Bearing Fault Diagnosis Using Continuous Wavelet Transform and Artifical Neural Network

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Abstract- *Bearings are widely used in various types of machines ranging from simple fan motors to complex turbines. Bearing faults are a common cause of failure in any rotating machinery. These faults are caused due to manufacturing defects, improper mounting, insufficient lubrication, foreign particles, bearing misalignment and so on. All mechanical systems generate vibrations and these vibrations generate a characteristic signal. Any variation from this characteristic signal is an indication of a defect. Therefore, an early detection of bearing defects helps in preventing machinery malfunction and efficiency. So, this paper explores a way of generating patterns of the phenomena associated with vibration of faults using Continuous Wavelet Transform (CWT) and Artificial Neural Network (ANN). These patterns may be used as an indication of bearing faults.*

Keywords- Bearing Faults, Condition Monitoring of Bearing Faults, Continuous Wavelet Transform, Neural Network.

I. INTRODUCTION

Bearings are widely used in various types of rotating machines daily to carry out various processes. So, usually when a machine breakdown it may be because of faulty or worn out bearings. Hence an early detection of these faulty bearings has steadily garnered importance over the years.There are several methods available to inspect raw vibration signals coming out of a working machinery which with the help of classical signal processing techniques and intelligent systems can be used to provide an effective bearing fault diagnostic technique which is critically needed for a wide array of industries for early detection of bearing defects so as to prevent machinery performance degradation and malfunction.

With advent of new computing tools and Artificial Intelligent techniques the signal processing techniques have become more intelligent and responsive to the minor changes the operating conditions thus giving their ample opportunity to investigate and meet the precise requirement of the industry easily.

In this work, a test rig is setup and run with healthy and faulty bearings for generating vibration signals for different bearing faults. Then, Continuous Wavelet Transform (CWT) and Artificial Neural Network is used based these vibration signals [1] to generate patterns for different types of bearing faults and classify them accordingly.

1.1 Condition Monitoring of Bearings.

All operating mechanical machines and systems create a general characteristic signal while operating. Any changes in the operating conditions (even the smallest one) indicates a small difference in the signal from the normal or healthy signal can be seen as a fault development. Condition Monitoring (CM) is the procedure of monitoring a parameter of condition in machinery, such that any small changes in a machine's condition is indicating a developing defect. These systems help in taking the proper corrective measure to evade catastrophic failure caused by the faulty elements. However, a deviation from a normal value will happen to indicate the hidden faults with the system effortlessly [2]. These indicated small changes in a machine's operating condition is so small that they are usually hidden by the background noise in the system. Therefore, condition monitoring involves the process of combining powerful transducers and signal processing techniques to differentiate between the background noise and the operations to detect the presence of a fault at the earliest stage and also predict the future time of the failure event [3].

Rolling element bearings are widely used in all rotating machines like pumps, motors, fansetc. Therefore, these are a very critical component of any machine. But like all mechanical parts bearing tend to wear out because of manufacturing defects, improper mounting, insufficient lubrication, foreign particles, bearing misalignment gradually so adoption of condition monitoring techniques like Vibration Analysis might help in identifying it beforehand itself [4].

1.2 Vibration Analysis of Bearings

As mentioned above the working machines give out vibration and it found that in case of rolling element bearing one of the main reason for failure is the localiseddefects [5]. The vibration signal of these bearings got from the transducer will be complex will and contaminated by background noise hence processing of the signal is necessary to extract useful information related to any bearing fault [6] They are many signal processing techniques available and all fall into one of three categories: time-domain, frequency-domain and time-frequency domain.

It is seen that the time frequency domain's wavelet technique is the most effective extraction of feature [5] and continuous wavelet transform available in the MATLAB software is ideal to be applied to healthy bearing along with bearings with inner race, outer races, cage and ball faults to obtain the characteristics plots of the bearing faults.

1.3 Artificial Neural Network

An artificial neural network (ANN) is a computational technique that has the ability to model relationships between the process variables, given sufficient number of values for the input and the corresponding output values. [6] An ANN with enough number of values set for inputs and outputs variables can be used to predict the unknown output values of some other input set. This feature of ANN can beneficial in identifying the faulty bearings.

