INSTABILITIES IN SLIDING SYSTEMS INDUCED BY SOLID VISCOELASTICITY

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ABSTRACT
When we analyze the stability of sliding systems, we usually assume a friction law. Exploring the dynamics of a physical model with the friction law, we obtain mathematical stability conditions (or stability maps shown schematically), which help the mechanical design of sliding systems. However, designing sliding systems should be done not only from mechanical perspectives but also from material perspectives. In the abovementioned approach, the material properties of sliding solids are always hidden within the friction coefficient.

This study analyzes the physical model (**Fig. 1**) that does not include any explicit friction laws. In this model, the drag force is subject to a parabolic rigid probe (mass: M, tip radius: R) in contact with a flat viscoelastic foundation, originating from the repulsive force between them. The probe is supported by the horizontal springs (stiffness: K_x) in the x-direction and subjected to the dead weight in the z-direction. The solid viscoelasticity is represented by the Kelvin-Voigt foundation (elastic constant: K, viscous constant: C, drive speed: V) consisting of an array of Kelvin-Voigt elements [1]. Note that the number of system parameters is six: It is the minimal model of sliding systems to analyze their instabilities without using any explicit friction laws.

Figure 2 shows the numerical results: time-series plots of the probe apex position A. The ordinates are the dimensionless positions in the x-direction $\tilde{x}$, and the abscissae are the dimensionless time τ. In this model, we find the four types of dynamics: (a) overdamped motion, (b) underdamped oscillation, (c) divergent oscillation, and (d) stick-slip-like oscillation. Surprisingly, various dynamics are generated from the sliding system with only six system parameters. In particular, similarly to the dynamic stiction [2], this sliding model exhibits stick-slip-like oscillations without using static friction.

In this presentation, we will discuss the mechanism that destabilizes the sliding system. It will be demonstrated that the "vertical lift" of the probe is crucial for the stability of the sliding system. "Vertical lift" generates velocity-weakening friction [1], leading to the instabilities (divergent oscillation or stick-slip-like oscillation). Finally, The stability condition without using friction coefficient will be presented.

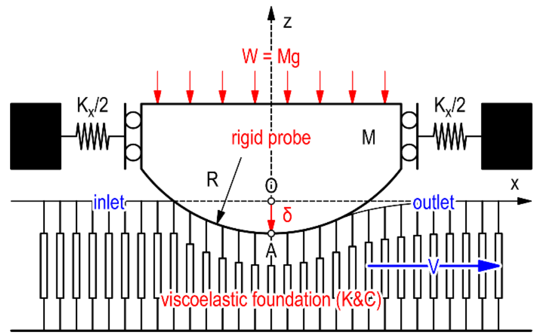

Fig. 1 Analytical model: Viscoelastic foundation model.

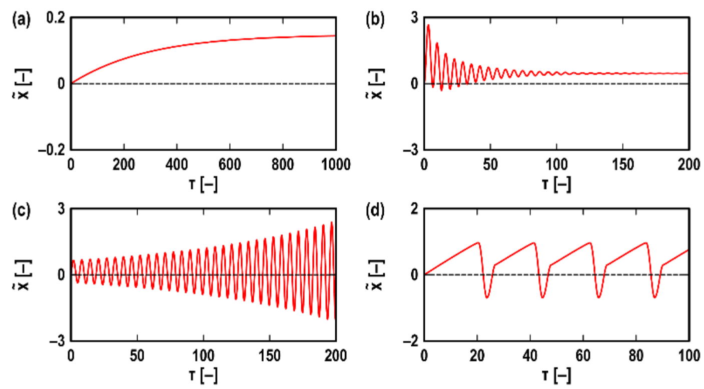

Fig. 2 Time-series plots of the dimensionless probe position in the x-direction: (a) overdamped motion, (b) underdamped oscillation, (c) divergent oscillation, (d) stick-slip-like oscillation.

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