Bearing Fault Analysis using Frequency and Wavelet Techniques

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Abstract

Bearing fault diagnosis is important in condition monitoring of any rotating machine. Early fault detection in machineries can save millions of dollars in emergency maintenance cost. Different techniques are used for fault analysis such as short time Fourier transforms (STFT), Wavelet analysis (WA), Cepstrum analysis, Model based analysis, etc. This Paper explains the procedure for detecting bearing faults using FFT and by using Wavelet analysis more specifically HAAR wavelet. The analysis is carried out offline in MATLAB.

Keywords: *fault diagnosis, Bearings, and wavelet Analysis methods.*

1. Introduction:

Condition monitoring in process control industry has got now a day's very big relevance. A vibration signal produced by the process, allows monitoring and making conclusions about the operational state of the machine, in addition to that allows taking appropriate measures to extend the time of use, and to minimize costs resultant from the machine's downtime which results in cost effectiveness. It has been found that Condition monitoring of rolling element bearings has enabled cost saving of over 50% as compared with the old traditional methods. The most common method of monitoring the condition of rolling element bearing is by using vibration signal analysis. More recently by taking thermal images of bearing also we can diagnose the bearing fault. But the problem in this method is that we cannot diagnose the exact location where the problem occurs. In rotating machines mainly faults occurs due to faulty bearings. IEEE analysis [1] reveals the following fact as shown in Table-1

Table: 1 Analysis of faults

Component	Failure
Bearing	40%
Stator	38%
Rotor	10%
Other	12%

2. Bearing Failure Mechanism:

Figure 1 shows the basic elements of Bearing. Bearing has Inner Race, Outer race, Balls as rolling elements. Each bearing is associated with it some characteristic frequencies which are dependent on bearing geometry.

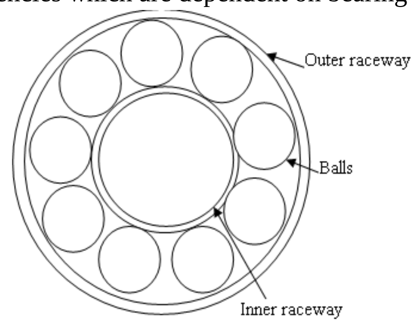


Fig 1: Bearing View

Such as ball diameter, pitch diameter, Inner race Diameter, Outer race diameter, rotational speed etc. There are number of mechanisms [2] that can lead to bearing failure, including mechanical damages, cracks, wear and tear, lubricant deficiency and corrosion etc. Wear results in gradual deterioration of bearing components. When lubrication is not proper the friction between metal to metal increases. Poor lubrication increases the bearing component temperature, which speeds up the deterioration process. Bearing that operates in an environment of high humidity may subjected to surface oxidation and produce subjected rust particles and pits. These particles can produce rapid wear.

3. Characteristic fault frequencies:

As explained in the previous paragraph, for the ball bearings with angular contact with the cage, the outer ring is static and the inner ring rotates at the shaft speed [1,2]. The characteristic fault frequencies can be calculated by the following equations:

Ball Pass frequency outer race (BPFO)

1) $$\text{BPFO} = \frac{n}{2} f\left(1 - \frac{d}{D}\cos\beta\right) \quad (1)$$

Ball Pass frequency inner race (BPFI)

2) $$\text{BPFI} = \frac{n}{2} f\left(1 + \frac{d}{D}\cos\beta\right) \quad (2)$$

Ball Pass roller frequency (BPRF):

3) $$BPRF = \frac{D}{d} f\left(1 - \left(\frac{d}{D} cos\beta\right)^2\right) \quad (3)$$

Where 'f' is the shaft frequency, 'n' is the number of balls', 'β' is the contact angle between inner race and outer race 'd' is the ball diameter 'D' is bearing pitch diameter.

3.1 Analysis Methods:

Accelerometers are used as Vibration sensor for the bearing fault Analysis. As they have metallic housing and magnetic coupling for adherence. They have same spring mass damper like internal arrangement as shown in Figure: 2.

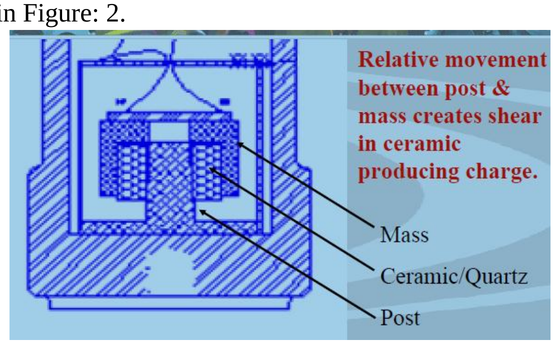


Figure: 2 Sectional view of Accelerometer

3.2 Experimental setup:

Figure 3: Experimental setup

As shown in Figure-3 the Accelerometer is mounted on motor vertically it has four channels for recording signals. Since it has inbuilt electronics there is not necessity of any kind of signal conditioning circuit. The recorded signals are then further post processed in MATLAB for analysis purpose.0.5 HP motor with 2880 RPM at no load with 230V,50Hz supply and full load Current 2.6 A is used. The bearing under Test is of type 6203-Z, with following details.ID (Inner Diameter):17mm OD (outer diameter): 40mm Ball diameter: 6mm Cage diameter: 30mm and Number of balls: 8.

