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Detecting natural crack initiation and growth in slow speed shafts with the Acoustic Emission technology

M. Elforjani *, D. Mba

School of Engineering, Cranfield University, Cranfield, Beds MK43 0AL, UK

A R T I C L E I N F O

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This paper presents results of an experimental investigation to assess the potential of the Acoustic Emission (AE) technology for detecting natural cracks in operational slow speed shafts. A special purpose built test rig was employed for generating natural degradation on a shaft. It was concluded that AE technology successfully detected natural cracks induced on slow speed shafts.

1. Introduction

Rotating machinery are fatigue loaded machines and operational experience with these machines showed that their components fail at high rates which perturbs the normal operating conditions. The primary causes of damages are misalignment, impacting and cyclic fatigue. Shafts are experience cyclic load conditions, are difficult to access for maintenance and are vulnerable to cracks nucleation and growth. Predicting and preventing the crack phenomenon has attracted the attention of many researchers and has continued to provide a large incentive for the use of condition monitoring techniques to detect the earliest stages of cracks. Slow speed rotating machinery results in reduced energy loss rates from damage related processes and therefore condition monitoring technologies (e.g. vibration analysis) tend to be more difficult to apply. Vibration diagnosis still remains the most widely used method for detecting cracks in rotating machinery though Jamaludin et al. [1] summarized the main problems in applying vibration to slow rotating machines. However, the Acoustic Emission (AE) technology is well suited to detecting very small energy release rates. Thus, considerable success has been reported in the application of AE to monitoring slow speed machinery components (e.g. bearings) [1–5].

Acoustic Emission (AE) is a term describing a class of phenomenon whereby transient elastic waves are generated by the rapid release of energy from localized sources within or on the surface of a material [6]. Sources of AE in rotating machinery include impacting, friction, turbulence, cavitations, leakage, etc. The typical frequency range associated with AE is between 100 kHz and 1 MHz. Limitations and difficulties in application of AE to machinery has been detailed [7]. Elforjani and Mba [4–5] applied the AE technology to detect natural crack initiation and propagation on slow speed bearings which is one of the few publications that address natural mechanical degradation on rotating machine components. This investigation presents a controlled experiment that ascertains the applicability of the AE technology for monitoring cracks initiation and growth on slow speed shafts.

* Corresponding author.
E-mail address: elforjani@gmail.com (M. Elforjani).

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2. Experimental program and setup

The test rig consists of three bearings on one rotating shaft which incorporated a coupling system and an electrical geared motor (MOTOVARIO-Type HA52 B3-B6-B7 j20, 46-Lubricated: AGIP). Two tapered roller bearings, single row (SKF 30207 J2/Q) were employed to support the shaft. An overhang cylindrical roller bearing, single row (SKF NU 1007 ECP) was used to locate the hydraulic load rod onto the shaft. To accelerate crack initiation and growth, a V-Notched shaft of 235 mm length and 35 mm diameter was designed. A radial load was applied to the shaft through the overhang bearing by a hydraulic system (Hi-Force HYDRAULICS-MODEL No: HP110-HAND PUMP-SINGLE SPEED-WORKING PRESSURE: 700 BAR). The design procedures of the shaft are presented in Appendix A. The test rig rotational speed was kept constant at 72 RPM. A flexible coupling was employed to absorb any vibration as a result of attaching the shaft to the geared motor, see Fig. 1. To capture AE's from the rotating shaft a specifically designed oil-bath was constructed onto which an AE sensor was placed, see Fig. 1. A plastic material was selected for the seals of both oil-bath sides and consequently there was no mechanical contact between the shaft and oil-bath that could result in a noise generation. This enclosed circular bath allowed for direct contact between the rotating shaft and the oil. The enclosed bath was completely filled with oil (CASTROL, Alpha, SP, 460, 3186DM).

3. Data acquisition system

Two Physical Acoustics Corporation WD transducers were employed. These are piezoelectric sensors with a bandwidth of 200–750 kHz. The AE sensors were attached to the overhang bearing and the oil bath using superglue and connected to variable gain preamplifiers 20, 40, and 60 dB which were in turn connected to a ruggedized PC, containing Physical Acoustics Corporation PCI-2 acquisition cards. The preamplifiers were set at a gain of 40 dB. The software (signal processing package "AEWIN") was incorporated within the PC to monitor AE parameters such as counts, amplitude and absolute energy (recorded at a time constant of 10 ms and sampling rate of 100 Hz). The absolute energy (atto-joules–10^{-18} J), is a measure of the true energy and is derived from the integral of the squared voltage signal divided by the reference resistance (10 kΩ) over the duration of the AE signal. In addition, traditional AE parameters such as counts, amplitude and ASL were also measured. The ASL is a measure of the continuously varying and averaged value of the amplitude of the AE signal in decibels (dB). The ASL is calculated from the r.m.s measurement and is given as:-

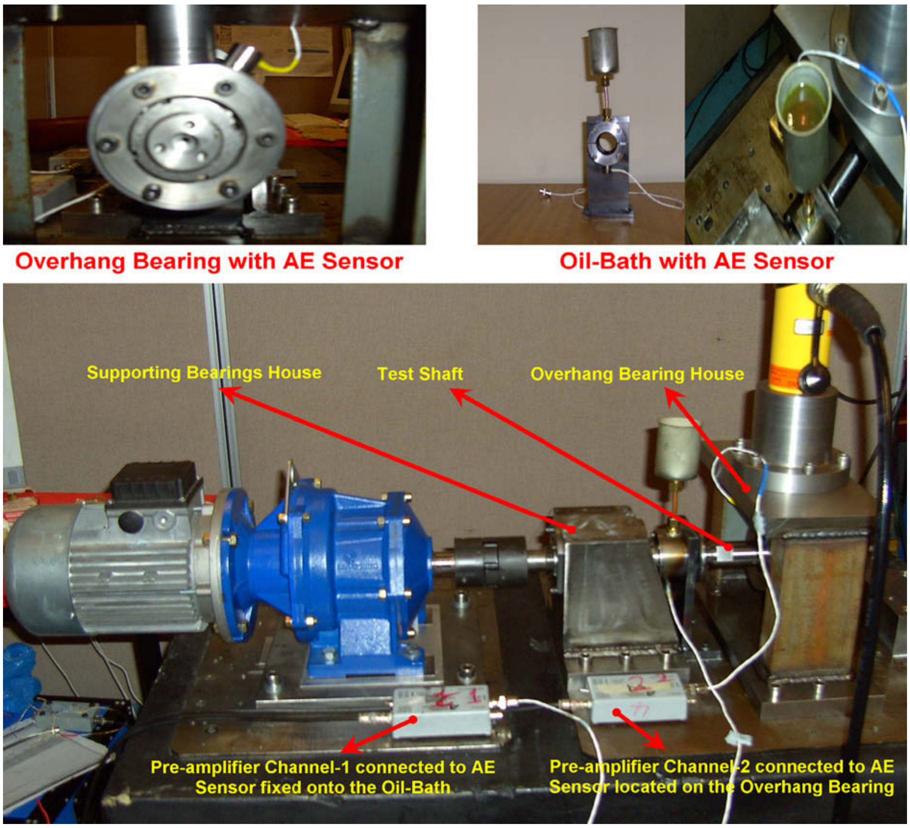

Fig. 1. Test rig components.