Japan Geoscience Union Meeting 2010
(May 23-28 2010 at Makuhari, Chiba, Japan)

SSS019-17 Room: 303 Time: May 24 11:45-12:00

Numerical modering for branching faults in a subduction system

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The major large earthquakes or subduction megathrust earthquakes often propagate through geometrically complex fault systems. Exploring governing factors of such propagation is important for understanding physics of macroscopic rupture process and disaster prevention to estimate the probability of rupture extensions. For example, when fault slip of a megathrust earthquake reaches the earth's surface in the subduction zone, predicting slip behavior in accretionary prism is essential to estimate the magnitude of tsunami excitation.
Various problems of dynamic rupture propagation under relatively simple condition have been studied. However, even slight complexity makes problems difficult to solve numerically, and many interesting problems still remain unresolved. For example, to model the rupture process in a subduction system, it is necessary to deal with inhomogeneous media, complex fault geometries including branching faults, and free surface boundary conditions. Our main issue is to evaluate these effects on a spontaneously propagating mode II crack on a bimaterial interface (the main fault) and a branching fault, which is a more complex problem than previous works. We develop an explicit finite element code to solve the equation of motion in a bimaterial elastic medium. Slip on the main and branching faults is implemented by split-nodes with a slip-weakening friction law. Outer boundaries are either absorbing boundary or free surface. We assume homogeneous prestress or linearly increasing prestress from the free surface.
We solve the dynamic rupture problem with a branching fault in homogeneous prestress with various values for the rupture velocity, the material contrast, the prestress state, and the angle between the main and branching fault. We find that the branching fault tends to be ruptured for the case of more compliant upper medium when we compare the results at the same rupture velocity normalized by the generalized Rayleigh velocity. If the rupture velocity approaches very close to the generalized Rayleigh velocity, the strong dynamic stressing activates the branching fault for even negative material contrast. Some differences are in the slip amount of the main fault after branching and rupture velocity along the branching fault.
When prestress linearly increases with depth from zero at the free surface, the only slight change of normal stress due to seismic waves cause an initiation of rupture on the branching fault at the free surface. On the other hand, the stress variation on the main fault is small and has little effects on the rupture propagation on the main fault. Therefore the distance between the initial crack and the branching point is a key parameter to the rupture process with such a condition. When the initial crack is distant, a rupture is initiated at the surface by seismic waves and arrives at the branching point earlier than the main fault rupture, which greatly change the stress field around the branching point and terminates the main fault rupture.

Keywords: subduction system, branching faults, modeling, rupture propagation