Support Vector Machine based Gear Fault Defect Classification using Wavelet De Noised Vibration Signal

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Abstract—In gearboxes and in all rotating elements in general, gear damage detection is often very critical and can lead to increased safety in aviation and in industry. Therefore the importance for their regular inspection and/or on-line health monitoring is growing and effective diagnostic techniques and methodologies are the objective of research efforts over the last 30 to 40 years. Gearbox is widely used in all industrial applications and hence there are many analytic techniques, which are used to prevent serious damage in a mechanical system. In general, the mechanical components produce abnormal transient signal when a fault condition occurs. These transient signals can be utilized to identify the fault in various conditions. These fault diagnosis techniques are mainly based on sound emission and vibration signals in time and frequency domains, some more advanced studies are continuous wavelet transform and discrete wavelet transform (DWT) can effectively detect weak impulse signals for fault conditions and hence wavelets can be used for the fault diagnosis of gearbox.

Keywords: Wavelet De Noised Vibration Signal, Support Vector Machine

I. INTRODUCTION

Gear drives are one of the common power transmission systems present in various kinds of rotating machinery and control systems. The service life of a gear system depends upon a number of factors like, lubrication, design, contamination, environment etc. Lubricating oils are used in a gear system to reduce friction and wear by creating a film of material between the gear teeth. If the lubricant film at the gear teeth contacting surfaces removed, the heat and wear on the gear teeth increases rapidly thereby causing various wear mechanism such as micro pitting, abrasive wear spalling, etc. The wear on the gear teeth reduces stiffness in the gear teeth contact and such an operating condition alters the vibration and sound signals of a gear system. In the last several years several researchers have published their research articles on detection and diagnosis of elements of machine such as gears, and cams. But very few researchers focused on the combination of condition monitoring techniques which provide more reliable fault diagnostic information. Condition monitoring is nothing but periodic or continuous assessment of the condition of a machine component while it is running. Condition monitoring allows action to be taken to avoid the failure or maintenance to be scheduled, before the failure occurs. It will reduce the cost also rather than allowing the machinery to fail which is loss in terms of cost also. Condition monitoring basically is a process of monitoring some of the parameters of the machinery, such that a significant change in the parameter can give information about the health or condition of the machinery.

II. EXPERIMENTAL DETAILS

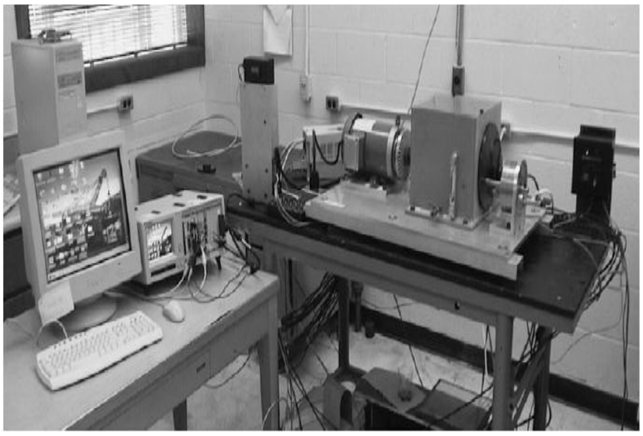

Fig. 1: Experimental Details

The setup consists of loading system, gear box, motor, bearing and coupling. The shafts of 25mm diameter connect gears with motor and loading system. The Gear mesh frequency (GMF) is calculated as 23*2500/60 =958.33Hz. The data is collected from gear box using the accelerometer (model 621B40, IMI sensors, and frequency range up to 18 kHz) with a NI Data Acquisition Device. The vibration signal is extracted from a healthy gear at speed of 2500 RPM under constant load condition. Further faults are induced and the vibration readings were taken accordingly. The frequency of 50Hz and 30Hz was used to collect the vibration data for two seconds.

