Generation patterns of frictional heat in a fault gouge zone during seismic fault slip

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Frictional heating during seismic fault slip is concerned with the origins of fault rocks such as pseudotachylyte or various phenomena accompanied with earthquakes. Recently, some researchers carried out the measurement of frictional heat temperature using a rotary-shear high-speed frictional testing machine [e.g. Shimamoto and Tsutsumi, 1994]. However, it is so difficult to detect pulsating frictional heat with very short duration less than 1 second because many existing thermal sensors have too low sensitivity or too long response time, and additionally are vulnerable to shearing. Fukuchi (2003) analyzed the foliated pseudotachylyte found along the Nojima Fault by ESR (electron spin resonance), and indicated that the ferrimagnetic resonance (FMR) signal of gamma-Fe2O3 was useful for the detection of such pulsating frictional heat. This FMR signal can appear by thermal dehydration of gamma-FeOOH in fault gouge during seismic fault slip, and is applicable to the detection of frictional heat generated in the fault gouge containing clay minerals such as kaolinite or smectite. In this work we carry out the detection of frictional heat generated during high-speed frictional shearing using the FMR signal. Here we shall suggest future problems to be solved with our experimental results. Furthermore we will present the result from computer simulation of the frictional heat generated along the Nojima fault in the 1995 Kobe Earthquake.

In this work we used for the high-speed shearing tests the Nojima fault gouge, which was screened into 8-20 microns and dried at 60 degree C for 1 day. As for the experimental conditions, the axial stress is 0.61 MPa, the rotational speed is 500-1500 rpm, and the duration of slip is about 5-17 seconds. The fault gouge samples after the shearing tests were divided into four portions of 0-3, 3-6, 6-9 and 9-12.5mm on the basis of the circumference (=0mm) of the circular shearing plane. The width of each portion has errors of 1mm. We measured ESR spectra of each portion. The equivalent slip rates along the four portions are respectively 1.74m/s (0-3mm), 1.27m/s (3-6mm), 0.81m/s (6-9mm) and 0.37m/s (9-12.5mm) under a speed of 1500rpm, whereas 0.58m/s (0-3mm), 0.42m/s (3-6mm), 0.27m/s (6-9mm) and 0.12m/s (9-12.5mm) under a speed of 500rpm. As a result of ESR measurements, the FMR signal increases with going away from the center of the circular shearing plane to the circumference. The evolution of frictional heat temperature was calculated from each equivalent slip rate and measured data of frictional coefficient using a one-dimensional frictional heat model by McKenzie & Brune (1972); the thermal conductivity and specific heat were set as 1.0 W/mK and 1.0 J/gK, respectively. The results calculated are consistent with those from isothermal annealing experiments in an electric furnace. The frictional coefficient during the shearing at 1500rpm decreased from 0.71 to 0.24 due to thermal expansion or thermal dehydration in the fault gouge. However the frictional heat temperature calculated from those frictional data remains unchanged or increases during the shearing. This result suggests that the frictional heat temperature during seismic fault slip does not immediately decrease operating together with the decrease of frictional coefficient due to thermal expansion or thermal dehydration. Natural fault gouge zones at deep positions under the ground may not be always saturated with water. Hence the frictional heat temperature may rise until about 400-500 degree C at deep positions although the frictional coefficient decreases due to thermal expansion or thermal dehydration. We will confirm it by high-speed shearing tests using fault gouge samples with various water contents. On the other hand, the thermal conductivity and specific heat of fault gouge may change with thermal dehydration. Hence must estimate in detail their evolutions with increasing temperature to reproduce natural seismic faulting in laboratory.