Dynamic rupture simulations for the 2016 Tottoriken-chubu earthquake

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In this study, we performed dynamic rupture simulations for the 2016 Tottoriken-chubu earthquake (M6.6). We used a boundary integral equation method, and supposed slip-weakening law as a frictional constitutive law. We assumed a vertical rectangular fault plane whose depth of the upper edge is 0.5 km, the fault size is 19.5 km (along strike)×18 km (down dip), and left lateral faulting. We also assumed a rupture initiation point coincided with its hypocenter (Hi-net automatic processing hypocenter), and the rupture spread from this point. In this study, we attempted to obtain spatial distributions of initial stress and critical slip weakening distance in the slip-weakening law, which can fit better the slip distribution obtained from inversion analysis of the observed seismic waveforms performed by Kobayashi et al. (2016). The final slip distribution obtained from the inversion analysis has an area whose slip amount is very large just above the hypocenter, reaching 1.3 m. In addition, the large slip, reaching 1.27 m, has completed within 1 s (0 s is rupture initiation time).
Firstly, we performed a simulation, assuming uniform dynamic parameters on the fault plane with initial stress of 10 MPa, critical slip weakening distance of 0.25 m, peak stress of 20 MPa, and residual stress of 0 MPa. The simulation shows that the whole area slipped, reaching 4.4 m. We found that it was impossible to explain the inverted slip distribution using uniform dynamic rupture parameters. Therefore, we introduced heterogeneity of dynamic rupture parameters on the fault plane.
We divided the fault plane into two areas, referring to the inverted slip distribution; one is the area with a large slip amount, and the other is the surrounding one with a small slip amount. We assumed that residual stress was 0 MPa, and peak stress was 20 MPa in both areas. Here, we estimated initial stress in these two areas, by fixing the values of critical slip weakening distance. For this purpose, we assigned initial stress of 2 MPa in the surrounding area of small slip, and varied initial stress value from 5 MPa to 15 MPa in the area of large slip. We attempted to obtain an initial stress value so as to minimize the residual between the simulated and inverted final slip distributions by a try-and-error method. As a result, we obtained 10 MPa as the optimal initial stress value in the area of large slip.
Next, we attempted to estimate spatial distribution of critical slip weakening distance values. For this purpose, we assumed the value to be 0.25 m in the surrounding, and divided the area of large slip into four areas in the depth direction (the deepest one included the rupture initiation point). We varied critical slip weakening distance value from 0.25 m to 0.30 m in these four areas. We attempted to obtain critical slip weakening distance values so as to minimize the residual between the simulated and inverted slip distributions at every 1 second by a try-and-error method. As a result, we found there are a trend that the value of critical slip weakening distance become larger toward the direction of the ground surface.
Comparing the inverted slip distribution with obtained heterogeneity in initial stress and critical slip weakening distance on the fault plane, we found that an initial stress value in the area of large slip was larger than that of the surrounding, and a critical slip weakening distance value was the smallest in the area including the rupture initiation point than the other upper three areas.

Keywords: dynamic rupture simulation, Tottoriken-chubu earthquake

