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## Sub-surface investigation of fretted Co28Cr6Mo and Ti6Al4V alloys

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**Introduction:** Cobalt-Chromium-Molybdenum (CoCr) and Titanium-Aluminium-Vanadium (Ti) alloys are the most commonly used alloys used for Total Hip Replacement due to their excellent biocompatibility and mechanical properties. However, both are susceptible to fretting corrosion In-vivo. The objective of this study was to understand the damage mechanism of both combinations through a sub-surface assessment of damage to the alloys at various fretting amplitudes using the Transmission Electron Microscopy (TEM – CM200 FEGTEM). The TEM was used to attain a cross sectional view of the alloys in order to see the effect of high shear stress on the grain structure.

**Methods:** The two combinations were fretted at a maximum contact pressure of 1 GPa in a Ball – on – Plate configuration for displacement amplitudes of  $\pm 10\mu\text{m}$ ,  $\pm 25\mu\text{m}$ ,  $\pm 50\mu\text{m}$  and  $150\mu\text{m}$ . The contact was lubricated with 25% v/v Foetal Bovine Serum (FBS), diluted with Phosphate Buffered Saline (PBS). The material loss as a result of wear and corrosion from the fretting contact were quantified using the Visual Scanning Interferometry (VSI). The TEM samples were obtained using the Focused Ion Beam (FIB – FEA Nova 200 Nanolab). Samples were obtained from regions of high stress (shaded in red) [Figure 1] for both the CoCr flat and Ti flat from the CoCr – CoCr and CoCr – Ti respectively.

**Result:** The TEM images of CoCr alloy (denoted as CC) reveal a progressive damage to the topmost surface of the alloy and loss of nano-crystalline layer. Evidence of severe grain damage from the topmost surface can also be seen at  $50\mu\text{m}$ . On the other hand, the Ti alloy (denoted as CT) at  $25\mu\text{m}$  reveal some recrystallization at the topmost surface and a progressive recrystallization of the bulk alloy was observed at  $150\mu\text{m}$ . Damage to the surface was also visible at this displacement amplitude which initiated a crack as circled in red in the image CT –  $150\mu\text{m}$ .

**Discussion:** Fouvry et al<sup>1</sup> discussed the effect of the interfacial shear work done (dissipated energy) on a fretted material; this energy is mainly expended on material structure transformation (as observed in Ti alloy) and/or wear generation (as observed in CoCr alloy) [Figure 2]. This intermediate damage mechanism helps to identify that CoCr – CoCr follows a wear dominated mechanism while CoCr – Ti preferably exhibits a fatigue behaviour until large displacement amplitudes are applied leading to accelerated wear of the top surface (seen at CT -  $150\mu\text{m}$ ). The recrystallization was observed over  $2\mu\text{m}$  below the surface at  $150\mu\text{m}$ . Consequentially, this could modify the metallurgy of the Ti alloy and may contribute to the clinically observed phenomena whereby, the softer Ti wears the harder CoCr component<sup>2</sup>.

**Conclusion:** TEM micrographs reveal large granular damage on the CoCr alloy and deep bulk recrystallization of the Ti alloy as a result of interfacial shear stress. This suggests that the Ti alloy may experience a change in its mechanical behaviour. On the other hand, it is identified that a CoCr – CoCr couple experiences a wear dominated mechanism.

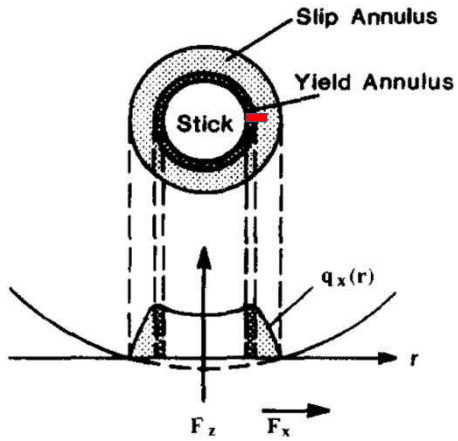


Figure 1: Schematic of extracted TEM sample region. Diagram obtained from Vingsbo et al 1988.

