CONDITION MONITORING AND FAULT IDENTIFICATION OF NEW DEEP GROOVE BALL BEARING USING LABVIEW

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Abstract: Rolling element bearing used in every industrial and non-industrial systems. The failure of bearing may lead to stoppage of the entire system which increases the down time of a system. It is necessary to detect the faulty bearing with the simple and fast technique. The study shows the fast, simple and cheaper way of monitoring the condition of bearing using a Labview. In the presented study we have calculated the kurtosis value of a vibration signal to identify the bearing condition and the Fast Fourier Transform (FFT) of a vibration signal to identify the type of defect in a deep groove ball bearing

Keywords: Deep groove ball bearing, Time and frequency domain analysis, Labview.

I. INTRODUCTION

Rolling element bearing support and locate rotating shafts in a machine. Rolling bearings are bearings with two components that move in opposite directions. These parts are the inner and outer ring and they are separated by rolling elements. Frequency of bearing failure is high in any machinery as compared to its other components and hence they are often responsible for the machine breakdown. The presence of bearing faults such as spalling, peeling, galling, or failure of the bearings due to misalignment, shaft slope, surface roughness, high extent of waviness and inclusions etc. causes a sudden failure of the system. Also bearing failure occurs due to heavy dynamic loads and also contacts forces which exist between the bearing components. If fault or any defect developed in the bearing we are not able to observe that defects by naked eyes in initial stage. But when these faults are increased to large amount, they will leads to severe damage so it is very necessary to detect faults in bearing at an earlier stage. When a bearing fails, the malfunction can lead to significant downtime, elevated maintenance costs, and the potential for a decrease in productivity. Bearing faults if detected at an early stage can prevent such failures and reduce downtime of equipment. The catastrophic failure of the machine may lead to decrease in productivity and increase in time. So it is necessary to set up the vibration analysis technique which will help to identify the initial fault in bearing. Health of rolling element bearings can be easily identified using vibration monitoring because vibration signature shows important information about the fault development within them. Numbers of vibration analysis techniques are being used to diagnosis of rolling element bearings faults such as wear debris analysis, motor current analysis, noise monitoring, temperature monitoring, vibration monitoring etc.

II. LITERATURE REVIEW

P Shakya et.al. A vibration-based method to detect and identify bearing damage is more common due to the ease in measurement, and the measured data can then be further processed to extract useful information that can be related to the severity and type of bearing damage using the time domain, frequency domain and time frequency domain [1] Attel Manjunath et.al. describes the vibration analysis technique to detect the defects in the ball bearing. The Fast Fourier Transform (FFT) detected the frequencies of damage present during the vibration analysis of a ball bearing. The root mean square (RMS) value for velocity response for new and defective bearings shows higher for higher radial loads. Also it is found RMS value for ball defect and new bearing are lesser compared to inner race and outer race defect. The Kurtosis value for new bearing is lies below 3 which is a clear indication that no defects in the bearing.[2] Vikram Talekar et.al states that FFT analyzer can helps to detects in various components without disturbing setting of that component. Every defect excites the system at its characteristic frequency. The location of the faults is indicated by the FFT in Frequency domain spectrum can be useful to find out the type of fault. [3] K. Raghavendra et.al carried out the time domain analysis of vibration signals acquired from ball bearings with respect to speed using an experimental set up. The method proves to be a simple, quick & cost effective method in the condition monitoring of ball bearings.[4] Dhanush N et.al studied the vibration response from ball bearing due to the change in mass, eccentricity for loading and with varying speed is found experimentally by using FFT analyzer. The author explains the application of FFT spectra as a smart tool for diagnosis and identification of bearing faults like inner race defect, outer race defect and ball defect.[5] In 2009, P.K. Kankar, et.al have discussed fault diagnosis of a rotor bearing system using response surface method. They have considered the distributed defects such as surface waviness and radial clearance of the bearing components. They have studied ball waviness, inner race waviness and outer race waviness individually and also taken readings of combined waviness.[6] Ruonan Liu et.al. developed short time machining method consists of a short time algorithm which is used to extract weak impact signal and the results reveals that method can eliminate the influence of irrelative noise and effectively extract the fault signal corresponding to the fault in strong noise.[7] Hussein Al-Bugharbee et.al proposed the method of pretreatment and autoregressive modeling. The purpose of signal pretreatment is to separate the noise from the original signal using singular spectrum analysis and high frequency filtrations by means of differencing. A pattern recognition approach is used to detect and localize the fault and its size.[8] S.H. Upadhyay et.al. presented the condition monitoring techniques like acoustic emission, vibration, oil debris, electrostatic and ultrasonic. Signal processing method like spectral kurtosis and kurtogram.[9].

