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A computational study of adhesion between rough surfaces in contact

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ABSTRACT

Adhesion plays a very important role in many phenomena, especially at small length scales. The roughness of surfaces in contact plays a crucial role in determining the adhesive force. JKR and DMT theories have been used extensively to model the adhesive response of single contacts. For adhesion of rough surfaces, Fuller and Tabor proposed a statistical model based on the Greenwood–Williamson framework with each contact modeled using JKR theory. Majumdar/Bhushan, Persson and others have proposed a model for adhesion representing surfaces as self-affine fractals. We present a numerical study of adhesion between two rough surfaces in contact. The contacting bodies are discretized into voxels (volume pixel) and the heights of the voxels are used to model the surface roughness. Surfaces are modeled as a two-dimensional Gaussian noise with a spatially exponentially decaying correlation. At the microscale, each voxel has an adhesive strength beyond which the contact is broken. The long range elastic interactions through bulk are incorporated using a Boussinesq type solution. A brute force computation of these long range interactions leads to an $O(N^2)$ algorithm, and this can be prohibitively expensive for reasonably large systems. To overcome this limitation, we use a Fast Multipole method where the interactions can be computed to prescribed accuracy in $O(N\log(N))$ operations. Using this, we study the macroscopic adhesive behavior. We simulate the indentation experiments. The two surfaces, initially apart, are compressed into contact to a prescribed dilatation and then pulled apart. During the process, the evolution of the macroscopic normal force is monitored. The macroscopic normal force is initially compressive and as the surfaces are pulled apart, goes through a tensile maximum and eventually becomes zero. The maximum tensile force is defined as the adhesive strength of the interface. We study the dependence of the adhesive strength on material properties, surface roughness, and initial indentation depth. We also consider a viscoelastic adhesion problem and study the dependence of the adhesive strength on the loading rate.