Revisiting the slip-weakening friction: probe into the true source properties from off-fault measurements

*Shiqing Xu[1], Eiichi Fukuyama[1], Futoshi Yamashita[1], Kazuo Mizoguchi[2], Shigeru Takizawa[1], Hironori Kawakata[3]

1.Nat'l Res. Inst. Earth Sci. Disas. Prev., 2.Centr. Res. Inst. Elect. Pow. Ind., 3.Ritsumeikan University

Slip-weakening friction, as evidenced by earlier pioneer rock fracture/friction experiments, has been widely used for numerically simulating earthquake ruptures, and for estimating earthquake source properties from seismological observations. Despite the great success, the accuracy of this constitutive relation is poorly known in the lab: measurements made close to the fault (yet still off the fault) were often assumed without validation to be the direct recordings of on-fault properties. Until recently, several works challenged this assumption, and showed that it may even lead to incorrect interpretation of rupture mode at speed close to the Rayleigh wave speed. This raises a concern on how to probe the true source properties on the fault using off-fault measurements, which was generally overlooked in the geophysical community.
To answer the question, we utilize a large-scale direct shear apparatus at NIED to monitor near-fault strain change during labquakes. By comparing our strain data with common slip-weakening model predications at various locations progressively away from the fault, we see systematically a decrease in apparent peak friction and an increase in apparent breakdown zone size. These features reflect the smearing out of the strain field away from the sharp rupture front. On the other hand, the initial strain before failure and the residual strain after the breakdown process are less sensitive to the sampling location, because the strain field is more homogeneous at those locations without sharp features. By fitting the strain data with templates created from a specific slip-weakening model, we are able to estimate the true source properties during labquakes within the framework of that model. If more data points were available, it would be even possible to probe the true “rupture distribution function” (Andrews, JGR 1976). In any case, our study suggests that care be taken when interpreting measurements during labquakes, especially when sharp features are involved during the rupture breakdown process (e.g. at a scale more than two times smaller than the source-recorder distance). Given the well-known Lorentz contraction effect, we may never be able to directly measure certain rupture properties at speed very close to the limit speed, which ultimately requires some indirect approaches.

Keywords: Slip-weakening friction, Dynamic rupture, Friction experiment

