Plastic deformation and surface roughening in static friction: A finite strain discrete dislocation study

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ABSTRACT

During plastic deformation, metal surfaces tend to roughen and this directly influences the surface quality of manufactured parts and the real contact area in forming processes. Two-dimensional discrete dislocation plasticity (DDP) simulations of contact [1, 2] have shown severe surface roughening due to dislocations gliding out of the metal and leaving pronounced crystallographic steps on the surface. The surface roughening not only has a significant impact on the evolution of the contact area but also on the traction profiles at contact, and therefore, on its frictional response. However, those simulations were performed using the classical DDP calculations based on the small strain formulation of van der Giessen and Needleman [3], which neglects finite lattice rotations and shape changes due to slip. The latter are expected to play an important role in roughening. To incorporate these effects, we employ the finite strain DDP formulation of Irani et al. [4] to study the shearing response of a single crystal loaded by means of a flat slider in adhesive contact with its surface.

Simulations are performed for sliders of different sizes. The finite strain simulations typically show a reduced shear flow compared to the small strain simulations, less distinct crystallographic steps but a more pronounced roughening, i.e. a deeper valley in the rear of the contact and a higher bump in its front. These differences are appreciable only for sliders that are large enough to induce appreciable dislocation nucleation and small enough to give a hardening response. Moreover, the impact of these results on size dependent plasticity is highlighted. Finally, the finite and small strain simulations are contrasted for the contact behaviour of a self-affine metal surface.

References

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