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ACOUSTIC EMISSION ANALYSIS FOR BEARING CONDITION MONITORING

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ABSTRACT

Acoustic emission (AE) was originally developed for non-destructive testing of static structures, however, over the years its application has been extended to health monitoring of rotating machines and bearings. It offers the advantage of earlier defect detection in comparison to vibration analysis. Current methodologies of applying AE for bearing diagnosis are reviewed. The investigation reported in this paper was centered on the application of standard acoustic emissions (AE) characteristic parameters on a rotational speed. An experimental test-rig was designed to allow seeded defects on the inner race, corrode and contaminated defect. It is concluded that irrespective of the rotational speed and high levels of background noise, simple AE parameters such as amplitude and AE counts provided an indications of bearing defect. In addition to validating already established AE techniques, this investigation focuses on establishing an appropriate threshold level for AE counts.

ABSTRAK

Pelepasan akustik (AE) pada asalnya dibangunkan untuk ujian tidak memusnahkan struktur statik, bagaimanapun, sejak beberapa tahun permohonan telah dilanjutkan kepada pemantauan kesihatan mesin dan bearing berputar. Ia menawarkan kelebihan mengesan kecacatan awal berbanding dengan analisis getaran. Metodologi semasa memohon AE untuk menanggung diagnosis dikaji semula. Penyiasatan yang dilaporkan dalam kertas ini berpusat pada permohonan pelepasan akustik standard (AE) parameter ciri pada kelajuan putaran. Eksperimen ujian pelantar telah direka untuk membolehkan kecacatan pilihan pada perlumbaan dalam, mengakis dan tercemar kecacatan. Ia menyimpulkan bahawa tanpa mengira kelajuan putaran dan tahap bunyi latar belakang, parameter AE mudah seperti amplitud dan tuduhan AE memberi tanda-tanda kecacatan bearing. Selain mengesahkan teknik AE telah ditubuhkan, penyiasatan ini memberi tumpuan kepada mewujudkan tahap ambang yang sesuai bagi tuduhan AE.

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LIST OF ABBREVIATIONS

AE	Acoustic Emission
NDT	Non Destructive Testing
dB	Decibels
N	Counts
A	Amplitude
D	Duration
R	Rise Time
COTS	Custom off the shelf
MB	Megabytes
RPS	Revolution Per Second

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Acoustic emission (AE) can be described as a phenomenon of transient elastic wave generation in materials under stress. Acoustic emission is related to the internal changes of material structure caused by external physical action such as temperature and load. The transient waves will form of displacement vibration in the material which can be recorded by sensor such displacement gauges or accelerator gauges.

Function acoustic emission (AE) technique is detects stress waves that generated during transient elastic waves release of stored strain energy in material subjected to external mechanical load, fracture mechanisms and material state can be evaluated in a non-destructive manner. Application acoustic emissions has been applied in many fields such as structural manufacturing process (Choi et al. 1992), machine tool monitoring (Cherfaouie et. al 1998) and tribological and wear process monitoring, gear defects monitoring and bearing monitoring.

In mechanical, application of the high frequency acoustic Emission (AE) technique in condition monitoring of rotating machinery has been growing over recent years. In test rig this is particularly true for bearing defect diagnosis and seal rubbing. The main drawback of acoustic emission with the application of AE technique is the attenuation of the signal and as such the AE sensor has to be close to its source. In test rig, it is often practical to place sensor AE on the non-rotating member of the machine such as bearing. Therefore, the AE signal originating from the defective component will suffer severe attenuation before reaching the sensor. Usually typical frequencies associated with AE activity range 20 to 1MHz.

The acoustic emission (AE) method is a high frequency analysis technique which initially developed as a non destructive testing (NDT) tool to detect crack growth in material and structure. Now, AE method has been increasingly being used as condition monitoring tool of engineering assets such as structures and industrial machines.

In this study, envelop analysis bearing condition monitoring for detecting of bearing defect in signal process.

