断層破壊により生じた亀裂群による弾性波の散乱

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Laboratory and field observations suggest that dynamically propagating earthquake faults excite a large number of tensile microcracks in their vicinity, which will contribute to the formation of fault zones. We numerically study how such tensile microcracks are excited and how dynamic growth of a macroscopic shear rupture and near-field elastic waves are affected by the distribution of excited microcracks.

It is essential to consider a large number of microcracks in such studies, so that it is impractical to consider each microcrack individually from the viewpoint of computation time and memory. We overcome this difficulty by representing microcrack distribution by anisotropic properties of the overall elastic coefficients on the basis of Hudson's (1980) study.

Our study provides the first detailed numerical simulation of the effects of excited tensile microcracks on the dynamic rupture growth and the radiated elastic waves. Earlier studies on the excitation of microcracks are based on quasistatic analyses [Vermilye and Scholz, 1998; Reches and Lockner, 1994]. In addition, they inferred only the orientation of microcracks from the analysis of quasistatic tensile stresses, that is, they could not actually consider media embedded with distributed microcracks. Dynamic analyses are indispensable for the investigation of radiated elastic waves.

While our simulation has a limitation that distribution of microcracks must be dilute, it is shown that even such microcracks may greatly affect the growth process of shear rupture. In fact, the excitation of microcracks with the density threshold $\varepsilon_0=0.05$ is shown to reduce the shear stress at the propagating crack tip as much as 18% compared to the case of the shear rupture growing in the uncracked medium (Fig.1). This suggests that the growth of a shear crack tends to be impeded by the generation of the microcracks. Spatial distribution of microcracks is shown to be in good agreement with field and laboratory observations. For instance, the microcracks on the dilational side of the shear rupture make larger angles to the rupture plane than those on the compressive side, which is consistent with laboratory observations (Fig.2).

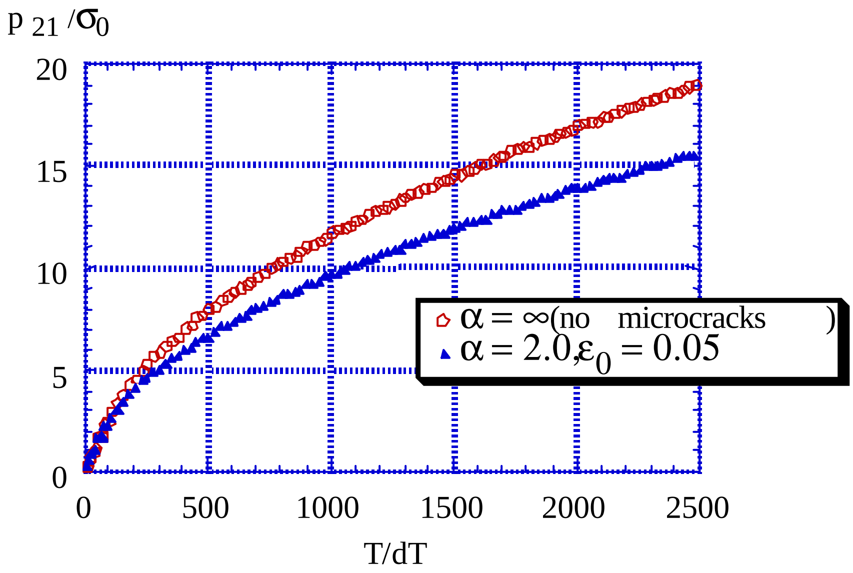

Figure 1 Effects of α and ε_0 on the temporal variation of the shear stress immediately ahead of the propagating tip of the main crack; α is the threshold for the generation of a microcrack.

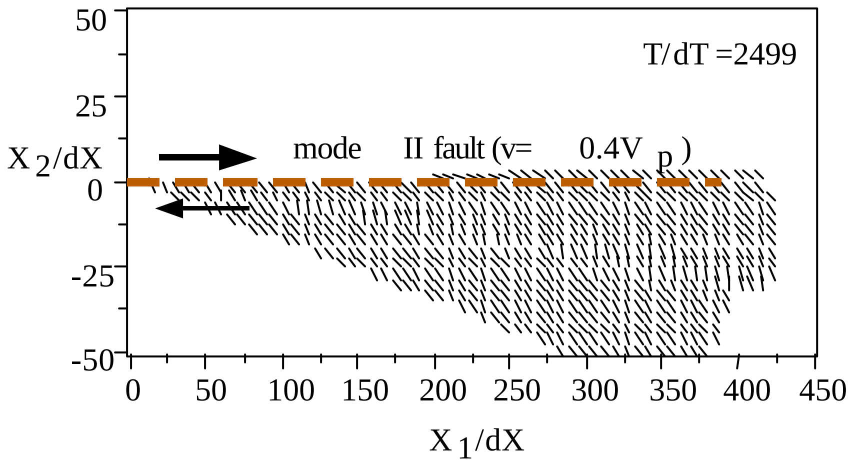

Figure 2 Distribution of microcracks in the fracture zone at time step T/dT=2499; α=2.0 is assumed. The tip of the main crack lies at X_1/dX=399 at this instant.

