Influence of Surface Roughness on the Fretting-Corrosion Regimes and Characteristics of Cemented Femoral Stems

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1. Introduction

Metal on Metal Total Hip Replacements (MoM THR) regained popularity over two decades ago as an effective method of treating degenerative hip diseases. However recent clinical studies have demonstrated unacceptably high revisions rates of MoM THR due to fretting-corrosion of the cemented portions of the femoral component due to the release in toxic metal ions [1;2]. In order to optimize the design at this interface a number of different mechanical surface treatments are employed depending of the design philosophy of the femoral stem. Studies have demonstrated that surfaces with an increased surface roughness exhibited a stronger mechanical interlocking with the bone cemented due to the interdigitation of the bone cement within asperities of the surface. In contrast, the Exeter polished femoral stem also has over 20 years of clinical data supporting its design philosophy. This study investigates the role surface roughness has on the initiation, propagation and fretting regimes of cemented femoral stems

2. Test Method

Low carbon CoCrMo Ultima TPS™ (DePuy International, Leeds. UK) collarless polished femoral stems (n=3) were utilized in this study. Each femoral stem went through a forging process and were either mechanically polished ($R_a \approx 0.05\mu m$) or subjected to an aqueous bead blast ($R_a \approx 0.8\mu m$). Surface roughness profiles of the polished and blasted surfaces were obtained using a Taylor-Hobson TalySurf CCI interferometer.

A test method, facilitating in-situ corrosion measurements, was developed and conducted in part reference to ISO 7206-4 to evaluate fretting-corrosion mechanisms at the stem-cement interfaces. Each stem-cement component was immersed in 0.9% NaCl at 37±1ºC and subjected to cyclic load between 300N to 2300N at 1Hz for 500,000. Intermittent Open Circuit Potential (OCP) and Linear Polarization Resistance (LPR) measurements were taken every 10hrs in order to observe the role surface roughness has on the fretting-corrosion currents from the stem-cement interface. A novel transducer arrangement was also developed in an attempt to quantify the fretting regimes at the stem-cement interface. A linear variable differential transformer has applied to the PMMA bone cement and metallic femoral stem to facilitate measurement of the relative displacement between the two components.

3. Results

Upon the application of cyclic loading a shift in the negative direction in OCP and increase in fretting-corrosion current was seen indicating depassivation of the metallic surface and increase in metal ion release. Polished femoral stems where seen to exhbit increased fretting-corrosion currents (Figure 1). Different fretting regimes where seen to exist at the interface (Figure 2). An increase in relative displacment was seen for the polished surfaces (≈12µm) compared to the roughened surfaces (≈3µm).

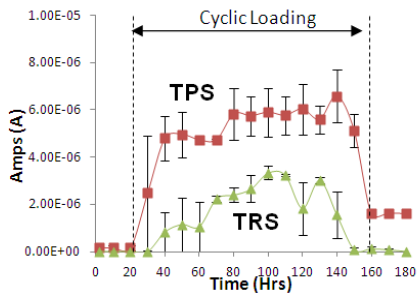

Figure 1 – Fretting corrosion currents obtained from LPR data for roughened and polished femoral stems

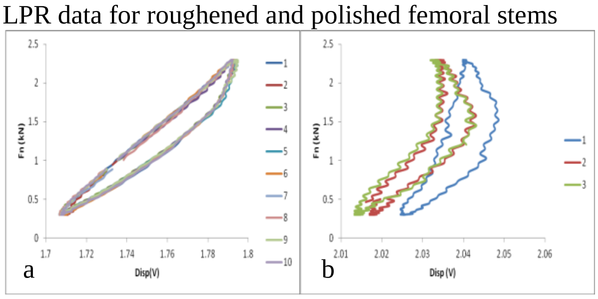

Figure 2 – Load vs displacments for a) polished and b) roughened femoral stems

References

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