7th World Tribology Congress, WTC 2022
July 10-15, 2022, Lyon, France

# In-situ Monitoring of Biomaterials in Fretting-Corrosion Couples

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Common biomaterials used in total joint replacement were investigated under a fretting-corrosion contact such as is found in modular tapers. The tribocouples were monitored using live in-situ sensing to asses degradation during sliding. Changing the fretting regime from ‘stick’ to ‘gross-slip’ resulted in increased acoustic emission hit detection and nanocrystallisation at the surface of the material. Under ‘stick-slip’ however subsurface cracking was observed in the sample; coupled with even higher hit counts. Quantification of AE signals could lead to further understanding in how energy is dissipated in such contacts and the formation of surface tribolayers.

**Keywords:** fretting, tribocorrosion, biomaterials, modular tapers

## 1. Introduction

Fretting-corrosion contacts in joint replacement modular taper operate under different regimes due to the transient nature of biomechanics and biomedical device geometry. These regimes are characterised by a fretting loop and can either be closed in a ‘stick’ regime, partially open in ‘stick-slip,’ or fully opened in ‘gross-slip’ [1]. The area inside the loop is known as the dissipated energy (DE) and is a measure of the work done to the surface (force x displacement). The DE can be related to other in-situ sensing technologies to further understand the degradation, subsurface changes and evolution of tribolayers in such contacts [2].

## 2. Methods

2.1. Fretting Rig

A custom fretting tribometer was used to articulate a 25 mm radius domed CoCrMo alloy pin against a Ti-6Al-4V plate; common biomaterials employed in THR. The samples were placed in a bath of foetal bovine serum diluted to 30 g/L total protein content with phosphate buffered saline. A load was selected to give a nominal contact pressure of 300 MPa and the tribo-couples were articulated at varying fretting amplitudes: 10, 25, 50 and 100 µm. This was done in order to capture a range of fretting regimes.

2.2. In-situ sensors

The fretting rig was fitted with in-situ sensors in order to monitor the surface degradation in real time. Force and displacement sensors were used to capture the fretting loop data. A three-electrode cell was used to monitor corrosive degradation whereby the pin and plate tribo-couple formed the working electrode. An Acoustic Emission (AE) sensor was also secured to the underside of the plate to record signal data from tribologically induced deformation.

2.3. Surface Analysis

After testing, a 10 µm surface cross-sectional slide was taken from within the wear scar in a focused ion beam (FIB) SEM. These slides were then investigated using NanoMEGAS TEM orientation imaging in order to map and quantify subsurface changes to the alloy articulating surface.

2.4. Results

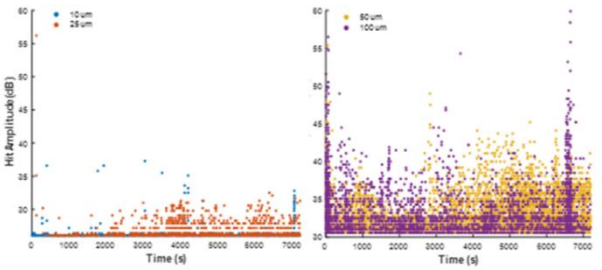


Figure 1: AE Hit Amplitude data for fretting couples at various amplitudes.

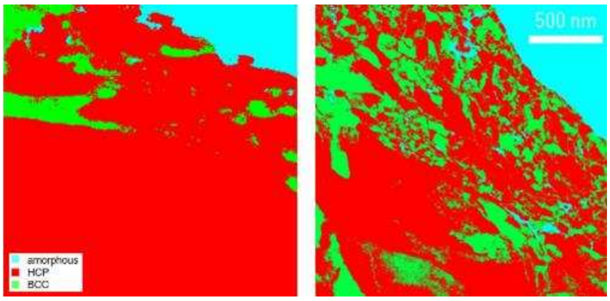


Figure 2: TEM from within the wear scar at 25 µm (left) and 100 µm (right).

## 3. Discussion

The corrosive degradation was found to scale with the fretting amplitude as the regime changed. Moving into ‘gross-slip’ increased DE was coupled with increased AE hit detection and subsurface nanocrystallisation. Under ‘stick-slip’ however lower levels of subsurface change were noted despite even higher levels of AE hit detection. This was explained by observed subsurface cracking; suggesting AE can help quantify different pathways of energy dissipation in-situ.

## 4. References

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