Does frictional melting trigger an earthquake? A simulation of frictional melting

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Dc (slip-weakening distance) is a parameter which depends on physical characters of a fault plane. Dc is defined as the distance at which the sliding force at a plane reaches a constant value after abrupt change of external driving force. A system is unstable for small Dc, and becomes stable if Dc is large. Dc=0.1- 1m is derived from the analysis of seismic waves. On the other hand, many laboratory experiments report Dc as 10 – 100 micron, which should be determined by the surface roughness of the samples.

Some of fault planes are accompanied by pseudotachylytes sandwiched between the planes. Pseudotachylytes are formed by frictional heating. If a melt is sandwiched between fault planes, Dc will be determined by the physical properties of the melt (viscosity, thermal conductivity), not by the surface roughness of the plane.

Shimamoto and Tsutsumi (1994) conducted sliding experiments of rocks by rotating cylindrical samples, and confirmed the formation of melting layer. They determined Dc as 29.7 m.

In their experiments, the formed melt escapes from the sides of the sample. The escape of the melt increases the frictional force because the thickness of the melting layer decreases. Therefore, Dc determined by the experiment might be affected by the melt escape. On the other hand, there should be many cracks around real fault planes. Melt can escape to those cracks.

The aim of this study is twofold: 1) determine the effect on Dc by the melt escape quantitatively, and 2) determine the relationship between melt thermal conductivity and Dc. The point 2) comes from the fact that the thermal conductivity can vary because the composition of the host rock and the melt can be different because of the variation in the melting temperatures of the minerals contained in the host rock.

We solved one-dimensional Navier-Stokes equation and heat conduction equation. A melt layer is sandwiched between two parallel infinite planes. One plane is moved at constant velocity relative to the other. The melting layer is dragged by the plane. Heat is generated by shear motion in the melting layer. The heat conducts to the plane (rock-melt boundary) and melts the host rock. The thickness of the melt layer increases as time, and the frictional force applied to the plane decreases. The decreasing rate determines Dc.

The main results of the simulation are summarized in four points.

1) The steady friction force decreases as the melt escaping rate increases..
2) Dc decreases as the melt escaping rate increases.
3) The steady friction force increases as the thermal conductivity of melt.
4) Dc increases as the thermal conductivity of melt.

Dc becomes to be small as 0.1-1m if the melt escaping rate is large or the thermal conductivity of melt is small. The former condition is realized for deep earthquakes, because large confine pressure promotes the melt escaping to surrounding cracks. Experimental measurements for thermal conductivities for various kinds of melts are desirable for checking of the latter condition.