III. THEORETICAL BACKGROUND

1) Fundamental characteristics frequency:

Bearings are one of the most widely used industrial machine elements, especially rolling element bearings and journal bearings. In industrial applications, these bearings are taken into account as important mechanical components and a defect may lead to sudden failure of the machinery. The different defects occurring in the rolling element bearing can be classified according to the damaged elements as: outer raceway defect, inner raceway defect, ball defect, and combination of bearing components defect. Each bearing element has a fundamental defect frequency that depends on bearing geometrical parameter. The product of multipliers with the shaft rotational speed gives the defect frequency of bearing running at given shaft speed by identifying the type of the bearing characteristics frequency, the cause of the defect can be determined. The bearing frequency multipliers equations provide a theoretical value of the frequency whenever the bearing element fault takes place.

To calculate fundamental characteristic frequency, following formulas are used:

FTF - Fundamental Train Frequency (frequency of the defected cage):

$$\mathrm{FTF} = \frac{\omega}{2}\left[1 - \left(\frac{D_e}{D_p}\right)\cos\beta\right] \qquad (1)$$

BPFI - Ball Pass Frequency of the Inner race (frequency produce when the rolling elements roll across the defect of inner race):

$$\mathrm{BPFI} = \frac{\omega Z}{2}\left[1 + \left(\frac{D_e}{D_p}\right)\cos\beta\right] \qquad (2)$$

BPFO – Ball Pass Frequency of Outer race (frequency produce when the rolling elements roll across the defect of outer race):

$$\mathrm{BPFO} = \frac{\omega Z}{2}\left[1 - \left(\frac{D_e}{D_p}\right)\cos\beta\right] \qquad (3)$$

BSF – Ball Spin Frequency (circular frequency of each rolling element as it spins):

$$\mathrm{BSF} = \frac{\omega D_p}{2D_e}\left[1 - \left(\frac{D_e}{D_p}\right)\cos\beta\right]^2 \qquad (4)$$

Rolling element defect frequency or 2XBSF:

$$\frac{\omega D_p}{D_e}\left[1 - \left(\frac{D_e}{D_p}\right)\cos\beta\right]^2 \qquad (5)$$

Where,
D_e = Ball diameter;
D_p = Pitch diameter;
β = Contact angle;
z = Number of balls;
ω =Shaft speed.

The following table shows the characteristics frequency factors which are calculated using above equation.

Table 1 Characteristics frequency factor

Bearing characteristics frequency	factor
Ball pass frequency of inner race	5.43
Ball pass frequency of outer race	3.56
Rolling element defect frequency	3.02

2) Time and frequency domain analysis:

Time domain analysis is carried out mostly for the condition monitoring of bearing. Time domain analysis consists of statistical tools like root mean square, kurtosis, crest factor, skewness and peak to peak etc. which are used to monitor the health of bearing. The disadvantage of time domain analysis is that it cannot tell us the exact type of fault and its location. In presented study we have used the kurtosis as a diagnosis tool. In frequency domain analysis the time domain signal are converted into frequency domain signal using FFT. The frequency domain signal can be used to identify the fault type. The characteristics frequency related to the inner race, outer race and ball are used as reference frequency to identify fault. Frequency domain analysis is more useful as it tell us the both condition and fault of the bearing.

3) Labview:

Labview is the software which is program to develop the custom applications which can used to interact real time data and signals in the field of engineering. The Labview is fast and simple in used. It is efficient tool to diagnosis the signal in any domain. The following figures shows the program which is used in presented study to diagnosis the signal from the sensor.

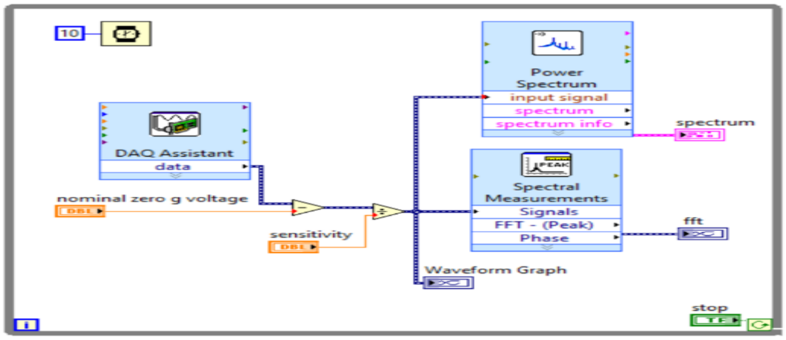

Figure 1: Shows the program used for time and frequency domain analysis.

