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Targeted energy transfer in laminar vortex-induced vibration of a sprung cylinder with a nonlinear dissipative rotator

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Abstract

We computationally investigate the dynamics of a linearly-sprung circular cylinder immersed in an incompressible flow and undergoing transverse vortex-induced vibration (VIV), to which is attached a rotational nonlinear energy sink (NES) consisting of a mass that freely rotates at constant radius about the cylinder axis, and whose motion is restrained by a rotational linear viscous damper. The inertial coupling between the rotational motion of the attached mass and the rectilinear motion of the cylinder is "essentially nonlinear", which, in conjunction with dissipation, allows for one-way, nearly irreversible targeted energy transfer (TET) from the oscillating cylinder to the nonlinear dissipative attachment. At the intermediate Reynolds number $Re = 100$, the NES-equipped sprung cylinder undergoes repetitive cycles of slowly decaying oscillations punctuated by intervals of chaotic instabilities. During the slowly decaying portion of each cycle, the dynamics of the cylinder is regular and, for large enough values of the ratio ε of the NES mass to the total mass (*i.e.*, NES mass plus cylinder mass), can lead to significant vortex street elongation with partial stabilization of the wake. As ε approaches zero, no such vortex elongation is observed and the wake patterns appear similar to that for a sprung cylinder with no NES. We apply proper orthogonal decomposition (POD) to the velocity flow field during a slowly decaying portion of the solution and show that, in situations where vortex elongation occurs, the NES, though not in direct contact with the surrounding fluid, has a drastic effect on the underlying flow structures, imparting significant and continuous passive redistribution of energy among POD modes. We construct a POD-based reduced-order model for the lift coefficient to characterize