Receiver Function Analysis of Laboratory Frictional Experiments

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A large number of laboratory frictional experiments have been conducted to clarify the behaviors of frictional slip to understand the occurrences of megathrust earthquakes and slow earthquakes in subduction zones. We apply the receiver function method to biaxial shear experiments to detect a gouge layer as a simulated plate interface; receiver function is one of the effective seismic tools to evaluate velocity discontinuity and detect primary structures such as continental Moho and oceanic crust in subduction zones (e.g., Ammon et al., 1991). Biaxial friction experiments can simulate the fault slip, although it is difficult to measure the temporal changing on a simulate gauge layer with acoustic, or seismological technique, especially using converting wave. Sliding tests can examine the temporal variation of frictional coefficients as shear deformation proceeds. Slide-Hold-Slide (SHS) tests can simulate the fault locking and the effects of aging (i.e., frictional healing). Previous studies have confirmed temporal variations of elastic wave responses from rock interface (e.g., Nagata et al., 2008) and simulated gouge layers (e.g., Scuderi et al., 2016), suggesting that elastic waves can be used as seismic waves and the response may reflect fault structures. Here, we present the preliminary results of the receiver function analysis in biaxial shear experiments.

Sliding and SHS tests with the slip velocity of 1.5 μm/s are conducted using the biaxial slip apparatus at Hiroshima University. We select antigorite serpentinite and Ca-Montmorillonite as simulated gouge layers. We simulate the interface with two sheets of sample powder layers (up to 1.5 mm thickness) by loading 20 kN (~10 MPa) of the normal force in Figure 1. Compressional waves with one cycle of 1 MHz sinusoidal wave are transmitted diagonally to the P and S receivers through the sample layers. The receiver function method is applied by regarding the P-wave receiver as the vertical component and the S-wave receiver as the radial component. The receiver functions are calculated with the Extended-Time Multitaper method (Helffrich, 2006; Shibutani et al., 2008). Frequency dependence is examined by setting Gaussian low-pass parameters; 500 kHz for low-frequency and 800 kHz for high-frequency receiver function.

Some continuous phases around 0.5 to 2 μs and 4 μs are detected in simulated high-frequency receiver functions in Figure 2. These phases are stable in the steady-state frictional condition. Synthetic receiver functions calculated under the velocity model with 1 mm thickness of a low-velocity layer duplicate continuous positive and negative phases around 0.5 to 2 μs and 4 μs, suggesting that the low-velocity sample layer closer to the receivers are detectable by the method. Monitoring of receiver function phases provides a clue to assess faulting processes or the generation of a slow slip on natural faults and plate interfaces, although the input acoustic wave with center frequency of 1 MHz, whose wavelength is around 5 mm in stainless brock, may be relatively low for receiver functions to find out internal structures with 1 mm thickness of the layer.

Keywords: Receiver function, Laboratory frictional experiment, Fault slip, Antigorite

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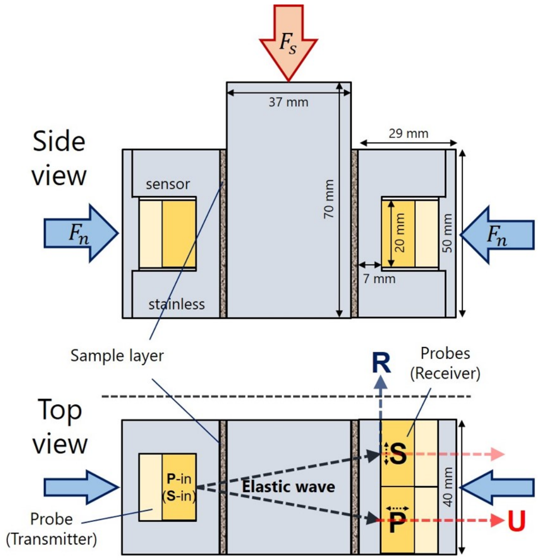

Figure 1. Schematic diagrams of the double-direct shear configuration. The top panel shows the side view, and the bottom panel shows the top view, partially drawn to see through stainless blocks (light blue). Two sheets of powder sample (shown as a rock texture) are sandwiched by stainless blocks. Rectangles colored gold indicate elastic-wave probes; P for compressional waves and S for shear waves. A transmitter probe is located in the center of the block. Two receiver probes are horizontally aligned to be symmetric.

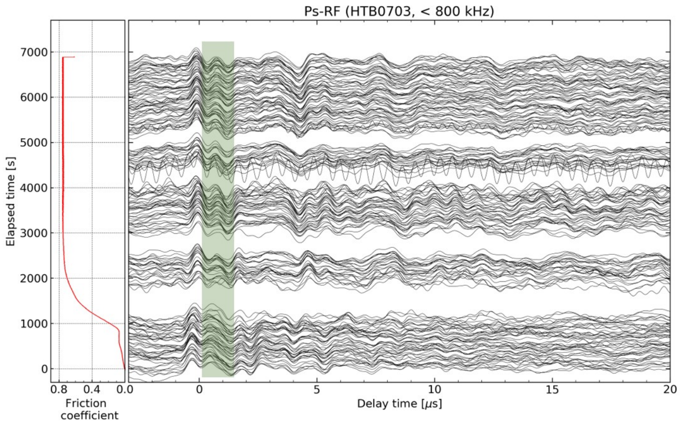

Figure 2. Simulated receiver functions in the sliding test of Antigorite powder (HTB0703) with the frequency content up to 800 kHz (right) and frictional coefficient (left). Horizontal axis denotes the delay time from direct P-wave arrival, and vertical axis denotes the elapsed time from the beginning of shearing. Twenty consecutive waveforms are stacked to calculate each RF trace. Area colored green indicates the conversion phase from the gouge layer on the receiver side. Phases around 4 μs indicate the multiples in the side-block.

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