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Rolling Element Bearing Fault Detection by Vibration Measurement

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Abstract:
Rolling element bearings are considered as critical components because any defect in this led to malfunctioning of complete system. Vibration and acoustic measurement are most commonly used for conditioning monitoring to study the vibration response of faulty bearing. In this work single point fault is created on rolling element, Inner race and outer race then vibration response of these bearing is considered. Also, by increasing the clearance between sleeve and shaft vibration response of the bearing is taken. These results are then compared to healthy bearing vibration response and different defects frequencies. The identification of bearing defects is obtained by extracting characteristic defect frequencies from vibration signal of effective bearing.
Key Word*: Defect frequency, Frequency defect domain, Vibration response, Acoustic response*.

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I. Introduction

The rolling element bearings are commonly used in the machinery for a wide range of applications. Therefore, detection of defects in bearing is important for smooth functioning of various machines and to avoid undue stoppages which have high economic impact. Different methods used for detection and diagnosis of bearing defects are vibration and acoustic measurements, temperature measurement, and wear analysis. Among these the vibration measurement is most common method used for fault detection [1-2]. To study the vibration response of defected bearing two methods are used as given below. a) Run the bearing until failure and see the changes in the vibration response in intervals of time and b) Create the defects in the bearing by different techniques like acid etching, spark erosion. He and Zhang [3] explained the method of defect diagnosis for rolling element bearing using acoustic emission. The result shows that acoustic emission method is superior than vibration analysis in some areas especially for incipient defect detection in rolling element bearing. Taha and Dung explained two methods for the fault detection in the rolling element bearing; one is experimental analysis in which by using frequency domain approach the vibration response of bearing is seen. In another method is by using finite element software a model of bearing housing and outer race is developed and defect frequency is calculated and vibration response is analyzed using commercial FEM software ABAQUS. Tandon and Choudhury [4-5] gives review of vibration and acoustic measurement methods for the detection of defects in rolling element bearings. Kadarno et. al [5] developed the FEM model simulation to analyze the vibration of ball bearing. Zeki Kiral and Hira Karagulle [6-7] presented a method based on finite element vibration analysis of rolling element bearing with single and multi-point fault defect on different components of the bearing by using time domain and frequency domain approach. Arslan and Akturk [8] developed a shaft bearing model to investigate the rolling element bearing vibrations for an angular contact ball bearing with and without defects.

The aim of this work is to study the vibration and noise response of the rolling element bearing by using experimental analysis. For this frequency domain approach and acoustic measurement technique is used. For this single point defects are created in bearing like on ball, inner race and outer race by different methods. The vibration response and acoustic measurement of healthy and faulty bearing is analyzed. These verified results will be used for detection bearing faults in industrial application.

II. Experimental

In this work our aim is to create the artificial faults in the bearing like fault on balls, fault on inner race, fault on outer race, increasing the clearance. To create these faults easily the self-alignment bearing 1209EKTN9+H209 is selected shown in Fig. 1 (a and b) having inner sleeve diameter (d) 40 mm, outer diameter of bearing (D) 85 mm, width of bearing (B) 19 mm, dynamic load carrying capacity(C) 22.9 N, static load carrying capacity (Co) 7.8 N, ball diameter 10mm. The proper coupling is selected as per need and the required shaft diameter size hole is drilled and bored in the coupling hubs. The key or tightening bolt is provided to avoid the relative motion between the two parts and enable power transmission. The setup consists of a simply supported shaft rested at his both ends in the bearing. The bearing housing is kept on the frames which are fixed to the foundation by using foundation bolts. Provision for loading at the centre is made by using another simple ball bearing. The motor is kept at one end to transmit power to the shaft. The shaft and motor is connected using jaw coupling. During assembly all misalignment problems minimized. At first both healthy bearings are used.

