determine and predict the machine failure. Early fault detection of the bearings is possible by analyzing the vibration signal using different techniques. This paper give a relative of various techniques used for finding the fault in the bearings based on vibration analysis method.

KEYWORDS: Bearings, Vibration Techniques, Fault diagnosis, Vibration Signature.

1.Introduction

Machine are made up of so many parts in which relative motion is transferred from one moving part to another moving part due to which generates lot of sound and vibration. According to principles of mechanisms each moving part in the machine have individual vibration signal. The signal changes along with the change in state of machine parts, due to change in the vibration signal there will be indication of fault in the machine incipient stage it can be detected and repaired before failure. This is the main application of condition monitoring. Condition monitoring is the process of systematic data collection and evaluation to identify changes in performance. The main advantage of Condition monitoring is to detect the condition of machine components by utilizing the selected measurement to identify the changes in operating Condition as depicted below.

- Condition Monitoring gives warnings before final failure.
- Condition Monitoring gives the nature of failure and information.
- Condition monitoring manages the machine life potential.
- Condition evaluates corrective action.
- Condition monitoring maintenance efficiency and risk can be avoided and hence save money

The vibration Analysis is a fundamental tool for condition monitoring. This can be done by using so many advanced electronic components such as transducers; computer and software etc. A review of so many diagnosis techniques for rotating components of machine has been presented by authors.

The two main streams of vibration techniques are first separation of signals of individual components and minimize noise in the beginning, second is to find the defective components. The various condition monitoring techniques are vibration monitoring, wear debris monitoring, temperature monitoring, soap techniques, on destructive test. In vibration monitoring, the widely used techniques are time domain analysis, frequency domain analysis, time-frequency domain analysis for determining fault and critical operation condition.

Signal Processing Techniques:

The condition monitoring system involves the signal processing techniques. There are different types of faults and processing these signals is crucial. The selection of the appropriate technique depends on the nature of the captured signal. These techniques include,

i. Time domain analysis: Time domain analysis involves the analysis of physical signals or time series of data, with respect to time. A time-domain graph is used for visualizing the change in a signal with respect to time. Time domain analysis adopts statistical analysis concept.
ii. Frequency domain analysis: Frequency domain analysis involves the analysis of physical signals or time series of data, with respect to frequency. It shows the number of signals lying within the given frequency band over a range of frequencies.
iii. Time Frequency domain analysis: It comprises the techniques used in both the time and frequency domains simultaneously. This analysis involves the study of two-dimensional signal.

2.Review

Many numbers of papers are presented on fault detection by using vibration techniques. There are three types of approaches, namely Time domain approach, Frequency domain approach, Time-Frequency domain approach.

S. I. Zakharov 2009: In this paper he studied the periodic vibrations of roller bearing and bearings test performance by considering lubrication. He also considered a special convertor and microprocessor for matching the analog signals. Correlation and regression analysis is used to determine the relations between the operational data for machines and their components. In this work they consider they required frequency of vibration testing for various roller bearings and investigate the influence of the lubricant viscosity in the drying-cylinder bearings of paper-making machines on mechanical breakdown of the oil layer, by monitoring the vibration acceleration and the electric resistance in the circuit formed by the cylinder pin and the bearing housing. They also present the structure of a simple analog-signal converter for microprocessors in data-collection systems and simple instruments indicating the state of bearings and gear transmissions.
B. I. Zubrenkov et al, 2010: In this paper the vibration excited by radial ball bearings is considered in the present work he considered regarding to avoid resonant operation in case of radial ball bearings, methods to find the Eigen frequencies and consider the oscillations of radial ball bearings. To produce new components in case of rotary machines we should know the dynamic behavior of the machines. In many cases it is necessary to reduce not only the overall level of vibrations but also specific frequencies. So such problems related to resonances which determine the vibration activity of the products. It is less difficult to reduce vibration in the production of rotary machines on roller bearings.
Roller bearings are intense sources of vibration in the low frequency range, where they form a discrete part of the spectrum, and in the high frequency range, where they appear mainly as Eigen frequencies.

In the production of machines with speeds of 1000 rpm or more, radial ball bearings are best in terms of noise and vibration.

Tunde Isaac Ogedengbe et al, 2011: In this paper he discussed regarding existing studies in the area of tool condition monitoring mainly he was observed that investigation the feasibility of using the main spindle and feed motor in the micromachining has not been carried out despite their advantage of low cost and simplicity, so this research further investigate spindle and feed motor current signals has to their ability for sensing and monitoring tool wear progression on a micro milling machine.

