Research Paper Engineering

Fault Detection In Bearing Using Envelope Analysis

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ABSTRACT

Fault detection in roller bearing with envelope analysis is well known technique. In this paper fault detection in bearing on a particular set up are presented. In this paper the basic characteristic frequency of rolling element bearing is presented and formulas are given for calculation of characteristic frequency and fault detection in bearing on the basis of vibration signature graph obtained in software utility (MATLAB®) are also presented, Because these are the basic fault in bearing and each fault having its own signature graph are obtained by envelope modulation/demodulation.

Keywords :

I. INTRODUCTION:

In any manufacturing or processing plant where rotating equipment is used, the majority of the Maintenance capital expenditure is spent on bearings. Every time an overhaul is performed, salesmen from the major bearing manufacturing make it their business to ensure that the bearings are replaced. Whatever the reason which caused the machine to break down, nine time out of ten time the bearings are replaced, and are indeed very often blamed for the machine breakdown. However, the bearing failure is a result of a number of different problems: a machine running unbalanced, misaligned, at a critical speed; a bearing fitted incorrectly; the wrong grease being used; or maybe no grease being used at all. A bearing rarely fails on its own accord, something causes it to fail. Very often bearings are replaced without the origin of the failure being addressed. It is well documented that the majority of machinery vibration problems are caused by unbalance or miss-alignment, often creating bearing failure.

The part that are generally failed in rolling element bearing are outer-race, inner –race and the ball. The characteristic frequency of failure of outer-race, inner-race and the ball are determined earlier by the formula which are based on shaft speed, ball diameter, pitch diameter and the geometry of bearing[1]. When there is a fault on outer-race or inner-race the bearing continuous generates series of vibration when running ball passes over the surface defect. These impacts re-occur at bearing characteristic frequency which is determined earlier. These impact generated by ball at bearing characteristic frequency distributes its energy over wide frequency range where the vibration from other reason such as miss alignment from shaft and from macro structural component are also present thus it is very difficult to determine the exact vibration of bearing component.

To allow easier detection of such fault of bearing component, the Envelope Detection technique(ED) has been used together with Hilbert Transform (HT). Envelope analysis offer strong and more reliable diagnostic potential because it form envelope on characteristicfrequency and separated frequency from other macro structure part by using Band Pass Filter (BPF).

II. BEARING CHARACTERSTIC FREQUENCY

Bearing characteristic frequency is the fundamental frequency that is of interest in the detection of bearing faults, not the resonance frequency at which the bearing rings, and it is the predicted frequency from the bearing geometry and the speed at which bearing rotate[5].

Assuming fixed outer race, moving inner race and no slippage for the rolling elements. The bearing characteristic frequency, ball pass frequency of inner race (BPFI), ball pass frequency of outer race (BPFO) and bass spin frequency (BSF) are expressed as follows.

$$BPFI_{inner} = \frac{N_B}{2} F_S \left(1 + \frac{D_b}{D_c}\cos\theta\right) \text{...........1}^{st}$$

$$BPFI_{outer} = \frac{N_B}{2} F_S \left(1 - \frac{D_b}{D_c}\cos\theta\right) \text{...........2}^{nd}$$

$$BSF_{ball} = \frac{D_c}{2D_b} F_S \left(1 - (\frac{D_b}{D_c}\cos\theta)^2\right) \text{............3}^{rd}$$

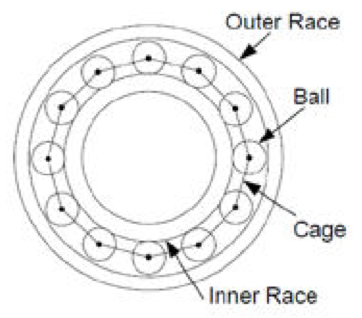


Figure 1 : Various parts of bearing

Where the number of rolling elements is, is the ball diameter, is the pitch diameter and is the contact angel of ball.

III. ENVELOPE ANALYSIS:

Enveloping/Demodulation is an advanced tool for vibration analysis. The phrase "Envelope Analysis" typically refers a sequence of procedure. Fundamental to the ED is the concept that each time a defect in a rolling element bearing makes contact under load with another surface in the bearing, an impulse is generated. This impulse is of extremely short duration compared with the interval between impulses, and its energy is distributed at a very low level over a wide range of frequencies. In these cases by extracting the BCF in a narrower band through bandpass filtering, the repetitive impact vibration will be revealed [6]. The purpose of bandpass filtering is to reject low level high-amplitude signals associated with misalignment and to eliminate the random noise by outside passband. Envelope is a signal processing technique for amplitude demodulation, the repetitive impacts, which have been modulated, will be demodulate and appear in the envelope spectrum.

A. Envelope Detection on basis of Modulation pattern.

The fault detection in bearing is also done on basis of modulation pattern of shocks, as basically there are three types of fault in bearing and every fault has its own modulation pattern. Suppose there is fault in outer race which is placed stationary, every ball continuously hits the outer race then we get pattern in which there is a continuous shocks peak of equal intensity at certain time interval. [9]If there is a fault in ball the frequency obtained is the frequency at which the fault strikes the same (inner or outer), so that in general there are two shocks per basic period.