(a) (b)

Fig.1 a) 1209 EKTN bearing and b) H209 Adapter sleeve

Fig. 2 Setup with DEWE soft acquisition system

Point defect is created on the inner race outer, outer race and on the single ball of the bearing with the help of EDM is used 9 (Fig. 2). The copper rod is used as electrode. The depth of the fault considered as 2 mm. This is done by setting the travel of the electrode using dial gauge micrometer. The 50 microsecond pulse on time and 5 amp current is used during machining. For measurement of acceleration, velocity and displacement the data acquisition system is used which has DEWE43 7.0 data acquisition system software. Accelerometers are used for the testing, mounted on both the bearing casing. 43V data acquisition system has 8 analog channels and 8 digital channels. The accelerometer and microphone are connected to the data acquisition system with help of connecter BR-ACC. The test is carried out at various speeds and at different loading. There is no axial load acting on the bearing and bearing is subjected to only radial loading so reading is taken only in vertical directions. The readings on non-driving end bearing are taken. Keeping drive end bearing same, only non-driving end bearing is changed. Speed of the shaft is varied by using variable frequency drive unit. The digital tachometer gives direct speed measurement.

III. Results and Discussion

3.1 Frequency Domain Approach

Frequency domain or spectral analysis of the vibration signal is most widely used approach of bearing defect detection. Assuming no skidding of rolling elements, the outer raceway defect frequency, inner race defect frequency and ball defect frequency are given by following equations. (Y. He and X. Zhang 2009, Z. Taha 2010)

- Defect on outer ring: $f_{or}=\frac{Z*f_s}{2*d_b}\left(1-\frac{d_b}{d_m}\cos\alpha\right)$
- Defect on inner ring: $f_{ir}=\frac{Z*f_s}{2}\left(1+\frac{d_b}{d_m}\cos\alpha\right)$
- Defect on the rolling element: $f_b=\frac{d_m*f_s}{d_b}\left(1-\frac{{d_b}^2}{{d_m}^2}\cos^2\alpha\right)$

Where,

Z= Number of balls or rollers,

f_s = Rotational speed of the shaft in rpm or in Hz.

d_m= Pitch diameter of the bearing

d_b= Ball diameter

α = Contact angle.

Considering contact angle as zero, the different frequencies for outer race, inner race and rolling element are calculated by considering different speed conditions. Table 1 below shows the different defect frequencies of outer race, inner race and ball at various speed conditions.

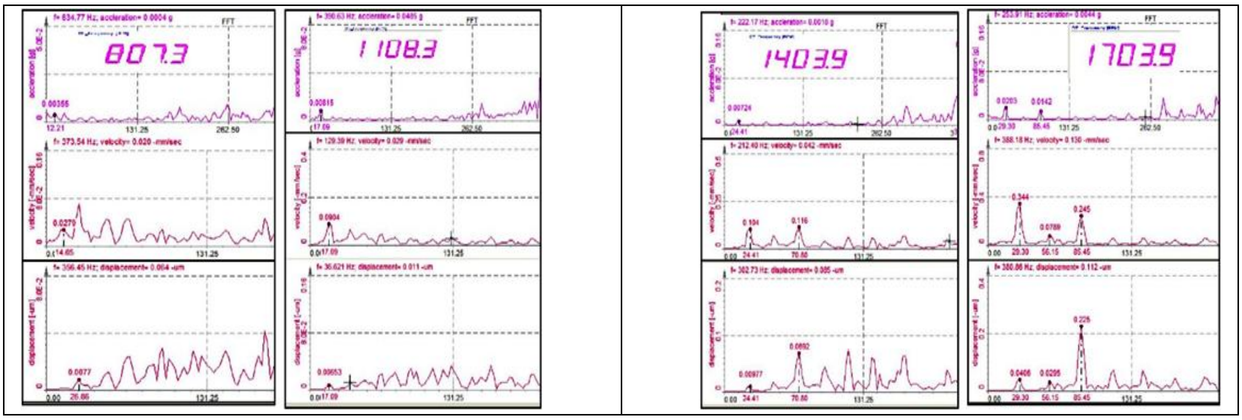
Table no. 1 Defect frequencies at various speeds

Speed (rpm)	Outer race (Hz)	Inner race (Hz)	Ball (Hz)
800	95.89	130.76	84.61
1100	131.859	179.80	116.34
1400	167.82	228.84	148.07
1700	203.78	277.88	179.80

The test is carried out at different speeds and loads. The 2 plates having 22.67 kg weight each and 8 plates having 9.07 kg weight each were readily available. Also, weight of the load carrying central rod is taken into consideration. Extra 3.5 kg wt is considered for this. Load steps are selected for trial analysis which is no load, 26.17 kg load, 48.65 kg load, 85.14 kg load and 121.43 kg load. The 4 speed steps are considered as 800,1100,1400 and 1700 rpm. The trial readings on healthy and faulty bearings are taken. From this it is seen that for no load and speed below 800 the vibration readings are not good. No load and 500 rpm combination is neglected.