IV. EXPERIMENTAL SETUP

The experimental bearing test rig is designed and fabricated to identify the presence of defects on a deep groove ball bearing by vibration analysis technique is shown in Figure 2. The test rig consists of a circular shaft with central load, which is supported on two deep groove ball bearings of 6206-z2 series. An induction motor of 1/4HP with variable speed drive is coupled to a jaw coupling which drives the shaft. A three-phase AC induction motor is connected to a auto transformer for achieving variations in speeds. The bearing test rig employed for this study has an operational speed of 300 to 1440 rpm, with central load of 200N capacity. For capturing vibrational data signal from test rig a provision is made to mount the accelerometer on the top of the bearing housing.

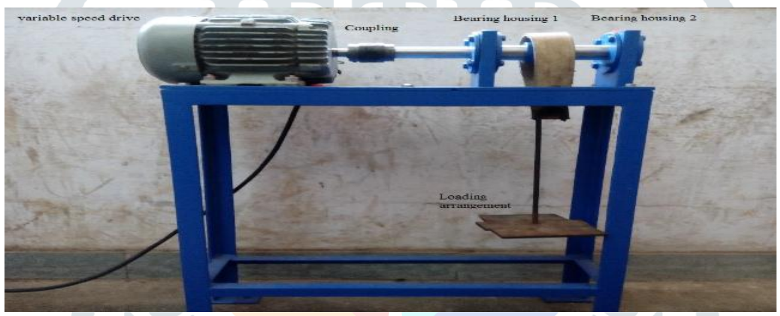

Figure 2: Experimental setup.

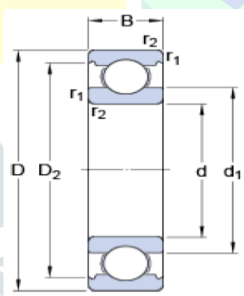

Figure 3: Dimensions of bearing

Table 2: Bearing Dimensions

Parameter	**Units**	**Value**
Inner race diameter(d)	Mm	30
Outer race diameter(D)	Mm	62
Width(B)	Mm	16
Outer diameter of inner race(d_1)	Mm	40.36
Inner diameter of outer race(D_2)	Mm	54.60

Table 3: Sensor specification

Measurement quantity	**Value**
Sensor name	ADXL335
Sensitivity	100mv/g
Frequency range	550hz
Sensor type	Analog

V. RESULTS AND DISCUSSION

Experiment is carried out on a healthy Deep groove ball bearing 6206-z2 type. The bearing is subjected to three different speed with no loading on shaft. The speed were kept as 1000rpm, 1200rpm and 1400rpm. The sensor readings are taken out by means of Data acquisition card and Arduino uno and are analyzed in labview. The readings from Data acquisition card are used for frequency domain analysis and readings from Arduino uno used for time domain analysis.

Following graphs shows the result after analyzing in labview.

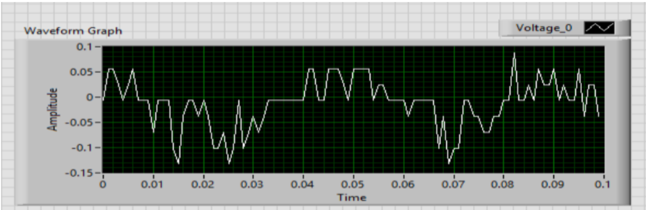

Figure 4: Raw signal at 1000rpm

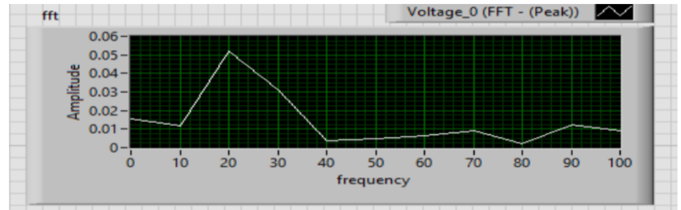

Figure 5: Frequency spectrum at 1000rpm

Fig. 4&5 shows the time and frequency domain signal at 1000rpm respectively. It shows the peak frequency at 20Hz which is clearly very less than the characteristic fundamental frequencies. For faulty bearing , we will get a peak at correspondence fault frequency. In above graph the next peak is at 70Hz and 90Hz which are not nearer to any of the fault frequency.

