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ACOUSTIC EMISSION ANALYSIS OF DEEP GROOVE POLYACETAL (POM) BALL BEARING

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ABSTRACT

Polymer matrix composites have shown the ability to balance traditional polymer properties such as low weight and ease of processability with the strength and stiffness of reinforcing agents. 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 ball bearing/machine element. In this paper, an effort is made to study the performance of polymer ball bearings made with Polyacetal (POM) material using acoustic emission analysis on different components of the bearing structure using the time and frequency domain parameters. This paper investigates the relationship between acoustic emission RMS, amplitude and kurtosis for different speeds on new and defective ball bearing conditions.

***Keywords**: Polyacetal (POM) ball bearing, acoustic emission, RMS, amplitude, kurtosis.*

I. INTRODUCTION

Ball bearings are one of the important basic components used in machinery for various engineering applications. Most of the engineering applications such as pumps, electric motors, bicycles and roller skates use these bearings. In general ball bearings are made of four different components, an inner ring, an outer ring, the ball element and the cage. The cage element helps in separating the rolling elements at regular intervals and also it holds them in place within the inner and outer raceways to allow them to rotate freely [5].

Thermoplastics have long demonstrated their suitability as sliding materials. For decades they have been used successfully in sliding applications in precision engineering, in small electrical appliances and in the electrical industry to mention only a few examples. Polymer bearings by their very nature do not have the high load-bearing capacity compared to metal bearings, but they offer other advantages such as operation in conditions of dry running and mixed friction, low noise, maintenance-free operation, chemical resistance, electrical insulation and also have processing advantages.

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, misaligned races and off size rolling elements. The sources of defects may be due to either manufacturing error or abrasive wear. Hence, study of vibrations and noise 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].

Inner race frequency,

$$f_{ir} = f_s \frac{N_b}{2}\left(1 + \frac{B_d}{P_d}\cos\emptyset\right) \quad (1)$$

Outer race frequency,

$$f_{or} = f_s \frac{N_b}{2}\left(1 - \frac{B_d}{P_d}\cos\emptyset\right) \quad (2)$$

Ball frequency,

$$f_b = f_s \frac{P_d}{2B_d}\left(1 - \frac{B_d^2}{P_d^2}\cos^2\emptyset\right) \quad (3)$$

Fundamental train frequency,

$$f_{ftf} = \frac{f_s}{2}\left(1 - \frac{B_d}{P_d}\cos\emptyset\right) \quad (4)$$

Acoustic emission (AE) is the phenomenon of transient elastic wave generation due to a rapid release of strain energy caused by a structural alteration in a solid material under mechanical or thermal stresses. Generation and propagation of cracks, growth of twins, etc. associated with plastic deformation are among the primary sources of AE. Hence it is an important tool for condition monitoring through non-destructive testing.

II. BEARING TYPE & BEARING MATERIAL

The bearing type used in this study is a single row deep groove ball bearing with bearing model 6204 series. The ball bearing is made with thermoplastic material called Polyacetal (POM) shown in Figure 1. The Polyacetal has melting temperature (T_m) 182-218^{o}C, density 1.41 g/cc and carbon Polyacetal known as polyoxymethylene (POM), is a high strength, crystalline engineering thermoplastic material having a desirable balance of excellent properties and easy processing [6]. Polyacetal is one of the thermoplastic materials that can replace metals and thermosets because of its long-term performance over a wide range of temperature conditions and harsh environments. It retains properties such as creep resistance, fatigue endurance, wear resistance and solvent resistance under demanding service conditions. Also, it is a lubricious, strong and has good dimensional stability. The details of the Polyacetal (POM) ball bearing used in the Acoustic emission analysis are shown in the Table 1 and Figure 1 & 2.

Table 1. Details of Polyacetal ball bearing.