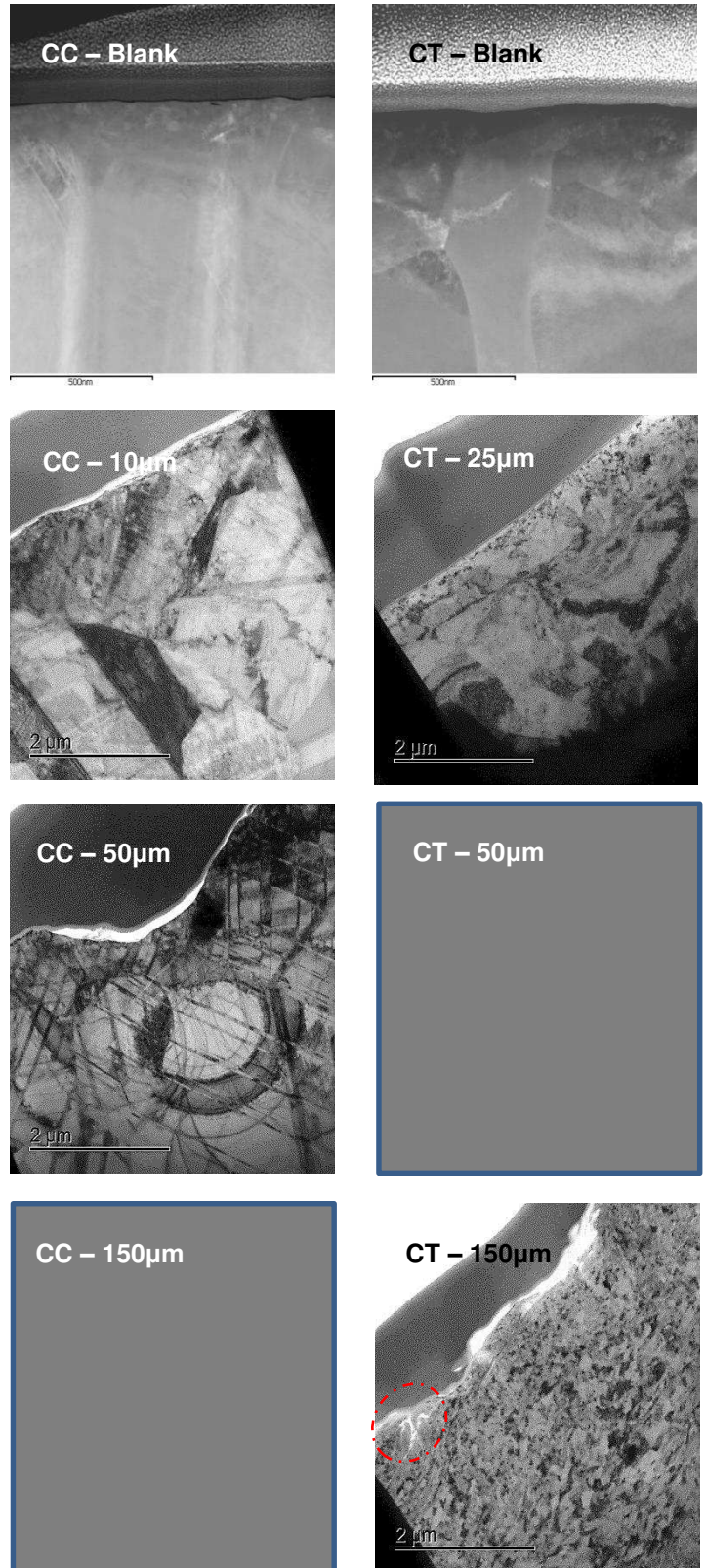


Figure 2: TEM micrographs of CoCr and Ti alloys. Missing images are yet to be obtained.

**Reference:**

1. FOUVRY, S., PHILIPPE KAPSA, AND LEO VINCENT. Quantification of fretting damage. *Wear*, 1996, 200(1), pp.186-205.
2. MOHARRAMI, N., D. J. LANGTON, O. SAYGINER, AND S. J. BULL. Why does titanium alloy wear cobalt chrome alloy despite lower bulk hardness: A nanoindentation study? *Thin Solid Films*, 2013, 549 pp.79-86.