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SUPERSONIC CRACK PROPAGATION IN BRITTLE FRACTURE FAULT ZONE: CAN EXPLAIN KERMAN AND KERMANSHAH FAULTS?

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In a recent article in Nature, a team of scientists from Max Planck Institute for Metals Research in Stuttgart and IBM Almaden Research Center in San Jose, California study the dynamics of brittle crack propagation with large-scale atomic simulations. In this article the scientists report the discovery of an important missing feature in the existing theories of dynamic fracture: The elasticity of solids depend on their state of deformation. Metals will weaken, or soften, and polymers may stiffen as the strain approaches the state of materials failure. "It is only for infinitesimal deformation that the elastic moduli can be considered constant and the elasticity of the solid linear," says Prof. Dr. Huajian Gao, Director at the Max Planck Institute for Metals Research in Stuttgart, Germany. "However, many existing theories model fracture using linear elasticity, and neglect the considerable difference in material behavior at small and large strains. Certainly, this can be considered questionable since materials fail at the tip of a dynamic crack because of the extreme deformation." The scientists hence postulated that hyperelasticity, the elasticity at large strains, can play a governing role in dynamic fracture. In their studies, the scientists show that hyperelasticity, the elasticity at large strains, can dominate the dynamics of fracture. Cracks moving in solids absorb and dissipate energy from the surrounding material.

METHOD

The methodology employed in this work was earlier applied to many seismic regions of the world for identifying seismogenic nodes capable of generating earthquakes of different target size. It combines a morphostructural zoning method, which defines loci of nodes over the study region, and a pattern recognition technique, which divides all the nodes into seismogenic and non-seismogenic ones with respect to a certain cutoff of magnitude. Below, we introduce the basic definitions of the methodology, while in every detail it is described by Freund (1990). In this paper, based on our current simulation model, we develop our earlier studies on transonic crack propagation in linear materials and supersonic crack propagation in nonlinear solids. Our finding centers on a bilayer solid that behaves under large strain like an interface crack between a soft (linear) material and a stiff (nonlinear) material. In this mixed case, we observe that the initial mother crack propagating at the Rayleigh sound speed gives birth to a transonic daughter crack. Then, quite unexpectedly, we observe the birth of a supersonic granddaughter crack. Verify that the crack behavior is dominated by the local (nonlinear) wave speeds, which can be in excess of the conventional sound speeds of a solid. In this problem, there are three important wave speeds in the solid. In order of increasing magnitude, they are the Rayleigh wave speed, or the speed of sound on a solid surface, the shear (transverse) wave speed, and the longitudinal wave speed. Predictions of continuum mechanics (Cherepanov, 1974; Degarmo et al., 2003) suggest that a brittle crack cannot propagate faster than the Rayleigh wave speed. For a mode I (tensile) crack, the energy release rate vanishes for all crack velocities in excess of the Rayleigh wave speed, implying that the crack cannot propagate at a velocity greater than the Rayleigh wave speed. A mode II (shear) crack behaves similarly to a mode I crack in the subsonic velocity range; i.e., the energy release rate monotonically decreases to zero at the Rayleigh wave speed and remains zero between the Rayleigh and shear wave speeds. However, the predictions for the two loading modes differ for crack velocities greater than the shear wave speed.

Whereas the energy release rate remains zero for a mode I crack, it is positive for a mode II crack over the entire range of interionic velocities. (Figure 1) From these theoretical solutions, it has been concluded that a mode I crack's limiting speed is clearly the Rayleigh speed. The same conclusion also has been suggested for a mode II crack's limiting speed because the "forbidden velocity zone" between the Rayleigh and shear wave speeds acts as an impenetrable barrier for the shear crack to go beyond the Rayleigh wave speed.

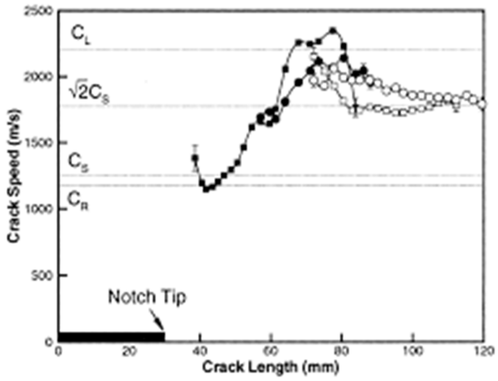

Figure 1. Classical dynamic fracture theories predict that Cracks faster than the Shear Wave Speed.

It seems this theory can explain the relationship between the recent Kermanshah and Kerman Earthquakes.

DATA SELECTED

In this study we used the USGS NEIC CD-ROM for this theory that can explain the relationship between the recent Kermanshah and Kerman Earthquakes.

DISCUSSION AND CONCLUSIONS

The results shows in Figure 1 that Classical dynamic fracture theories predict that Cracks faster than the Shear Wave Speed in the recent Kermanshah and Kerman Earthquakes. Nodes show that hyperelasticity, the elasticity at large strains, can dominate the dynamics of fracture. Cracks moving in solids absorb and dissipate energy from the surrounding material. We discovered a new length scale characterizing the zone near the crack tip from which the crack draws energy to sustain its motion.

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