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Study of fault in outer race of Roller Bearings using Acoustic emission and Vibration analysis

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ABSTRACT: *Vibration monitoring of rolling element bearings is probably the most established diagnostic technique for rotating machinery. Usage of probes is a classical method which is known. The application of acoustic emission (AE) for bearing diagnosis is gaining ground as a complementary diagnostic tool; however, limitations in the successful application of the AE technique have been partly due to the difficulty in processing, interpreting and classifying the acquired data. The experimental investigation reported in this paper was centered on comparison of results obtained by the application of the AE technique and Probes for identifying the presence of a defect on a radially loaded bearing. An experimental test rig was designed such that defects of different sizes could be seeded onto the outer race of a test bearing. Comparisons between AE and vibration analysis over a range of speed and load conditions are presented.*

Keywords*: Roller Bearings, fault detection, vibration analysis and acoustic emission*

I. INTRODUCTION

Fault detection of the rolling elements, i.e. gear and bearing faults, has been gaining importance in recent years because of its detrimental influence on the reliability of the machines. Vibration signature analysis is the most commonly used fault-detection technique employed in rotor- bearing systems. Detection of the fault and its severity are two important steps or features of a condition monitoring system. Lifetime of a machine component is determined by the severity of the fault. It is crucial, especially in critical systems, where continual operation is generally indispensable. The bearing defects can be either distributed or local type or combination of both. The distributed defects can be the surface roughness, waviness, misaligned races, and off-size rolling elements. Localized defects are developed in the raceways, rollers and cage of a bearing. The periodic impacts occur at ball-passing frequency (characteristic defect frequencies), which can be estimated from the bearing geometry and the rotational speed. Sometimes the defect frequencies are not observable with the help of the Fast Fourier Transform (FFT) spectrum, because the impulses generated by the defects are masked by noise. To overcome this problem, signal processing techniques are implemented by many researchers. Several methods, based on vibration and acoustic signal processing, have been developed to detect bearing local faults. The interaction of surface asperities and impingement of the bearing balls over the seeded defect on theouter race generates acoustic emissions (AEs) which is basically the transient elastic waves. During thelast few years a significant progress in the capabilities of acoustic instrumentation together with the signalprocessing techniques has made it possible to extract useful diagnostic information from acoustic signals.

Acoustic emissions (AEs) are defined as transient elastic waves generated from a rapid release of strain energy caused by a deformation or damage within or on the surface of a material [1]. There have been numerous investigations reported on applying AE to bearing defect diagnosis. Yoshioka and Fujiwara [2,3] have shown that selected AE parameters identified bearing defects before they appeared in the vibration acceleration range. In addition, successful applications of AE to bearing diagnosis for extremely slow rotational speeds have been reported [4,5]. The modulation of AE signatures at bearing defect frequencies has also been observed by other researchers [6–8]. Investigators reported that AE parameters can identify bearing defects before they appeared in the vibration acceleration range [9,10]. Identification of variations of standard AE count parameters can also be helpful in diagnosis of different defects in ball bearings. There are many analytical techniques such as resonance demodulation, instantaneous power spectrum distribution and conditional moment analysis etc. which have been developed for processing vibration signals to obtain useful diagnostic information [11,12]. In highly transient signals such as AE, time and frequency components are very much dependent on each other. This prompted many researchers to work on automatic defect identification using wavelet algorithm [13,14]. Abdullah et al reported relationship between AE r.m.s. amplitude and kurtosis for a range of defect conditions and relationship between the defect size and AE burst duration [15]. In this paper a test rig was prepared with bearings and shaft and results obtained from AE and vibration analysis are compared.

II. MATHEMATICAL MODELING

Mathematical formulas to identify different frequencies in rolling element bearings given by T. A. Roque, T. A. N. Silva as following,

$$FTF = \frac{1}{2}(f_i)\left(1 - \frac{dcos\theta}{D_p}\right)$$

$$BPFO = \frac{N}{2}(f_i)\left(1 - \frac{dcos\theta}{D_p}\right)$$

$$BPFI = \frac{N}{2}(f_i)\left(1 + \frac{dcos\theta}{D_p}\right)$$

$$\mathrm{BSF} = \frac{\mathrm{D_p}}{\mathrm{2d}}(\mathrm{f_i})\left(1 - \left(\frac{\mathrm{dcos\theta}}{\mathrm{D_p}}\right)^2\right)$$