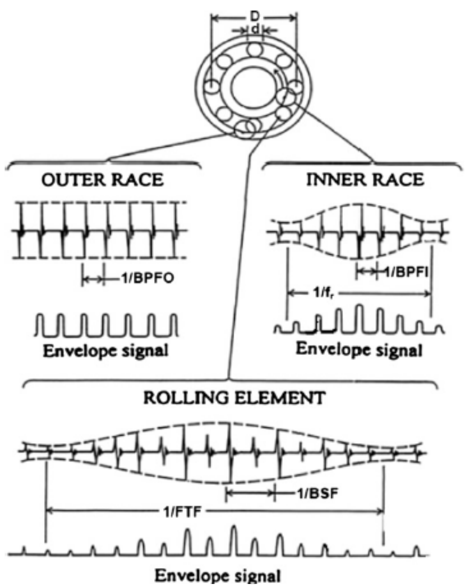


Figure 2: Signal and envelope pattern of local fault in roller element bearing.

B. Traditional Envelope Detection

In general, the traditional envelope detection contains two steps. First, in which the obtained signal firstly filter by use of band pass filter around the resonate frequency. Second the above signal is demodulated by an envelope detector to extract the carrier frequency and then we also determined the spectrum of envelope [1]. Here diagnosis is possible, since the impact frequencies are determined and can related to characteristic frequency of ball inner-race, outer-race, or spin frequency that are calculate with the help of formulas.

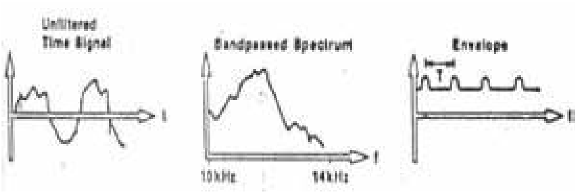


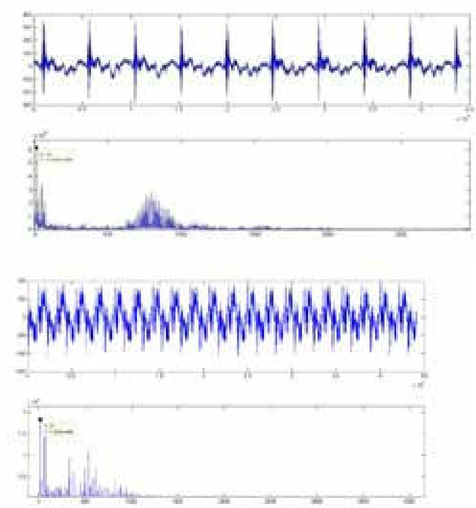
Figure 3: Envelope detection in time domain

Figure 4: Envelope detection in frequency domain

a. Piezoelectric Element

The accelerometers has been manufacturing for over 40 years utilize the phenomenon of piezoelectricity. When a piezoelectric material is stressed it produces electrical charge. Combined with a seismic mass it can generate an electric charge signal proportional to vibration acceleration. The active element of accelerometers consists of a carefully selected ceramic material with excellent piezoelectric properties called Lead-Zirconate Titanate (PZT). Piezoelectric accelerometers are widely accepted as the best choice for measuring absolute vibration.

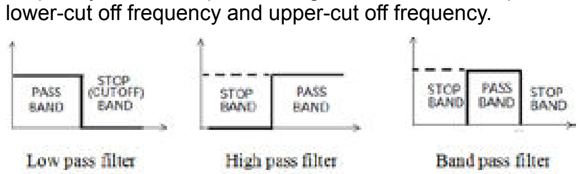
The active element of an accelerometer is a piezoelectric material. We have used directly piezoelectric element for taking signal instead of accelerometer. Signal obtained from piezoelectric element is verified from Electrodynamics type vibration exciter. In which we artificially produced vibration at a particular frequency the output in exciter is in volt form, which is then calculated by piezoelectric element and converted in to Hz in software utility MATLAB®. Piezoelectric element give the peak at same frequency at which the vibration exciter was set up earlier.



Here in this we set exciter at 10 Hz & at 20 Hz corresponding vibration in oscillator is taken by piezoelectric element which is converted in to frequency in software utility gives the peaks same at 10 Hz and at 20 Hz. The above graph shows that using piezoelectric element for taking signal from bearing is good alternative for accelerometer. And also piezoelectric element is to much low cost as compared to accelerometer.

b. Band pass Filtering

Band pass filtering removes the large low-frequency components as well as the high frequency noise only specified frequency vibrations pass through them. We have specified lower-cut off frequency and upper-cut off frequency.



In Hilbert transform, when data is collected from band pass the envelope of signal is displayed.

d. Spectrum Analysis

Spectrum is calculated by using Fast Fourier Transform (FFT). FFT transform time varying signal from time domain in to frequency domain and there by provide a continuous update of signal frequency.

