Modeling the composite abrasive-adhesive wear response of "W-shape" gross slip fretting interface: a multi-physic approach

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Composite abrasive-adhesive wear processes inducing disturbed "W-shape" worn profiles are classically observed in gross slip fretting sliding contacts. Displaying metal adhesion in the inner part of the fretted interface, these fretting scar morphologies are very detrimental regarding the cracking risk due to over cyclic stressing d at the interface between abrasive and adhesive domains. The purpose of this research work is to develop an extended finite elements friction-energy wear approach taking into account the presence of debris layer and adhesive wear by simulating the interfacial di-oxygen partial pressure by applying a finite difference Advection-Dispersion-Reaction modeling.

Keywords: Modeling, Fretting Wear, Adhesive wear, Contact oxygenation

1. Introduction

Increasing frequency, normal force or contact size can shift gross slip fretting interfaces from homogenous "U-shape" pure abrasive worn profiles to disturbed composite "W-shape" adhesive-abrasive morphologies. This evolution modifies the global wear rate, the maximum wear depth evolution as well as the contact stressing and therefore the cracking risk prediction. By considering numerical strategy combining mechanical solicitation and advection-diffusion-reaction phenomena in the interface, it was allowed to predict realistic fretting wear scar taking into account the presence of adhesive metal wear rate.

2. Methods

Focusing on a cylinder/plane Ti-6Al-4V interface, the friction energy wear approach expressing the local wear depth $h(x)$ as a function of the accumulated friction energy density $\varphi_i(x)$ [1] is here updated by considering a varying distribution of the local friction wear coefficient $\alpha(x)$ which is expressed as a function of the partial pressure of dioxygen estimated within the interface so that:

$$h(x) = \sum_i^{i=N} \alpha_i(x) \times \varphi_i(x) \quad (1)$$

with $\alpha_i(x) = f\left(P_{O_2}(x)\right)$ (2)

The partial pressure of di-oxygen $P_{O_2}(x)$ is here estimated by transposing an Advection-Dispersion-Reaction simulation O_2 transport within the porous debris layer and solving the equation 3 using finite difference schemes and 4 order Runge-Kutta method:

$$a\frac{dP_i}{dt} = -\nabla.(J_i) + R_i = -\nabla.\left(J_{a,i} + J_{d,i}\right) + R_i = -\nabla.(-D_i \nabla P_i + vP_i) + R_i \quad (3)$$

As expected, increasing the reaction rate by rising the friction power density, the O_2 molecules are faster consumed on the lateral sides of the contact due the re-oxidation of fresh metal exposed by the wear process. The O_2 concentration decreases sharply in the inner part of the contact favoring the adhesive wear process.

3. Results

Pure adhesive (α_{ad}) and abrasive (α_{ab}) wear rates were previously estimated from a select number of experiments. Then using continuous sigmoid evolution of the energy wear coefficient as a function of the O_2 partial pressure,

$$\alpha(x) = \alpha_{ad} + \left(\frac{1}{1+\left(P_{O_2}(x)/P_{O_2,th}\right)^{\beta}}\right) \times (\alpha_{ab} - \alpha_{ad}) \quad (4)$$

very nice prediction of the transition from "U-shape" to composite "W-shape" adhesive-abrasive profiles can be achieved (Fig. 1). This proposal was also supported by very good correlations with experimental worn profiles.

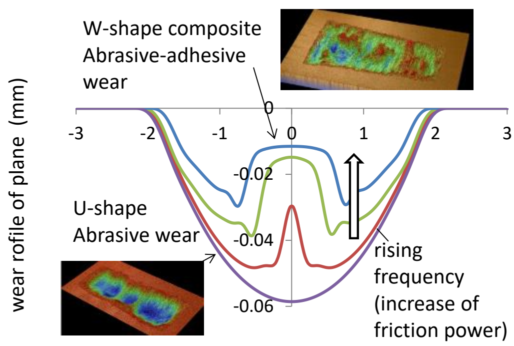

Fig. 1: Simulation of "U to W shape fretting scar transition.

4. Conclusion

For the first the time a physical description of adhesive-abrasive fretting scar is provided. Despite the simplicity of the hypotheses and the limited number of variables required, this multi-physic modeling provides rather good prediction of the complex "W-shape" abrasive-adhesive fretting wear profiles.

5. References

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