Continuous measurement of electrical conductivity for monitoring contact state of simulated fault during frictional sliding

*Futoshi Yamashita[1], Eiichi Fukuyama[1], Kazuo Mizoguchi[2]

1. National Research Institute for Earth Science and Disaster Resilience, 2. Central Research Institute of Electric Power Industry

In laboratory experiments, monitoring the mechanical parameters of simulated fault with other observables during fault slipping will provide us with valuable information to understand the frictional property of rocks and thus the mechanics of earthquake. From this viewpoint, we focused on the electrical property of fault, which has a potential to monitor the contact state on the sliding surfaces. We used a pair of cylinders of metagabbro from India as the specimens and installed them into the rotary-shear frictional testing apparatus at NIED. This testing apparatus allows us to take electrical signals of sensors on the rotary specimen via the slip ring even during the rotation. The diameter of the specimen was 25 mm and the length was 30 mm. To measure the extremely high resistance of dry rock specimens, we adopted two electrometers (Keithley 6514) whose maximum input impedance was 200 TΩ. One electrometer was used to input DC current across the simulated fault and another one was used to measure electrical potential across the fault. First, we conducted a preliminary test under stationary condition to grasp the electrical property of the simulated fault. Since transient response of the electrical potential was observed by the sudden input of electrical current, we recognized that the contacting fault should be modeled as a parallel circuit of resistors as well as capacitors. From the transient response curve, we estimated the resistance and capacitance of the fault under the normal stress ranged from 0.1 MPa to 8 MPa. The experimental results showed that the resistance decreased and the capacitance increased as the normal stress increased This can be interpreted as increase in real contact area of asperities and decrease in height of the asperities at high normal stress under the assumption that the real contact area and the rest of the area (i.e., the noncontact area) work as the resistor and the capacitor, respectively. This suggests we can estimate the real contact area from the measurements of resistance and capacitance as far as the conductivity (inverse of resistivity) of the asperity is constant. Next, we monitored the conductivity of fault under a subseismic slip rate (5.3×10^{-3} m/s) and a constant normal stress of 3 MPa. Friction coefficient, defined as the ratio of shear stress to normal stress, showed typical slip weakening; it increased to 0.8 when slip started, then decreased to 0.2 followed by the fluctuation between 0.2 and 0.6. The electrical conductivity data demonstrated quite similar variation to the frictional strength; when the friction coefficient increased, the conductivity increased, and vice versa. From the measured conductivity data, we further estimated the change in the real contact area and its strength with slip. The estimated change suggests that the initial asperities were fully destroyed at a very early stage and the subsequent gouge comminution phase was dominant in the slip-weakening process. We also conducted similar experiments at seismic slip rate (1 m/s) under the normal stress of 3 MPa. In this mechanical condition, the fault rock melted by the frictional heating and lost its strength so much. Hirose and Shimamoto (2005) reported that the weakening process in this condition is composed of two weakening stages and one strengthening stage between them. They interpreted that these are related to the formation of melt patches and the subsequent growth to molten layer during frictional melting. Our conductivity monitoring quantitatively but clearly confirmed these processes by the rapid increases in conductivity in the two weakening stages. These results confirm that the conductivity is a superior tool to probe the contact state of the fault slipping at various slip rates.

Keywords: Electrical conductivity, Friction experiment, Fault, Asperity