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The relationship between acoustic emissions and wear particles for repeated dry rubbing

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Abstract

Acoustic emission (AE) is the emission of elastic stress waves resulting from the deformation and fracture of materials. The application of AE measurement techniques permits in-process monitoring of tribological characteristics. For practical applications, it is necessary to determine the relationship between AE signals and tribological phenomena, so we measured AE signals generated by tribological actions for repeated dry rubbings. The experimental results indicate that the features of AE parameters differ depending on the type of wear particles that are produced. The amplitude variation in the AE count rate is proportional to the surface damage at a friction interface. There is a good correlation between the AE cumulative count and the number of wear particles. In addition, there may be a negative correlation between the AE mean value and the elastic energy stored in wear particles between sliding surfaces. The generation and actions of wear particles between sliding surfaces has a marked effect on AE signals detected under repeated dry rubbing.

Keywords: Acoustic emission; Adhesive wear; Transfer; Debris; Elastic energy; Maintenance

1. Introduction

Acoustic emission (AE) is defined as, "the class of phenomena whereby transient elastic stress waves are generated by the rapid release of energy from localized sources within a material" [1]. AE is generated by deformation and fracture of materials. Since tribological phenomena such as friction and wear involve deformation and fracture, AE is generated during tribological processes. Thus, AE techniques can be used in the in-process monitoring of tribological characteristics. From the viewpoint of monitoring and maintenance (especially condition-based maintenance) of machinery, it is extremely important to recognize and quantify tribological phenomena, such as the progress of wear and the state of friction at interfaces. Methods based on electrical resistance, temperature, vibration methods, or oil analyses [2–5] are generally used in tribological estimates to diagnose abnormal states. However, these methods give secondary estimations of tribological phenomena and the information that they provide is insufficient. AE, in contrast, is intimately related to the deformation and fracture of materials and the AE-based method is useful in obtaining large quantities of information relating to tribological phenomena. Accordingly, the AE method, unlike other estimation methods in current use, permits direct estimations and is very effective for the in-process monitoring of the state of rubbing surfaces.

For the recognition and quantification of tribological phenomena, it is necessary to elucidate the relationship between AE signals and tribological phenomena. The effectiveness of AE in recognizing and quantifying transient phenomena (e.g., the detection of failure of a lubricant [6], the prediction of seizure [7], and the detection of cracks in bearings [8]) has already been identified. Also, several investigations have demonstrated a correlation between AE signals and tribological characteristics [9–12]. However, little is known regarding the relationship between AE and tribological phenomena, because of the complexity of such phenomena.

We discuss the relationship between AE signals and tribological phenomena, as well as the source of AE in repeated

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dry rubbing, an accelerated macroscopic wear phenomenon. The discussion focuses on the formation and removal of wear particles.

2. Experimental apparatus and method

2.1. Experimental apparatus

Fig. 1 is a schematic diagram of the experimental apparatus used in this study. Friction and wear experiments were carried out by using a pin-on-cylinder test rig. A pin specimen was attached to an octagonal elastic ring for measurement of the frictional resistance. The pin was then rubbed against a rotating cylindrical specimen while a normal load was applied from a dead weight through a wire. AE signals generated by friction and wear were detected by an AE sensor installed on the friction surface on the side opposite the pin specimen. The progress of wear was determined from the position of the pin as measured by a non-contact displacement sensor attached to a slider. The amount of wear on the pin specimen was estimated from the decrease in volume calculated from the weight loss of the material after sliding.

2.2. AE measurement system

Fig. 2 is a block diagram of the instrumentation used for signal acquisition. The AE sensor was made of lead zirconate titanate (PZT) piezoelectric ceramic (resonance frequency: 1 MHz, frequency band: 50 kHz–2 MHz). Because the voltage of signals detected with the AE sensor was quite low, the signals were amplified by a preamplifier and a main amplifier to a level of 60 dB. AE signals were passed through a 500-kHz high-pass filter, because much of the information relating to wear is contained in the frequency component of the AE signals above 500 kHz [13]. AE parameters measured in this study were the AE mean value, the AE count rate, and the AE cumulative count.

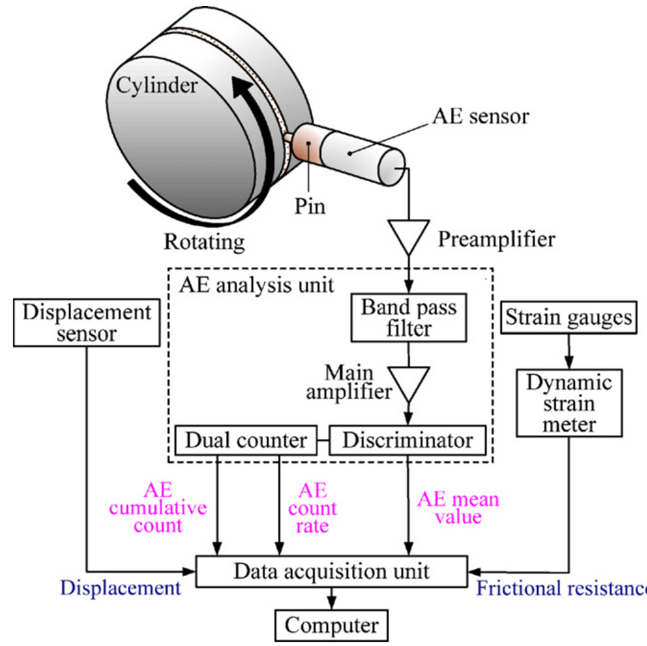

Fig. 2. Block diagram of the instrumentation for signal acquisition.

The AE mean value is the voltage signal that passed through a half-wave rectification, an enveloping process, and an averaging process with a discriminator after the filter. The AE count rate is the event number of burst-type AE signals generated per unit time. The AE cumulative count is the total number of AE events during an experiment. Each signal was processed with the measuring instruments and then displayed and recorded on a personal computer.

2.3. Experimental conditions

Five materials were used as pin specimens in the experiments: steel (C15E4), aluminum (Al-Cu4MgSi), copper (Cu-OF), brass

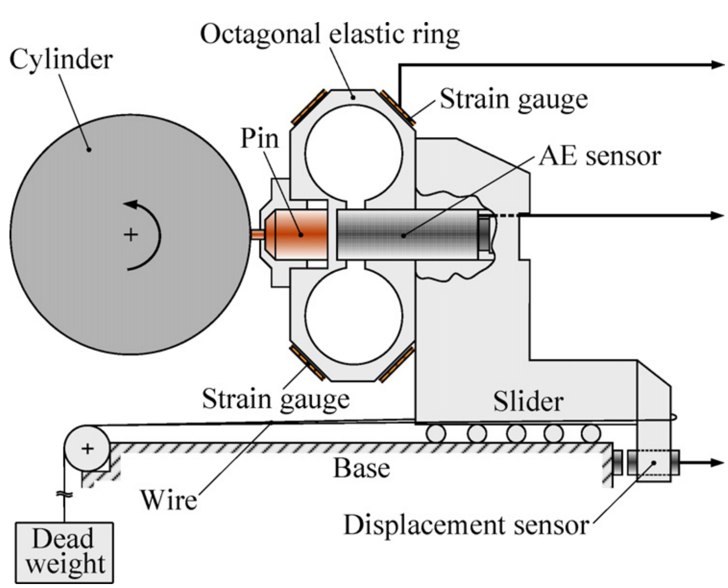

Fig. 1. Schematic diagram of the experimental apparatus.