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Detection of Missing Ball in Bearing using Decomposition of Acoustic Signal

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A wavelet transform based technique has been presented to process the contaminated acoustic signal and diagnose defect in the rotating element. Experiments were conducted on cage ball bearing. Compared to the bearing with no missing ball, there is a sudden variation in acoustic emission when missing ball position comes in front of the mike while rotation. Exact position of the missing balls was determined from the analyzed signal and verified by physical examination.

Key Words: Acoustic, Condition monitoring, Fault diagnosis, Signal processing

INTRODUCTION

Condition monitoring and fault diagnosis of a bearing is essential to know performance and prevent breakdown of a machine. Vibration analysis is one of the methods to diagnose such faults. There are many analytical techniques such as resonance demodulation[1], instantaneous power spectrum distribution[2] and conditional moment analysis etc. which have been developed for processing vibration signals to obtain useful diagnostic information. Harsha developed an analytical model to investigate the nonlinear dynamic behavior of rolling element bearing[3]. The acoustic emission (AE) method is a high frequency analysis technique which was initially developed as a non-destructive testing (NDT) tool to detect crack growth in materials and structures. During the last few years a significant progress in the capabilities of acoustic instrumentation together with the signal processing techniques has made it possible to extract useful diagnostic information from acoustic signals[4,5]. Now, applications of AE technique can be found in structural health monitoring, machine tool monitoring, tribological, wear process monitoring, gear defects monitoring and bearing fault monitoring. Investigators reported that AE parameters can identify bearing defects before they appeared in the vibration acceleration range[6]. Identification of variations of standard AE count parameters can also be helpful in diagnosis of different sized

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ball bearings[7]. Morhain and Mba undertook an investigation to ascertain the most appropriate threshold lever for AE count diagnosis in rolling element bearings[8]. At low speed and steady loads, the base bending/strain of the bearing housing could enable the AE transducer to detect the acoustic emission signature from very small defects of a rolling element bearing. At higher speeds the base bending appears as low-frequency noise. Mean spectral density function of the root-means-square voltage can also be effectively used to distinguish bearing defect in different simulated conditions. Widodo *et al.* investigated a method for fault diagnosis of low speed bearings using pattern classification method based on relevance vector machine[9]. Pan *et al.* investigated wavelet packet decomposition and support vector data description method for designing health index of a bearing which can reflect effectively bearing performance degradation comparing with many other parameters[10].

In this paper, wavelet based technique has been presented to process the contaminated acoustic signal and diagnose defect in the rotating element. The acoustic emission from cage ball bearing with missing balls at different positions was recorded with the help of mike. Daubechies wavelet was used as mother wavelet for analysis. The signal was processed in Matlab environment.

EXPERIMENTS AND RESULT

Experiments were conducted to diagnose the missing balls in a cage ball bearing and identify its position. The ball bearing was having 10 balls. The bearing was mounted on the shaft which was connected to 390 Watt motor. Photograph of the experimental setup along with a view of the ball bearing with one missing ball is shown in Fig. 1. The shaft was rotated at 1460 rpm. After stabilizing the rotation for 20 minutes acoustic emission from bearing assembly were recorded using a mike (logistic make). Different conditions of missing ball/balls in the bearing such as no missing ball, one missing ball, two missing balls, and three missing balls have been studied. The recorded signals of specific time duration were processed in Matlab environment.

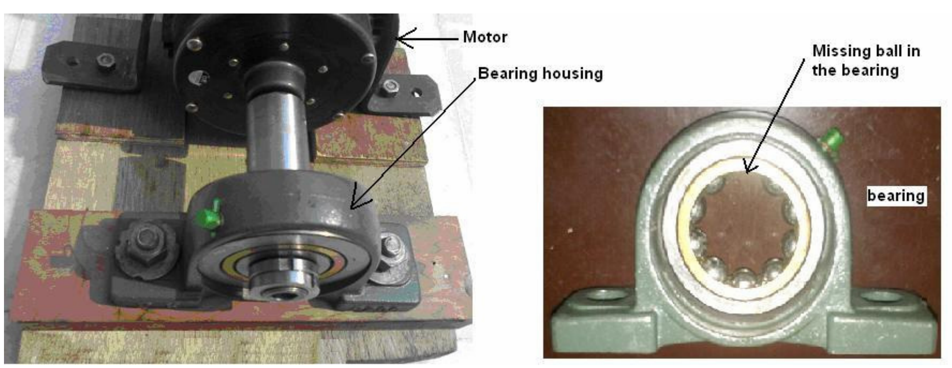

Fig. 1: (a) Experimental setup Fig. 1: (b) Bearing with one missing ball

Wavelets have unique decomposition facility to view the signal at different frequency range/level, keeping time information of occurrence of an event[4]. The decomposition process can be iterated, with successive approximations being decomposed in turn, so that one signal is broken down into many lower resolution components. The original signal 'S' is decomposed to lower resolution components like 'cA1' and 'cD1' as approximation and details respectively. Approximation is low frequency and details are high frequency components of the signal at that particular level. Then 'cA1'it is further decomposed to 'cA2' and 'cD2' and so on. A typical raw signal and its decomposition is shown in Fig. 2(a) and Fig. 2(b) respectively. Daubechies (db) wavelet was used as mother wavelet for analysis.

