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A stochastic description on the traction-separation law of an interface with non-covalent bonding

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Abstract: We formulate a stochastic description about the mechanical response of an interface composed of non-covalent bonds. In such interfaces, the evolution of bonding probability in response to deformation plays the central role in determining their traction-separation behavior. The model connects atomistic and molecular level bonding properties to meso-scale traction-separation relationship in an interface. In response to quasi-static loading, the traction-separation of a stochastic interface is the resultant of varying bonding probability as a function of separation, and the bonding probability follows the Boltzmann distribution. The quasi-static stochastic interface model is applied to understand the critical force while detaching a sphere from an infinite half space. We further show the kinetics of interfacial debonding in the context of the Bells model and two of its derivatives – the Evans-Richie model and the Freund model. While subjected to constant force, an interface creeps and its separation-time curve shows typical characteristics seen during the creep of crystalline materials at high temperature. When we exert constant separation rate to an interface, interfacial traction shows strong rate-sensitivity with higher traction at faster separation rate. The model presented here may supply a guidance to bring the stochastic nature of interfacial debonding into theories on cracking initiation and growth during fatigue fracture.

Keywords: stochastic interface; cohesive model; bonding/debonding; rate-sensitivity; adhesion