Where,

FTF = Fundamental Train Frequency

BPFO = Ball Pass Frequency of the Outer race

BPFI = Ball Pass Frequency of the Inner race

BSF = Ball Spin Frequency

D_p = Pitch diameter

f_i = Rotation frequency of inner race

N = Number of rolling elements

d = diameter of rolling element

2. Experimental Test rig and Test bearing set up:

The bearing test rig shown inFig-1, has been set up for this study with an operational speed range of 10–3000 rpm with a maximum load capability of 16kN via a hydraulic ram. The RPM of the test rig is regulated through VF drive. The test bearing employed was a roller bearing (N312). Characteristics of the test bearing were:

- Inner diameter : 60mm
- Outer diameter : 130mm
- Width : 33mm
- Number of rollers : 12
- Rolling element diameter : 18mm
- Pitch circle diameter : 96mm
- Contact angle (θ) : 0^0

Fig-1: Bearing Test Rig.

Fig-2: Test Bearing with Probes.

N312 bearing is a Roller bearing and outer race can be separated. The reason for selection of this bearing is, for easy assembly and dismantling of outer race. Inside of the outer racesurface, 0.9mmwidth defectcreated with Wirecut EDM. Two types of probes were used for acquisition of vibrationdata, CSI Vibration analyser and MHC-Pro Acoustic Emission instrument.No. of test runs conducted on test rig to check the consistency of the data acquisitioned. On the first instance a new bearing assembled to conduct Test run-1. After that, outer race removed, defect seeded on same outer race and conducted Test run-2. In both the Test runs, 2KN and 4KN load were applied at different RPMs. Both Acoustic Emission and Vibration data were taken at same time.

III. RESULTS & DISCUSSION

Defect frequencies calculated at different speeds are shown in Table-1.

Table-1:

	Characteristic defect frequency in Hertz			
RPM	**FTF**	**BSF**	**BPFI**	**BPFO**
300	2.03	12.86	35.63	24.38
500	3.38	21.43	59.35	40.61
700	4.74	30.03	83.15	56.89
900	6.09	38.59	106.88	73.13
1100	7.45	47.16	130.60	89.36
1300	8.80	55.76	154.40	105.64
1500	10.16	64.32	178.13	121.88

Table-2: Shows readings of Acoustic Emission and Vibration measurement

Table-2:

RPM	BPFO	Acoustic Emission (dB level)				Vibration (RMS velocity)			
		Test Run-1		Test Run -2		Test Run-1		Test Run -2	
		2KN	4KN	2KN	4KN	2KN	4KN	2KN	4KN
300	24.38	1.73	1.38	0.80	1.49	0.287	0.191	0.152	0.142
500	40.61	1.34	1.44	1.48	2.53	0.784	0.593	0.742	0.650
700	56.89	1.87	1.72	2.70	4.55	0.932	0.812	1.100	0.959
900	73.13	1.53	1.47	3.75	6.94	1.140	1.060	1.470	1.280
1100	89.36	0.90	1.25	4.58	8.55	1.480	1.380	1.780	1.720
1300	165.64	1.43	1.33	5.47	9.76	1.770	1.640	2.170	2.110
1500	121.88	0.58	1.30	6.76	11.80	2.310	2.030	2.550	2.430

Spectrums of both Vibration and Acoustic emission techniques are given below.

