The response of nonlinear circular viscoelastic panels to electrodynamic excitation

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Abstract. We investigate the response of nonlinear circular micro- and nano- viscoelastic panels that are subjected to electrodynamic excitation. We make use of a von-Karman strain-displacement relation with a Voigt-Kelvin constitutive law to derive a nonlinear initial-boundary-value problem that consistently incorporates viscoelastic damping in both the field equation and corresponding compatibility condition. A multi-mode dynamical system is then obtained via a Galerkin ansatz which includes coupled linear and nonlinear contributions for both stiffness and damping augmented by combined parametric and external excitation terms. A detailed numerical investigation of the resulting model enables a consistent construction of the dynamical system frequency response culminating with multiple combination and internal resonances which demonstrate the significant contribution of non-negligible nonlinear viscoelastic damping.

Introduction and Problem Formulation

Circular micro and nanopanels are widely used in various applications such as sensors and actuators. Experiments show that damping increases significantly with amplitude increase with both external [1] or self-excited excitation [2]. We thus extend the formulation of Vogl and Nayfeh [3] for a circular nonlinear von-Karman plate [4] by incorporating the contribution of viscoelastic damping based on a Voigt-Kelvin constitutive law in addition to linear viscous damping. A schematic diagram of a clamped circular plate subjected to electrodynamic excitation is depicted in Figure 1(left). A multi-mode dynamical system is then obtained via a Galerkin ansatz which includes coupled linear and nonlinear contributions for both stiffness and damping augmented by combined parametric and external excitation terms derived from a parallel-plate electrodynamic model.

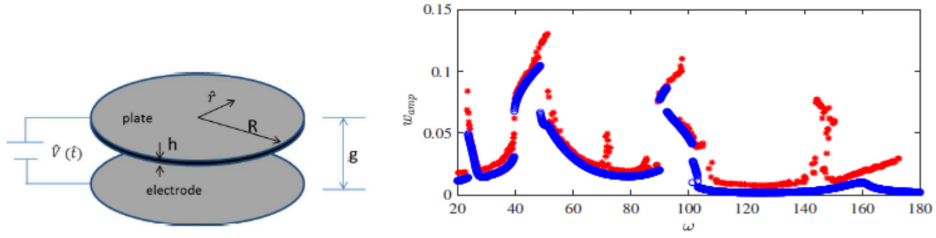

Figure 1: Definition sketch (left) and frequency response curves (right) depicting primary internal resonances and secondary ultra-subharmonic resonances with linear viscous damping (red) and combined linear and nonlinear viscoelastic damping (blue).

Results and Discussion

We investigate the frequency response for three mode interaction and compare the dynamical system frequency response with the linear viscous damping model [3] to a system governed by combined linear and nonlinear viscoelastic damping where the magnitude of the linear viscoelastic damping component is identical to that of the linear viscous damping. We consider combined external and parametric excitation of the first three modes to capture primary, parametric, internal and combination resonances. We present the resulting frequency response curves in Figure 1 (right) where system response to linear viscous damping is portrayed in red and the response to combined linear and nonlinear viscoelastic damping is portrayed in blue. Note that the selected first three natural frequencies associated with the first axi-symmetric modes ($\omega_{1,2,3}$ = 51.94, 92.29, 155.80), yield a condition for a 3:2:1 internal resonance demonstrating in Figure 1 (right) that consideration of only linear viscous damping can lead to erroneous conclusion of response magnitude. A detailed numerical investigation of the resulting model thus enables a consistent construction of the dynamical system frequency response culminating with multiple combination and internal resonances which demonstrate the significant contribution of non-negligible nonlinear viscoelastic damping.

References

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