Proposing a new Acoustic Emission Parameter for Bearing Condition Monitoring in Rotating Machines

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Abstract-*The process of systematic data collection and evaluation to identify changes in performance or condition of a system, or its components, such that remedial action may be planned in a cost effective manner to maintain reliability. Above concept is applied to rotating part i.e. bearing using Acoustic Emission Parameter as a part of conditional monitoring to avoid absurd failures.*

I. INTRODUCTION

Bearings are important machine parts and their condition is often critical to success of an operation or process, hence there is a great need for periodic knowledge of their performance. According to reported research works in the past several years, it is believed that the extracted information from acoustic emission (AE) signals can be used for bearing condition monitoring. In this work, a novel parameter based on using ratio of AE mean (m) and AE standard deviation (s), formulated as m=s is proposed to distinguish between lubricated and dry bearings. Test rig used on which various levels of radial loads and rotational speed (w) were applied to rotating shaft connected to Bearings. It was found that, except few cases, regardless of various levels of radial loads used, at higher levels of rotational speed, dry and lubricated bearings can be clearly distinguished when using proposed parameter.

II. CONCEPT AND THEORY

Acoustic emission is a natural phenomenon of sound generation applied to the spontaneously generated elastic wave produced within a material under stress the research into the fundamentals of AE has led to the huge growth of interest resulting in the rapid development of instrumentation for characterization of AE behavior in many materials. The main sources of AEs are crack growth, plastic deformation, friction, corrosion, leak, and defect growth such as fatigue that appear as high-frequency AE events in the range from 20 kHz to 1 MHz. AE signals propagate in shear modes and longitudinal direction inside the bearing, and in the Rayleigh mode on the surface of the raceways [3].

III. AE PARAMETERS

Time domain analysis is directly based on time waveform itself. In this work, all AE parameters were calculated on the basis of AE events. The standard deviation (σ) was automatically calculated for each AE event. In order to avoid noise effect, the acquisition threshold was assigned as 4σ. Only those events that rise above this threshold were considered for further analysis. It is to note that only six AE events that pass the threshold were recorded in each test [1] The following AE parameters were computed from AE events:

1) Maximum value of signal or amplitude
2) Mean value
3) Variance
4) Skew ness
5) Minimum value of the signal (Min)
6) Standard deviation (σ)[1]

This article investigates the effectiveness of proposed AE parameter (μ/σ) to distinguish between lubricated and dry bearings in a rotating machine. The (μ/σ) is formulated as a function of arithmetic mean $(\mu)$and standard deviation (σ), where

$$\mu = \frac{1}{N}\sum_{i=1}^{N} X_i$$

$$\sigma = \frac{1}{N}\sum_{i=1}^{N}\sqrt{(X_i - \mu)^2}$$

Where, Xi,(i = 1,………..N) are data points recorded from each AE signal.[2]

IV. EXPERIMENTAL STUDY

Experimental setup is prototype of actual machine and hence the A three-phase AC motor was chosen to replace the original motor so that adjustable speed and high torque can be achieved. The motor was foot mounted on to the base plate. The connection of the three-phase stator windings of the motor is delta (Δ), so that this would accept a three-phase input voltage range of 220–240 V for a 50 Hz supply frequency. The power of the motor is rated at 0.55 kW (or 0.75 hp). Its analogue speed control is of range 0–10 V or 4–20 mA. The application power of inverter is 0.75 kW. It can be set up and operated using the integral keypad. [2]

The overview of the experimental test rig is presented in Fig.3. The sensor is mounted in a place that mostly extracts the signal information from the testing bearing (see Fig. 2).However, to justify this statement, the released energy from each individual bearing was examined. [1]

