Investigation of the Tribocorrosion Between Polyethylene and Cobalt-chromium

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Statement of Purpose: Thousands of total hip replacement (THR) operations are performed worldwide each year to restore functionality to the many suffers of osteoarthritis (OA) [1] . Considering the relative success of the operation in terms of pain relief and restoration of mobility it is disconcerting to find a number of patients have reportedly suffered due to the ill effects of metallic nano-particle and ion release following implantation [2]. It is thought that metallic wear debris occurring at the bearing surfaces in metal on metal (MoM) THRs is the source of these particles, and that corrosion of both the bearing surface and particle debris accounts for the elevated ion levels experienced by patients [3, 4]. Some investigations have been made into the ion release caused in MoM however there is a lack of literature relating to the subject concerning MoP conditions, which would enable a clear comparison of the two systems and quantification of the increased level of metallic wear debris produced by MoM THRs as opposed to MoP.

Method: Pin on plate tests were performed on a reciprocating tribometer instrumented with a three electrode electrochemical cell. In all tests performed the pin sample consisted of a truncated cone polymer pin made from GUR 1050 with a face roughness of 0.8µm<Ra<1µm. The plate samples used were comprised of a medical grade low-carbon cobalt-chromium (LC CoCr) polished to Ra<10nm and passivated in 30% nitric acid for 30 minutes. Two different lubricants were used: 0.35% NaCl solution and 25% foetal bovine serum solution. The samples were loaded such to give a mean contact pressure of 2.5MPa. The three electrode electrochemical cell consisted of a working electrode which in each test was the LC CoCr plate sample, a silver silver-chloride reference electrode and a platinum mesh counter electrode. Tribological contact was maintained at a stroke length of 10mm at a frequency of 1hz for a duration of 6 hours. For the duration of the test friction and open circuit potential (OCP) were monitored, in addition polarization resistance and metallic ion concentration was measured periodically throughout. Additional electrochemical testing included cyclic polarization tests which were performed both before during and after the initiation of friction. The materials and surface finishes used were selected to represent materials currently used in commercially available metal on polymer (MoP) THRs. The loading conditions used were chosen to represent realistic maximum pressures achieved in MoP THRs whilst walking. To improve reliability each test consisted of three repetitions.

Results: The average coefficient of friction after 6 hours for tests performed in NaCl solution was 0.072 and for tests performed in serum a slightly lower value of 0.066 was achieved. Both in serum and NaCl solution the effect of relative motion between the pin and plate sample produced an immediate negative shift in OCP, for tests performed in serum this shift was accompanied by ennoblement back to initial potential levels in >1000s, but for samples tested in NaCl ennoblement of OCP continued for the duration of the test. Periodic measurements of polarization resistance R_p show that the initiation of relative motion causes an increase in corrosion current i_{corr} and upon its termination a corresponding drop in corrosion current occurs. Scanning electron microscope (SEM) imagery of the samples tested in NaCl solution gave evidence of polymeric material transfer from the pin to the plate sample, EDX analysis of these regions showed an increase in carbon percentage when compared to the bulk material. See figures 1and 2. Polymeric transfer was not detected in tests performed in serum however, EDX analysis revealed evidence of adsorbed proteins.

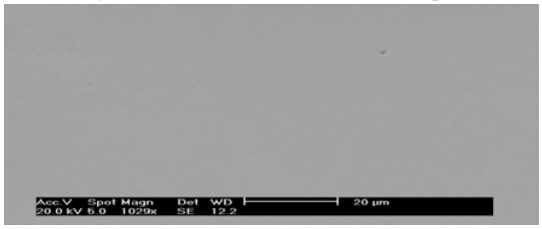

Figure 1: SEM image of unworn surface

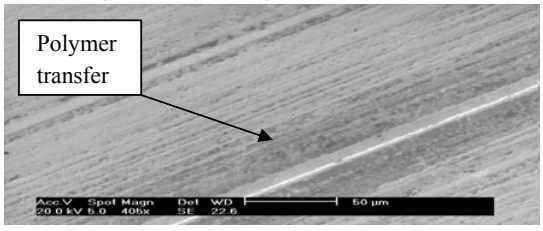

Figure 2: SEM image of worn surface

Conclusions: In both serum and NaCl solutions tribological contact from a polymeric surface leads to an increase in corrosion of the LC CoCrMo counterface. In both lubricants initiation of relative motion between the metal and polymer surfaces causes a negative shift in potential of the LC CoCrMo plate, in serum solution this is swiftly followed by ennoblement back to the initial potential.

References: 1.(Culliford DJ. J Bone Joint Surg Br. 2010;92-B(1):130-135.) 2. (Huber M. Acta Biomaterialia. 2009; 5(1):172-180.) 3. (Yan Y. J of Physics D: Applied Physics, 2006; 39(15): 3200-3205.) 4. (Yan Y. Tribology International. 2006; 39(12): 1509-1517.)

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