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Fast fracture in slow motion: Dynamic fracture and the effect of near-tip elastic nonlinearities in brittle gels

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We present recent results of fracture experiments in poly-acrylamide gels [1]. These gels are soft polymers in which the characteristic sound speeds are on the order of a few meters/sec - thereby slowing down fracture dynamics by 3 orders of magnitude. We first show that the dynamics of rapid cracks are universal; the fracture of gels exhibits characteristic features that are identical with those seen in "classic" materials such as glass. These include:

- Excellent quantitative agreement with the two different equations of motion for single dynamic cracks predicted by Linear Elastic Fracture Mechanics (LEFM) – each for different classes of loading conditions.
- The same branching instabilities, localized waves confined to the crack front, and the characteristic structure formed on the resulting fracture surface as observed in "standard" amorphous brittle materials, such as soda-lime glass.

We utilize the "slow motion" inherent in the fracture of gels to experimentally and theoretically investigate the structure of the deformation fields that surround the tip of highly dynamic cracks. We find that:

- The singular fields predicted by LEFM change their structure due to nonlinear elastic effects that dominate the near-tip region [3].
- This non-linear elastic region provides a quantitative explanation for the oscillatory instability of cracks [2,4] as their speed approaches the Rayleigh wave speed.

These results provide a quantitative first-principles description of how elastic nonlinearity influences the rapid dynamics of a crack.

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