II. EXPERIMENTAL SETUP AND PROCEDURE

2.1 Experimental setup

The experimental setup used in this experiment consists of 1HP induction motor which is fixed at 1410RPM and an extended shaft is mounted on the main shaft of the motor so that the seeded fault bearings can be mounted on the shaft for taking vibration data for different loads of the loading arm. In this experimental setup a DYTRAN 3041A2 accelerometer is used to capture the vibration data from bearing housing, the faulty bearings are mounted on the shaft and they are covered by the bearing housing and the accelerometer is mounted on the housing. In order to collect data from the accelerometer it connected with an accelerometer amplifier and a data acquisition unit which is compatible with MATLAB R2017 [7] where the data can be captured and processed as shown by figure 2.

Figure 2- Experimental setup

2.1.1 Rolling element bearings

The Bearings used for this project is an Unsealed Cylindrical Roller Bearing (N304 type) manufactured by INDIAN METAL BEARING LTD is shown in Fig 2.1. The inner and outer diameter of the bearing is 20mm and 52mm with a thickness of 15mm.

Fig 2.1 Cylindrical Roller Bearing (N304)

Fourteen of these N304 type bearing was procured are various types of faults are seeded by a laser marking machine. Indentations was made on the inner race, outer race and the roller of the bearing as shown in figure 2.2(i), (ii) and (iii) for simulating the bearing faults.

Fig 2.2(i) Outer defect (ii) Inner race defect (iii) Roller Defect

2.1.2 Loading of the test rig.

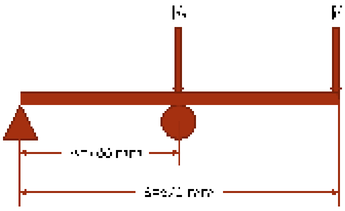


Fig 2.3 Schematic Diagram of testrig load

The schematic diagram of the test rig as shown in figure 2.3 who's load arm consists of a circular plate at the end to hold weights for loading of the bearings. By the following formula, the weights to be placed on the load arm is calculated below –

$$F = F_L \frac{A}{B}$$

- If load to be applied is 26.2% of rated loading which is 4.9KN for the bearing in this project, then

F = 0.262 X 4.9 = 1.2838KN = 1283.8N

$F = F_L \, {}^{A}/_{B} = 1283.8 \, \frac{180}{675} = 342.34N$

Weight (W_L) = ${}^{342.34}/_{9.81}$ = 34.89kg = 35kg

So, the weight used on the loading arm is 35kg.

2.1.3 Accelerometer and Data Acquisition unit

An accelerometer is a device that measures proper acceleration ("g-force"). Proper acceleration is not the same as coordinate acceleration (rate of change of velocity). Accelerometers have multiple applications in industry and science. Highly sensitive accelerometers are components of inertial navigation systems for aircraft and missiles. Figure 2.4 (i) shows a DYTRAN 3041A2 accelerometer is used in the experiment and Figure 2.4 (ii) shows the accelerometer being attached to the bearing housing which on vibration recodes the time and frequency domain values into an excel sheet of a laptop through the Data Accusation Unit and the Accelerometer amplifier as shown in figures 2.4 (iii) and 2.4 (iv).

These time and frequency domain values recorded by the accelerometer is imported into MATLAB R2017a software to perform Continuous Wavelet Transform (CWT) for detection of the bearing faults and an Artificial Neural Network (ANN) to classify them with the healthy bearing as reference.

Fig 2.4 (i) DYTRAN 3041A2 Accelerometer

Fig 2.4 (ii) Housing with Accelerometer

Fig 2.4 (iii) Accelerometer Amplifier

Fig 2.4 (iv) Data Acquisition Unit

So, the weight used on the loading arm is 35kg.

2.1.4 Data handling in MATLAB

After the data was acquired in the time domain, they were imported to MATLAB R2017a using the excel sheet import function.

Using our signal algorithm and the in built CWT and ANN function the results was processed and is discussed below.

III. RESULTS AND DISSCUSSION

3.1 CWT Results

The signature generated in the CWT graphs of different conditions can easily be used to differentiate between the location of the line defects and the magnitude of the defect. The normalized frequency range of interest lies between 0.0078125 and 0.015625 cycles/sample. The bands above and below are noise signals due to vibrations of the test rig and motor and other environmental factors that could not be controlled.

The signature generated in the Frequency graphs of bearings at different conditions show the variations in frequency peaks with respect to different location of faults. The frequency range of interest lies between 15 to 25 Hz. The peaks in frequencies higher and lower are mostly due to the noisy data.

The CWT plots for the healthy bearing and faulty bearings are shown below in figures.