3.2. Healthy bearing vibration response

For healthy bearing following graphs as shown in Fig. 3 are taken on FFT for four speed conditions. Acceleration, velocity and displacement value is measured on y axis. The y axis shows vibrational frequencies of the bearing. As observed from Fig.3 above vibration response of healthy bearings it is seen that there are no predominant peaks. Some small peaks are due to inherent bearing characteristics. The peaks observed are not in line with the frequencies calculated in the table 1 which indicates that the bearing is not having any particular problem. Hence the bearing is considered as healthy bearing and above FFT plots are used as baseline reference for further work.

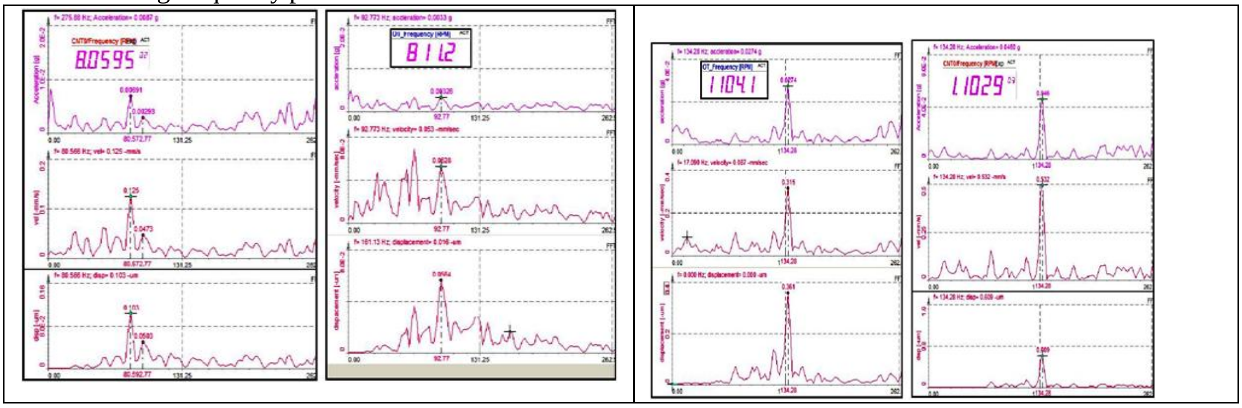


(a) 800 rpm (b) 1100 rpm (c) 1400 rpm (d) 1700 rpm

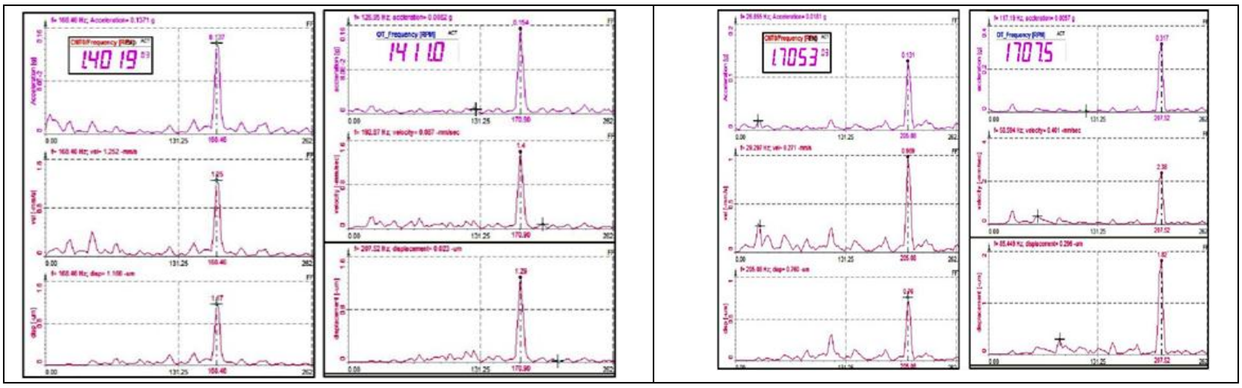
Fig. 3 FFT plot for Healthy Bearing

3.3. Fault on outer race

3.3.1. Bearing frequency plots



(a) 26.17 kg load 800 rpm (b) 121.43 kg 800 rpm c) 26.17 kg 100 rpm (d) 121.43 kg 1100 rpm



