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The effect of cyclic load on the evolution of fretting current at the interface of Metal-on-Metal and Ceramic-on-Metal taper junction of hip prostheses

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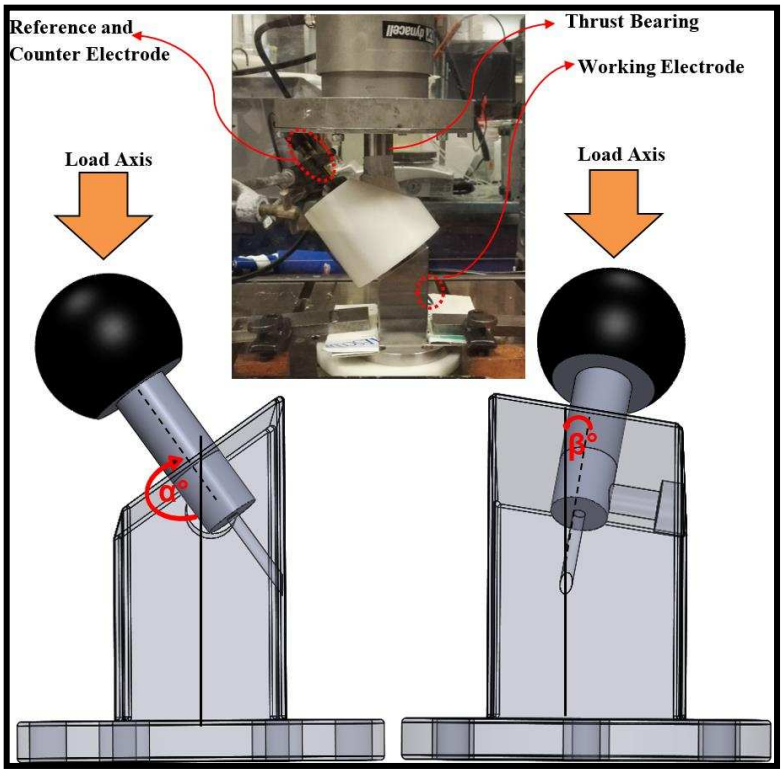
Introduction: Fretting corrosion at the Head-Neck taper interface of Large Metal on Metal (MoM), Metal on Polymer (MoP) and Ceramic on Ceramic (CoC) total hip arthroplasty (THA) remains a clinical concern. Ceramic femoral heads have gained a lot of attention more recently as a possible way to mitigate/reduce the dissolution of Cobalt Chromium ions. The objective of this study is to assess the fretting corrosion currents emanating from four material combinations for which Ti6Al4V and Co28Cr6Mo are the neck components of Co28Cr6Mo and BIOLOX®delta femoral heads at three different cyclic loads.

Method: 12/14 Ti6Al4V and Co28Cr6Mo spigots (designed to geometrically represent the stem) were impacted against Ø36mm Co28Cr6Mo and BIOLOX®delta femoral heads with a static force of 2kN as shown in Figure 1. The tapers were immersed in 25% v/v diluted Foetal Bovine Serum, PBS balance and 0.03% Sodium Azide at room temperature. In-situ electrochemistry was facilitated using a 3-eletrode cell arrangement whereby the neck components were the working electrode, Ag/AgCl was the reference electrode and a platinum counter electrode completed the cell. All combinations were held at a potential of 0V vs. Ag/AgCl and the cyclic load applied unto each couple were 1kN, 3kN and 5kN at 1Hz consecutively (see Figure 2). The fretting corrosion currents were converted into cumulative charge transferred (Q) by integrating the wear enhanced corrosion current.

Results and Discussion: Bergmann et al.[1] plotted the loading profile of a patient weighing 1000N doing various daily living activities. In their study, the range in loading cycles vary from 1kN (standing on one leg) to ~9kN (stumbling). For this study, Figure 2 shows the sinusoidal loading profile used and the corresponding charge transferred as a result of wear enhanced corrosion. The results reveal an increase in the cumulative charge for all four combinations as cyclic load increases. While for all combinations, no negligible amount of cumulative charge was measured at 1kN, no significant difference was observed at 3kN and at 5kN, the charge transferred from both MoM and CoM fretting couples where Ti6Al4V is the neck component were significantly lower than the couples with Co28Cr6Mo neck (see figure 3). The BIOLOX®delta – Ti6Al4V couple was observed to generate the least wear enhanced corrosion current. This, we observe, is due to thick agglomerated oxides resulting from wear and corrosion products which can adhere to the anodic fretting interface (see figure 3).

Conclusion: This study reveals that for both MoM and CoM combinations, the charge transferred through wear enhanced corrosion of Ti6Al4V prove to be significantly lower than the combinations with Co28Cr6Mo alloy. Furthermore, this study proposes that the agglomeration of wear and corrosion products (oxides) can lead to the reduction of fretting corrosion currents at modular fretting interfaces as seen in combinations involving Ti6Al4V alloys. This is relevant as titanium alloys are known to form thick oxides at fretting contacts.

Reference: 1. Bergmann, G., et al. "Realistic loads for testing hip implants." Bio-medical materials and engineering 20.2 (2010): 65-75.