Bearing Type	POM 6204
Inner diameter (d), mm	20
Outer diameter (D), mm	47
Pitch diameter (Pd), mm	31.5
Number of Balls (Nb)	8
Ball diameter (Bd), mm	6
Width of the ring (W), mm	14
Contact angle (β)	0

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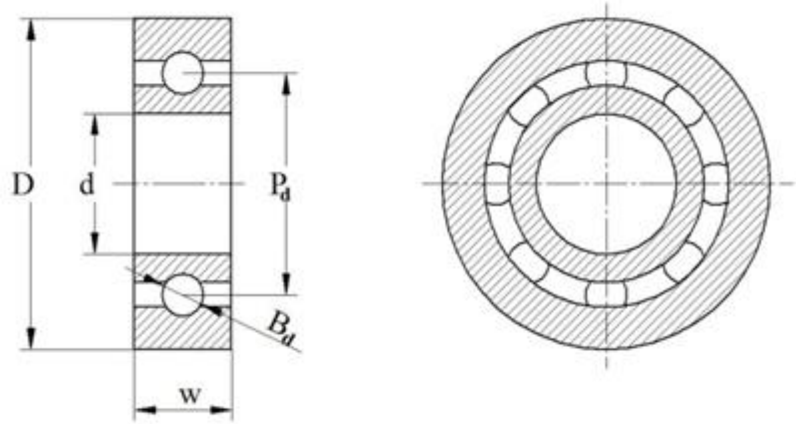

Figure 1. Details of Polyacetal ball bearing for Acoustic Emission Analysis.

Figure 2. Polyacetal (POM) ball bearing used for Acoustic Emission Analysis.

III. BEARING TEST RIG

The experimental bearing test rig is designed and fabricated to identify the presence of defects on a radially loaded Polyacetal deep groove ball bearing by vibration and acoustic emission analysis technique is shown in Figure 3 &4.

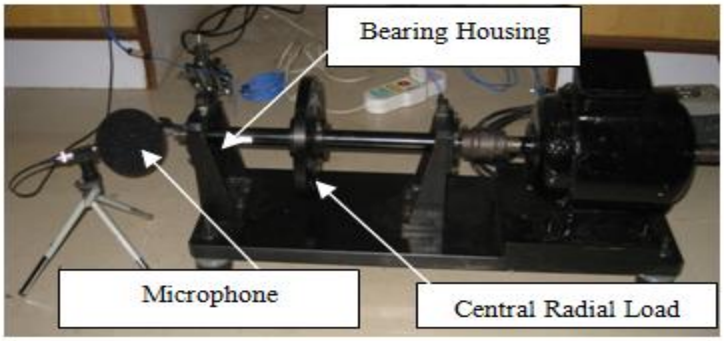

Figure 3. Experimental set up for capturing Acoustic Emission/Noise Signals.

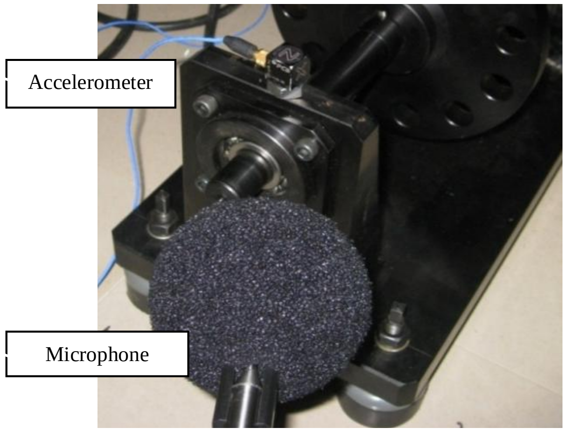

Figure 4. Position of accelerometer and Microphone.

The test rig consists of a circular shaft with central radial disc rotor, which is supported on two deep groove polymer ball bearings of 6204 series. An induction motor with variable speed drive is coupled to a flexible coupling which drives the shaft. The bearing test rig employed for this study has an operational speed of 10 to 2000 rpm, with central load of 200N capacity. Considering the shaft subjected to both combined twisting and bending moment the diameter of the shaft found to be 25mm and a bushed pin type flexible coupling is used to connect two shafts. For capturing vibration signals from the test rig a provision is made to mount the accelerometer on top of the test bearing housing and microphone is placed near the bearing housing to capture the AE/noise signals produced during the test.

