SUPPRESSION OF FRICTION-INDUCED VIBRATIONS BY DAMPING FROM IN-PLANE ANGULAR MISALIGNMENT

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ABSTRACT

Recently, it has been theoretically and experimentally shown that the in-plane angular misalignment (i.e., yaw angle misalignment (YAM)) can generate a damping to suppress friction-induced vibrations (FIVs) in a 1DOF sliding system with velocity-weakening friction [1,2]. This paper describes a subsequent study aiming to extend this YAM theory from 1DOF to 2DOF. The stability conditions of a 2DOF sliding system were investigated via numerical simulations and eigenvalue analysis.

Figure 1 shows the analytical model of the 2DOF sliding system. A "ball" with a mass m is in contact with a "plate" parallel to the xy plane at a constant normal load W. The ball is supported elastically (i.e., with no dampers) in the xy plane by two springs. The stiffnesses of the system in the x and y directions are denoted by k_x and k_y, respectively. They represent the anisotropic stiffness of the system (i.e., $k_x \neq k_y$), where the x and y axes are the principal axes. The plate is driven at a constant velocity V in the xy plane. The direction of V is represented by the in-plane angular misalignment φ ($0° < \varphi < 90°$) from the x-axis.

The dynamic behaviors of the system were simulated by solving the equations of motion (EOMs) numerically using the Runge-Kutta method for various conditions. For example, FIVs occurred when φ was small (e.g., 0.1°) due to the velocity-weakening friction. The FIVs were suppressed when $\varphi = 45°$. However, FIVs occurred again when φ was large (i.e., 89.9°).

The EOMs were linearized around the equilibrium point. By introducing five dimensionless parameters, the dimensionless linearized EOMs were derived. Then, eigenvalue analysis was conducted for the dimensionless linearized EOMs to find the stability conditions. As the results, the following four important conclusions were obtained to suppress the FIV using the damping generated by YAM:

(1) Lower and upper limits exist for the YAM to suppress the FIV, being smaller and larger than 45°, respectively, meaning that the YAM of $\varphi = 45°$ is a promising setting.

(2) Decreasing λ is effective to suppress the FIV, where λ is a dimensionless parameter composed of m, k_x, V, W, and parameters determining the velocity-weakening friction characteristics.

(3) The stiffness of the system must be anisotropic (i.e., $k_x \neq k_y$) to suppress the FIV. Increasing k_x is effective to suppress the FIV when $k_x > k_y$. Inversely, increasing k_y is effective when $k_x < k_y$.

(4) Increasing V is effective to suppress the FIV. In addition, the suppression effect becomes strong when V is far from V_f, where V_f is the velocity constant determining the velocity-weakening friction characteristics.

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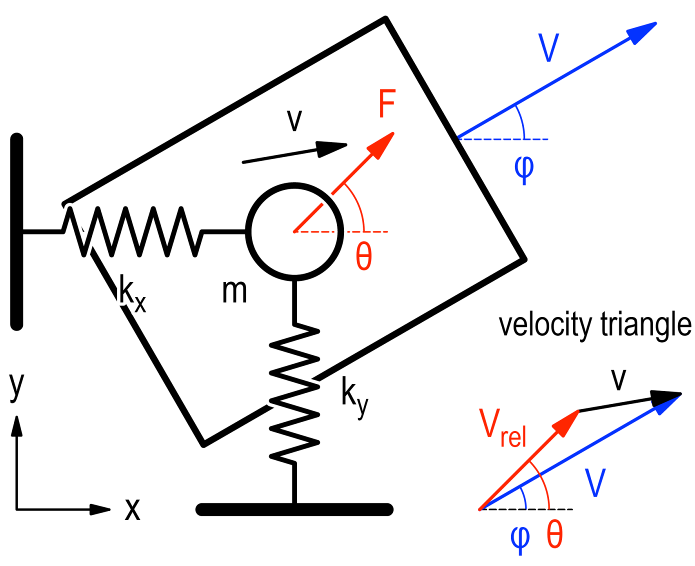

Fig. 1 Analytical model of 2DOF sliding system with in-plane anisotropic stiffness (i.e., $k_x \neq k_y$) and in-plane angular misalignment (i.e., $\varphi \neq 0°$).