Numerical simulation for rupture process of surface and subsurface faults

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1 Introduction

Fault rupture process is so complicated, and depends on the location, shape, stress condition of the fault and so on.Especially, the propagation and scale of fault is considered to be different between surface and subsurface fault, because of difference in their surrounding stress conditions.Growth of surface and subsurface faults affects on their growth itself and on the final scale of fracture area.

In this study, two-dimensional finite element model for generation and propagation of fault is developed.Using this model, we simulated rupture process of surface and subsurface faults in order for studying fault growth and its influence on the generation of the fracture zone.

2 Method

In the elastic model of the finite element method with linear triangular elements, the quadrilateral joint elements (Goodman et al., 1968) of zero thickness which express the fault plane, insert between linear triangular element.If the stress in a joint element satisfies with the Coulomb-Mohr criterion, the joint element behaves as a slider and transtorms anelastically with frictional force, otherwise the joint element behaves as an elestic body.

First, we verify the validity of our model.By comparison with cases of using joint element and not using joint element in continuous condition, we confirmed that the error of the displacement is less than 0.003%.We also confirmed that the proper frictional force works on the fault surfaces, and both tensile and shear faults occurred at the proper locations and propagated rational direction.Therefore, our finite element model is appricable for simulating fault processes.

3 Model

Numerical simulation for fault growth is carried out for following two cases.

(1) The structual model of calculation is rectangle (5000m long and 1200m depth).The bottom and right side of the walls are fixed in position.Initial displacements are calculated with a load of 10000000N on the left side without fault.In a case, we set a surface fault at 3000m-4000m long from the left wall and 0m-400m depth, and in another case, subsurface fault is set to be at 3000m-4000m long from the left wall and 800m-1200$m depth.Then, both the models are subjected 10000000N/s load to the left side.

(2) The structual model of calculation is rectangle (3500m long and 3000m depth).The bottom and right side of the walls are fixed in position.Initial displacements are calculated with a load of 1000000000000N on the left side without fault.In a case, we set a surface fault at 1500m-2500m long from the left wall and 0m-400m depth, and in another case, subsurface fault is set to be at 1500m-2500m long from the left wall and 1200m-1400m depth.Then, both the models are subjected 1000000000000N/s load to the left side.

4 Result and Discussion

In the surface fault models of both (1) and (2), rupture zone occured only near surface, and did not expand to the deeper part.In the subsurface fault model of case (1), however, initial fault grew itself and new surface fault were generated.Initial subsurface fault and new surface fault combined and formed large rupture zone.In the subsurface fault model of case (2), initial fault did not grow, but new suface fault occured and propagated toward the initial crack direction.

This difference of subsurface rupture process may depend on the boundary condition near initial fault.Subsurface fault model of case (2) can release the stress to the surrounding elastic body and the growth of the fault is prevented.However, in the case of (1), initial subsurface fault is pressed to grow by the rigid boundary just beneath the initial fault and thus the stress concentrates on the area near subsurface fault.

We also found that the existing of the subsurface fault may be possible to form larger rupture zone compared with the case of existing the surface fault.