Self Aligned Bearing Fault Detection Using vibration Signals Analyzed by Spectrum analysis.

Gaikwad Rajendra Dattatraya, Prof. Khaire N.D.
rajendragaikwad355@gmail.com
(M.E. (Design) Student, RSCOE, Tathawade, Pune.)
(Prof. in Mechanical Engineering, RSCOE, Tathawade, Pune.)

ABSTRACT

Over the past decades there have been many major advances in the development of fault diagnosis of deep grove ball bearing and roller bearing had take placed In this paper an effort is made to study the performance of Self aligned ball bearings. Self aligned ball bearings are widely used in industry from home appliances to aerospace industry. Proper functioning of these machine elements is extremely important in order to prevent catastrophic damages. It is therefore, important to monitor the condition of the bearings and to know the severity of the defects before they cause serious catastrophic damages. Hence, the study of vibrations generated by these defects plays an important role in quality inspection as well as for condition monitoring of the self aligned ball bearing/machine element. This paper describes the vibration analysis technique to detect the defects in the self aligned ball bearing. The Fast Fourier Transform (FFT) detected the frequencies of damage present during the vibration analysis of a ball bearing. This faults and their related frequency is simulated with MATLAB software.

KEYWORDS

Self aligned ball bearing, signal analysis Spectrum analysis, FFT, MATLAB simulation.

1. INTRODUCTION

Ball bearing is the most basic component used in machinery for various engineering applications. Most of the engineering applications such as textile industry, agricultural industry and food and beverage industry use self aligned ball bearings, which enable rotary motion of shafts apart from complex mechanisms in engineering such as power transmissions, rolling mills and aircraft gas turbines. Self-aligning ball bearings have two rows of balls and a common sphered raceway in the outer ring. The bearings are insensitive to angular misalignment of the shaft relative to the housing. Self-aligning ball bearings generate less friction than any other type of rolling bearing, which enables them to run cooler even at high speeds.

As ball bearing is most commonly used component in machinery, it has received a great attention in the field of condition monitoring. Even a newly manufactured bearing may also generate vibration due to components running at high speeds, heavy dynamic loads and also contact forces which exist between the bearing components. Bearing defects may be classified as localized and distributed. The localized defects include cracks, pits and spalls caused by fatigue on rolling surfaces [7]. The distributed defects include surface roughness, waviness, and off size rolling elements. The sources of defects may be due to either manufacturing error or abrasive wear. Hence, study of vibrations generated by these defects plays an important role in quality inspection as well as for condition monitoring of the ball bearing/machinery [2]. In order to prevent bearing failure there are several techniques in use, such as, oil analysis, wear debris analysis, vibration analysis and acoustic emission analysis. Among them vibration and acoustic emission analysis [8] is most commonly accepted techniques due to their ease of application. The time domain and frequency domain analysis [3] are widely accepted for detecting malfunctions in bearings. The frequency domain analysis is more useful as it identifies the exact nature of defect in the bearings. These frequencies of the ball bearing depend on the bearing characteristics and are calculated from the relations shown below [4].

Cage defect frequency (F_C)

$$F_{cage} = F_c = \frac{F_r}{2D_p}\left[D_p - D_b \cos\beta\right] Hz$$

Inner race defect frequency (F_{IRD})

$$F_{IRD} = \frac{nF_R}{2D_P}\left[D_P + D_B \cos\beta\right]$$

Outer race defect frequency (F_{ORD})

$$F_{ORD} = \frac{nF_R}{2D_P}\left[D_P - D_B \cos\beta\right]$$

Ball defect frequency (F_B)

$$F_B = \frac{F_R}{D_B D_P}\left[(D_P)^2 - (D_B)^2 \cos\beta\right]$$

2. LITERATURE REVIEW

The effect of vibration on perfect bearing can be considerably reduced by selecting the correct preload and number of balls [9]. The vibration monitoring technique is used to analyze various defects in bearing and it also provides early information in case of progressive defects [8]. Radial vibration measurement was used to capture the signals and it was found that defect bearing has a strong effect on the vibration spectra [10]. In case of defect on the fixed ring the frequency spectrums generated will appears at its multiples. If the defect is located on the inner ring or the ball, frequency spectrum is amplitude modulated. The more is the wear, higher are the amplitudes of the components. Low speed fault simulation tests were conducted with various defects on the bearing. This study gives the best frequency bandwidth for early detection of bearing defects running at lower speeds [11].

3. EXPERIMENTAL SETUP

The experimental bearing test rig is designed and fabricated to identify the presence of defects on a radially loaded self aligned ball bearing by vibration analysis technique is shown in Figure 1. The test rig consists of a 1.5 Hp motor connected with step pulley which is connected with another step pulley. Test bearing is mounted on shaft supported by two support bearings. Test bearing is loaded with dead weight.

