Nonlinear Dynamics Enabled Design and Control

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Nonlinear dynamics is a mature field of research that has been traditionally focused on investigation and prediction of nonlinear phenomenology ensuing from geometric and constitutive aspects or interaction forces. There is a growing interest towards design of high-performance structures and devices by seeking ways to exploit advantageously different nonlinearities at different scales rather than constraining operations to avoid nonlinear phenomena. Advanced tools of robust nonlinear modeling and analysis can be turned into design tools tailored for achieving high levels of vibration control authority and synthesis of engineered systems and materials.

First, the general principles of active resonance cancellation based on perturbation techniques are illustrated in the context of magnetically levitated bodies, cranes, and beams. The active control inputs (delivered by rotary motors or piezoceramic actuators) can be shaped to cancel completely resonances possessing an activation threshold as is the case for parametric resonances or subharmonic/superharmonic resonances. Perturbation techniques are also exploited to determine suitable control laws that can attenuate primary resonances in systems such as straight or curved beams.

Nonlinear passive absorbers based on hysteretic constitutive nonlinearities can also be designed to perform better than linear viscoelastic absorbers in predefined ranges of operation. This is achieved by using wire ropes where the interwire friction is the primary mechanism of energy dissipation. The phase-locking/synchronization phenomenon allows this class of absorbers to perform well away from the antiresonance region.

In conclusion, recent work on high-damping nanomaterials made of a hosting matrix with dispersed carbon nanotubes is shown. The microhysteresis exhibited as stick-slip between carbon nanotubes and the matrix can be tuned within the developed computational framework to optimize vibration and noise absorption in the investigated materials.