The geometry of fracture zone can change abruptly when the rupture tip velocity varies discontinuously. This may complicate the formation process of fault zones and cause fault zone expansion even on the compressive side of the rupture. When the rupture growth is arrested abruptly, a large fracture zone is formed near the arrested rupture tip (Fig.3). Aftershocks are expected to cluster in this zone because of shear stress enhancement there and high density of distributed microcracks, which facilitates aftershock occurrence due to dynamic coalescence of microcracks.

Our simulations also show that the component of radiated displacement waves perpendicular to the rupture plane is significantly affected by the generation of microcracks. For example, the excitation of microcracks with the density threshold ε_0=0.05 can reduce the amplitude of the perpendicular component of displacement wave as much as 33% compared to that radiated by shear rupture growing in an isotropic homogeneous medium in the assumed range of the model parameters (Fig.4).

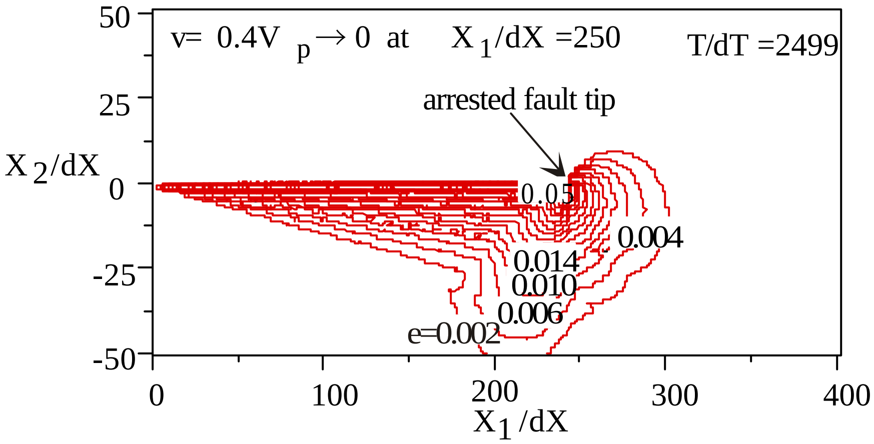

Figure 3 Distribution of microcrack density at T/dT=2499; the growth of the main crack is assumed to be arrested abruptly when the tips arrive at X_1/dX=240. We assume α=2.0 and ε_0=0.05. Curve parameters indicate the distribution density of the microcracks.

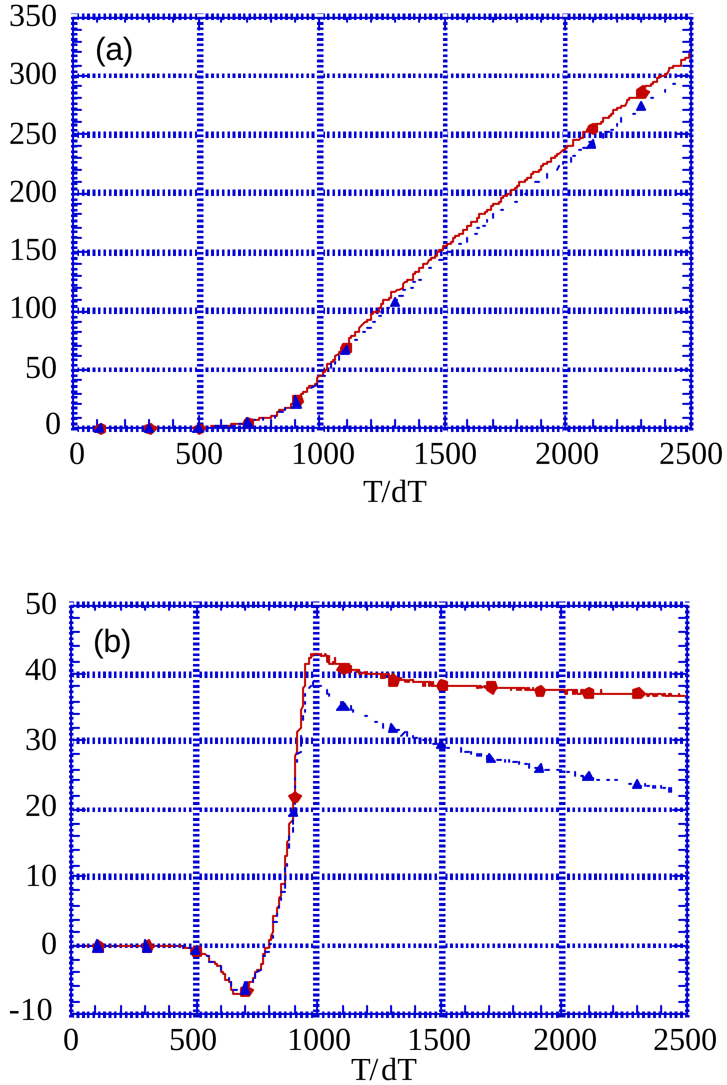

Figure 4 (a) the X_1 and X_2 components of radiated displacement. We assume α=2.0 and ε_0=0.05 for the calculation of the curves shown with blue symbols, while the red symbols denote the waves radiated by the crack propagating in a homogeneous isotropic solid. The waves are observed at X_1/dX=150, X_2/dX=10/.