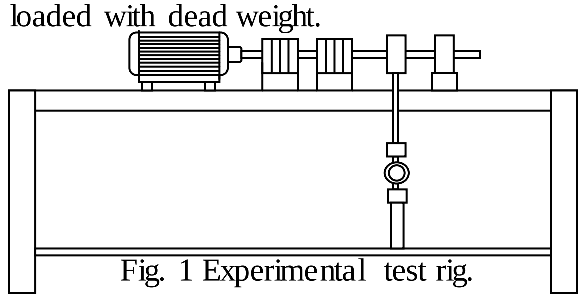

Fig. 1 Experimental test rig.

3.2. Bearing type and fault creation

The bearing type used in this study is a double row self aligned ball bearing with bearing model 1206 series. The self aligned ball bearing is shown in Figure 2. 1206 Self Aligning Ball Bearing has a spherical outer ring raceway, the balls and cage continue to rotate, this type of bearings is suitable when the displacement of the centers around which the shaft and housing rotate and shaft deflection are likely to occur. Bearing is made of Chrome Steel.

Figure 2 Double row self aligned ball bearing

The details of the ball bearing used in the vibration analysis is as below,

- Bearing: 1206 Ball Bearing
- Type: Self Aligning Bearing
- Dimensions: 30mm x 62mm x 16mm/Metric
- Inner Diameter: 30mm
- Outer Diameter: 62mm
- Width: 16mm
- Size: 30 x 62 x 16 mm
- Dynamic load rating C: 15,600 N
- Static load rating Co: 4,650 N

Figure 3 Fault created on ball.

Figure 4 Fault on inner race.

3.3. Experimentation

Experiments were carried on four sets of self aligned ball bearings, a new bearing and three defective bearings, i.e., inner race defect, outer race defect and ball defect. The faults are created on outer race, inner race and on one ball by laser machining. Initially a new self aligned ball bearing was fixed in the bearing test rig and vibration signals were captured using FFT analyzer. Then the new bearing is replaced with the three defective bearings for capturing the vibration signals. Recording of signals were observed for three running conditions for each bearing. The central radial load on the ball bearing was set to 177N, 216N and 255N. The speed variation is done for 1090rpm 1820 rpm and 3025rpm.

4. RESULTS AND DISCUSSIONS

The vibration analysis or condition monitoring is based on the principle that all systems produce vibration. When a bearing is running properly, the vibrations generated are very small and generally constant. But, due to some of the dynamic processes that act in the machine, defects develop causing the changes in the vibration spectrum. Firstly, Vibration signals collected in the form of time domain are converted into frequency domain by FFT analyzer. Fast Fourier Transform (FFT) on each of the four bearings. The frequency domain signals and amplitude of vibration at predominant frequencies are considered for the analysis. Vibration signals of a new bearing and defective bearings for a radial load of 177N, 216N and 255N. at 1090rpm 1820 rpm and 3025rpm.are shown in Figure 5, 6and 7. The fundamental frequency theoretically calculated for the inner race defect bearing from equation (1) is found to be 143.71Hz, 239.96Hz, and 398.84Hz. The experimental frequency spectrum of the vibration signals for the inner race defective bearing (fir) shows higher peaks at 100Hz and 275Hz and 300 Hz (Figure 7,8 and 9) compared to new bearing frequency spectrum peaks. The frequency spectrum of the vibration signals for the outer race defective bearing shows peaks at 125Hz, 255Hz and 295Hz which are closely matches with the fault frequency of outer race defect from equation (2) is 143.71Hz., 284.691Hz and 306.98Hz

Table 1 Fault frequency (analytical and experimental)

Speed (N) (rpm)	Theoretical outer race faulty freq. BPFo	Experimental Fault freq. using FFT (Hz)
1090	125	143
1809	255	284
3015	295	306

MATLAB has used to develop the particular algorithm which makes it easy to find the faulty frequencies. The power spectrum code has also generated in the MATALAB. The following steps were used to generate the MATLAB program.

- Code for a clean signal
- Adding noise to clean signal
- Calculating and Adding faulty frequencies

Clean signal are generated using MATLAB program. Next step was to add noise to the clean signal then small amount of noise has added in clean signal, to add this noise array function and random noise is used. Program output clearly shows the clean and noisy signals. MATLB also helps to calculate the all faulty frequencies at same time using properties of the bearing. The program has developed using ‘for loop’ properties to calculate and add faulty frequencies i.e. (BPFo, BPFi, BSF and FTF). One of the output of MATLAB has shown in Fig. 10 and 11

