Crack Nucleation in the Adhesive Wear of an Elastic-Plastic Half-Space

Lucas Frérot[1,2)*], Guillaume Anciaux[2)] and Jean-François Molinari[2)]

[1)]Department of Physics and Astronomy, Johns Hopkins University, Baltimore, USA.
[2)]Civil Engineering Institute, École Polytechnique Fédérale de Lausanne, Switzerland.
*Corresponding author: lfrerot1@jhu.edu

Understanding the physics of adhesive wear requires an accurate description of rough contact interfaces and of the asperity detachment process that leads to material removal. We investigate in this work the effects of plastic deformation on the crack nucleation in the vicinity of micro-contacts using a J_2 plasticity model which explicitly accounts for plastically deformed volumes. Our results show that plastic zones increase tensile stresses around contacts, enhancing the likelihood of nucleating cracks. We also show that this effect is stronger for more ductile materials.

Keywords (from 3 to 5 max): roughness, contact, plasticity, crack

1. Introduction

In adhesive wear, the removal of a debris particle occurs when a crack propagates in the vicinity of an asperity encounter and separates a third body from the initial surfaces in contact. As a fracture process, its occurrence is governed by a critical length-scale [1] which characterizes the balance between available elastic energy and dissipated energy. While several attempts at up-scaling the debris particle formation process to a multi-asperity contact setting have provided valuable insight on the importance of roughness parameters and contact energy balance, they have all relied on the hypothesis of purely elastic contact. Experiments have shown that plastic deformations are expected to develop in rough surface contacts to accommodate the large contact pressures. This leads to a true contact area larger than what elastic theories predict, but plasticity may have further effects on the wear particle formation process. In this work, we focus on the influence of plasticity on the nucleation of cracks in the vicinity of micro-contacts.

2. Methods

We use a state-of-the-art volume integral equation method to simulate the rough contact interface with J_2 plasticity [2]. This method, which uses volume integral operators formulated directly in the Fourier domain, allows large scale simulations with a fine level of detail of both the plastic zones and the micro-contact geometry. We also employ, for comparison, a surface plasticity model which is widely used in plastic rough contact simulations. It consists in solving an elastic contact problem with the added constraint that the contact pressure not exceed the material hardness.

For both models, after solving the contact problem, we compute the principal tensile stress σ_I on the entire surface, and compare it to σ_c, the critical tensile stress for crack nucleation. Zones where $\sigma_I > \sigma_c$ are called crack nucleation sites, and their distribution with various normal and shear loading is quantified.

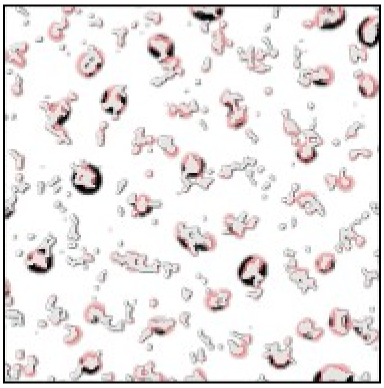

Figure 1: Crack nucleation sites (black), plastic zones (red) and micro-contacts (gray) for the J_2 plasticity model.

3. Discussion

Figure 1 shows the crack nucleation sites (in black) for the J_2 plasticity model, with an applied shear loading (oriented vertically). Crack nucleation sites only occur in the vicinity of contacts where the plastic zones have reached the surface. We show that these plastic zones actually increase the tensile stresses, which leads to larger crack nucleation densities for the J_2 model than for elastic and surface plasticity models [3]. The amplitude of the tensile stress enhancement effect increases when the yield stress decreases, meaning that more ductile materials are more likely to nucleate cracks.

4. References

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