IV. Bearing Fault Diagnosis Using Envelope Analysis

For test purpose firstly artificial vibration exciter was used to generate vibration to verify that signal recorded by piezoelectric element is accurate. A set up consist AC motor driving a shaft gear assembly; shaft were rested on bearing, which were induced with fault. The instrument used for the experiment includes a piezoelectric element connected to microphone socket through cable, a tachometer to record the RPM of motor and shaft. We also required a PC with good configuration having MATLAB® to storing and analyzing the vibration signal. The Envelope analysis with FFT was performed by Matlab codes using Hilbert transform.

Experiment

A variety of artificially fault induced in ball-bearing type SKF 6002-2Z was used. The type of fault included a defective outer-race, a defective inner race, and a defective ball. Although motor was set to rotate at 25 Hz, the actual rotating speed of faulty bearing monitored by the tachometer was found to be 2.05Hz. The BCF was calculated using Eqs. (1) to (3), the geometric parameter of bearing are d=5 mm, D= 28.7 mm, n= 9, α= 0. The calculated BCF for each type of fault are presented in table below.

Fault Type	Outer Race (BPFO)	Inner Race (BPFI)	Roller (BSF)
BCF for shaft frequency = 3.56 Hz	7.43 Hz	10.83 Hz	5.70 Hz
Time interval of impact	134.58 ms	92.3 ms	175 ms

Calculated BCF for different fault

Experimental setup

V. Result of Fault Diagnosis

Here the characteristic frequency of inner race and outer race fault are found to be 10.83 Hz and 7.43 Hz respectively.

The original vibration signal of outer race defect is displayed in figure 5. It is clear that there is periodic impact in the vibration signal. There is significant fluctuation in the peak amplitude of signal, and there are also considerable variations of frequency content. From figure we hardly find the characteristic frequency of outer race.

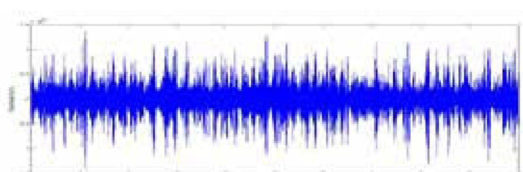


Figure 5: Original signal of bearing

To the data of figure 5 filtering of signal is applied, filtering is applied for the fault detection of bearing and after filtering data shown in figure 6 is as below.

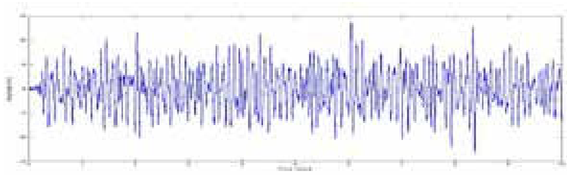


Figure 6: Filtered Signal of bearing

After filtering the signal, we formed envelope of signal. Envelope is formed by the Hilbert Transform. It shows the envelope of filtered signal as shown below in figure 7.

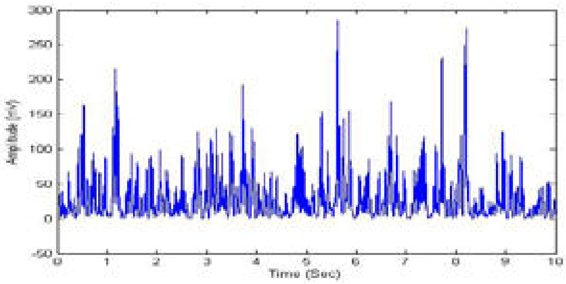


Figure 7: Envelope of bearing

After enveloping we are doing Fast Fourier Transform of signal in this we are converting the time domain signal to frequency domain. In FFT we seeing the peak of frequency and correlate it with characteristic frequency we are able to find the fault in bearing. In figure 8 below we obtained frequency at 7 Hz and other peaks shown in this figure are the harmonics of fault. As above the characteristic frequency of outer race fault is 7 Hz, by correlating it with obtained frequency we conclude that there is fault in outer race of bearing.

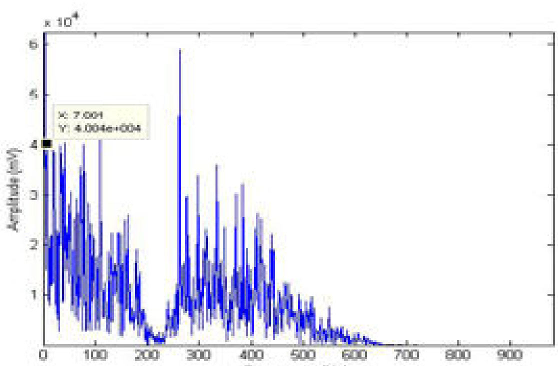


Figure 8: FFT of signal showing a peak at 7 Hz

VI. Conclusion

In this paper, a method for fault detection of ball bearing was presented based on newly developed technique for obtaining signal with piezoelectric element. This work is also done with accelerometer but the cost of accelerometer is to high as compared to piezoelectric element. The original vibration signal from piezoelectric element is obtained and characteristic frequency of different fault is find out by formulas. By correlating the fault frequency with characteristic frequency we are able to find fault in bearing.

VII. Acknowledgement

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