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Statistical properties of the characteristic length in friction constitutive law and a evolution law for flash heating

Takahiro Hatano[1*]

[1]ERI, the University of Tokyo

Despite the long history since 1979 (Dieterich) and 1983 (Ruina), the physical meaning of rate-state dependent friction (RSF) law is not very clear to this date. Heslot et al. (1994) were astute to find out that the time-dependent increase of the true contact area and the thermally activated sliding play essential roles to RSF law. Dieterich and Kilgore (1998) and Nakatani (2001) experimentally confirmed some consequences derived from a theory of Heslot et al.

However, some important problems are still left open. For example, evolution laws (the aging law, the slip law, or others) have not been derived from the rheological properties of true contact area. Thus, the important parameters, which are typically denoted as "a", "b", and "L", are just phenomenological constants, although at least it is well known that the constant "a" is proportional to temperature. Under this circumstance, the application of the RSF law to natural faults involves the blind extrapolation from laboratory to geoscale, which requires brute courage. Along the line of thought, the derivation of the RSF law from the "first principle" is essential to the theoretical basis of the application of the RSF law to natural fault (at least aseismic slip rate).

Here we reformulate the RSF law together with evolution laws (the aging and the slip laws) using only the microscopic rheological properties of true contact area. Taking the statistical properties into account, we show that the critical slip distance in the evolution law is a weighted power mean of a linear dimension of true contact patches.

We also take the frictional heat into account to derive an evolution law for flash heating, which is different from that of Beeler et al. Comparison with experiments by Han et al. (2006) reveals that our theory works well.

Keywords: rate- and state-dependent friction, critical slip distance, flash heating