J Antoni and R B Randall, 2002: has differentiated bearing faults from gear faults through the analysis of vibration signals. The bearing faults are recognized as cyclostationary, whereas the gear faults are recognized as periodic. The distinction between the localized and distributed faults was also made. For localized faults pseudo cyclostationary vibration signal are produced. They can be considered as cyclostationary in first approximation. For distributed faults a specific diagnostic procedure based on advanced spectral analysis. The effectiveness of this method was checked based on experimental and actual vibration signal.

Amar Pawar, 2016, has presented the technique for detecting fault in two stage helical gear box. The aim of the work is to process the waveforms using advanced signal processing technique. This is achieved by Acoustic Emission (AE) and vibration measurement. He has presented the instrumentation of each monitoring methodology along with experimental setup. The conventional and novel parameters features of potential diagnostic value are extracted from the waveforms. The discrete wavelet transform is used for proposing innovative wavelet features. The Acoustic Emission was found to be superior to the vibration recordings of the early diagnosis of natural wear in gear systems.

Muhammad Rizal et al, 2014: This study presents a review of the state-of-the-art in sensor technologies and its application in milling process to measure machining signal for Tool Condition Monitoring (TCM) systems. Machining signals such as cutting force, torque, vibration, acoustic emission, current/power, sound and temperature from milling operation are briefly reviewed with the goal of indentifying the parameters for TCM. Sensors reviewed include both commercial and research devices that can measure machining signals. In this study describes trends in the sensor systems used and its potential for future research.

Z Karim et al, 2013: In this paper he proposed the study on condition monitoring flank wear progression of cutting tool by considering low cost piezoelectric sensors. The wear of cutting tool was measured and he used mitutoyo microscope to record the different operational condition in turning process. He also studied new tool wear by different experimental set up. He found good results between predicted and measured tool flank wear band width. This is one of the efficient and low cost methods to find flank wear which can be used in the real machining industry.

Xian feng Fan et al, 2005: He studied the combined effect of Hilbert transform and wavelet packet transform. The method is verified by the virtual signals and real vibration signals collected from a simulator. The proposed method was found to be effective in selecting the particular modulating signal and detect the early gear fault. The non-stationary signals also can be analyzed by this method. Hilbert Transform has more benefits of good accuracy, efficiency and easy fault detection as compared to wavelet packet transform.

Dejje tu et al, 2005: He studied on Empirical Mode Decomposition (EMD) and Hilbert Transform (HT) to find faults on roller bearing. By using orthogonal wavelet source the vibration signals are converted into time domain signals.The local Hilbert marginal spectrum gives the faults and its pattern. The EMD method and Hilbert transform are applied to the envelope signal. This method is better than the old envelope spectrum method.

Enayet B. Halim et al, 2008: Has presented a technique by taking the average of time domain. The periodic waveforms at different scales are extracted from noisy vibration signals by combining the time synchronous average and wavelet transformation. The local and distributed faults are eliminated

effectively at the same time. A peak in the plot of TDAS can be found due to the fault in any gear. A large peak is produced due to missing tooth and a peak with a parallel side peak at the meshing frequency results due to chipped tooth. By observing the peaks of the fault of TDAS, instantaneous multiple faults can be detected. The efficiency of the proposed technique is validated by presenting a pilot plant case study.

Kious Mecheri et al 2014: Has presented the on line monitoring of the cutting tool wear to prevent the deterioration of the machining quality. But there is not a direct method to measure the cutting tool signals by on line. So used an indirect method where wear will be estimated from the measurement of some parameters during the machining process such as the cutting force, the vibrations, etc…. In this work, a neural network system is elaborated in order to estimate the flank wear from the cutting force measurement and the cutting conditions.

M. Lokesha et al 2011: has presented Fault diagnosis in gear using wavelet envelope power spectrum. The faults in vibration signals with no stationary, transient characteristics/components can be efficiently detected using wavelet analysis**.** The diagnostic capability of FFT power spectrum and the wavelet envelope power spectrum are compared by using experimental data. They are computed using Laplace and Morlet wavelet functions respectively. A healthy and a faulty gear are used for obtaining vibration signal. The results are compared for various stages of induced gear fault. The Morlet wavelet and Laplace wavelet based enveloped power spectrum shows better results as compared to the FFT power spectrum.