IV. EXPERIMENTATION

Experiments were carried on four sets of Polyacetal ball bearings, a new bearing and three defective bearings, i.e., inner race defect, outer race defect and ball defect. The defects were artificially produced by a drill tool, one on the inner race, one on the outer race and the other on the rolling ball. Initially a new Polyacetal ball bearing was fixed in the bearing test rig and noise signals were captured by using PCB 130 series microphone via eight-channel FFT analyzer (LMS SCADAS Mobile SCM01). Then the new bearing is replaced with the three defective bearings for capturing the AE/noise signals. Recording of signals were observed for five speed running conditions (200, 400, 600, 800 and 1000 rpm) for each bearing at a constant central radial load on the ball bearing was set to 30N [12].

V. RESULT & DISCUSSION

The AE/noise analysis or condition monitoring is based on the principle that all systems produce noise and 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 noise level and vibration spectrum.

Firstly, AE/noise signals collected in the form of time domain are converted into frequency domain by processing Fast Fourier Transform (FFT) on each of the four bearings. The RMS values and Kurtosis values computed from the frequency domain signals and amplitude of vibration at predominant frequencies are considered for the analysis.

AE/noise signals for a new bearing and defective bearings for at a radial load of 30N and at varying speeds of the motor (200, 400, 600, 800 and 1000 rpm) are shown in Figure 5 through 9.

The fundamental frequency theoretically calculated for the inner race defect bearing from equation (1) is found to be 79.38 Hz. The experimental frequency spectrum of the noise levels for the inner race defective bearing (f_{ir}) shows higher dB at 80Hz and 160Hz compared to new bearing frequency spectrum dB. The frequency spectrum of the noise signals for the outer race defective bearing (f_{or}) shows peaks at 55Hz, 115Hz and 170Hz which are closely matches with the fault frequency of outer race defect from equation (2) is 53.97Hz. The frequency spectrum of the noise signals for the bearing with ball defect (f_b) shows peaks at 40Hz, 90Hz, 135Hz and 180Hz which also closely matches with the fault frequency of ball defect bearing calculated theoretically as 42.17Hz.

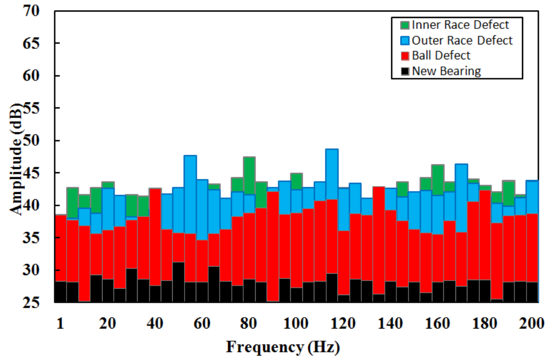

Figure 5. Variation of noise spectra in dB for bearings running at 200 rpm.

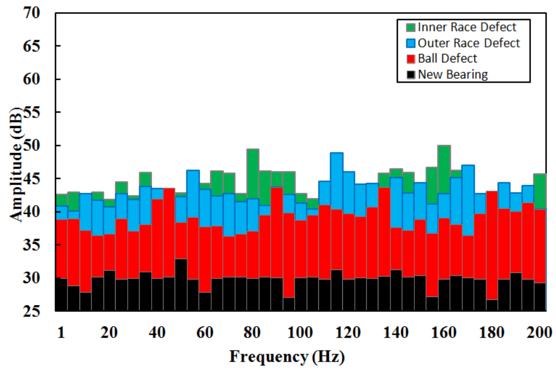

Figure 6. Variation of noise spectra in dB for bearings running at 400 rpm.

