
Theoretical and Experimental Analysis of Axial Wave Transmission in a Rod with a Nonlinear Absorber

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Abstract

Nonlinear vibration absorbers can feature benefits for vibration suppression as compared to their linear counterparts such as the high level of tunability and a wider frequency bandwidth of vibration suppression. While an active area of research, there is still a lack of comprehensive theoretical understanding of the dynamics of continuous systems, such as rods, beams and plates, when one or more nonlinear vibration absorber is attached. Analytical and numerical analysis has been completed that investigates elastic wave transmission through 1D structures with attached damped absorbers featuring Duffing-type nonlinearity. General equations for wave transmission through a rod with a single nonlinear absorber attached were derived via the wave approach and solved using the Method of Varying Amplitudes. Results from the theoretical analysis revealed that the fundamental harmonic dominates, softening and hardening nonlinearity imply qualitatively different responses, and the nonlinear absorber can feature a wider frequency band of effectively reduced vibration transmission as compared to the linear one. An experimental study has been completed to support the theoretical work.

Clamped-clamped beams offer a relatively simple realizable design to achieve stronger nonlinearity, therefore, a nonlinear vibration absorber of this type has been designed and built for experiments. The experimental prototype of the nonlinear resonator consists of an aluminium base frame to which a thin piece of steel shim is attached. Magnets placed at the center of the shim act as the displaced mass. The resonator can be tuned by adjusting the tension in the steel shim, changing the thickness of the shim and increasing the displaced mass. The nonlinearity is characterized by the backbone curve identification and analysis. The absorber is designed such that axial vibrations of the base structure will excite bending in the thin steel material, leading to hardening nonlinearity. The absorber is attached to a rod undergoing axial vibrations and transmissibility is determined by measuring accelerations of the base structure, to either side of the attached absorber.

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