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On the relevance of thermal-viscous coupling as a model of frictional constitutive relationship

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We propose a thermal-viscous coupling of shear deformation of a viscoelastic material as a possible mechanism of frictional constitutive relationship. We consider a shear deformation of one-dimensional layer composed of a Maxwell viscoelastic material under a constant velocity and temperature at the outer boundaries. The strain rate due to viscous deformation depends on shear stress as well as the temperature 'Tc' at the core of the layer. The temperature inside the layer changes owing to heating by viscous dissipation and conductive cooling.

We carried out the linear stability analysis of steady-state deformation and studied the evolution of infinitesimal perturbations of 'Tc' and shear stress. We found that the evolution of the perturbations is classified into four regimes depending on whether it is stable or not and whether it is monotonous or oscillatory with time. We further compared the result with that of the linear stability analysis of the steady-state slip of the spring-block model with the rate- and state-dependent friction law. By regarding 'Tc' as a state variable and shear stress as a friction coefficient, we obtained the direct correspondence of the parameters appearing in the rate- and state-dependent friction law to the nondimensional parameters which characterize thermal-viscous coupling. This study may imply that a further improvement of this approach is important to estimate the actual values of frictional constitutive parameters along faults or plate boundaries.