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A possible mechanism for short-period seismic waves from the final stage of asperity rupture

Naoyuki Kato[1]

[1] ERI, Univ. Tokyo

Circular crack models for earthquakes assume that rupture starts from a point on a fault and it uniformly propagates with self-similar circular shape. Although this model is useful as a simple source model, it is not realistic as a model for interplate earthquakes when the seismic coupling coefficient is low. On such a plate boundary, seismic slip repeatedly occurs at some patches (asperities), while steady aseismic sliding takes place in the other regions, leading to stress concentration at the perimeters of the asperities before the occurrence of an earthquake. In this case, seismic rupture will start from a point in the stress concentrated region in the perimeter of the asperity, and rupture propagates easily in the region. The rupture first encircles the asperity, and then it propagates into the center of the asperity, causing rupture front focusing on a point in the final stage of asperity rupture. When the rupture front focusing occurs, slip rapidly increases, generating short-period seismic waves. This rupture process of a circular asperity in a creeping region was numerically examined by Das and Kostrov (1983), and the rupture front focusing for a mechanism of short-period elastic radiation has been discussed by Fukuyama and Madariaga (2000) and Page et al. (2005). In the present talk, I perform a numerical simulation of stress concentration process and rupture process of a circular asperity during a seismic cycle using a rate- and state-dependent friction law to discuss mechanics of short-period seismic radiation.

A model of two-dimensional planar fault in an infinite uniform elastic medium is considered in the simulation. The fault is shear loaded so that the fault slips at a relative plate velocity on the average. The frictional stress on the fault is assumed to obey a rate- and state-dependent friction law. Nonuniformity in friction parameter A-B, which represents the rate dependence of steady-state frictional stress, is introduced, and a region with negative A-B values is called an asperity. Since frictional stress decreases with an increase in sliding velocity (velocity weakening) for negative A-B, seismic slip may occur. On the other hand, for positive A-B (velocity strengthening), aseismic sliding occurs. During an interseismic period, stress concentration occurs in the perimeter of an asperity due to steady aseismic sliding in velocity-strengthening regions. Such stress concentration in asperities may occur on real plate boundaries with nonuniform fictional property.

The simulation result of rupture process of an asperity is as follows: Seismic rupture starts from a point on the stress concentrated perimeter of the asperity. The rupture speed is relatively high in the perimeter region of the asperity, while it is relatively low in the interior of the asperity, where shear stress is relatively low, resulting in a crescent-shaped slip region. In the final stage of asperity rupture, rupture front focusing occurs near the edge of the asperity on the opposite side of rupture initiation, causing large slip rates. The spatial distribution of coseismic slip with the slip rate larger than 1 cm/s is relatively uniform over the asperity, while that with the slip rate larger than 1 m/s shows a significant peak where rupture front focusing takes place. The moment rate time function during the simulated asperity rupture shows that the moment rate increases nearly with a constant rate at first and it rapidly increases in the final stage of asperity rupture corresponding to the rupture front focusing. This simulation result suggests that significant short-period seismic waves are radiated in the final stage of asperity rupture when rupture front focusing occurs. The simulation result that significant short-period seismic waves are radiated from the edge of the asperity on the opposite side of rupture initiation is consistent with the observation by Kanda and Takemura (2006) for large interplate earthquakes.