1.2 PROBLEM STATEMENT

Acoustic emission is non-destructive testing for detection in rotating machinery that can be conducted to investigate the acoustic emission response of defective bearings. In acoustic monitoring is can even detect the growth of subsurface cracks whereas vibration monitoring can normally detect a defect when it appears on the surface (Tandon,1990) and in this study we have attempted to provide corroborative evidence that bearing defect can be measured and analyzed using acoustic emission method.

In this research was develop fabricate and design bearing used test rig to investigate the changes acoustic emission signal of simulated defects on the defect on cylindrical roller bearing and the analysis of the result will do with this test.

1.3 OBJECTIVES

The main objective for this research is:

i. To detect bearing condition using acoustic emission method

1.4 SCOPE OF RESEARCH

For this research, the acoustic emission testing will be done to detect a signal from test rig. From test rig can used in non-destructive testing for the detection of defect bearing and failure detection in rotating machinery. The result from the test will be analyzed according to the acoustic emission technique.

With different defect of the bearing such as contaminant, corrode and inner race have different result for acoustic parameter. From this experiment also want to study the parameter of acoustic emission such as counts and energy counts and amplitude. Data from acoustic emission parameter will be analyzed to get the characteristic of acoustic.

1.5 HYPOTHESIS

In this research, some of the hypothesis has done such as:

i. Different defect bearing used in test rig, so the prediction of the result will get different result from acoustic parameter such as different ring-down counts, events and peak amplitude of the signals.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to provide a review of past research efforts related to acoustic emission testing, type of bearing, type of bearing defect and mechanical testing that test rig. A review of other relevant research studies also provides. The review is organized chronologically to offer insight to how past research efforts have laid the groundwork for subsequent studies, including the present research effort.

2.2 ACOUSTIC EMISSION

Acoustic emission is defined as generation of transient elastic waves produced by a sudden redistribution of stress in a material. Detection and analysis of acoustic emission signal can get valuable information of a discontinuity in material such as bearing defect (Mathews, 1983). Typical sources of acoustic emissions include plastic deformation, wear, micro fracture, bubble collapse, impact and friction. When these waves reach the surface of the material they can be detected and measured by acoustic emission sensors. Acoustic emission signals are generally only a few microvolts to milivolts in amplitude when measured at the sensing element and range from several kHz to a MHz. At these frequencies, signals are strongly attenuated in air so a suitable couplant is required between the sensor and material to ensure signal transmission.

2.2.1 Acoustic emission and bearing defect diagnosis

Yoshioka have shown on research state that acoustic parameters identified bearing defects before they appeared in the vibration acceleration range whilst Catlin reported acoustic emission activity from bearing defects were attributed to four main factors, including random noise generated. It was noted that signals detected in the acoustic emission frequency range represented bearing defects rather than other defects such as imbalance, misalignment, looseness and shaft bending.

Tandonet on research investigated acoustic emission counts and peak amplitudes for an outer race defect using a resonant type transducer. It was concluded that AE counts increased with increasing load and rotational speed. However, it was observed that AE counts could only be used for defect detection when the defect was less than 250μm in diameter; through AE peak amplitude provided an indication of defects identification on various sized bearings and rotational speed. It was observed that AE counts were low for undamaged bearings. In addition, it was observed that AE counts increased with increasing load and speed for damaged undamaged bearing.

A clear relationship between rms level, rotational speed and radial load has been reported. The use of AE counts is dependent on the particular investigation and the method of determining the threshold level is at the discretion of the investigator. For this reason, the investigation presented in this paper firstly validates the use of rms for diagnosis and secondly, ascertains the suitability of AE counts for bearing diagnosis. In addition, selection of the appropriate threshold level is investigated.

