Using Machine Learning to Predict Friction Based on Acoustic Emission Data

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Acoustic Emission (AE) – *i.e.* the high frequency stress waves caused by micro deformations of the component surface and propagate through the material – has recently been shown to be a rich source of tribological information. This raises the possibility of using AE sensors to listen in on sliding contacts and measure friction in situations that are usually inaccessible. However, this has not yet been implemented in practice, since the relationship between friction behavior and sound is highly complex. The approach taken in this study is to conduct sliding tests and use machine learning techniques to process the recorded high frequency sound emitted and correlate with friction and wear signals. This is shown to be highly effecting and paves the way for acoustic measurements of friction.

Keywords: Acoustic Emission, Machine Learning, Friction, Wear, Monitoring.

1. Introduction

A powerful, non-invasive, means of acquiring detailed information about the frictional mechanisms occurring within a sliding interface is to monitor and interpret the sound emitted. This is known as acoustic emission (AE) monitoring and is practically viable since it requires only that piezoelectric sensors are positioned at locations remote from the sliding interface (for instance on the outside of the cylinder block). These sensors can detect stress waves caused by micro deformations of the component surface and propagate through the material. Since these deformations are the result of asperity interactions and damage, the waves provide a potential means of listening in on the in-contact frictional mechanisms that are occurring. This approach has shown promise [1] however it has eluded practical application until now because the relationship between recorded acoustic emission signals and frictional response is highly complex. We address this problem in the current study by using machine learning to correlate certain aspects of the AE signal frictional response.

2. Methods

2.1. Tribometer testing: Reciprocating tribological tests were performed using a ball-on-disc High Frequency Reciprocating Rig (HFRR, PCS Instruments) (Fig. 1). The AE sensor (Micro200HF, Mistras) was bonded with the disc holder using cyanoacrylate adhesive. The AE set-up consisted of a sensor, preamplifier (Mistras - 2/4/6) and a PCI-2 Analogue to Digital (A/D) card (Mistras). The analogue AE signal detected by the sensor passed through the preamplifier and was converted into a digital sample by the PCI-2 card at a speed of 2 MHz. The data was acquired displayed and stored by the software AEwin (Mistras) before bing exported to MATLAB for processing.

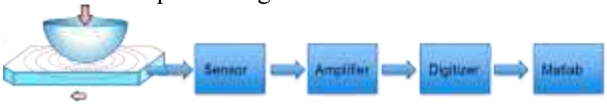

Figure 1: Schematic diagram of test setup.

2.2. Results: In order to reduce this data size before applying the machine learning, a number of techniques were investigated. The method which was shown to reduce data size with minimum loss of information was to first apply a moving window FFT to produce a spectrogram (frequency vs. time plot) as shown in Fig. 2 and then average this data over time.

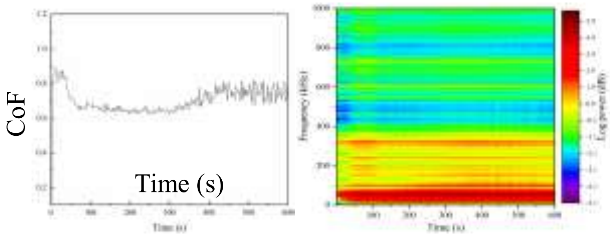

Figure 2: a) HFRR friction data, b) AE spectrogram.

A number of machine learning techniques were trialed and applied to sets of data in order to train algorithms to predict friction based only on AE. An example result is shown in Fig 3, where the ability of a Gaussian Process Regression algorithm to predict friction coefficient of an unknown test has a high degree of accuracy is demonstrated with correlation higher than 0.9.

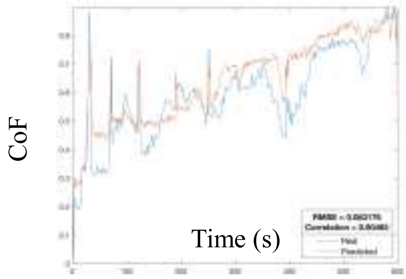

Figure 3: Evolution of CoF,, measured and predicted.

3. Discussion

This study has 1) confirmed that acoustic data is rich in tribological information, 2) demonstrated that an appropriate way to reducing file size without losing tribological information is to apply a moving window FFT to the data and then average in the time domain, 3) machine learning techniques such as Gaussian Process Regression algorithm under supervised regression model are effective in predicting the coefficient of friction based on AE data alone.

4. References

[1] Geng, Z., Puhan, D. and Reddyhoff, T., 2019, Tribology International, 134, pp.394-407.