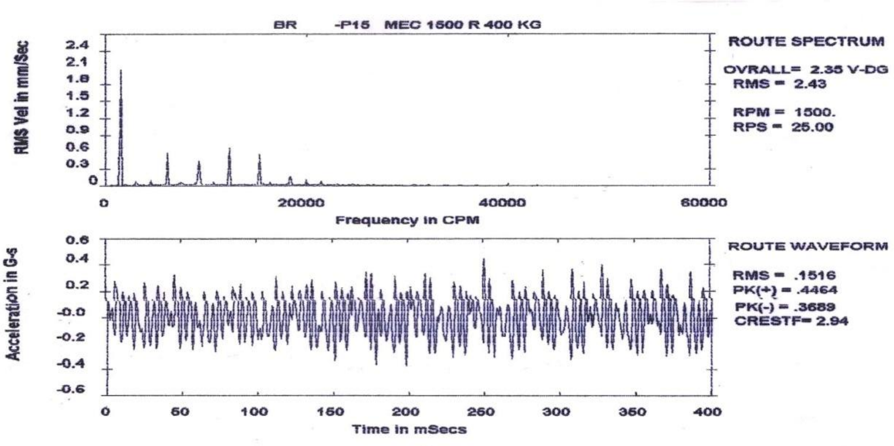

Fig-3: Vibration Spectrum: 4KN load and 1500 RPM without defect

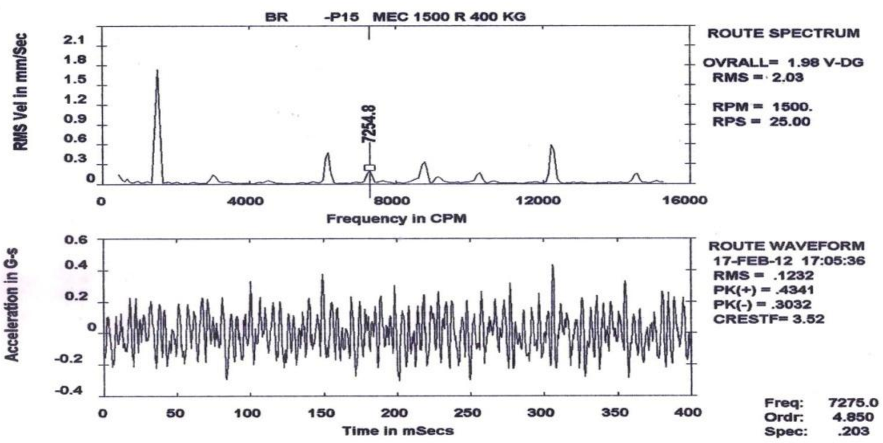

Fig-4: Vibration Spectrum: 4KN load and 1500 RPM with defect (0.9mm width)

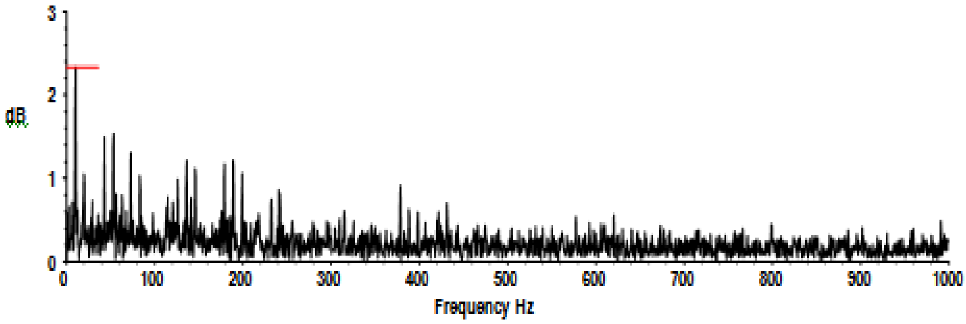

Fig-5: AE Spectrum: 4KN load and 1500 RPM without defect.

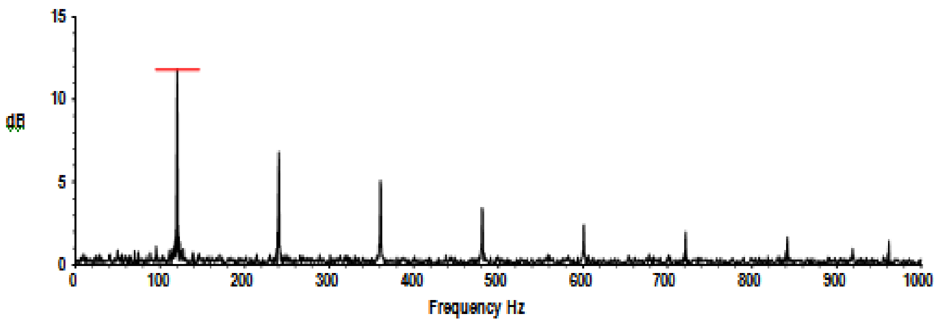

Fig-6: AESpectrum: 4KN load and 1500 RPM with defect (0.9mm width)

From the Table-2, it was observed that with increase in load andRPM the vibration level and acoustic emission level increases. In the vibration RMS velocity values there is no much range difference in values with respect to increase in RPM and Load.From Fig-4 there is a small rise at defect frequency(7254.8 CPM/ 121.88 hertz). In Fig-6 the peak is raised perfectly at defect frequency i.e. 121.88 hertz. In Fig-3 & Fig-5 there is no much difference in spectrums as the bearing is without defect.

IV. CONCLUSIONS

Both the raw signals (bearing without defect and with defect on outer race) were analyzed by acoustic emission and vibration analysis. There is significant difference in Vibration and Acoustic emission spectrums. The Vibration spectrums don't have clarity in its peak raising at defect frequency where as AE spectrums provide a clear peak at defect frequency. There are other peaks in vibration spectrum which are not associated with bearing defect. Experimental investigations reveal that AE technique is superior to Vibration technique and gives better analysis to diagnose the defects in bearings. AE technique is also useful inanalyzing the acoustic signal transmitted from bearing in order to characterize and find out the size of the defect.

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