2.2.2 Features of Acoustic Emission (AE) Signal

The commonly measured acoustic emission parameters are counts, events and peak amplitude of the signal. Ringdown counts involve counting the number of times the amplitude exceeds a preset voltage (threshold level) in a given time and gives a simple number characteristic of the signal. An event consists of a group of ringdown counts and signifies a transient wave. Each of the AE signal feature shown in the image described below

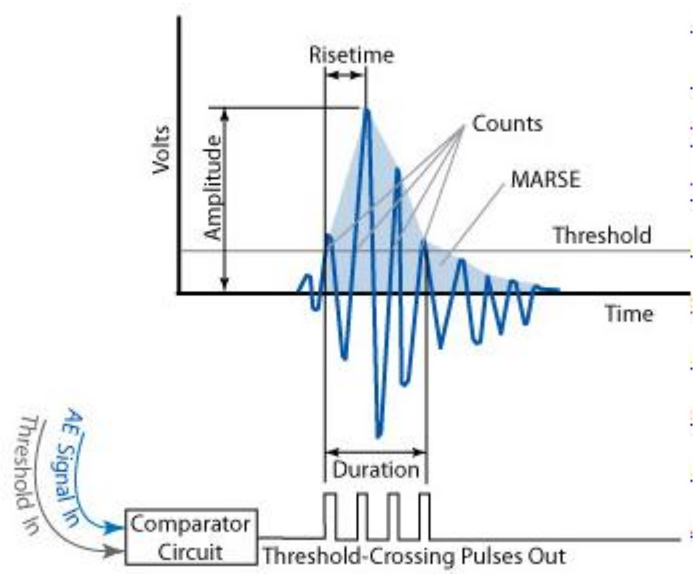

Figure 2.1: AE signal features

(Source:Yoshioka and Fujiwara, 1984)

Amplitude, A, is the greatest measured voltage in a waveform and is measured in decibels (dB). This is an important parameter in acoustic emission inspection because it determines the detectability of the signal.

Signals with amplitudes below the operator-defined, minimum threshold will not be recorded (Yoshioka and Fujiwara, 1984).

Rise time, R, is the time interval between the first threshold crossing and the signal peak. This parameter is related to the propagation of the wave between the source of the acoustic emission event and the sensor. Therefore, rise time is used for qualification of signals and as a criterion for noise filter (Yoshioka and Fujiwara, 1984).

Duration, D, is the time difference between the first and last threshold crossings. Duration can be used to identify different types of sources and to filter out noise. Like counts (N), this parameter relies upon the magnitude of the signal and the acoustics of the material (Yoshioka and Fujiwara, 1984).

MARSE, E, sometimes referred to as energy counts, is the measure of the area under the envelope of the rectified linear voltage time signal from the transducer. This can be thought of as the relative signal amplitude and is useful because the energy of the emission can be determined. MARSE is also sensitive to the duration and amplitude of the signal, but does not use counts or user defined thresholds and operating frequencies. MARSE is regularly used in the measurements of acoustic emissions (Yoshioka and Fujiwara, 1984).

Counts, N, refers to the number of pulses emitted by the measurement circuitry if the signal amplitude is greater than the threshold. Depending on the magnitude of the AE event and the characteristics of the material, one hit may produce one or many counts. While this is a relatively simple parameter to collect, it usually needs to be combined with amplitude and/or duration measurements to provide quality information about the shape of a signal (Yoshioka and Fujiwara, 1984).

2.2.3 Concept wave propagation

The main deficiency of this analysis is that the wave propagation through the structure exhibits several dispersive wave modes. Due to the characteristics of propagation of these wave modes, there are certain characteristic frequency ranges that propagate with sufficient magnitude to be sensed by the AE sensors. These frequency ranges vary as a function of structural properties and geometry even when the damage mechanism is identical (Tandon, 1990). Thus, it is not reasonable to directly associate certain AE signal frequency ranges with certain damage mechanisms in a way that is independent of the material and geometry of the structure. None of these AE signal analysis techniques used in laboratory studies has proven to be capable of consistently dealing with the difficulties encountered in large structure, namely, large amounts of data, the elimination of noise sources, material anisotropy, and the influence of wave propagating effects (attenuation and dispersion). These analyses often gave controversial results because they lack a physical justification (based on the theory of AE) for the signal features used to sort the experimental signals into different source mechanisms.