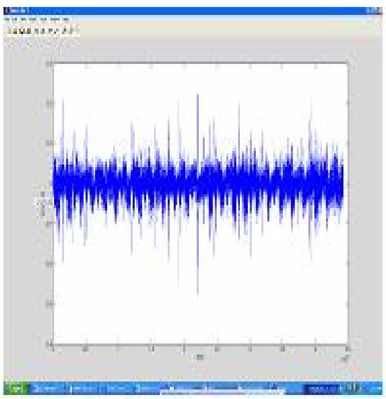

Fig. 2 (a): A typical raw signal

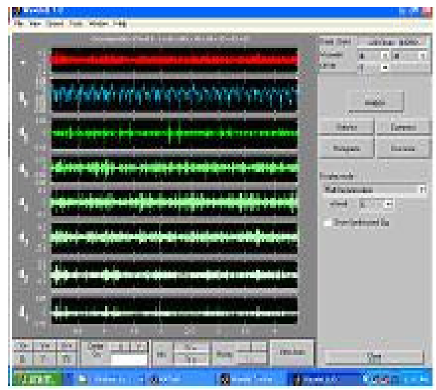

Fig. 2 (b): Decomposition of raw signal

For the recorded signals, decomposition by db4 up to 6th level was sufficient to extract the information of missing ball in the bearing. A typical enlarged view of decomposition graph for one ball missing is shown in the Fig.3.

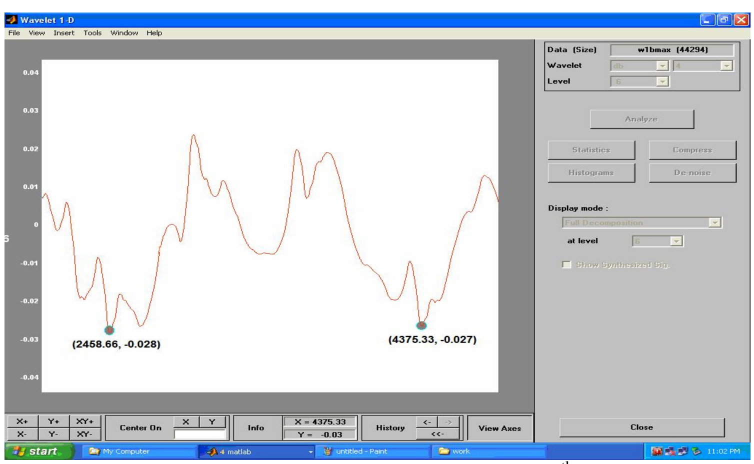

Fig. 3: Enlarged view of decomposition of a typical signal at 6th level using db4 for the case of one ball missing in the bearing rotating at 1460 rpm.

From fig.3, it can be observed that amplitude of the signal varies with time. The two points marked in the figure at coordinates (2458.66, -0.028) and (4375.33, -0.027) have sudden change in energy level. Compared to the bearing with no missing ball, there is a sudden decrease in acoustic emission when missing ball position comes in front of the mike while rotation. The coordinate (4375.33, -0.027) represents repetition of missing ball event in the next cycle. In between these two data points, one more noticeable dip was observed which was also there in signal for the case when there was no missing ball. This dip may be due to looseness in the bearing. Exact position of the missing balls along with the revolution (rpm) of the shaft was determined from the analyzed signal with the help of data points. Verification of the result for the position of missing ball and rpm of the shaft were made physically and by tachometer respectively and are in good agreement.

In another experiment, two balls were removed from the bearing. If ball number 1 to 10 denotes the position of 10 balls in the bearing, two balls at positions 1 and 3 were missing. Decomposition of the raw signal for this case was made in the similar fashion as in the previous experiment. Enlarged view of approximation signals at 6th level for this case using db4 is shown in Fig. 4. From this figure it can be observed that at coordinate (12488.48, -0.037) amplitude is low. It denotes the first missing ball in the bearing. After this there is increase in amplitude of the signal which denotes presence of ball (i.e. at position 2). Just after that at coordinate (12694.98, 0.018) amplitude of the signal has reduced. It denotes presence of the missing ball at position 3 in the bearing. At coordinates (14265.99, -0.04) and (14776.03, -0.01) there is repeat of the evidence of missing balls for the next cycle.

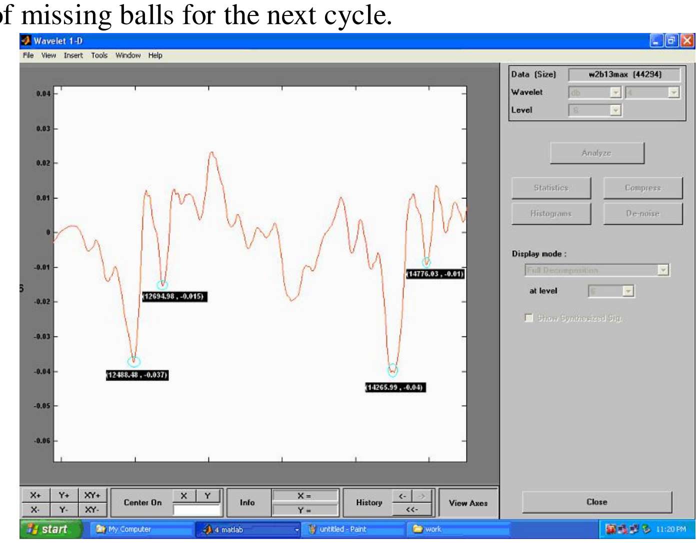

Fig. 4: A typical portion of approximation at 6th level for the bearing having two missing balls (at locations 1 & 3) rotating at 1460 rpm.

Results of the three missing balls at different positions in the bearing follow the similar trend of variation in amplitude of the decomposed signal.

Conclusion

Wavelet based technique is very effective in diagnosis of faults in a ball bearing. Compared to the bearing with no missing ball, there is a sudden decrease in acoustic emission when missing ball position comes in front of the mike while rotation. Position of missing ball and rotation of shaft on which bearing is mounted can be easily estimated by analyzing the decomposed signal.

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