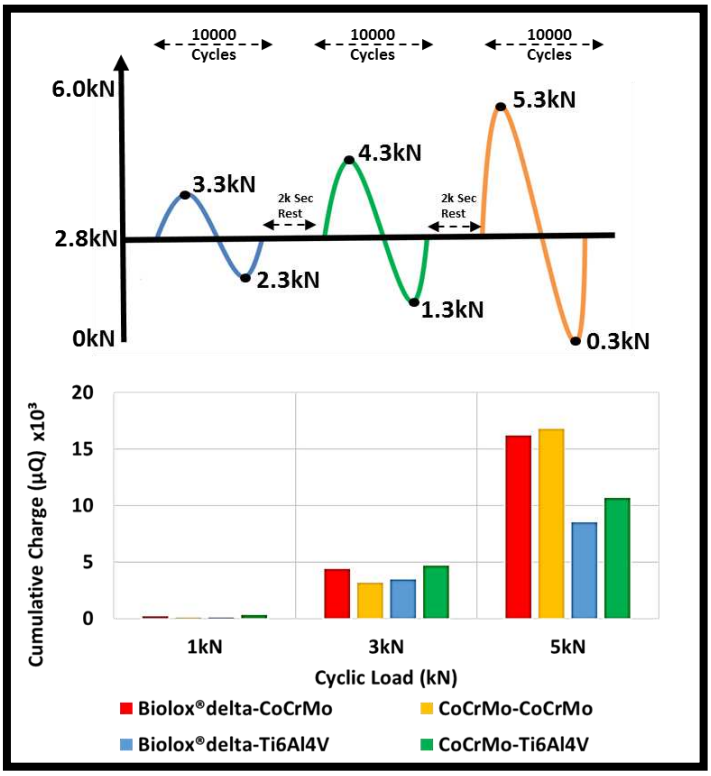


Figure 1: The image shows the femoral head position of a spigot which represents the neck. The Angle (α) is 145° which is the ISO 7206-4:2010 of 135° + 10° increase in neck inclination which accounts for the angle difference between the stem axis and the load axis that exist on a full stem. The Angle (β) was 9° according to (ISO 7206-4:2010).

Figure 2: The image shows the sinusoidal load, the duration of each load cycle the rest time allowed for re-passivation. The cumulative charge for all couples (obtained by integrating the area underneath the fretting current in figure 3) is shown. This plot is an average of n = 2.

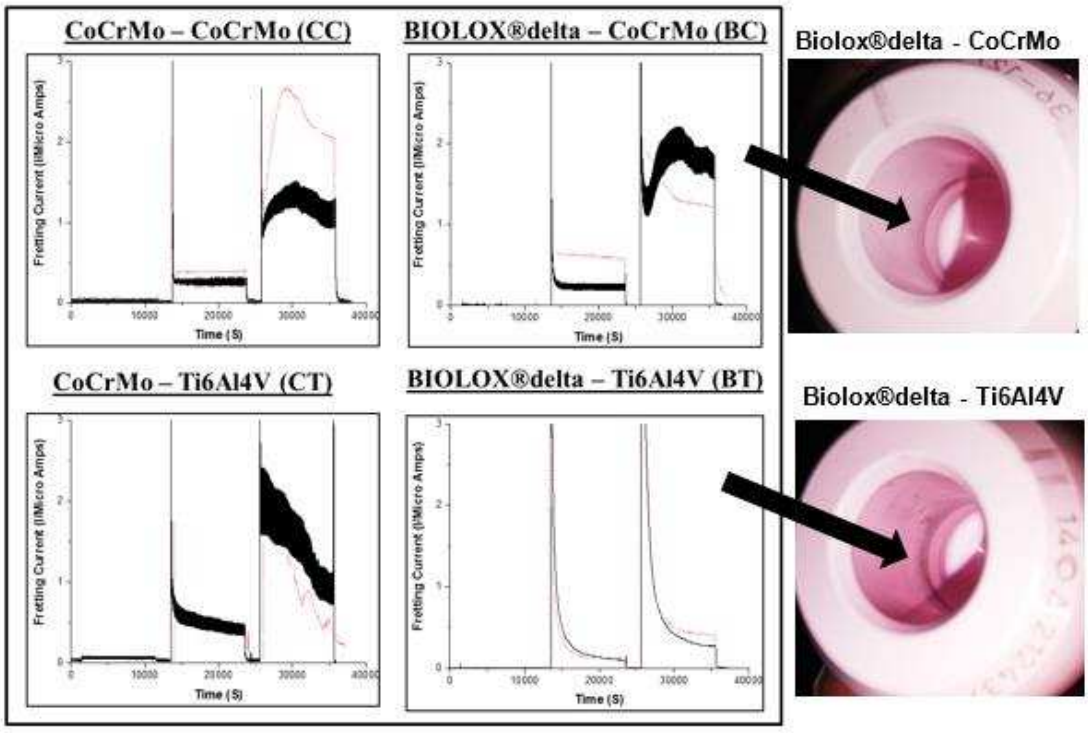


Figure 3: This image shows the n = 2 fretting corrosion current of all the material couples at 1kN, 3kN and 5kN. The data represented with the red dashed line were obtained at low resolution whilst the black, at high resolution (10Hz).The Biolox®delta heads from the *in-vitro* tests reveal agglomerated oxides belonging to the metallic components: CoCrMo and Ti6Al4V.