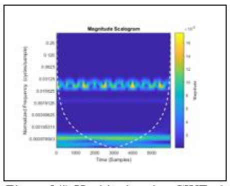
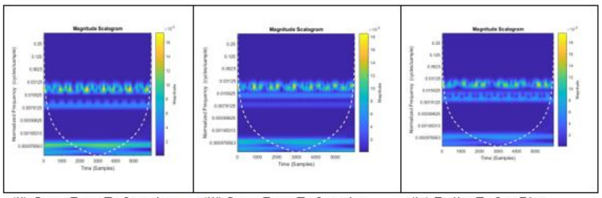


Figure 3(i) Healthy bearing CWT plot



(ii) Outer Race Defect plot (iii) Inner Race Defect plot (iv) Roller Defect Plot

3.2 ANN Results

Neural Network was trained using an inbuilt MATLAB program called Neural Network Training which was called using the call ‘nntraintool’ and a screenshot of the window is shown in Figure 4.

However, due to a non-uniform and non-repetitive patterns in the time domain signals coupled with excessive noise due to external factors such as motor and test rig vibrations, the Neural Network (NN) gives very poor accuracy with a maximum performance of 0.4843 or 48.43%.

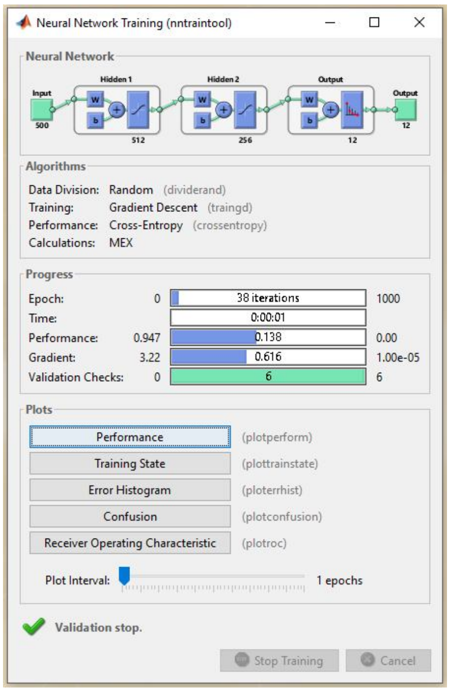


Fig 4 A Neural Network Training Program.

IV. CONCLUSION

CWT analysis is an effective tool for analyzing bearing fault data because in this one gets all the three details i.e. time detail; frequency detail; and amplitude detail. CWT signatures are the unique feature which is shown in this paper and these can be used to classify the bearing faults visibly. We can conclude this that cwt signatures can be used as fault classification tool in ball bearing fault diagnosis.

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REFERNCES

[1] Manoj Gupta, Rajesh Kumar, R. A. Gupta, “A Study on Neural Network Transfer and Training Functions for Recognition of Power Quality Disturbances”, International Journal of Artificial Intelligence and Neural Networks, Vol: 2, Issue:2, pp.30-35, 2012.

[2] O. Duque, M. Pérez, D. Moríñigo, "Detection of bearing faults in cage induction motors fed by frequency converter using spectral analysis of line current," Proceedings of the IEEE International Conference on Electric Machines and Drives

[3] (IEMDC "2005), San Antonio (USA), pp. 17-22, 2005.

[4] R.R. Obaid, T.G. Habetler, J.R. Stack, "Stator current analysis for bearing damage detection in induction motors," Proceedings of the 4th IEEE International Symposium on Diagnostics for Electric Machines, Power Electronics and Drives (SDEMPED '2003), Atlanta (USA), pp. 182-187, 2003.

[5] Abdusslam, S.A., Gu, Fengshou and Ball, Andrew (2009) Bearing fault diagnosis based on vibration signals. In: Proceedings of Computing and Engineering Annual Researchers' Conference 2009: CEARC’09. University of Huddersfield, Huddersfield, pp. 93-98. ISBN 9781862180857.

[6] Madhavendra Saxena et al, "Continuous Wavelet Transform for bearing damage detection in electric motors," Proceedings of the IEEE Mediterranean Electrotechnical Conference (MELECON '2006), Malaga (Spain), pp. 1130-1133, 2005.

[7] Li, C. J. & Ma, J. (1997) Wavelet Decomposition of Vibrations for Detection of Bearing-Localized Defects. NDT & E International, Vol. 30, No. 3, pp. 143-149.

[8] S. N. Sivanandam, ―Introduction to Neural Networks Using Matlab, Tata McGraw Hill (2006)