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Mathematical and numerical analyses of quasi static crack in a two-layered medium

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We theoretically studied how the deformation caused by quasi static mode-II and mode-III cracks is affected by the existence of an interface that separates two different semi-infinite elastic media. We employed the boundary integral equation method (BIEM) for the analysis. For an analysis of a crack, the relative slip is obtained numerically in BIEM by solving the boundary integral equation on the assumption of a stress drop on the fault. What is essential in the application of BIEM is to derive the analytical solution for the kernel function, which is the solution for the stress change generated by the relative slip localized at a point. The point is that nobody had derived the kernel function for arbitrarily oriented mode-II crack in the two-layered medium. We, however, successfully did it analytically for the first time in this paper applying the Fourier transform and introducing a sequence of complex functions.

We also study the local stress field around the crack tip or at an intersection of crack with the interface, which help us understand the generation mechanism of secondary faulting. These analyses are calculated by BIEM with non-equally-sized and non-orthogonal grid.

We executed some calculation with this kernel function. Consequently we showed that the stress generated by a crack in the two-layered medium is significantly different from that observed for a homogeneous medium. First, our calculation for mode-II crack showed that the stress intensity is more affected by the existence of the interface when the crack is closer to the interface; such behavior had been found by Kame et al. 2008 for mode-III crack. Second, we calculated stress field caused by mode-II and mode-III crack that intersect with the interface at an arbitrary angle. In this calculation, we assumed that the value of stress drop is equal to the initial stress. Here, we have to note that the orientation of initial principal stresses and their values are different in the two media because of the continuity condition of stresses and displacement across the interface (Rybicki and Yamashita 2008). We found that the stress generated by such crack depends on the orientation of maximum initial principal stress relative to the orientation of the interface. The dependence was found to be much larger for mode-II crack. These two outcomes imply that distribution of secondary faulting like aftershocks and fractured zone varies with direction of maximum principal stress or a positional relationship between the crack and the interface.

On the other hand, it had been pointed out that a mode-III crack can create a stress singularity at the intersection of crack with the interface and can cause secondary faulting when the stress drop does not satisfy the specific condition over the crack (Bonafede et al. 2002). So we studied whether the mode-II crack can do so or not. It is difficult to mathematically analyze the kernel function for mode-II crack because of its complexity and thus we inspected by numerical study. As a result, while it was found that the numerical calculation about mode-III shows local enhancement of stress around the intersection, the calculation about mode-II crack does not so in the same scale. Therefore, we concluded that the singularity is almost negligible for mode-II crack, if any.