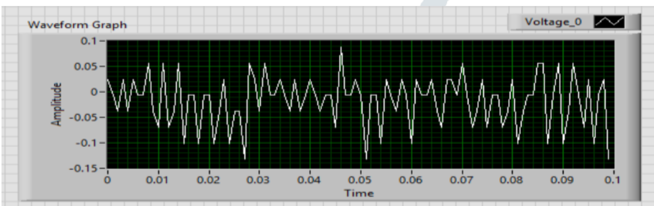

Figure 6: Raw signal at 1200rpm

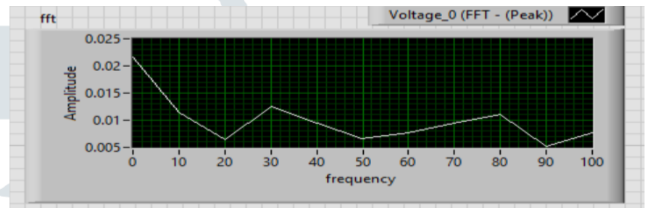

Figure 7: Frequency spectrum at 1200rpm

Fig, 6&7 shows the time and frequency domain signal at 1200 rpm respectively. It shows the peak frequency at 30Hz Which is less than the calculated characteristic frequency.

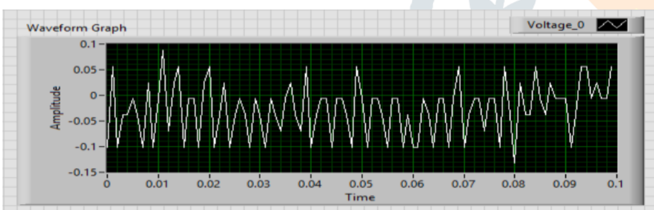

Figure 8: Raw signal at 1300rpm

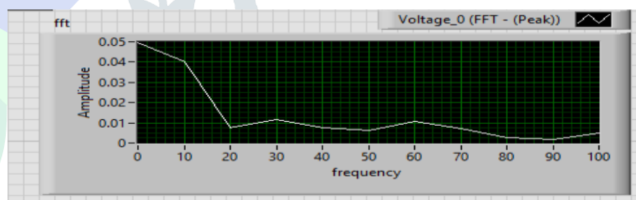

Figure 9: Frequency spectruml at 1300rpm

Fig. 8&9 shows the time and frequency domain signal at 1300rpm respectively. It shows the peak frequency at 30Hz. All the frequency are less than the calculated fundamental frequency which shows the bearing is not faulty. The following table shows the comparison of experimental frequency and theoretical frequency.

Table 4 Theoretical and Experimental Frequencies.

RPM	**HZ**	**FAULT FREQUENCIES CALCULATED THEORETICALLY**			**FAULT FREQUENCIES CALCULATED EXPERIMENTALLY**		
		BPFI	BPFO	2 X BSF	BPFI	BPFO	2 X BSF
1000	16.66	90.46	59.3	50.3	20	20	20
1200	20	108.6	71.2	60.4	30	30	30
1300	21.66	117.61	77.69	65.4	30	30	30

The kurtosis value are calculated using the following formula:

$$K=\sum_{n=1}^{N} \frac{[x(n)-\mu]^4}{N.(s^2)^2} \qquad (6)$$

Where, $x(n)$ is the time series, μ is the mean value of the data, s is the standard deviation of the data and N is the total number of data points. The following table shows the kurtosis value at different speed.

Table 5. Kurtosis values.

Speed (rpm)	Value
1000	2.1446
1200	2.1113
1300	2.1141

From the above table we can say that all the values are positive and lie between the range of 0.1to 3. For bearing without fault has theoretical kurtosis value is less than 3. All the values are less than 3 which means condition of bearing is good and it is fault free.

VI. CONCLUSION

The experiment is carried out to monitor the health of a bearing. The experiment is carried out at three different speed with no load condition. The signals are diagnosis in time and frequency domain using Labview.

- The kurtosis value is less than the theoretical value at all the speed it means condition of bearing is good.
- The kurtosis value aren't change significantly with increase in speed which shows that it doesn't vary with the speed. The time domain analysis is useful in condition monitoring of a bearing
- The experimental frequencies at all the three speed were less than the fundamental frequencies which shows the bearing hasn't got inner race, outer race and ball defect.
- The amplitude vibration also get decreases with the increase in speed. The frequency domain analysis is useful technique to find out the type of defect.

From the above study we find out that the time domain analysis is useful for condition monitoring purpose and frequency domain analysis is useful for both condition and fault identification.

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