Micromechanics of adhesive wear: Did Archard get it right?

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KEYWORDS

Archard's wear law, debris formation, Frictional energy

ABSTRACT

Despite the three-centuries-long history of inquiry into the understanding of wear and the existence of empirical laws (e.g. Archard's wear law [1]), wear remains one of the least understood areas of mechanics. The process emerges from a rich variety of complex mechanisms at disparate time and length scales (e.g. contact, friction, severe inelastic deformation, fracture, and fatigue) which has restricted wear prediction to empirical models.

A recently-developed novel numerical technique [2] presents a novel step towards understanding the physical origins of material detachment process. It reveals the existence of a critical length scale for junction size, above which surface asperities lead to "fracture" and thus produce wear debris particles, while smaller junctions exhibit "plastic" deformation (see figure 1).

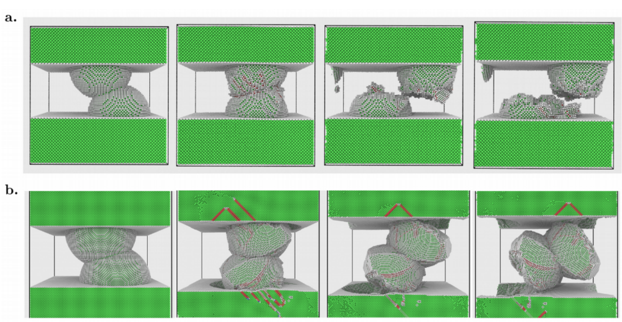

Fig.1 Numerical simulations of adhesive wear mechanisms: **a.** gradual plastic smoothing versus **b.** fracture-induced particle formation. See [2] for detailed information.

Inspired by this new finding, we analyze and quantify wear at the most fundamental level, i.e. wear debris particles. Our simulations [3] show that the asperity junction size dictates the debris volume, revealing the origins of the long-standing hypothesized correlation between the wear volume and the real contact area. No correlation, however, is found between the debris volume and the normal applied force at the debris level, contradicting the macroscopically-observed linear relation (Archard's law).

Alternatively, we show that the junction size controls the tangential force and sliding distance such that their product, i.e. the tangential work, is always proportional to the debris volume, with a proportionality constant of one over the junction shear strength. This provides an accurate prediction of the debris volume without any empirical factor, resulting for a wear coefficient of unity at the debris level. Discrepant microscopic and macroscopic wear observations and models are then contextualized on the basis of this new understanding.

ACKNOWLEDGMENTS

Authors acknowledge financial support from the European Research Council (ERC-STG UFO-240332, "Uncovering the origins of friction").

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