Rough surfaces and interactions between micro contacts

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During this talk I will reflect on recent advances in our understanding of rough contact mechanics. The year 2020 was sadly marked by the premature death of Mark Robbins. I will discuss some salient results and novel understanding that I have been able to gather through my interactions with Mark, starting in 2001, at the Johns Hopkins University. This personal and partial view will focus on the numerical modeling of elastic and elastic-plastic contact of rough self-affine surfaces, in connection to friction and wear mechanisms.

Keywords : roughness, micro contacts, adhesive wear, numerical modeling

1. Introduction

It is well known that man-made and natural surfaces are rough, with roughness observed over many scales. Surface roughness has the important consequence that the real contact area is much smaller than the nominal contact area. Contacts junctions are called micro contacts and vary in size and shape. Ultimately the micro contacts morphology controls the frictional and wear properties of the interface.

2. Methods and results

Numerical simulations, either in a discrete form (molecular dynamics, discrete element method), or a continuum form (finite elements, boundary element method), provide a bridge between theory and experiments. They have been instrumental at understanding the link between micro contacts at a rough surface, and roughness features (r.m.s. of slopes), load, and mechanical parameters.
We will discuss how, over the years, our ability to model with computer simulations surfaces with increasing complexity and details has improved, starting from finite-element modeling [1], figure 1, and finishing with boundary-element simulations incorporating plasticity and FFT [2].

As shown in figure 1, elastic interactions between nearby micro contacts matter. Elastic interactions are felt over long distances, and affect the location and average size of micro contacts. This has important consequences in the emerging properties of frictional response and wear. In particular, in the case of adhesive wear [3], we show how crack shielding mechanisms between nearby asperities promote the formation of larger debris, thereby providing a mechanistic understanding of the transition for mild to severe wear at a critical load. While these results were initially observed through molecular dynamics simulations, we will discuss our recent efforts at generalizing those early observations with computationally efficient continuum solvers, through the boundary-element method or the finite-element method incorporating phase-field modeling of fracture.

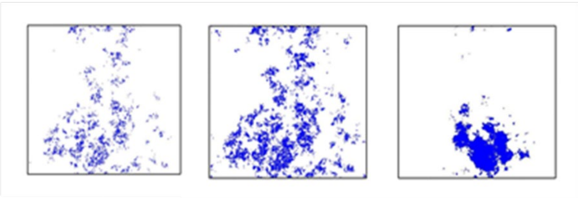

Figure 1: Looking down on a square rough contact interface, blue regions show where contacts occur, and give the important message that mechanics matters [1]. Finite-element simulations demonstrate that elastic interactions (left) or elastic-plastic behavior (middle) yield a configuration of micro contacts that is drastically different than what is predicted from a pure geometrical model, the overlap model (right).

3. Discussion

Interactions between asperities help revise our understanding of the contact area, and the notion of what is a contact asperity, which in fact can be the assembly of nearby interacting contact junctions. In the context of wear mechanisms, the effective contact area appears to be a quantity bounded by the real contact area, at the low end, and the nominal contact area at the high end. The presentation will also explore optimization strategies in order to maximize elastic interactions and provide optimal contact shapes for cutting tools technology.

4. References

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