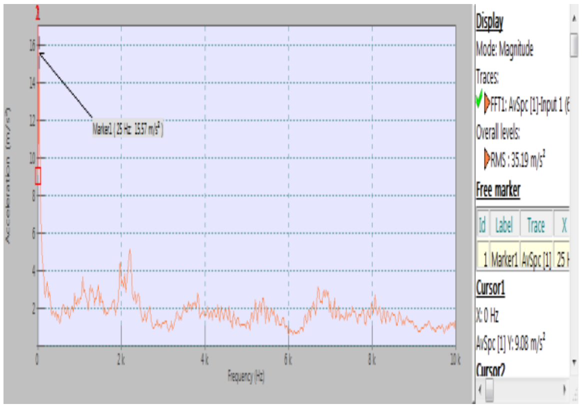

Figure 5 Vibration for new bearing at 1090rpm

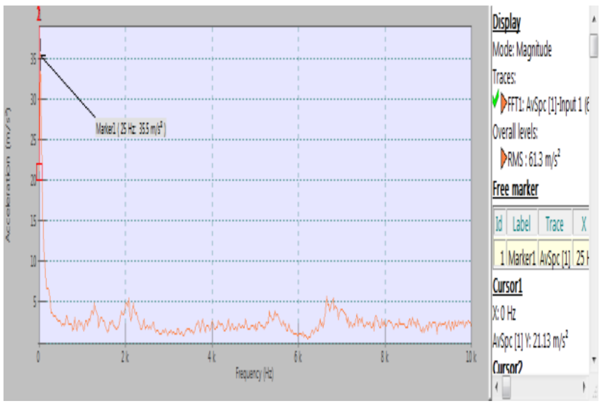

Figure 6 Vibration for new bearing at 1820rpm

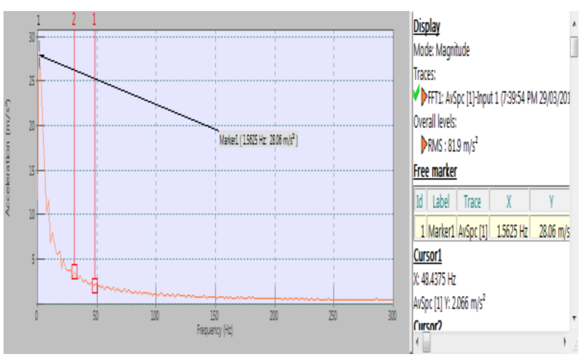

Figure 6 Vibration for new bearing at 3025rpm

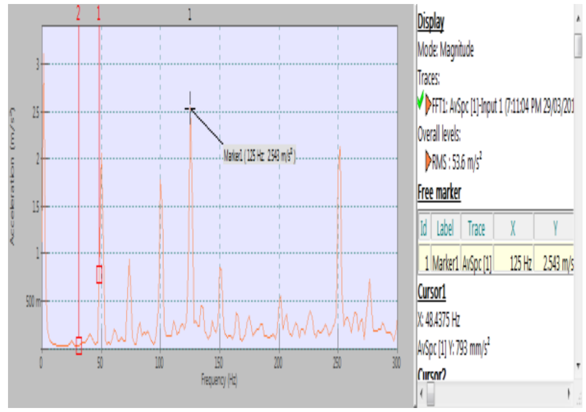

Figure 7 Vibration for inner race defect at 255N and 1090rpm

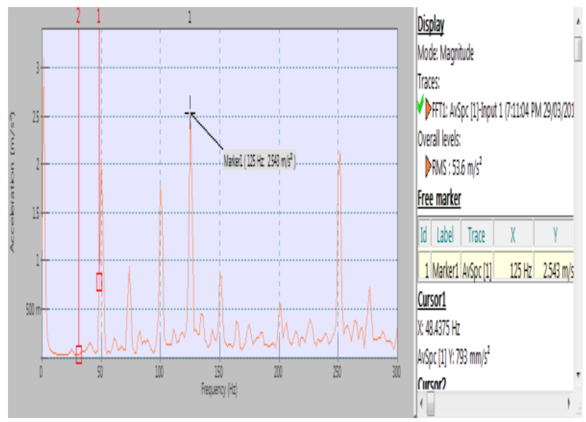

Figure 8 Vibration for inner race defect at 255N and 1820rpm

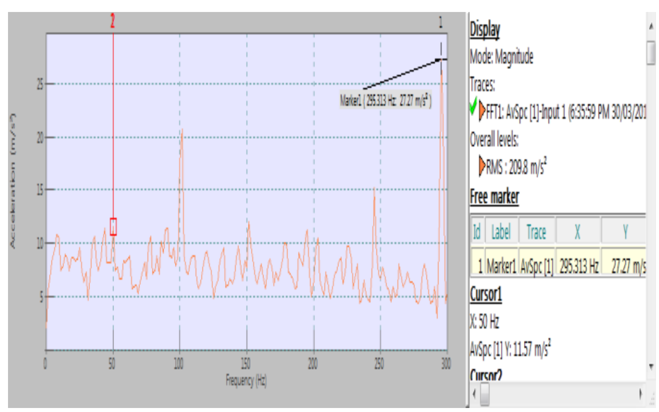

Figure 9 Vibration for inner race defect at 255N and 3025rpm

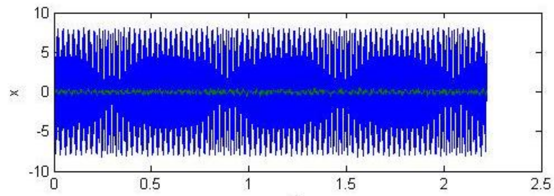

Figure 10 Time domen MATLAB output for inner race defect at 1820rpm

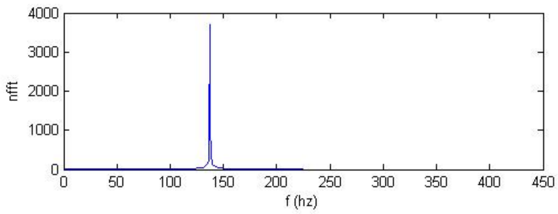

Figure 11 Time domen MATLAB output for inner race defect at 1820rpm

5. CONCLUSIONS

The vibration response of new and defect self aligned ball bearing is compared. The Fast Fourier Transform are performed on each of the four bearings. From the vibration data, the amplitude of vibration spectra is relatively small for new bearing and defect ball bearing cases, where as vibration spectra is comparatively larger in both the cases of load i.e., 177N, 216N and 255N.for defects on inner race and outer race. Also from Figure 5 and 7, the values computed from the frequency domain signals and amplitude of vibrations for new and defect bearings shows the location of the fault and severity of the defect. The value shows that as the load increases, the magnitude of vibration response also increases. Additionally, the amplitude value for new bearing is lies below 5 which is a clear indication that no defects in the bearing, for inner race defect the value lies between 20 and 25, it shows the moderate defect in the bearing, where as for inner and outer race defects the amplitude value exceeds 25, which shows larger indication of damage on inner and outer race ways. Hence amplitude value shows the state of the bearing.

REFERENCES

[1]Purwo Kadarno & Zahari Taha, Tatacipta Dirgantara, Kimiyuki Mitsui, (2008) “Vibration Analysis of Defected Ball Bearing using Finite Element Model Simulation”, Proceedings of the 9th Asia Pasific Industrial Engineering & Management Systems Conference, Indonesia, Vol. 1,pp2832-2840.

