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A CLUSTER OF RUPTURE EVENTS IN A MODELED FAULT DAMAGE ZONE

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ABSTRACT

We study rupture development of a set of small-scale parallel cracks in a brittle solid medium, which models a geological fault damage zone under quasi-static loading. Experimental observations using a high-speed digital video camera show the significant mechanical roles of the initial inclination angle of the set of parallel cracks in generating a cluster of rupture events.

1. INTRODUCTION

As briefly mentioned previously[1)], we have been studying the dynamic characteristics of a fault damage zone containing small-scale cracked segments, in particular, those of the local, subsidiary ruptures induced by the development of the primary rupture. In this contribution, we continue our investigation into rupture and wave evolution in a brittle linear elastic solid material having a set of pre-existing small-scale parallel cracks that model dip-slip normal fault planes in the two-dimensional framework.

2. EXPERIMENTAL INVESTIGATIONS

We prepare rectangular polycarbonate specimens with small-scale, parallel but inclined multiple cracks by a digitally controlled laser cutter. Using a tensile testing machine, we apply quasi-static loading to each specimen at a prescribed constant strain rate, and observe the dynamic development of the primary rupture, rupture-induced waves and subsidiary ruptures with a high-speed digital video camera. In the case of a group of vertically dipping small-scale parallel cracks, we have found spatiotemporally complicated but ordered rupture evolution[1)], i.e. (I) an upward-propagating primary rupture, which upon surfacing jumps to remote positions; and (II) downward-moving secondary ruptures, followed by significantly delayed further ruptures. The cluster of ruptures or subsidiary ruptures are initiated even without the existence of additional external loading, and they are obviously generated by the waves related to the primary rupture. We can numerically support the idea of important dynamic roles of rupture-induced waves in these experimental findings by employing a finite difference scheme with a second-order accuracy[2)].

For other different dip angles, experimental observations suggest that the rupture evolution can be either fully dynamic or quasi-static[2)]. For example, for a relatively large dip angle of 60 degrees, shown in Fig. 1 (top), the rupture development is essentially identical to the vertically dipping one. During the upward movement, the primary rupture 1 dynamically bridges the gaps between the pre-existing inclined cracks. Then, the secondary rupture 2 travels downwards, which is followed by another downward rupture 3. All three ruptures dynamically develop and can radiate waves into the far-field. In the case of more gently inclined pre-existing cracks, on the other hand, the rupture develops totally differently (Fig. 1 (bottom); dip angle 40 degrees). The upward primary rupture i evolves quasi-statically and connects the pre-existing cracks in a step-by-step fashion, and only the secondary rupture ii, initiated on the top free surface, propagates dynamically downwards and emits “seismic” waves of some practical significance[3)].

3. CONCLUSIONS

We have conducted a series of experiments to observe rupture development in brittle linear elastic specimens having small-scale, parallel but inclined cracks modeling dip-slip fault planes under quasi-static tensile loading. The snapshots taken by a high-speed digital video camera show that the rupture behavior depends strongly on the dip angle of the parallel cracks and the primary rupture development can become either dynamic or quasi-static. In the case of more steeply dipping cases, the primary as well as subsidiary ruptures may generally propagate dynamically. In contrast, when the dip angle is in a smaller range, the primary rupture tends to develop in a quasi-static way. The experimentally obtained photographs also indicate that in both steep and gentle cases, ruptures can jump to remote positions without difficulty in a brittle solid medium with small-scale cracks[3]. We are now trying to find geometrical and loading conditions needed for the quasi-static and dynamic evolution of the primary rupture, by changing distribution patterns of pre-existing cracks and externally applying not only quasi-static loading but also dynamic impacts.

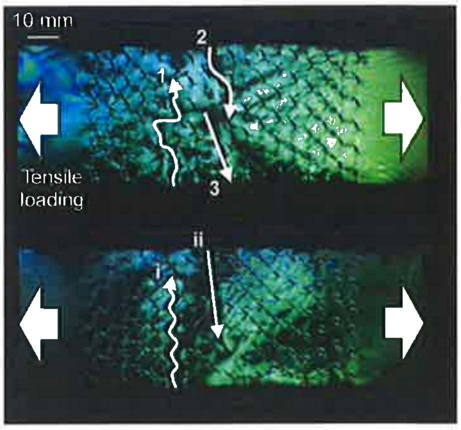

Fig. 1 Archetypal dynamic rupture development in specimens with pre-existing small-scale cracks under quasi-static loading, which models normal faulting. The dip angles are 60 (top) and 40 (bottom) degrees (constant strain rate of 1.2×10^{-2} /s externally applied).

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