2.2.4 Acoustic Emission signal

AE signals is a characteristic of the process which produces it. Hence the AE signals contain information about the AE source, which includes location, magnitude, and damage mechanisms; the structure through which the wave propagates in the form of transient stress waves; and the monitoring system including the sensor (i.e., piezoelectric sensors) either mounted on or embedded in the structure and the associated signal processing electronics. With the ever increasing power of data acquisition systems and the increased sensitivity of new sensors, recording the entire waveform with high fidelity becomes feasible. This waveform approach characterizes AE signals by employing transient wave theory to predict the signals generated by different types of damage mechanisms. This, in turn, enables experimentally measured acoustic emission data to be interpreted in a physically meaningful manner.

2.2.5 Acoustic emission pre-processing

AE pre-processing involves amplification and filtering to refine the bandwidth and avoid aliasing. Signals are characterized as continuous, burst or mixed mode. Continuous emissions are burst that occur too closely together to differentiate between individual events, appearing as an increase in the background signal level. They typically have no distinguishing features other than their amplitude and frequency content. Burst emissions are typically discrete transients with relatively short decay times and even shorter rise times. Last is mixed mode AE contains a number of large individual burst above a background emissions. As most AE is broadband, processing is usually done in the time domain.

Hits and events are important concept to traditional AE signal analysis. A hit is defined as AE burst that exceeds a certain voltage threshold. Generally speaking, an event occurs when the peak voltage remains above the threshold for consecutive hits. Both hit and event date features are therefore a function of the type and value of the selected threshold (Bansal, 1990). Thresholds are referred to as fixed, in which case they are set to an absolute value for the duration of the rest or floating, where the threshold level is set as a defined amount (a fixed voltage or fixed number of standard deviation) above the background level. Fixed thresholds are typically used when monitoring static equipment, whilst rotating machinery requires floating thresholds to avoid swamping acquisition hardware when fluctuations in operating conditions cause the background signal level to rise. Unfortunately, the ability of COTS (custom off the shelf) AE hardware to manipulate thresholds is limited. Modern AE systems are theoretically capable of detecting and analyzing up to 20,000 hits per second.

Whilst hit features are extracted from a sensor's amplified filtered voltage output, continuous signal descriptors are generally extracted from the signal envelope or from filtered, digitalized waveforms. The number of simultaneous waveforms that can be collected depends on the amount of data, which is a function of acquisition rate and resolution, and the acquisition system's digital bandwidth: 4 channels of 16-bit waveform data, collected at 5MHz, will result in 40 megabytes (MB) of data per second. This data must pass across the computer's PCI bus to the hard disk for storage. Hard disk is typically restricted to writing data at approximately 40MB per second. As a result, undertaking multi-channel AE data acquisition consumes a large proportion of the computing power available in standard desktops and portable computers. It is therefore difficult to perform real-time advanced signal analysis of digitalized waveforms, such as discrete-wavelet or short-time-frequency transformation, on unoptimized consumer-grade- hardware

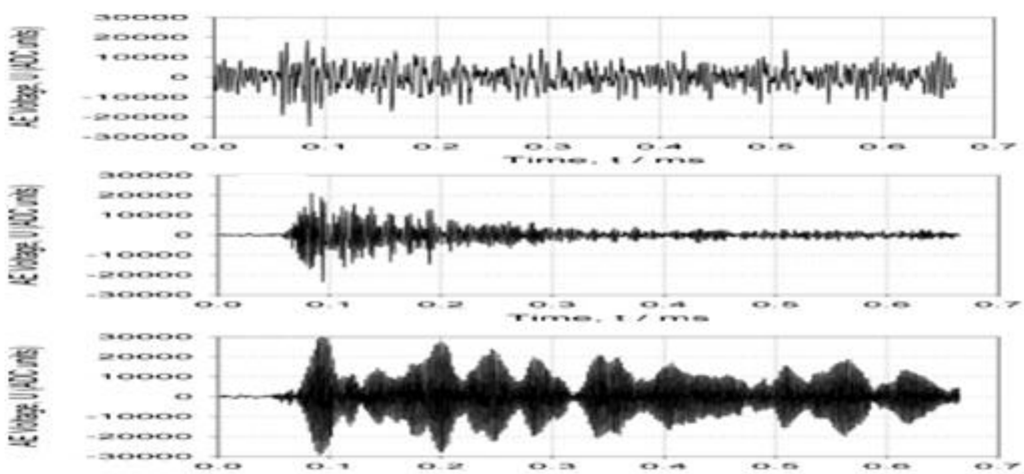

Figure 2.2: Type of acoustic emission signal

(Source: Yoshioka and Fujiwara, 1984)

