7th World Tribology Congress, WTC 2022
July 10-15, 2022, Lyon, France

Multiphysics modelling of fretting wear phenomena

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Wear phenomena in fretting interfaces involving abrasive, adhesive surface damages but also third body effects are very complex to simulate. The purpose of this research work is to expose an extended friction-energy wear approach taking into account the presence of debris layer and adhesive wear by simulating the interfacial di-oxygen partial pressure using an Advection-Dispersion-Reaction approach. This multiphysics modeling estimates locally if the fretted interface is running under adhesive or abrasive wear condition. For each situation, a specific energy wear coefficient is considered which finally allows the simulation of the composite adhesive-abrasive (W-shape) fretting scar. A good correlation is observed with literature Ti-6Al-4V cylinder-on-flat fretting wear experiments.

Keywords: Adhesive wear modeling, Fretting Wear, Third body, Friction energy, Contact oxygenation.

1. Introduction

Predicting the fretting scar evolution is a key issue for many industrial applications to estimate properly the wear depth extension, the coating durability but also the contact stress field distributions. This is however very complex since local fretting wear damages implies numerous and coupled damage phenomena including abrasive, adhesive wear processes, material transfers and debris layer distribution within the interface.

2. Methods

A Multiphysics approach so called WTO (Wear, Third body & contact Oxygenation approach) [1] is developed to simulate the evolution of the fretting scar morphology of a 2D cylinder/plane interface using a FEM-python framework (Fig. 1).

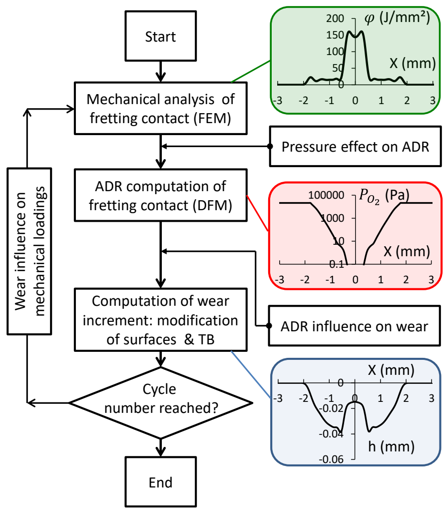

Fig. 1: Illustration of the WTO modelling.

The local debris formation rate is expressed a function of the local friction energy density dissipated in the interface (φ). In the meantime, an Advection-Dispersion-Reaction (ADR) approach assuming the debris layer as a porous medium is applied to compute the partial pressure of di-oxygen molecules (i.e. $p_{O2}(x)$) within the debris layer. When this latter (in the inner part of the contact) is lower than a threshold value (i.e. $p_{O2,th} = 0.1$ Pa) adhesive wear and metal transfers are assumed. Otherwise (on the lateral borders) surface oxidation and abrasive wear phenomena are operating. Using this ADR approach various energy wear coefficients are considered depending on the $p_{O2}(x)$ distribution. Finally, a homogeneous description of the debris layer profile within the fretted interface is combined assuming a "conversion factor" approached based on the third body theory.

3. Results

Using this WTO modeling which can easily be calibrated using a restricted number of fretting experiments, both 'U"-shape and "W"-shape of Ti-6Al-4V contacts can be predicted.

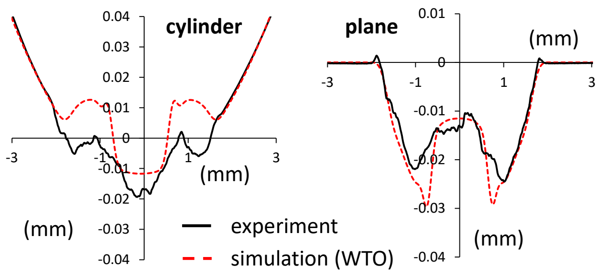

Fig. Comparison between experimental and simulated (WTO) fretting scar profiles.

4. Conclusion

This WTO Multiphysics approach appears as a reliable strategy to predict the fretting wear profiles, the maximum wear depth evolution but also the contact stress fields and potentially the fretting cracking.

5. References

[1] P. Arnaud et al., Modeling adhesive and abrasive wear phenomena in fretting interfaces: A multiphysics approach coupling friction energy, third body and contact oxygenation concepts, Trib. Int. 161 (2021) 107077