

A会場 | 一般セッション：S08. 地震発生の物理

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[S08] 地震発生の物理

座長:AOCHI Hideo(BRGM)、大久保 蔵馬(防災科学技術研究所 地震津波防災研究部門)

9:00 ~ 9:15

[S08-01] Developing a method for accurate estimation of local fracture energy using the steady-state rupture model and dynamic rupture simulations

*大久保 蔵馬¹、山下 太¹、松本 圭晶¹、福山 英一^{2,1} (1. 防災科学技術研究所、2. 京都大学大学院工学研究科)

The dynamic stress field near the earthquake rupture front provides a key constraint for estimating fracture energy during rupture propagation. For simulated faults in laboratory experiments, fitting the analytical solution of steady-state rupture to the local stress evolution from near-fault measurements has been proposed as an efficient approach to estimate local fracture energy (e.g., Kammer and McLaskey, 2019). However, it does not account for shear stress peaks that precede the rupture front associated with the spontaneous rupture propagation (Svetlizky et al., 2016), leading to systematic discrepancies from the observed shear stress evolution. Consequently, the full shear stress waveform cannot be directly used for the estimation of local fracture energy in spontaneously nucleated ruptures. In contrast, dynamic rupture simulations can reproduce such stress peaks, but are computationally expensive and thus impractical for evaluating spatial variations of fracture energy. Therefore, to efficiently estimate the local fracture energy using the analytical solution of the dynamic stress field, it is necessary to optimize the fitting time window and criteria, and to calibrate the estimation method with dynamic rupture simulations with predetermined fracture energy, which serve as the ground truth.

We focused on a newly developed large-scale biaxial rock friction apparatus with a simulated fault of 6 m in length and 0.5 m in width (Yamashita et al., 2024, JpGU). Stick-slip events on this apparatus generate dynamic rupture propagation approaching the limiting speed of sub-Rayleigh ruptures. To model these laboratory ruptures, we used the spectral-element software SEM2DPACK (Ampuero et al., 2024, v2.3.9) with a linear slip-weakening friction law. The computational setup was based on Xu et al. (2019) but adapted to the present experimental conditions. The normal stress was fixed at 3 MPa, and the static and dynamic friction coefficients were set to 0.3 and 0.2, respectively, consistent with the macroscopic friction drop observed during the experiments. The critical slip distance D_c was set as 1 μm (Xu et al., 2019), yielding a predetermined fracture energy of 0.15 J/m² and a critical nucleation length L_c of 1.3 m.

Although the initial shear stress in the experiments is typically heterogeneous due to repeated stick-slip events, we assumed a uniform distribution of 0.675 MPa in order to simplify the fracture energy estimation based on the analytical rupture model. This corresponds to the seismic ratio (e.g., Andrews, 1976) of 3. Absorbing boundary

conditions were imposed at the top and bottom of the computational domain to suppress wave reflections. Rupture was nucleated from the edge of the fault by locally reducing the normal stress with a Gaussian profile, with a peak reduction of about 30%. The near-fault shear stress time histories were computed 15 mm away from the fault plane, corresponding to the positions of strain gauges installed on the rock specimen. The average grid spacing was 6 mm.

The simulations reproduced the dynamic stress field as the rupture approached the limiting speed, including the shear stress peak preceding the rupture front. Preliminary fitting of the analytical steady-state solution to the simulated shear stress waveforms, using the time window after the first peak of the shear stress with the predetermined fracture energy, demonstrated good agreement, indicating the potential of the analytical model for accurate estimation of local fracture energy. Further quantitative tests are in progress to determine the optimal fitting time window and to assess the accuracy of the estimation.