Abdulrahman Abdulshakoor Bulushi et al, 2015: has analyzed the belt drive using Vibration monitoring method. The experiment was conducted to study the system for healthy and faulty running condition. Three kinds of faults where induced in the system. The faults used are, side-cut-in, side-cut-out and loose & side-cut-out. They have used a minimum speed of 540RPM and a maximum speed of 1000RPM. The relation between severity of fault, vibration amplitude and speed are explained. The running speed of the belt has an effect on the frequency of the belt drive. The intensity of the vibration increases with the increase in the RPM. The loose & side-cut-out condition recorded the maximum level of vibration.

Saurabh garg et al, 2013: Has analyzed a particle swarm optimization (PSO) technique to train an artificial neural network (ANN) for prediction of flank wear in drilling process and compares the performance with back propagation neural network (BPNN). The technique is analyzed for so many drill bits and conducted so many experiments for HSS steel work pieces under different speeds and working conditions. In his study he noted RMS valve for spindle motor as well as average flank wear in each case. The results which he got under PSO and ANN not only give prediction results and reduced computational times compared to the BPNN.

Vijay Kumar Karma et al, 2016: has used frequency domain technique to study the improper chamfering and pitting defects of spur gear. The vibration signals are obtained from spur gear in a two-stage spur gear box setup. He has used the Fast Fourier Transformation technique to determine the frequency contents of the signal for predicting the faults. The tooth faults present in the gear produces peaks and sidebands. The FFT analysis can predict the fault. But it cannot be used for determining the severity of the fault.

Jalel Chebil et al, 2011: He worked on the Time domain, frequency domain to identify the faults in the outer race, inner race of ball bearings. His study also gives comparison between other techniques used for monitor the Condition of bearings. All Bearings produces noise when the elements roll over the raceways and rub against the internal cage and flanges. The noise which is generating at high frequency and low amplitude can be measured by sensitive accelerometer, after filtering the noise signals these signals can be represented as a frequency series in real time; this is one of the regular conditions monitoring method used to measure the vibrations of roller bearings.

Nader Sawalhi et al, 2004: He worked on Spectral kurtosis, it is one of the exciting new technique used for the fault diagnostics of roller bearing. It can be used to indicate the best band to demodulate for envelope analysis. It can also be used to analyse the optimum bandwidth as well as centre frequency to maximize the kurtosis of the filter output. The spectral kurtosis can also be used to generate filters to separate the most impulsive part of a signal from stationary masking components and aid diagnosis. It can be an advantage to use prewhitening of the signal before analysis in order to best extract the bearing fault signal from the background noise.

Bing Liu, V. Makis et al, 2006, have used dynamic principal component analysis (PCA) and condition monitoring technique for the gear failure diagnosis based on vector autoregressive modeling of high – frequency vibration data and dimensionality reduction. They have used the multivariate Q control chart for the detection of localized fault on the gear. The vibration data is obtained using dynamic PCA and all useful information are extracted. Then a real gearbox vibration data is used for the implementation of a failure diagnosis scheme. When there is any damage in the gear, the gear teeth failure pattern can be indicated by the failure diagnosis scheme. Then the PCA is applied to the same data set for the purpose of comparison. The dynamic PCA indicates the occurrence of incipient fault more accurately. It also indicates actual gear condition with lower false alarm rate. The study can point out to what degree the results of the analysis can be trusted and it also recognizes the severity of failure, location of the failure on the gear.

3. **Conclusion**

The vibration monitoring technique helps to remove the noise from the signal. Time domain techniques used in vibration signal analysis develops waveform generation indices (RMS value, peak level value, crest factor etc.) and do not provide any diagnostic evidence under varying load condition. Earlier FFT analysis was commonly used concept for fault diagnosis and can predict the fault. But it cannot be used for determining the severity of the fault; also FFT analysis assumes vibration signals as stationary signals. By Artificial Neural Network (ANN) automatic fault diagnosis can be achieved. It also gives better classification of various faults in the machine components. By using Convolution Neural Network the maintenance cost can be reduced. It is also used for online diagnosis of the fault, hence providing a guaranteed continuous production. The EMD method and Hilbert transform are applied to the envelope signal. This method is better than the old envelope spectrum method. The Morlet wavelet and Laplace wavelet based enveloped power spectrum shows better results as compared to the FFT Power spectrum. The Spectral Kurtosis can also be used to generate filters to separate the signals. It can be an advantage to use pre whitening of the signal before analysis in order to best extract the bearing faults signal from the background noise.

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