QUANTIFICATION OF CORROSIVE MATERIAL LOSS FROM COCRMO-TI6AL4V FRETTING CONTACTS

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Introduction

Modern Total Hip Replacements (THR) frequently feature modular taper connections, particularly in between the femoral head and stem. Under cyclic loading as a result of patient gait, these taper connections undergo fretting. *In vivo* they can also rapidly form an electrochemical crevice resulting in synergistic degradation referred to as mechanically assisted crevice corrosion or fretting-corrosion [1]. Recently several studies have measured the micro-motion taking place at the taper interface and noted a range of amplitudes from as low as 2 µm up to approximately 50 µm depending on seating conditions [2-4]. The aim of this study was to quantify the corrosive degradation taking place under these parameters and beyond into 'gross-slip' and to correlate corrosive material loss with dissipated energy.

Methods

A simple configuration sphere-on-flat fretting tribometer was used to recreate different fretting regimes under contact conditions commonly found in THR modular tapers, as reported in the literature [2-4]. The contact consisted of a CoCrMo pin with domed surface (r = 25 mm) and a Ti-6Al-4V plate. The pin was loaded such to give an initial contact pressure of 300 MPa (P_{mean}). The lubricant used was Foetal Bovine Serum (FBS) diluted to a total protein concentration of 30 g/L with deionized water and made to 1x Phosphate Buffered Saline (PBS). Sodium Azide (0.03%) was added in order to retard bacterial growth. The couple was articulated for 10,000 cycles at 10, 25, 50, 100 and 150 µm displacement amplitudes. Tangential force and displacement was recorded to calculate the dissipated energy per cycle.

The fretting tribometer was instrumented with a three-electrode electrochemical cell in order to measure the corrosive material loss *in situ* during fretting. A connection was taken from the pin and thus the working electrode (WE) consisted of the immersed surfaces of both the pin and plate. A combination Reference Electrode (RE, vs. Ag/AgCl) and platinum Counter Electrode (CE) was used to complete the cell. The Open Circuit Potential (OCP) was monitored throughout the experiment and sampled at 0.1 Hz. Periodically the WE was polarized to +50 mV vs. OCP and the resultant anodic current sampled at 10 Hz. The charge transferred as a result of the overpotential was calculated which is linked to the corrosive material loss.

Results

The charge transferred as a result of fretting articulation can be seen in Figure 1. During fretting the measured charge transferred increased from approximately 3.8 µC at 10 µm amplitude to approximately 17.2 µC at 150 µm amplitude. This increase did not occur linearly however and was highly dependent on the fretting regime as it transitioned from 'stick' at 10 µm to 'stick-slip' and finally 'gross-slip' at 150 µm.

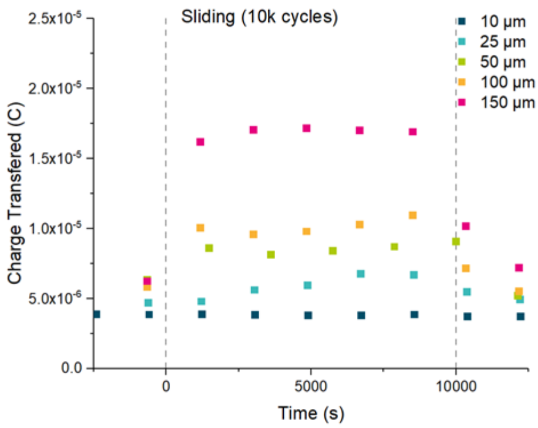

Figure 1: Charge Transferred during 10,000 cycles of fretting under 'stick' (10 µm), 'stick-slip' (25 & 50µm) and 'gross-slip' (100 & 150 µm) fretting regimes.

Discussion

In modular tapers the total degradation is dependent on both the mechanical fretting processes and corrosive material loss, as well as their synergistic effects. The mechanics of the contact correlate with the electrochemical degradation. With increased fretting amplitude, dissipated energy and different fretting regime the charge transferred increased.

References

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Acknowledgements

This work is supported by the Engineering and Physical Sciences Research Council (grant number EP/R001766/1) as a part of 'Friction: The Tribology Enigma' (www.friction.org.uk), a collaborative Programme Grant between the universities of Leeds and Sheffield.