Size Selection of Crack Front Defects in Soft Materials: Multiple Fracture-Plane Interactions and Intrinsic Length Scales

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Abstract

Failure of soft materials is mediated by the propagation of cracks which, in realistic 3D media, typically involves multiple coexisting fracture planes. Multiple fracture-plane interactions create poorly understood out-of-plane crack structures, such as step defects on tensile fracture surfaces. Steps form when a slowly moving crack front fragments into disconnected and overlapping segments, separated by a stabilizing distance. The stepped crack fronts leave, in their wake, step defects on the fracture surface. In this talk, we will show that the stabilizing distance of the steps depends linearly on both a nonlinear elastic length and a dissipation length, as demonstrated through numerous fracture experiments on various brittle hydrogels. Here, the nonlinear elastic length scales with the ratio of the crack velocity–dependent fracture energy to the material's shear modulus. Additionally, using the energy balance, we will explain why the steps are topologically stable along the crack front. These intrinsic length scales, which govern the fracture of soft materials, point the way to a fundamental understanding of multiple-crack interactions in 3D that lead to the formation of stable out-of-plane fracture structures.

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