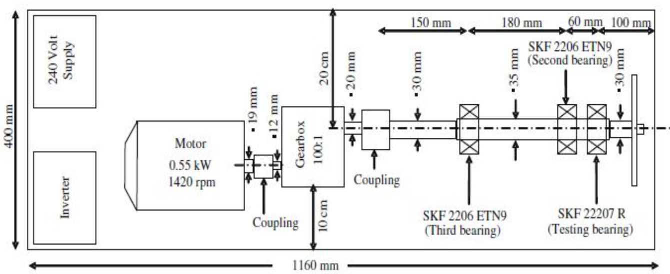

Fig.1 Schematic diagram of the test rig

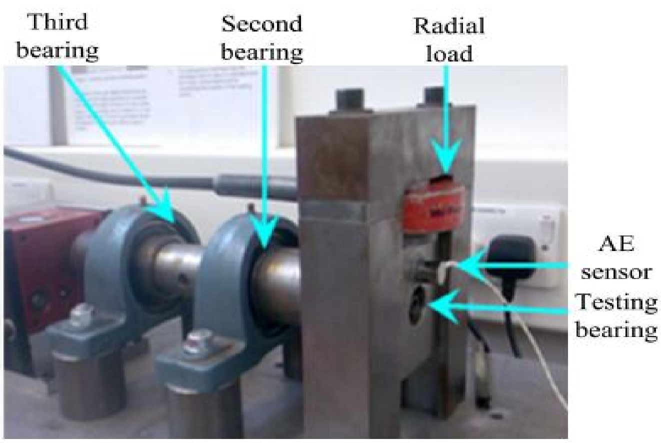

Fig.2: Overview of experimental test rig, testing bearing and AE sensor

V. DATA ANALYSIS

The data acquisition system consisted of a Pentium PC with a 1 GHz-CPU that was fitted with a high performance National Instruments NI 6110 data acquisition card. The NI 6110 card comprises four 12-bit input resolution channels, simultaneously sampled analogue-to-digital (A/D) input channels with scalable input limits and adjustable sampling rates up to 5M samples/s, both controllable by software. The detected signals from AE sensors were recorded on the data acquisition card simultaneously with a sampling frequency of 3 MHz. The signals were then converted to digital format that can be stored in the PC for further data processing. The software used was LABVIEW (version 5.1). No satisfactory results were obtained during preliminary tests when using the threshold levels of 2s and 3s. Therefore, 4s was used as threshold level to avoid noise effects. In addition, in each test, six trial points were recorded for each AE parameter. The average values of these points were recorded for further analysis. [2]

Data for the testing bearing (SKF 22207 E) presented in Fig.2 and fig 3 [2]

Radial load	Average of μ/σ							
(N)	30 Hz	40 Hz	50 Hz	60 Hz	70 Hz	80 Hz	90 Hz	100 Hz
2268	0.909	0.921	1.061	0.795	0.879	0.369	0.91	0.777
4537	0.815	1.205	1.138	0.627	0.868	0.372	0.706	0.769
6805	0.828	0.854	0.989	0.884	0.856	0.582	0.677	0.730
9073	0.928	1.023	0.898	0.902	0.718	0.523	0.693	0.385

Table 1. The (μ/σ) values when using dry bearing

Radial load	Average of μ/σ							
(N)	30 Hz	40 Hz	50 Hz	60 Hz	70 Hz	80 Hz	90 Hz	100 Hz
2268	0.932	0.941	1.053	1.043	1.042	1.002	0.987	0.884
4537	0.965	0.968	0.962	1.106	0.978	0.961	0.998	0.926
6805	0.887	0.917	1.054	1.111	0.981	0.934	1.032	0.731
9073	0.921	0.985	1.144	1.105	0.949	1.003	0.949	0.941

Table 2. The (μ/σ) values when using lubricated bearing

Graph for Observation from tables:

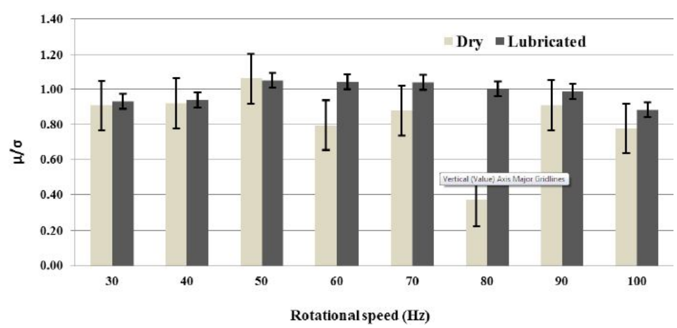

Fig 5: The (μ/σ) values when using all levels of rotational speeds, radial load of 2268 N