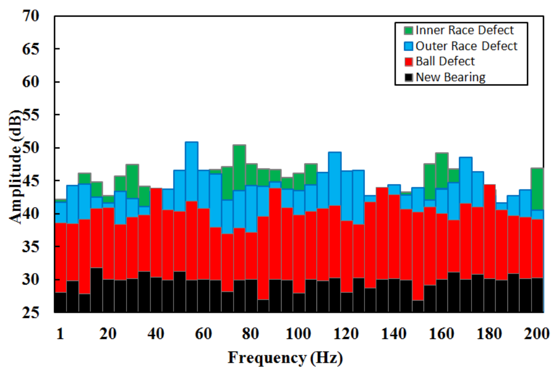

Figure 7. Variation of noise spectra in dB for bearings running at 600 rpm.

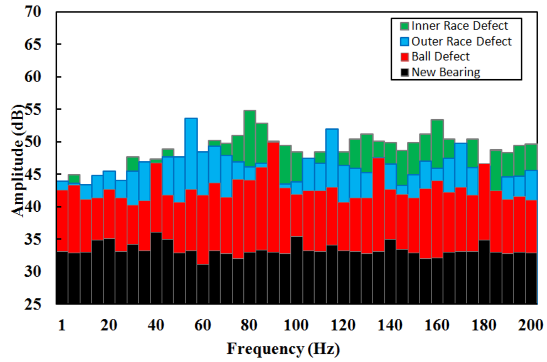

Figure 8. Variation of noise spectra in dB for bearings running at 800 rpm.

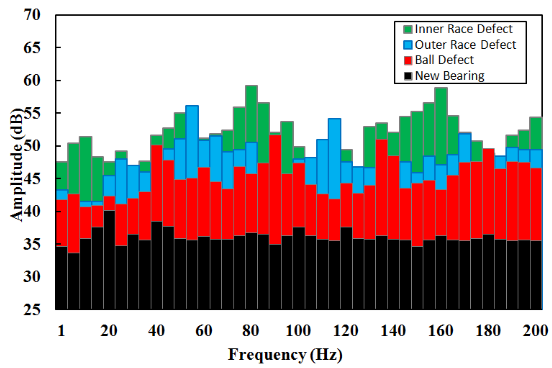

Figure 9. Variation of noise spectra in dB for bearings running at 1000 rpm.

The RMS values of AE for new bearing and three defective bearing conditions were compared for increasing speeds for all test conditions, the AE RMS value remained almost constant for 200, 400 and 600 rpm compared to the speeds of 800 and 1000 rpm at a fixed load of 30N. Also it is found that RMS value is higher for outer race, inner race and ball defect compared to new bearing as shown in Figure 10.

It was observed that AE peak to peak value in dB remained almost constant for 200, 400 and 600 rpm compared to the speeds of 800 and 1000rpm for a fixed load of 30N as shown in Figure 11.

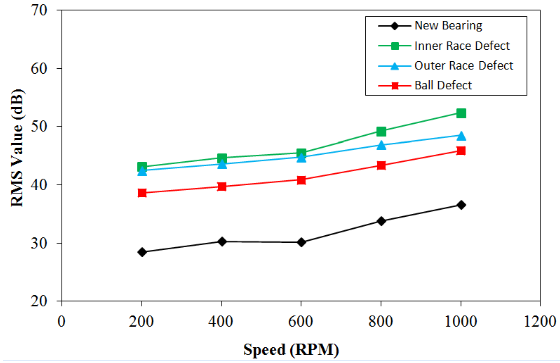

Figure 10. The RMS value of noise spectra in dB for varying speed and with central radial load of 30N.

