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International
Journal
Of Modern Engineering Research (IJMER)

Conditioning Monitoring of Gearbox Using Different Methods: A Review

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Abstract: *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. Fault diagnosis plays an important role in condition monitoring to enhance the machine time. In view of this, the present investigation focused on the development of Fault diagnosis system of gearboxes based on the vibration signatures and Artificial Neural Networks. In the present investigation to generate the vibration signatures an experimental set-up has been fabricated with sensing and measuring equipment. The prominent faults, wear, crack, broken tooth and insufficient lubrication of the gear were practically induced in the present investigation. Vibration signatures of the gearbox were collected by transmitting the motion at constant speed with gears having no fault, without applying any load. By inducing one fault at a time, vibration signatures were collected with different degrees of wear on a gear tooth, a gear with a broken tooth, tooth with crack and with insufficient lubrication. As the vibration data of maximum amplitudes was found to be inseparable, fault diagnosis based on this data was not possible. Five prominent statistical features were extracted based on data pertaining to maximum amplitudes of vibration and used fault diagnosis. Due overlapping of this data, it was decided to use ANN based fault diagnosis system for the present investigation. The set of statistical features were extracted based on data pertaining to maximum amplitudes of vibration and used them as input parameters to the ANN based fault diagnosis system designed.*

Keyword: *Gearbox, Conditioning Monitoring, Acoustic Signals, Wavelet Transform, ANN.*

I. Introduction

Today, most maintenance actions are carried out by either the predetermined preventive or the corrective approach. The predetermined preventive approach has fixed maintenance intervals in order to prevent components, sub-systems or systems to degrade. The concept of condition monitoring is to select measurable parameters on the machines, which will change as the health or condition of a machine. Regular monitoring is done and the change is detected. Once a change is detected it is possible to make a more detailed analysis of the measurements to determine what the problem is, and hence arrive at a diagnosis of the problem [1-3].

The parameters most often chosen to detect this change in conditions either vibration, which tends to increase as a machine moves away from a smooth running condition into a rough mode with development of a fault, or an analysis of machine noise or acoustics, or machine lubricants where samples are tested for items such as wear debris from a developing fault [4-6]. There are various sensors to detect and monitor the early signals of electrical, mechanical, electronic, pneumatic, hydraulic, etc. and provide an aid to fault diagnosis and to establish an effective maintenance management procedure to predict and prevent system failure just in time [9].

Typical applications of gearboxes include electric utilities, automotive industry, ships and helicopters. A practical and robust monitoring system is critically needed to provide the earliest warning of damage or malfunction in order to avoid sudden failure. Currently, there are three approaches to the detection of faults in geared system: acoustic signal analysis, debris monitoring and vibration analysis. The vibration based diagnosis has been the most popular monitoring technique because of ease of measurement. When vibration features of component are obtained, its health condition can be determined by comparing these patterns with those corresponding to its normal and failure condition [8].

In new technique, wavelet analysis possesses particular advantages for characterizing signals at different localization levels in time as well as frequency domain. It has a wide variety of applications in many engineering fields such as signal processing, image processing, pattern recognition, seismology, machine visualization, etc. In the field of mechanical fault diagnosis, wavelet analysis has been used in gear diagnosis [7].

The time domain vibrational signal is typically proceed into frequency domain applying Fast Fourier Transform. Wavelet Transform (WT) has attracted many attention.The WT was utilized to represent all possible possibilities of transients in vibration signals generated by faults in gear box [10].

II. Condition Monitoring using Wavelet Transform

N. Baydar & A. Ball [1], have used vibration analysis is widely used in machinery diagnostic and the wavelet transform has also been implemented in many application in the conditioning monitoring of machinery. Vibration signal to detect the various local faults in gearboxes using wavelet transform, vibration and acoustic signals for detection failure of gear. Two commonly encountered local faults, tooth breakage and tooth crack, were simulated. The results of acoustic signals were compared with vibration signals.

III. Condition Monitoring using Acoustic Signals

Baydar and Andrew Ball [2], examines whether acoustic signals can be used to detect faults in gearbox using smoothed pseudo-winger-ville distribution. Three types of progressing local faults, broken tooth, gear crack and localized wear, were simulated and results are from acoustic signals were compared crack and localized were estimated.

IV. Use of Time domain techniques for vibration signal for Fault Detection in Gear Box

F. A. Andrade, et al [3], introduces a new technique for early identification of spur gear tooth fatigue cracks, namely the Kolmogorov minor test. This test works on the null hypotheses that the cumulative density function (CDF) of a target distribution is statistically similar to the CDF of a reference distribution. In fact, this is a time-domain signal processing technique that compares two signals, and returns the likelihood that the two signals have the same probability distribution function. Based on this estimate, it is possible to determine whether the two signals are similar or not. Therefore, by comparing a given vibration signature to a number of template signatures (i.e., signatures from known gear conditions) it is possible to state which is the most likely condition of the gear under analysis.

