Wear-corrosion Synergism under Fretting and Sliding Contacts in Hip Prosthesis

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Statement of Purpose:

The synergistic interaction of wear and corrosion at the various interfaces of a metal-on-metal hip prosthesis is little understood [1,2]. Fretting-corrosion at stem-cement interface and sliding wear-corrosion at the articulating surfaces of ball and cup are two areas of concern. Sliding wear is characterized by relative displacements exceeding the dimensions of contact. During fretting, motion amplitudes are smaller than the contact area [3]. Here, we report the results from two laboratories [1,2] at two different prosthetic locations applying the same theoretic concept to disentangle the contribution of wear, corrosion and their synergistic interaction at the stem-cement and ball-cup interface. We hypothesized that the synergistic component of wear and corrosion will be higher for fretting than sliding. .

Methods:

Two sets of experiments were performed (n=3). Fretting corrosion (± 40µm @1 Hz, 17 MPa contact pressure) of 316L SS alloy (flat specimen) against PMMA pins was investigated in bovine calf serum (BCS; 20 $g.L^{-1}$). Sliding wear-corrosion (±15° 28mm ball @ 1 Hz, 10 MPa final contact pressure), of CoCrMo alloy (flat specimen) against a ceramic ball was performed in BCS @ 30 $g.L^{-1}$. This contact should resemble the head and cup of a hip prosthesis. During both fretting and sliding wear tests, the experiments were conducted at applied potential (fretting corrosion: -400 mV/SCE; wear-corrosion: -280 mV/SCE) to measure the current evolution during rubbing. Total wear volume (W) was estimated from the wear scar dimensions. Wear factor (k) was calculated to compare both systems. k = W/(FxD), F: Force in (N) D=sliding distance (m). To discern chemical from mechanical damage, the following synergistic approach was applied in each case [4]: $W = Wc + Wm + (\Delta Wcm + \Delta Wmc)$

W: total wear volume; Wc: wear volume due to corrosion; Wm: wear volume due to mechanics; ΔWcm: synergistic wear volume, corrosion enhancing wear due to mechanical factors; ΔWmc: synergistic wear volume, mechanics enhancing wear due to corrosion. S will be synergistic term, i.e. equal to ΔWcm + ΔWmc.

Results:

Figure 1 shows the wear factor (k) from both experimental cases. In case of fretting-corrosion condition, wear factor is 10 times higher than the one related to sliding wear-corrosion. Figure 2 shows the synergistic term (S) in percentage, compared to isolated mechanical wear loss and isolated corrosion loss. In fact, the synergistic term (S) indicates the combined action of mechanical events and corrosion processes. The fretting corrosion condition seems to be more heavily affected by synergistic interactions (synergistic term: 87%), compared to sliding wear-corrosion (S=57.8). This validates our hypothesis.

It is known that fretting mechanism quite different from the sliding wear situations and the most deleterious mechanism in terms of wear [5,6]. Further, under fretting mode, there is a high chance of retain of wear particles in the contact zone than sliding. Studies also indicate that the

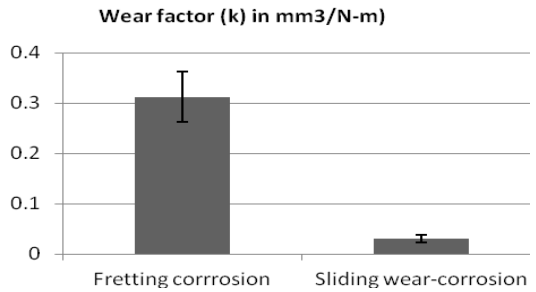

Figure 1: Wear factor (k) for two tribocorrosion system.

generation of oxidative environment under fretting leads to high plastic deformation [6]. Moreover the variation of electrochemical kinetics due to the presence of protein and its lubricating nature at the contact interface could not be neglected [6].

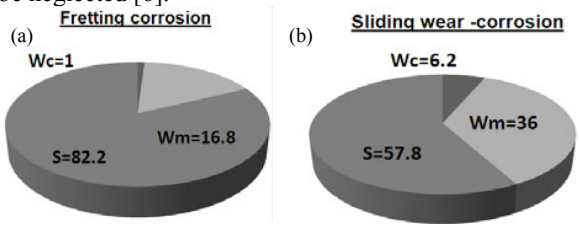

Figure 2: Synergism under (a) Fretting corrosion b) wear corrosion; percentage of Wc, pure corrosion, Wm, pure mechanical wear, S = synergistic term.

Conclusions:

The primary objective of this investigation was to identify the role of synergistic interaction of wear and corrosion in two important tribocorrosion systems of a hip joint. For this particular hip system (cemented stainless steel stem with a CoCrMo-on-CoCrMo articulation), fretting corrosion promotes synergistic effects that exceeded those of sliding wear-corrosion. The experimental conditions and material combinations were chosen with respect of the relevant clinical interfaces. This limitation does not allow generalized conclusions.

References:

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