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The role of the roughness spectral breadth in elastic contact of rough surfaces

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Abstract.

We study frictionless and non-adhesive contact between elastic half-spaces with self-affine surfaces. Using a recently suggested corrective technique, we ensure an unprecedented accuracy in computation of the true contact area evolution under increasing pressure. This accuracy enables us to draw conclusions on the role of the surface's spectrum breadth (Nayak parameter) in the contact area evolution. We show that for a given normalized pressure, the contact area decreases logarithmically with the Nayak parameter. By linking the Nayak parameter with the Hurst exponent (or fractal dimension), we show the effect of the latter on the true contact area. This effect, undetectable for surfaces with poor spectral content, is quite strong for surfaces with rich spectra. Numerical results are compared with analytical models and other available numerical results. A phenomenological equation for the contact area growth is suggested with coefficients depending on the Nayak parameter. Using this equation, the pressure-dependent friction coefficient is deduced based on the adhesive theory of friction. Some observations on Persson's model of rough contact, whose prediction does not depend on Nayak parameter, are reported. Overall, the paper provides a unifying picture of rough elastic contact and clarifies discrepancies between preceding results.

Keywords. roughness, contact area, Nayak parameter, spectrum breadth, pressure-dependent friction, Hurst exponent.

1 Introduction

Many engineering systems include components with contacts: rolling bearings, tire/road and wheel/rail, pieces assembled by bolts and rivets, gears, electric switchers, vehicle and aircraft brakes, NEMS and MEMS, etc. Macroscopic behavior of these components are often determined by complex electro-thermo-chemico-mechanical interactions at contact interfaces at small scales. For many materials and structures the mechanical behavior at such scales is microstructure-dependent and near the surface can differ significantly from in-bulk behavior due to surface tension, coatings/tribo-films and oxide layers. Moreover, in most metallic devices, near-surface layers are cold hardened and recrystallized giving considerably different plastic properties. In addition, in systems with high interface stresses and/or high temperatures due to friction or fracture dissipation, near-surface microstructure may change in operation. An interplay between complex thermo-mechanical behavior at small scale and surface roughness coupled to other relevant physics determine the macroscopic response of the system, its life cycle and failure modes. Thus, understanding mechanical behavior of rough surfaces in mechanical contact is a key point in understanding numerous tribological systems: macroscopic friction and wear laws but also mass and heat transport along and across contacts.

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