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THE ROLE OF NAYAK'S PARAMETER IN ELASTIC CONTACT OF ROUGH SURFACES

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ABSTRACT
Properties of contact between solids, whose surfaces are inevitably rough, to a great extend are related to characteristics of their roughnesses. In real life, surface topography can be very complex and, in general, it does not obey simple assumptions such as normality of high distribution, isotropy and self-affinity. However, some surfaces (for example, electroplated and, to a certain extend, sandblasted) respect them, and thus can be assumed to posses stationary roughness properties, i.e. the height distribution does not depend on the scale, at which the roughness is studied. For such isotropic self-affine surfaces with a Gaussian height distribution, Nayak's theory of roughness [1] can properly describe all geometrical characteristics needed to study the mechanical contact between rough surfaces, in particular, probabilities of summits and their curvature at different heights. Nayak's parameter is one of the key surface parameters in this theory and it is related to the breadth of the surface spectrum. Many multi-asperity models [2] are thus based on this theory, and all of them predict in the asymptotic limit of infinitesimal contact a linear growth of the true contact area with the increasing nominal pressure as it does Persson's model too [3]. But the constants of proportionality in these models differ significantly. For realistic values of the contact area, all multiasperity models predict a non-linear evolution of the contact area, which is strongly dependent on the Nayak's parameter: the greater it is, the smaller the contact area is for the same normalized pressure. On the other hand Persson's model predicts the contact area evolution, which does not depend on this parameter.

All aforementioned models are inevitably based on certain assumptions, because the contact problem is very complex as well as the roughness topography and cannot be fully treated analytically even in terms of the mean fields. To address the question “how the true contact area grows with the pressure?” and “what are the relevant roughness parameters?” we carry out a numerical study of normal non-adhesive and frictionless contact between linearly elastic half-spaces with the effective Gaussian self-affine roughness. A special contact-area correction technique is used to ensure that the results are independent of the surface discretization [4], which enables us to obtain the results with unprecedented accuracy even for surfaces with broad spectra including harmonics of several orders of magnitude.

Our numerical results confirm the dependence of the contact area on the Nayak's parameter, but contrary to multiasperity models, this dependence is significantly weaker: we found that for a fixed normalized nominal pressure, the contact area decreases logarithmically with the Nayak's parameter. Interestingly, surfaces with different Hurst exponents but the same Nayak's parameters show the same contact area for the same load. Moreover, our numerical results suggest that the contact area evolution up to approximately 20% obeys a second order polynomial dependence on the normalized pressure, with parameters changing logarithmically with the Nayak's parameter [5]. Finally, this parameter can be expressed through the Hurst exponent of the roughness or equivalently through its fractal dimension and the cut-off wavelengths. Thus we can estimate phenomenologically the effect of the Hurst exponent (which is sometimes easier to measure than the Nayak's parameter) on the true contact area growth.

In conclusion, this numerical study permits to deduce simple phenomenological equations for the contact area growth with the load, and to determine, based on roughness characteristics,physical meaning of coefficient in pressure-dependent friction laws.

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