2.3 TYPE OF BEARING

In experiment test rig, type of bearing use is cylindrical rolling bearings. Rolling bearings come in many shape and varieties, each with its own distinctive features. However, when compared with sliding bearings, rolling bearings all have the following advantages:

i. The starting friction coefficient is lower and there is little difference between this and the dynamic friction coefficient.
ii. They are internationally standardized, interchangeable and readily obtainable.
iii. They are easy to lubricate and consume less lubricant
iv. As a general rule, one bearing can carry both radial and axial loads at the same time
v. Maybe used either high or low temperature applications.
vi. Bearing rigidity can be improved by preloading.

Most rolling bearing consist of rings with raceway (inner ring and outer ring), roller and cage. The cage separates the rolling element at regular intervals, holds them in place within the inner and outer raceways and allows them to rotate freely. The surface on the rolling element roll is called the “raceway surface”. The load placed on the bearing is supported by this contact surface. Generally the inner ring fits on the axle or shaft and the outer ring on the housing. Theoretically, rolling bearing are so constructed as to allow the rolling elements to rotate orbitally while also rotating on their own axes at the same time. The function of cages bearing is to maintain rolling elements at a uniform pitch so load is never applied directly to the cage and to prevent the rolling element from falling out when handling the bearing.

Rollers bearing on the other hand are classified according to the shape of the rollers; cylindrical, needle, tapered and spherical. Rolling bearings can be further classified according to the direction in which the load is applied; radial bearings carry radial loads and thrust bearings carry axial loads.

2.3.1 Cylindrical roller bearings

In our study, we used cylindrical roller type NU203. Cylindrical roller bearing uses rollers for rolling elements, and therefore has a high load capacity. The rollers are guided by the ribs of the inner or outer ring. The inner and outer rings can be separated to facilitate assembly and both can be fit with shaft or housing tightly. If there are no ribs, either the inner or the outer ring can move freely in the axial direction. Cylindrical roller bearings are therefore ideal to be used as so-called “free side bearings” that absorb shaft expansion. In the case where there is a rib, the bearing can bear a slight axial load between the end of the rollers and the ribs. Cylindrical roller bearings include the HT type which modifies the shape of roller end face and ribs for increasing axial load capacity. And the E type standardized for small-diameter sizes.

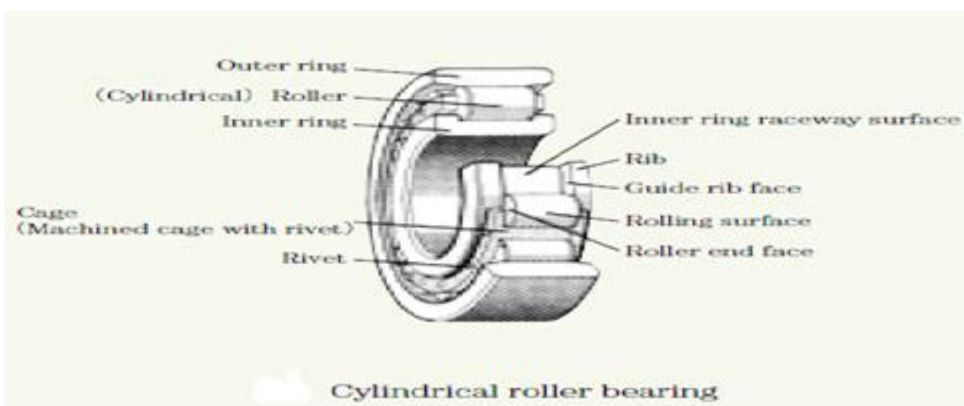

Figure 2.3: Cylindrical roller bearing schematic

(Source:Tandon. and Nakra, 1990)