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Understanding of diversity of the secondary fracture based on energy change due to damage evolution

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We consider damage effect to investigate how the secondary fracture evolves with dynamic crack extension. The secondary fracture, defined as the fracture created near and around the main fault plane by the fault motion, shows many aspects. Some experimental studies show many microcracks distributed in a medium around the fault plane after the main fault slip. In addition, the region where the rocks are pulverized sometimes appears around the fault plane. For example, Dor et al. (2006) investigated San Andreas Fault zone and found homogeneous pulverization and selective pulverization zones. The former is defined as the zone where the crystals yield a rock-flour texture, while the latter is defined as the zone where only some of the crystals yield powdery texture. Though these various behaviors about the secondary fracture are known to exist, the unified model explaining all of them has not been established. We will construct the model based on the framework of Murakami and Kamiya (1997). We assume damage tensor D and energy release tensor Y here. The damage tensor describes the damage state of the medium and the energy release tensor denotes the strain energy released by unit damage evolution.

We consider a 2-D crack embedded in a medium causing damage. The fracture criterion is introduced for the energy release tensor as follows. First, the tensors Y and D are rotated with the principal axes for Y, which makes Y diagonal. If 1-1 (2-2) component of the diagonalized Y exceeds the criterion Yc, the 1-1 (2-2) component of the rotated D is set to be unity artificially. If all the eigenvalues of the tensor D become unity, we can regard the region as homogeneously pulverized. On the other hand, if not all of the eigenvalues become unity, the region is regarded as selectively pulverized. We have here Yc and other two parameters, eta2 and eta4, and diversity observed for the secondary fracture can be understood in terms of those parameters. The homogeneous pulverization is represented by the situation where eta2 has a finite value, eta4 equals to zero and Yc is sufficiently so small that the fracture criterion is satisfied. The tensors D and Y are proportional to the unit tensor in this case and pulverization occurs in an isotropic way. On the other hand, the selective pulverization is represented by the condition where eta4 has a finite value and Yc is sufficiently small. The nondiagonal components of D and Y appear in this case and they generate the anisotropic pulverization. If Yc is sufficiently high, pulverization does not occur and microcracks distribute around the fault plane. Both the open and shear microcracks can be understood in our framework because we can consider both maximum extension direction and normal directions of microcracks in the medium. Their parallel components describe the open mode, while perpendicular components stand for the shear mode. The results obtained here suggest that the damage effect should be treated by the tensor, not by scalar parameters.

Keywords: damage tensor, energy release tensor, secondary fracture, microcrack, pulverization