Nonlinear damping in large-amplitude vibrations

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Abstract

An increase in damping is relevant for the passive control of vibrations and noise; therefore, it is very significant in design. Experimental data shows a strong and nonlinear dependence of damping on the vibration amplitude for beams, plates, and shells of different sizes and made of different materials (metal, composite materials, silicone rubber, and graphene). While the frequency shift of resonances due to stiffness nonlinearity is commonly 10 to 25 % at most for common structural elements, a damping value up to several times larger than the linear one can be obtained for vibrations of thin plates when the vibration amplitude is about twice the thickness. This is a huge change in the damping value! Therefore, the nonlinear nature of damping affects structural vibrations much more than stiffness nonlinearity. Despite this experimental evidence, nonlinear damping has not been sufficiently studied yet. A model of nonlinear damping was derived from linear viscoelasticity for single-degree-of-freedom systems and for rectangular plates by introducing geometric nonlinearity. The resulting damping model was nonlinear and the model parameters were identified from experiments. Numerical results for forced vibration responses of different structural elements in large-amplitude (nonlinear) regimes were obtained and successfully compared to experimental results, validating the nonlinear damping model. Recently, the effect of nonlinear damping into one-to-one internal resonances was addressed. This type of resonance appears in the case of symmetry: circular cylindrical shells and square plates are examples, as well as beams with circular cross-section in the three-dimensional space. The results of this new development in the study of nonlinear damping are particularly interesting.

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