 Proceedings of ICCES'08, pp.1277-1277

The Role of Microscopic Roughness in Depth-Dependent Contact Hysteresis

Haneesh Kesari[1], Adrian Lew[1] and Wei Cai[1]

Mechanical probing apparatus such as AFM are often used to measure mechanical properties. This is done by fitting the Load-indentation (P-h) measurements into a contact mechanics theory. Hysteresis is a common feature in many P-h curves. Generally inelastic effects such as plasticity are considered the cause of hysteresis. However hysteresis in indentation of some soft polymeric samples is seen to be repeatable. This along with post indentation imaging seems to suggest that the material may remain elastic throughout the contact process. Classical elastic contact theories such as Hertz, JKR, and Maugis do not capture some qualitative attributes of the experimental P-h curves, such as the observed depth-dependent amplitude of the hysteresis loop.

Atomistic simulations were performed to check foremost the possibility of having probing depth-dependent hysteresis during perfect elastic contact and gain understanding into the plausible mechanisms operating behind this phenomenon. The simulations consisted of calculating the net interaction forces between two bodies as they are quasistatically brought into and out of contact at 0K. The elastic deformation energy and resultant hysteresis were also calculated during the contact process. The simulations were performed for different degrees of adhesion between the bodies.

It was seen from the simulations that repeatable probing depth dependent hysteresis can indeed occur without plasticity. It was also seen from simulations that the contact region grew/receded through a series of discrete jumps. This quantized nature of contact growth/recession is seen to contribute to hysteresis.

Analytical P-h relations for JKR type elastic contacts, which capture this hysteretic mechanism, are developed. These relations capture the probing depth dependence and repeatability of adhesion hysteresis during perfect elastic contact. These relations may be used to obtain unique estimates for elastic mechanical properties in probing experiments of soft materials where similar hysteretic mechanisms might be operating. It is strongly suggested from these relationships that microscopic roughness is critical to interpret the experimental results, an inherently multi-scale effect.

[1]Mechanical Engineering, Stanford University