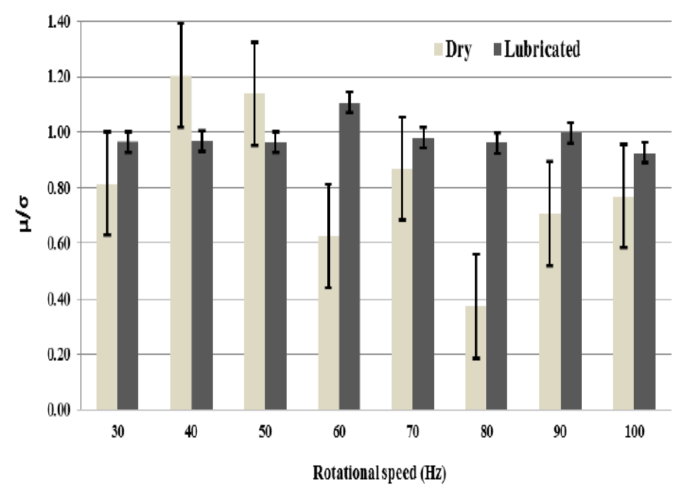

Fig 6: The (μ/σ) values when using all levels of rotational speeds, radial load of 4537 N. [2]

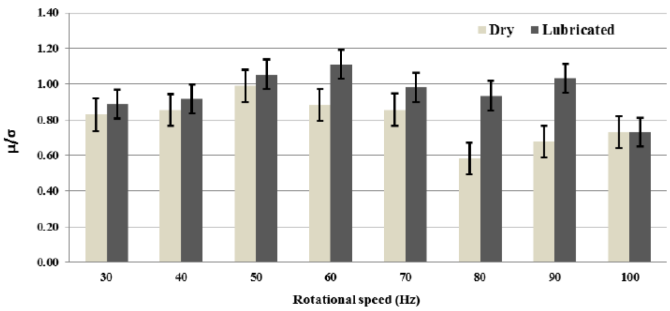

Fig 3: The (μ/σ) values when using all levels of rotational speeds, radial load of 6805 N [2]

VI. RESULTS

The computed values of (μ/σ) for dry and lubricated bearings are presented in Tables 2 and 3. As shown in Figs.5-8, when using rotational speeds 30–50 Hz, regardless of using various levels of radial loads, variation of (μ/σ)values cannot be interpreted scientifically. In this interval, the proposed AE parameter cannot be used to distinguish between lubricated and dry bearings. When using a rotational speed of 60– 100 Hz (see Figs. 5-8), regardless of any level of radial load used, larger resulting values of (μ/σ) are obtained for lubricated bearing [2]

Difference between the computed values of (μ/σ) from lubricated and dry bearings are not within error limits. This exhibits that when the test rig shaft is rotated with 60–100 Hz, the proposed AE parameter can clearly distinguish between dry and lubricated bearings. In this operational condition, due to lack of lubrication, more friction occurs in the bearing surfaces which leads to lower values of (μ/σ) in dry bearing the sensitivity of proposed parameter (μ/σ) becomes weaker when a lower value of radial load is used. Based on Fig.5, within the speed interval of 60–100 Hz, the difference between computed values of (μ/σ) from lubricated and dry bearings are not within error limits when using rotational speeds 60 and 80 Hz.[2]

It is anticipated that the proposed parameter may show more efficient performance when using higher levels of radial load and rotational speeds. The results of this study can be useful for subsequent studies dealing with real time bearing health condition monitoring [2]

VII. CONCLUSION

AE signal used in detection in failures of bearing will ensure reliability of rotating parts in various and this experiment is part of this process. Conditional monitoring will help people to get alert about machine failures earlier of its happening and hence will be able to take precautionary steps to avoid disturbances in production environment.

SUMMERY:

1) This study presented the effectiveness of a proposed AE parameter (μ/σ) that can be used to distinguish between lubricated and dry bearings in a rotating machine under similar operating conditions.
2) Irrespective to radial load used, at higher levels of rotational speeds (60–100 Hz), larger resulting values of (μ/σ) were obtained for lubricated bearing. It was found that the proposed parameter (μ/σ) can clearly distinguish between dry and lubricated bearings at higher levels of radial load and rotational speed (60–100 Hz).
3) The experimental data in this article are limited to the maximum rotational speed of 100 Hz. More consistence results can be obtained in further experiments at higher rotational speeds.

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