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Frictional melting: results of numerical modeling of rotary experiments

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Field observations of pseudotachylites and experimental studies of high-speed friction indicate that melting on a slipping interface may significantly affect the magnitude of shear stresses resisting slip. We investigate the effects of rock melting on the dynamic friction using theoretical models of shear heating that couple heat transfer, thermodynamics of phase transitions, and fluid mechanics. Results of laboratory rotary experiments (Hirose and Shimamoto, 2005) conducted at high (order of m/s) slip velocities but low (order of MPa) normal stresses suggest that the onset of frictional melting may give rise to substantial increases in the effective fault strength, presumably due to viscous effects. However, extrapolation of the modeling results to in situ conditions suggests that the efficiency of viscous braking is significantly reduced under high normal and shear stresses. The amount of energy dissipation associated with the formation of pseudotachylites is governed by the temperature dependence of melt viscosity and the average clast size in the fault gouge prior to melting. Clasts from a coarse-grained gouge have lower chances of survival in a pseudotachylite due to a higher likelihood of nonequilibrium overheating. If the gouge is fine-grained the temperature and clast content are strongly stabilized at the level where the melt becomes effectively liquid. Our modeling results indicate that the thermally activated fault strengthening and rupture arrest are unlikely to occur in most mafic protoliths but might be relevant for quartz-rich rocks, especially at shallow ($<$5–7 km) depths where the driving shear stress is relatively low. We discuss also the effects of the wear

migration along the sliding interface occurring in the rotary experiments due to the radius dependence of the dissipation rate.