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Bidirectional Pendulum Vibration Absorbers with Homogeneous Variable Tangential Friction: Modelling and Design

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Abstract : Passive resonant vibration absorbers are among the most widely used dynamic control systems in civil engineering. They typically consist in a single-degree-of-freedom mechanical appendage of the main structure, tuned to one structural target mode through frequency and damping optimization. One classical scheme is the pendulum absorber, whose mass is constrained to move along a curved trajectory and is damped by viscous dashpots. Even though the principle is well known, the search for improved arrangements is still under way. In recent years this investigation inspired a type of bidirectional pendulum absorber (BPA), consisting of a mass constrained to move along an optimal three-dimensional (3D) concave surface. For such a BPA, the surface principal curvatures are designed to ensure a bidirectional tuning of the absorber to both principal modes of the main structure, while damping is produced either by horizontal viscous dashpots or by vertical friction dashpots, connecting the BPA to the main structure. In this paper, a variant of BPA is proposed, where damping originates from the variable tangential friction force which develops between the pendulum mass and the 3D surface as a result of a spatially-varying friction coefficient pattern. Namely, a friction coefficient is proposed that varies along the pendulum surface in proportion to the modulus of the 3D surface gradient. With such an assumption, the dissipative model of the absorber can be proven to be nonlinear homogeneous in the small displacement domain. The resulting homogeneous BPA (HBPA) has a fundamental advantage over conventional friction-type absorbers, because its equivalent damping ratio results independent on the amplitude of oscillations, and therefore its optimal performance does not depend on the excitation level. On the other hand, the HBPA is more compact than viscously damped BPAs because it does not need the installation of dampers. This paper presents the analytical model of the HBPA and an optimal methodology for its design. Numerical simulations of single- and multi-story building structures under wind and earthquake loads are presented to compare the HBPA with classical viscously damped BPAs. It is shown that the HBPA is a promising alternative to existing BPA types and that homogeneous tangential friction is an effective means to realize systems provided with amplitude-independent damping.

Keywords : amplitude-independent damping, homogeneous friction, pendulum nonlinear dynamics, structural control, vibration resonant absorbers
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