III. WAVELET BASED DENOISING

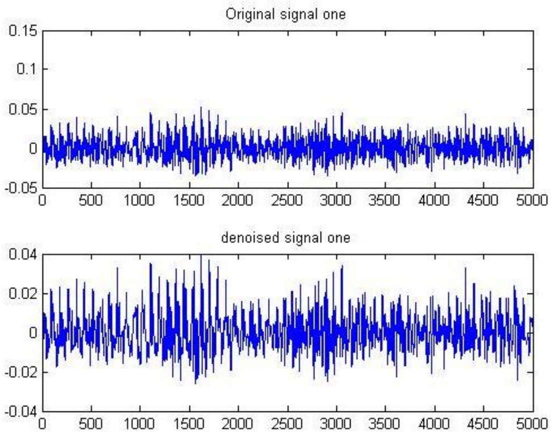

Fig 2: Graph

The main aim of the denoising is to minimize the influence of noise without affecting the information of raw signal of parts. Vibration analysis is very important tool to identify the defects and faults in rotating elements Wavelet based de-noised is used to eliminate the noise in order to keep the useful signal. In this paper the gear vibration signals have been denoised by using soft thresholding by Conventional Soft Thresholding (CST) scheme readily available in MATLAB wavelet tool box, where the threshold is selected based on SURE, In CST, suppression of detailed coefficients is done.

The signal energy and kurtosis values for the raw and denoised vibration signal for three conditions of bearing are shown in the table.3.1

S.No	Gear Condition	K(raw)	K(Denoised)
1	BG50H	6.7485	5.2557
2	GG50H	4.3343	4.0931

It is clear that kurtosis values for denoised vibration signals are less when compared to raw vibration signals for normal gear. Also the values of Kurtosis are high for defective gear when compared to normal gear for both raw and denoised vibration signals and can be used as an indicator to detect the presence of defects in gears.

IV. FEATURE EXTRACTION

Feature extraction is a process performed on the denoised signal. Its aim is to obtain a suitable transform of data to enhance the further process i.e. for classifications. Extraction of features is important in to get high accuracy of classification. We can say if the feature extraction is good, higher the classification accuracy. Vibration signal data (260000 × 1) has been divided into 50 non-overlapping bins with each bin having 50000data.

The signals are divided into multiple windows of size "winsize" and the windows are spaced "wininc" apart. Extract the features these include: Energy, Variance, Standard Deviation, and Waveform Length. Using a window size of 128 at 32 increments, features are extracted from the wavelet tree. I assumed 10 decomposition levels (J=10) in my code. For a full tree at 10 levels we should get 11 features as we are extracting 4 types of features then we get 11 x 4 =44 features.

V. SVM BASED GEAR DEFECT CLASSIFICATION

In 1992 the Support Vector Machine (SVM) classification method introduced by Vapnik Boser, and Guyon, is a state-of-the-art. [9] It is used to deal with high dimensional data. If we want to use SVM effectively first we have learn how its work. A number of decisions have to take for training an SVM. Performance may reduce due to uninformed choices.
Support vector Machine can be effectively apply for following types of data

– Data which is easily Separable
– Data which is non-separable

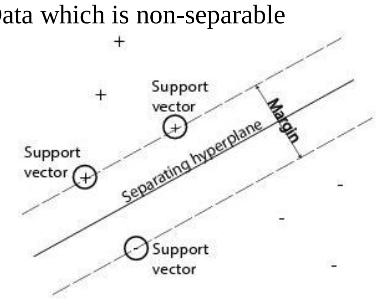

Fig. 3: SVM

Vapnik has shown that if the training features are separated without errors by an optimal hyper-plane, the expected error rate on a test sample is bounded by the ratio of the expectation of the support vectors to the number of training vectors. The smaller the size of the support vector set, more general the above result. Further, the generalization is independent of the dimension of the problem. In case such a hyper-plane is not possible, the next best is to minimize the number of misclassifications whilst maximizing the margin with respect to the correctly classified features.

VI. RESULTS AND DISCUSSION

The SVM's performance in terms of accuracy on training and test data were recorded for the four types of feature sets shown in table. Vibration signals acquired for four gear conditions were denoised by wavelet based denoising schemes. Features extracted were used as input to SVM.

S. No	**Classification**	**Kernel function**	**Training Efficiency (%)**	**Testing Efficiency (%)**
1	GG50H Vs. BG50H	rbf	94.93	94.29
2	GG30H Vs. BG30H	rbf	93.53	93.53
3	GG50L Vs. BG50L	rbf	94.93	94.29
4	GG30H Vs. BG30H	rbf	94.93	94.29

Table 1: Classification

GG50H=Good gear at 50Hz at high speed, BG30L=Bad gear at 30Hz at low speed.

VII. CONCLUSION

Fault diagnosis of gear box is one of the core research areas in the field of condition monitoring of rotating machines. The method developed using SVM carry out the fault diagnosis of the gear box efficiently. The use of SVM is found to be extremely useful in fault diagnosis of rotating equipment like gear box.

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