3.3 Frequency Analysis:

Frequency analysis is the most commonly used method for analyzing a vibration signal. The most basic type of frequency analysis is an FFT, or Fast Fourier Transform, which converts a signal from the time domain into the frequency domain [4, 5]. FFT has few limitations that only stationary signals can be analyzed. For non-stationary random signal analysis we can use wavelet analysis. In this method continuous wavelet analysis method is used.

4. Results:

Calculated frequencies by formulae given above

1) BPFO=153.6Hz.
2) BPFI= 240 Hz.
3) BPRF=80Hz.

FREQUENCY	ACCELERATION
Hz	m/s2
50	1.75
149	0.23
248	0.07
347	0.08
548	0.04
743	0.05

Table 2 Frequency Vs Acceleration

Figure-4 Shows FFT of Healthy Bearing along with frequency versus acceleration

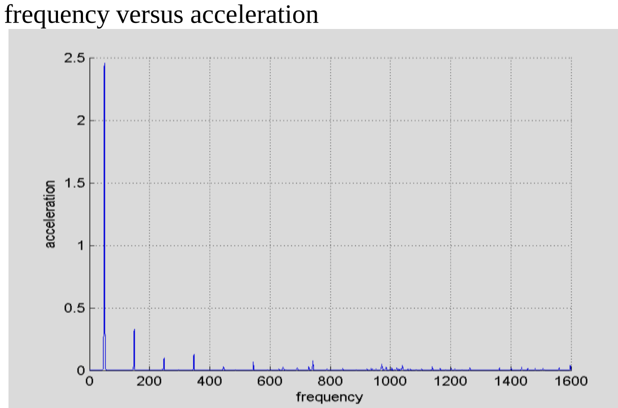


Figure- 4: FFT of Healthy Bearing.

Table-2 shows the Acceleration value at each frequency in tabular form. Note carefully in above FFT the magnitude of 50Hz and 149Hz components.

First harmonic at 50Hz indicate that there is unbalance in Power supply, as shown in Figure- 4.It can be noted that at a 149Hz there is dominating component in Figure-5 and from Table-3 if we compare calculated result of frequency for outer race then it is at 153.6Hz.

Hence we can conclude that there is fault in outer race.

Figure 5 Outer race fault

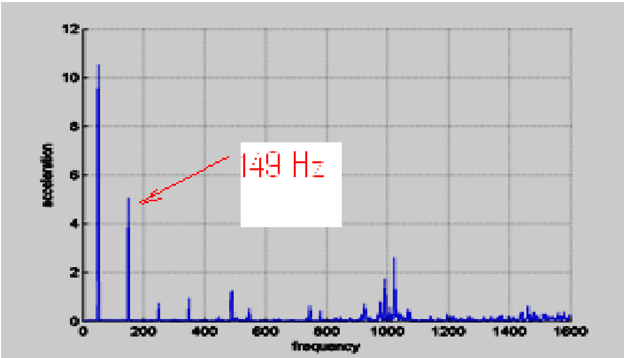
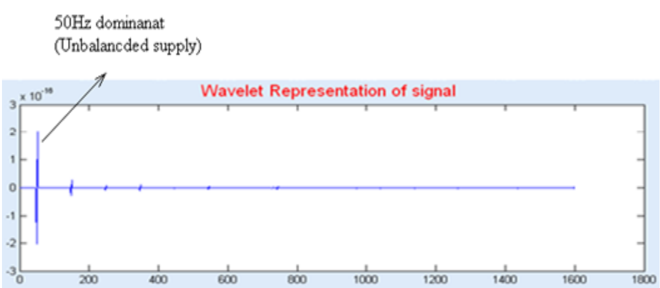


Table: 3 Frequency Vs Acceleration for faulty bearing

FREQUENCY	ACCELERATION
Hz	m/s2
50	7.4
149	3.5
248	0.53
992	1.2
1023	1.8

Figure- 6-a. Wavelet Representation of Healthy bearing



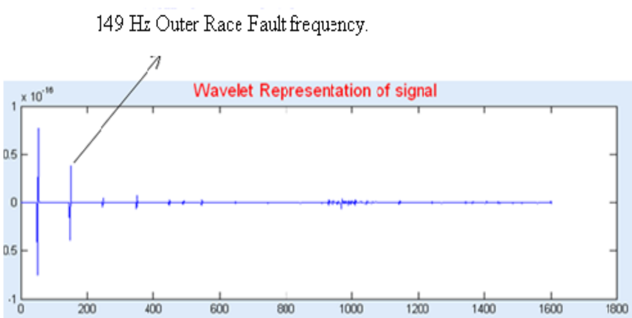


Figure -6-b. Wavelet representation of Faulty bearing

Figure-6-a and figure-6-b shows the Haar wavelet representation of the signal which clearly shows the fault frequency around 149 Hz.

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