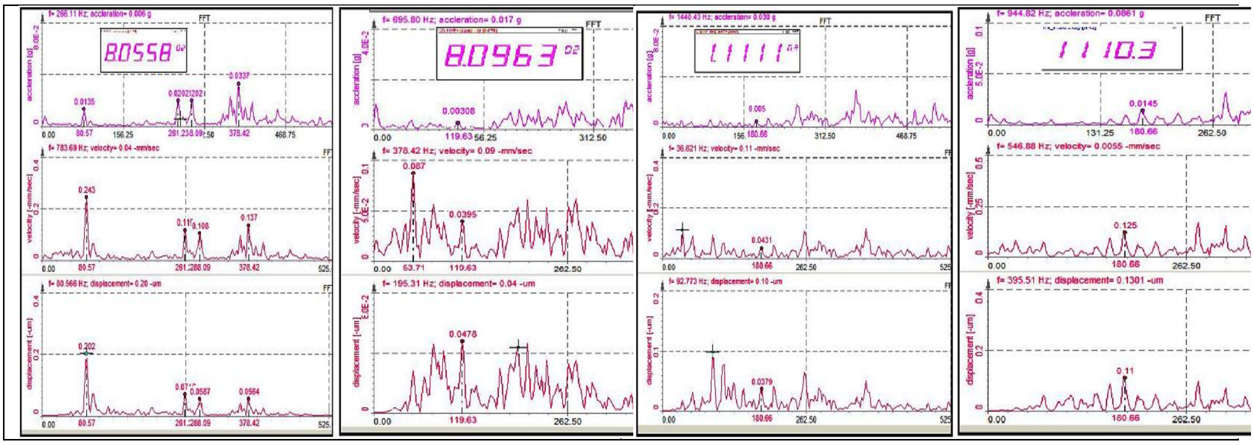
(e) 26.17 kg 1400 rpm (f) 121.43 kg 400rpm (g) 26.17 kg 1700 rpm (h) 121.43 kg 1700 rpm

Fig 4 FFT plots for bearing with outer race fault

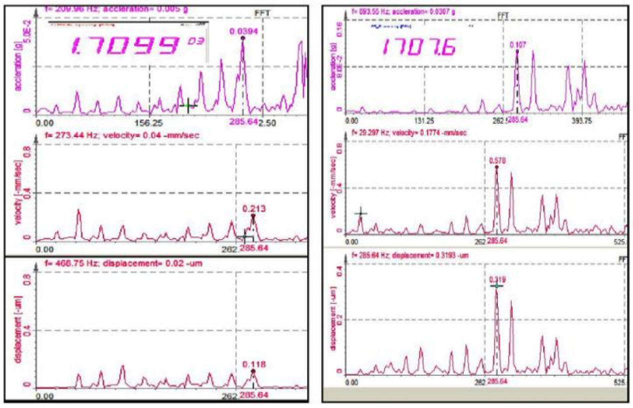
Fig. 4 shows the vibration response of the bearing with fault on outer race. These are taken on minimum and maximum load and at various speeds. The fault is created on the outer race of bearing and effect of this fault on the frequency is seen. It shows that due to the fault on the outer race one predominant peak occurs in all readings. The table no. 2 below shows the frequencies of predominant peak for four speed steps. It shows that there is a fault on the outer race. Also, there is big difference between defected and healthy bearing vibration signal in frequency domain approach, but there is no effect of load on the frequency.

