A lubricated tribocorrosion model incorporating surface roughness

S. Cao[1], S. Mischler[1]

[1] TIC, EPFL École Polytechnique Fédérale de Lausanne. CH-1015 Lausanne, SWITZERLAND.

*Corresponding author: Stefano.mischler@epfl.ch

In this study, a tribocorrosion model for passive metals was developed which included the hydrodynamic lubrication effect using a mechanistic approach based on the worn surface roughness. The model was applied to dedicated tribocorrosion experimental results obtained by testing a biomedical CoCrMo alloy by varying the lubricant viscosity and contacting surface roughness. Good correlations were found between the mechanical and chemical wear rates and corresponding variables, which validated the model.

Keywords: tribocorrosion, topography, wear, friction

1. Introduction

Passive metals are able to spontaneously generate a protective oxide film once exposed to aqueous corrosive environments that reduces the corrosion rate. Passive materials such as CoCrMo alloys are thus widely used for hip or knee biomedical implants that have to withstand not only the sliding conditions established on the joint but also the corrosive nature of body fluids. The thin passive film, normally only several nanometers thick, could easily be removed by sliding and expose the metal to enhanced corrosion. The passive films also affects the wear behaviour of the passive metals as it can interfere with its plastic response to sliding. Thus combination of wear and corrosion (tribocorrosion) may results in material loss that cannot be predicted on the basis of separate corrosion or wear approaches. Models describing the complex interplay between wear and corrosion are needed. Recently Cao et al [1] proposed a comprehensive tribocorrosion model of CoCrMo alloys considering effects such as plastic deformation, depassivation/repassivation cycles and elasto-hydrodynamic fluid films. The model was able to predict with high precision tribocorrosion material wastage of CoCrMo alloys as observed in laboratory tribometers as well as in hip joint simulators. The generalization of the model requires however to replace the empirical formalism used to link wear to elasto-hydrodynamic film thickness (as calculated using Hamrock-Dowson equation) with a mechanistic approach.

2. Methods

2.1. Model development

Surface topography is described using Abbot-Firestone curves. Asperities with heights (after conformal surface subtraction) exceeding the hydrodynamic film thickness *h* (Hamrock-Dowson equation) are considered defining the solid-to-solid contact area subject to plastic deformation and depassivation/repassivation events yielding tribocorrosion material wastage (Figure 1). Considering a Gaussian height distribution one can describe tribocorrosion wastage by Equation 1.

$$V_{tot} = k'_{mech}\frac{F_n}{H}v_s\frac{1+\mathrm{erf}\left(\frac{z_n+h}{\sqrt{2}R_q}\right)}{1+\mathrm{erf}\left(\frac{z_n}{\sqrt{2}R_q}\right)} + k'_{chem}\frac{Q_pMv_s}{nF\rho}\left(\frac{F_n}{H}\right)^{0.5}\left(\frac{1+\mathrm{erf}\left(\frac{z_n+h}{\sqrt{2}R_q}\right)}{1+\mathrm{erf}\left(\frac{z_n}{\sqrt{2}R_q}\right)}\right)^{0.5} \quad (1)$$

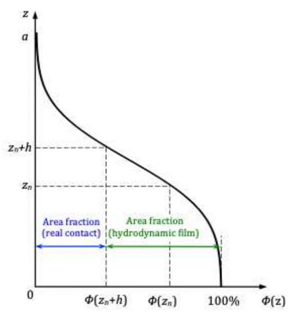

Figure 1 Determination of the fraction of the real contact area to the total area based on the Abbott–Firestone curve of the asperity profile

2.2. Tribocorrosion experiments and results

Experiments were carried out using the same set-up, materials and methodology as described in [1]. Alumina balls of R_a 20 nm or 1 µm were used as counterparts. Mixtures of glycerol and 0.5 M H_2SO_4 of different volume fraction were used as lubricant. Surface topography of the worn surfaces was assessed using 3D white light interferometry.

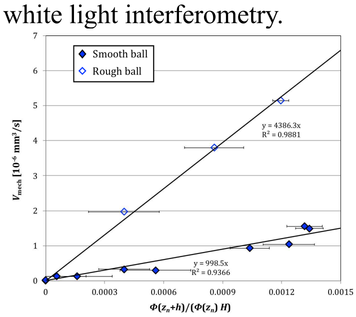

Figure 2 The correlation between measured mechanical wear rates and the group of variables of the model.

3. Discussion

The model was found to correctly describe the wear of the tested CoCrMo alloys. The model clearly takes into account the surface roughness of the metal but requires different k'_{mech} proportionality constants depending on indenter roughness.

4. References

[1] Cao S. et al, “Tribocorrosion of a CoCrMo alloy in sulfuric acid – Glycerol mixtures” Wear 458-459, 2020 203443