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Fractal surfaces in adhesive wear processes

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Wear of materials plays a key role in the durability of manifactured objects and it has thus an economical importance in our society [1]. In spite of the efforts, a unified picture of the underlying physics of the phenomenon is still far from being reached, because of the numerous mechanisms and processes that constitute the complexity of wear. Moving one step closer to the understanding of the physics of wear would mean enhancing our understanding of all the related fields that it affects, like friction and contact mechanics.

The evolution of the surfaces morphology upon sliding is one of the aspects that need further investigations. In fact, while it is known that newly created surfaces by means of crack propagation are self-affine [2], what happens to existing surfaces rubbed against one another is still unclear. What is known from experimental studies is that self-affinity is preserved for highly abrasive wear [3] and that in other cases the worn surface undergoes asymmetric changes with respect of its original mean plane [4]. Surface roughness is also linked to the wear rate, as rough surfaces are found to deteriorate more in the running-in, up to the point that they have been smoothed enough and the wear rate becomes smaller and constant (the opposite happening for surface that are initially too smooth) [5].

As atomistic simulations have been proved to be an effective means of investigation for the understanding of the physics of wear, we adopt a recently developed approach [6] to investigate the surface roughness evolution under adhesive wear processes (i.e, when the material loss is mainly due to transfer of particles from one body to another). The simulated system is two-dimensional, with periodic boundary conditions along the horizontal direction to allow for continuous sliding at constant velocity of the top surface over the bottom one. In the early stages of contact, the two surfaces form a debris particle that continuously rolls between them, interacting with them by removing material and deforming them.

The peculiarity of the performed simulations is that they are long enough to allow for an investigation of the surfaces geometry evolution over time. The simulations display the two-regime evolution of the surfaces, characterized by high wear rate at running-in and lower wear rate in later stages of the process. Once the running-in is over, the morphology of the sliding surfaces and of the rolling debris particle are analyzed by means of their PSD. All the analyzed surfaces appear self-affine, and their heights are positively correlated. This type of roughness is consistent with the ones found in faults [7] and, by analogy with gradient percolation models, hints that short range interactions prevail on long range elasticity [8].

In some cases it is also observed that, after the running-in, the debris particle can heavily perturb the process increasing again the roughness of the mating surfaces, similarly to the running-in conditions. Despite the fact that this is not the picture commonly expected, it can be explained analyzing the debris particle geometry and the stress state at the contact interface. In particular, roughness enhancement happens by removal of material from the opposing surfaces when the particle is approximately round, while an irregular shape favours the presence of stress singularities in the particle itself and thus the deposit of material from the particle on the opposing surfaces.

In this presentation we analyze different initial setups (i.e. different morphologies, system size, materials), seeing how the final self-affine morphology is independent of the initial state and how the shape of the rolling particle can alter the wear process.

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