Table no. 2 Frequency value of predominant peak

Speed (rpm)	**Predominant peak frequency (Hz)**	
	26.17 kg load	121.43 kg load
800	95.21	95.21
1100	134.28	134.28
1400	170.90	170.90
1700	207.52	207.52



(a) For 26.17 kg load (b) For 121.43 kg load (c) For 26.17 kg load (d) for 121.43 kg load



(e) 26.17 kg load (f) 121.43 kg load

Fig 5 FFT plots for bearing with inner race fault

The fault is created on the inner race of bearing and effect of this fault on the frequency is seen (Fig. 5). It shows that due to the fault on the inner race one predominant peak occurs in all readings. The table no. 3 shows the frequencies of predominant peak for speed steps. When there is fault on inner race, predominant peaks at different frequency level occurs. As speed increases the vibration level goes on increases at high load. At same speed when there is increase in load then increase in the vibration level occurs.

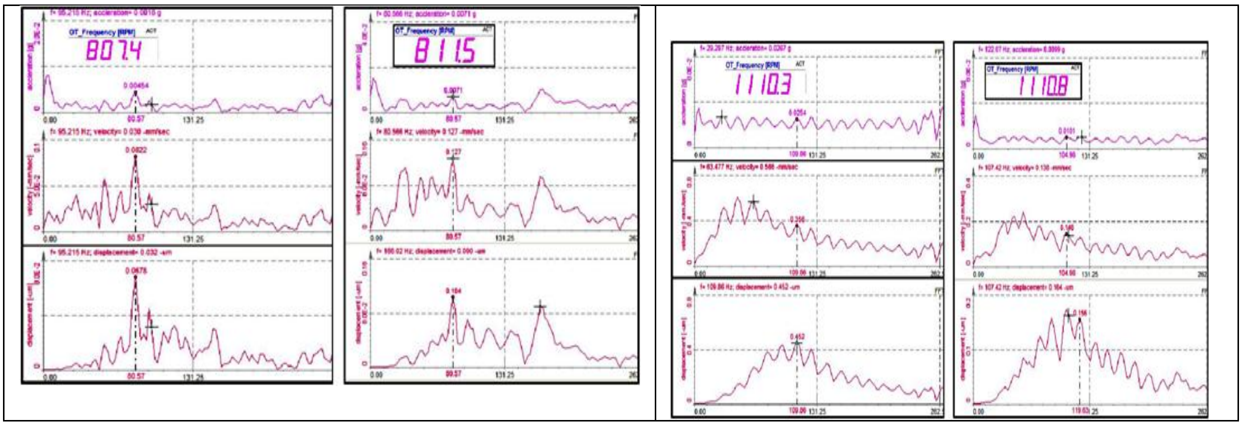
Table no. 3 Frequency value of predominant peak

Speed (rpm)	**Predominant peak frequency (Hz)**
800	78 and 136.72
1100	180.66
1700	285.64

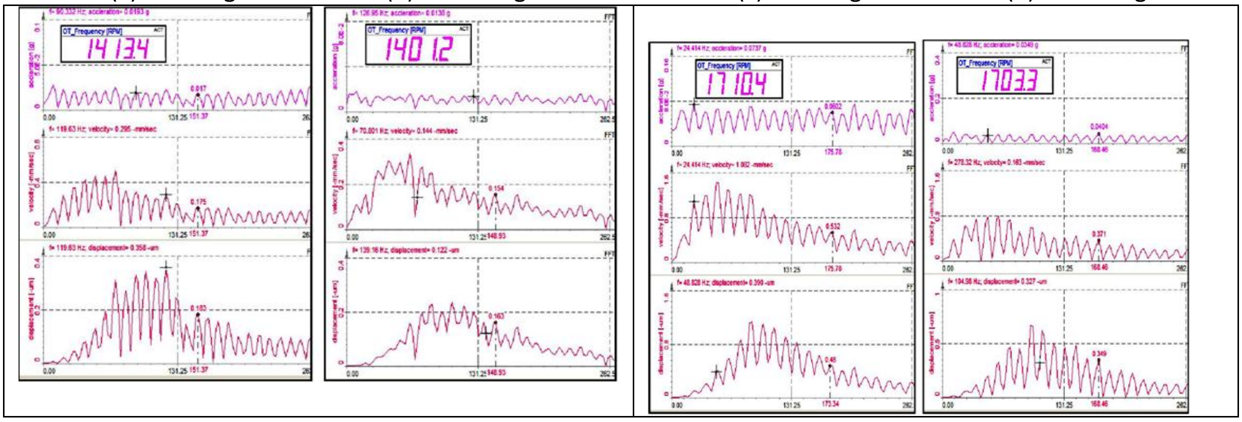
3.5 Fault on ball

3.5.1. Bearing frequency plots

Following graphs as shown in Fig. 6 gives vibration response of bearing on FFT at minimum and maximum load and at different speed conditions. The fault is created on the ball of the bearing and effect of this fault on the frequency is seen. It shows that due to the fault on the ball there are many predominant peaks occurs