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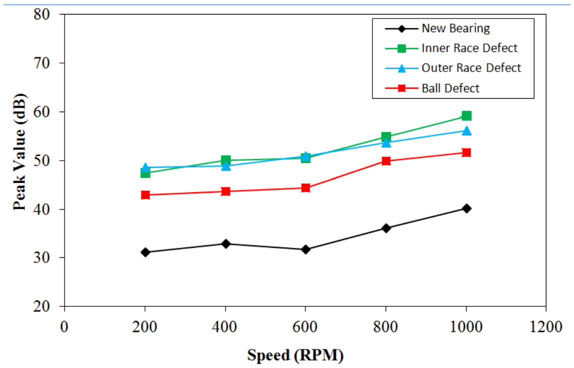

Figure 11. The peak to peak value of noise spectra in dB for varying speed and with central radial load of 30N.

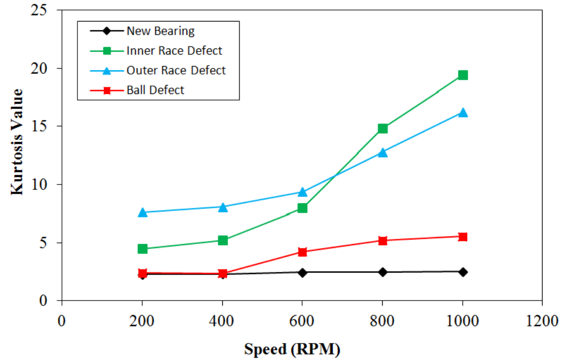

Figure 12. The kurtosis value of noise spectra for varying speed and with central radial load of 30N.

Kurtosis is a measure of the peakness of a distribution and is widely established as a good indicator of bearing health. For a defect free bearing the value of kurtosis is equal to 3. From Figure 12 the value of kurtosis for new bearing falls below 3 which indicate the fault free state of the bearing. For ball defect the kurtosis value falls below 5 which indicates lower noise signals has less effect on the bearing. For defects on the inner race, outer race the kurtosis value lies between 5 and 20. This is the clear indication of the defects in the bearing.

VI. CONCLUSIONS

The AE/noise spectra response of new and defect Polyacetal (POM) deep groove ball bearing is compared. The frequency of noise spectra, RMS peak value and Kurtosis are performed on each of the four bearings. From the AE data, the amplitude of noise spectra in dB is relatively small for new bearings running at 200, 400, 600, and 800 rpm, compared to 1000 rpm which indicates the higher noise at larger speeds. Also, for defective bearings the noise spectra is largely increasing as the speed increases.

Peak to Peak values for new bearing falls between 30 to 40 dB, for ball defect the peak value lies between new bearing and inner & outer race defect bearings as shown in Figure 11, which clearly indicates that the defect in the raceways will have more effect on noise and vibrations in the bearing compared to new and ball bearing defect cases.

From Figure 10, The RMS value shows that as the speed crosses over 600 rpm, the magnitude of noise spectra also increases. Additionally, the Kurtosis value for new bearing lies below 3 which is a clear indication that no defects in the bearing, for ball defect the value lies below 5, it shows the moderate defect in the bearing, where as for inner and outer race defects the kurtosis value raises from 5 to 20, which shows larger indication of damage on inner and outer race ways. Especially at speeds 800 and 1000 rpm the value of kurtosis increases drastically which concludes that POM bearings with fewer defects will run moderately at lower speeds compared to higher speeds. Hence kurtosis value shows the state of the bearing.

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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.*
12. *Attel Manjunath, D.V.Girish, (2013) "Defect Detection in Deep Groove Polymer Ball Bearing Using Vibration Analysis", International Journal of Recent advances in Mechanical Engineering (IJMECH), Vol. 2, No. 3,pp45-52.*
13. *Miettinen, J., Pataniitty,P., (1999) "Acoustic Emission in Monitoring Extremely Slowly Rotating Rolling Bearing", Proceedings of COMADEM '99, Oxford, Coxmoor Publishing Company, pp 289-297.*
14. *Abdullah M. Al-Ghamd, David Mba., (2005) "A Comparative experimental study on the use of acoustic emission and vibration analysis for bearing defect identification and estimation of defect size", Mechanical Systems and Signal Processing Journal, pp 1-35.*