Jing Lin, et al [4], commences with technique of wavelet de-noising for mechanical fault detection. For gears and roller bearings, periodic impulses indicate that there are faults in the components. However, it is difficult to detect the impulses at the early stage of fault because they are rather weak and often immersed in heavy noise. Existing wavelets, which do not match the impulse very well and do not utilize prior information on the impulses. A new method for wavelet threshold de-noising is proposed in this paper; it not only employs the Morlet wavelet as the basic wavelet for matching the impulses, but also uses the maximum likelihood estimation for thresholding by utilizing prior information on the probability density of the impulse. This method has performed excellently when used to de-noise mechanical vibration signals with a low signal-to-noise ratio.

W. X Yang and X.M. Ren [5], studied development of an effective impulses detection technique is necessary and significant for revaluating the working condition of these machines ,diagnosing their malfunctions, and keeping them running normally over prolong periods. With the aid of wavelet transforms, a wavelet –based envelope analysis method is proposed. In order to suppress any undesired information and highlight the features of interest, an improved soft threshold method has been designed so that inspected signal is analyzed in a more exact way.

V. Condition Monitoring using Continuous Wavelet Transform

H.Zheng, et al [6], worked on new approach of gear fault diagnosis based on continuous wavelet transform is presented. Continuous wavelet transform can provide a finer scale resolution than orthogonal wavelet transform. It is more suitable for extracting mechanical fault information. In this, the concept of time-averaged wavelet spectrum (TAWS) based on Morlet continuous wavelet transform is proposed. Two fault diagnosis methods named spectrum comparison method (SCM) and feature energy method (FEM) based on TAWS are established. The results of the application to gearbox gear fault diagnosis show that TAWS can effectively extract gear fault information.

Wilson Q. et al [7], experimentally investigates the sensitivity and robustness of the currently well-accepted techniques: phase and amplitude demodulation, beta kurtosis and wavelet transform. Four gear test cases were used: healthy gears, cracked, filed and chipped gears. The vibration signal was measured on the gearbox housing and processed, online, under three "filtering conditions: general signal average, overall residual and dominant meshing frequency residual. Test results show that beta kurtosis is a very reliable time-domain diagnostic technique.

G. Dalpiaz, et al [8], worked on the detection and diagnostic capability of some of the most effective techniques discussed and compared on the basis of experimental results, concerning a gear pair affected by a fatigue crack. In particular, the results of new approaches based on time-frequency and cyclostationarity analysis are compared against those obtained by means of the well accepted spectrum analysis and time-synchronous average analysis. Moreover, the sensitivity to fault severity is assessed by considering two different depths of the crack. The effect of transducer location and processing options are also shown.

VI. Condition Monitoring using Discrete Wavelet Transform

S. A. Adewusi and B. O. Al. - Bedoor [9], presented an experimental study of the dynamic response of an overhang rotor with a propagating transverse crack using the discrete wavelet transform (DWT)-a joint time frequency analysis technique. Start-up and steady state vibration signatures are analyzed using Daubechies (Db6) mother wavelet and the results are presented in the form of scalograms and space-scale energy distribution graphs.

VII. Use of Spectral Analysis for Detection and Diagnosis of Shaft Faults in Gear Box

Darley Fiacrio de Arruda Santiago [10], concluded that 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. 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, statistical analysis and artificial intelligence techniques.

VIII. Condition Monitoring Using Artificial Neural Network

N. Saravanan, et al [11], presented the paper deals with the effectiveness of wavelet-based features for fault diagnosis of a gear box using artificial neural network (ANN) and proximal support vector machines (PSVM). Vibration signals extracted from rotating parts of machineries carries lot many information within them about the condition of the operating machine. Further processing of these raw vibration signatures measured at a convenient location of machines unravels the condition of the component or assembly under study. The statistical feature vectors from Morlet wavelet coefficients are classified using J48 algorithm and features were fed as input for training and testing ANN and their relative efficiency in classifying the faults in gear box was compared

IX. Conclusion

In this paper, authors have been presented a brief review of some current vibration based techniques used for condition monitoring in geared transmission systems. After the review of literature on gear fault analysis, the following points are concluded.

(i) 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.

(ii) 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.

(iii) Spectral analysis may be useful in the detection and diagnosis of shaft faults.

(iv) 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.

(v) 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 nonsynchronous 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.

From the literature survey it is seen that the theories are developing to detect fault of gearbox. Now it is moving towards new technique like Artificial Neural Network (ANN). Expert system based on ANN and fuzzy logic can be developed for robust fault categorization with the use of extracted features from vibration signal.

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