[2] Andy C.C. Tan, Katie L, McNickle and Danieal L. Timms, (2003) “A practical approach to learning vibration condition monitoring”. Journal of World Transactions on Engineering and Technology education, Vol.2, No.2, pp 217-220.

[3] Zeki Kiral, Hira Karagulle, (2003) “Simulation and analysis of vibration signals generated by rolling element bearing with defects”. Journal of Tribology International, 36, pp. 667-678.

[4] P. N. Botsaris, D. E. Koulouritis, (2007) “A preliminary estimation of analysis methods of vibration signals at fault diagnosis in ball bearing”. Proceedings of the 4th International Conference on NDT, Chania, Crete-Greece, Vol.1, pp 1-6.

[5] 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, Vol. 32, pp469–80.

[6] Attel Manjunath, D.V.Girish, (2010) “Characterization of short carbon fiber reinforced Polyacetal”, Proc. of International conference on Advanced Materials, Manufacturing, Management and Thermal Sciences. Tumkur, Karnataka, India, Vol.1, pp79-85.

[7] Sadettin Orahan, Nizami Akturk, Veli celik, (2006) “Vibration monitoring for defect dignosis of rolling element bearings as a predictive maintenance tool: Comprehensive case studies”,

Journal of Non Destructive Testing & Engineering International. Vol.39, pp 293-298.

[8] M. Amarnath, R Shrinidhi, A. Ramachnadra and S.B. Kandagal, (2004) "Prediction of defects in antifriction bearings using vibration signal analysis", Journal of IEI, Vol. 85, pp 88-92.

[9] R. K. Purohit and K. Purohit, (2006) "Dynamic analysis of ball bearings with effect of preload and number of balls", International Journal of Applied Mechanics and Engineering, Vol. 11, No. 1, pp 77-91.

[10] H. Mohamadi Monavar, H. Ahmadi and S.S. Mohtasebi, (2008) "Prediction of defects in roller bearings using vibration signal analysis", World Applied Science Journal. Vol.4(1). pp 150-154.

[11] Eric Y.Kim, Andy C.C.Tan, Bo-suk Yang and Vladis Kosse, (2007) "Experimental study on condition monitoring of low speed bearings: Time domain analysis", 5th Australasian Congress on Applied Mechanics,Brisbane, Australia. pp 1-7.