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Numerical simulation of the generation and thickening process of frictional melt layer considering Stefan condition

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We numerically simulate generation and evolution of frictional melt layer. We divide frictional behavior into three regimes. In Regime I, slip continues without melting. In Regime II, melting starts and the frictional property changes from frictional slip to viscous friction. In Regime III, continuous melt layer is formed, and the thickness of melt (h) increases. We assume that frictional stress is constant in Regime I, and determined by viscous friction in Regime III. In Regime II, we assume that frictional property continuously changes from Regime I to III as the temperature (T) increases. We adopt Stefan condition to calculate the growth of h and a viscosity expressed as $\eta = A \exp\left[-B/(T+C)\right]$. Supposing that all frictional work is converted to heat within inelastic layer and slip velocity (v_e) is constant, we solve the evolution of 1D thermal field by a finite difference method. This model reproduces both of the transient increase and subsequent decrease in frictional stress around the onset of frictional melting, as seen in the experiments of Hirose and Shimamoto (2005). Normalizing variables in the equations, it is found that six dimensionless numbers control the behavior, and simulations are executed varying these numbers to reveal the role of each number. Among the numbers, $H_v = \eta_0 v_e^2 / \left[k\left(T_M - T_0\right)\right]$ controls the behavior in Regime III (T_M: melting point of rock, T_0: initial temperature, η_0: η at T_M, k: thermal conductivity). For a small H_v, thickening of melt layer causes reduction in shear stress while T remains slightly above T_M. The numerical result simulating Hirose and Shimamoto's experiment holds on this case (H_v=0.03). For larger H_v, as temperature exceeds T_M sufficiently, abrupt decrease in friction is caused by the reduction of viscosity. For an example of other dimensionless numbers, friction in Regime I affect the peak stress. Though our model is too simplified to analyze natural pseudotachylyte, it is important to reveal the role of each physical process in frictional melting.