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Rate effects on toughness in elastic nonlinear viscous solids. (English) Zbl 1419.74272

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Summary: A micromechanics-based constitutive relation for void growth in a nonlinear viscous solid is proposed to study rate effects on fracture toughness. This relation is incorporated into a microporous strip of cell elements embedded in a computational model for crack growth. The microporous strip is surrounded by an elastic nonlinear viscous solid referred to as the background material. Under steady-state crack growth, two dissipative processes contribute to the macroscopic fracture toughness-the work of separation in the strip of cell elements and energy dissipation by inelastic deformation in the background material. As the crack velocity increases, voids grow in the strain-rate strengthened microporous strip, thereby elevating the work of separation. In contrast, the energy dissipation in the background material decreases as the crack velocity increases. In the regime where the work of separation dominates energy dissipation, toughness increases with crack velocity. In the regime where energy dissipation is dominant, toughness decreases with crack velocity. Computational simulations show that the two regimes can exist in certain range of crack velocities for a given material. The existence of these regimes is greatly influenced by the rate dependence of the void growth mechanism (and the initial void size) as well as that of the bulk material. This competition between the two dissipative processes produces a U-shaped toughness-crack velocity curve. Our computational simulations predict trends that agree with fracture toughness vs. crack velocity data reported in several experimental studies for glassy polymers and rubber-modified epoxies.

MSC:

74-XX Mechanics of deformable solids

Keywords:

viscoelasticity; fracture mechanisms; polymeric material; porous material; rate dependence

Software:

ABAQUS/Standard

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