(a) 26.17 kg load (b) 121.43 kg load (c) 26.17 kg load (d) 121.43 kg load



(e) 26.17 kg load (f) 121.43 kg load (g) 26.17 kg load (h) 121.43 kg load

Fig. 6 FFT plots for bearing with ball defect

in all readings. The table 4 below shows the frequencies of predominant peak for speed steps.

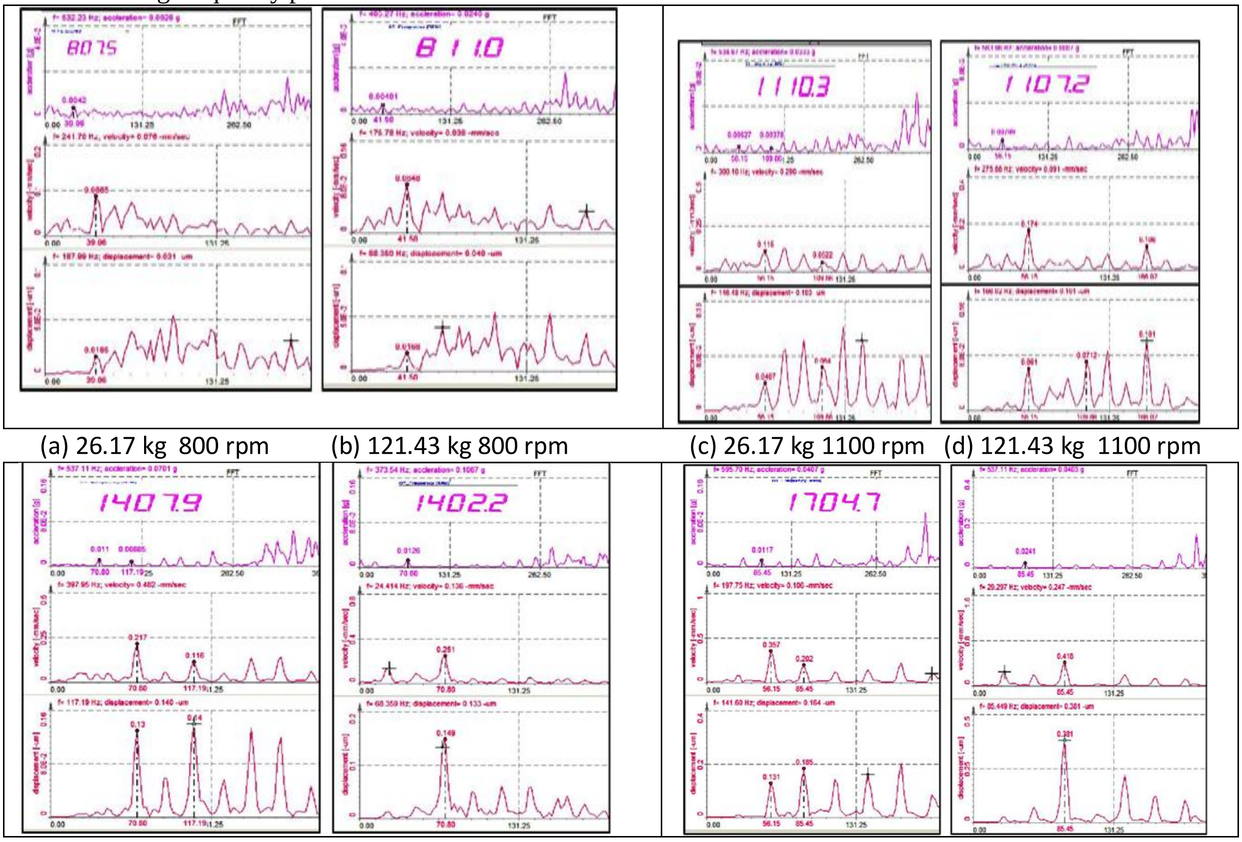
Table no. 4 Frequency value of predominant peak

Speed (rpm)	Outer race (Hz)
800	80.57
1100	105 and 119
1400	118.35 and 144.04
1700	85.45, 109.88 and 180.66

The increase in the speed and load increases vibration level at some speed and load level. But this increase in level is not linear, there is drop in the vibration level at some high speed and load. This is because fault on the ball does not make complete contact with the inner race and outer race while spinning. When there is complete contact of fault to inner or outer race the vibration level increases rapidly. At partial contact the vibration level goes down. Following graphs as shown in Fig. 7 gives vibration response of bearing on FFT at minimum and maximum load and at different speed conditions, when there is looseness in the sleeve.

3.6 Sleeve looseness

3.6.1. Bearing frequency plots



(a) 26.17 kg 800 rpm (b) 121.43 kg 800 rpm (c) 26.17 kg 1100 rpm (d) 121.43 kg 1100 rpm

(e) 26.17 kg 1400 rpm (f) 121.43 kg 1400 rpm (g) 26.17 kg 1700 rpm (h) 121.43 kg 1700 rpm

Fig. 7 FFT plots for bearing with sleeve looseness

IV. Conclusion

In this study experimental analysis is done on the self-align bearings with different fault conditions. Various faults like faults on rolling element, inner race, and outer race are made and by using FFT vibration response and acoustic measurement is carried using frequency domain approach. Absolute values are taken during measurement. For healthy bearing less vibration level is observed. For the fault on the outer race the vibration response shows predominant peaks at same outer race defect frequency which is calculated by calculation. So, it is concluded that there is a defect on the outer race way. For the fault on the inner race predominant peaks are observed as per calculated inner race defect frequency. But this value slightly differs. Also these peaks does not give accurate results as compare to fault on the outer race. This is because of inner race is rotating and the position of the fault changes every time.

For fault on the rolling element, predominant peaks observed as per calculated ball defect frequency. There is also variation in the vibration level for same speed and load level. This is happened because ball is rotating around the inner race and rotating about its own axis and also spins. The defect area does not come in contact with inner and outer race completely. When there is looseness in the sleeve there is a predominant peak at 3 multiples of the bearing rotational frequency. For outer race defect the vibration level increases with increase in the speed and load. For inner race fault the vibration level increases at increase in the speed. Fault on the ball do not gives linear curves of vibration level with increase in load and speed. When there is looseness in the sleeve, the vibration level increases with increase in the speed. As 2 mm diameter fault is created on the ball, inner race and outer race, the vibration measurement technique is more useful than acoustic measurement technique.

References

[1]. Y. He and X. Zhang, "Defect diagnosis for rolling element bearings using acoustic emission", Journal of Vibration and Acoustics, vol. 131, 2009, 061012-1061012-10.

[2]. Govt of India, ministry of railways, 2009," Guidlines of use of acoustic emission techniques on railway bridges", BS104.

[3]. Z. Taha and N. T. Dung, 2010, "Rolling element bearing fault detection with a single point defect on the outer raceway using Finite Element Analysis", 11th Asia Pacific Industrial Engineering and Management Systems Conference, Melaka,

[4]. N. Tandon and A. Choudhury, 1999, "A review of vibration and acoustic measurement methods for the detection of defects in

rolling element bearings", Tribology International 32, 469-480.
[5]. P. Kadarno, Z. Taha, 2008, T. Dirgantara and K. Mitsui, "Vibration Analysis of Defected Ball Bearing using finite element model simulation", Master of Engineering Thesis Report, Faculty of Engineering, University of Malaya, Kuala-lumpur, 2832-2840.
[6]. Zeki Kiral, Hira Karagulle 2006, "Vibration analysis of rolling element bearings with various defects under the action of an unbalanced force", Mechanical System and Signal Processing, 20, 1967-1991.
[7]. Zeki Kiral, Hira Karagulle, 2003 "Simulation and analysis of vibration signals generated by rolling element bearing with defects", Tribology international 36, 667-678.
[8]. H. Arlsan and N. Akyurk, 2008," An investigation of rolling element bearing vibrations caused by local defects", Journal of Tribology130, 041101-1-12.
[9]. SKF bearing Catalogue.

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