Dynamics and Wave Propagation in Nonlinear Piezoelectric Metastructures

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Abstract

This paper reports dynamical effects in onedimensional locally resonant piezoelectric metastructures that can be leveraged by nonlinear electrical attachments featuring either combined quadratic and quartic, or essentially quartic potentials. The nonlinear electromechanical unit cell is built upon a linear host oscillator coupled to a nonlinear electrical circuit via piezoelectricity. Its dynamical response to prescribed longitudinal harmonic displacements is approached in the frequency and time domains. Semi-analytical harmonic balance (HB)-based dispersion relations are derived to predict the location and edges of the nonlinear attenuation band. Numerical responses show that weakly and moderately nonlinear piezoelectric metastructures (NPMSs) promote a class of nonlinear attenuation band where a bandgap and a wave supratransmission band coexist, while also imparting nonlinear attenuation at the resonances around the underlying linear bandgap. Besides, strongly nonlinear regimes are shown to elicit broadband chaotic attenuation. Negative capacitance (NC)-based essentially cubic piezoelectric attachments are found to potentiate the aforementioned effects over a broader bandwidth. Excellent agreement is found between the predictions of the HB based dispersion relations and the nonlinear transmissibility functions of undamped and weakly damped NPMSs at weakly and moderately nonlinear regimes, even in the presence of NC circuits. This research is expected to pave the way towards fully tunable smart periodic metastructures for vibration control via nonlinear piezoelectric attachments.

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Full Text

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Figures

Figure 1

Lumped-parameter model of a nonlinear piezoelectric unit cell (NPUC): mechanical host oscillator piezoelectrically coupled with a nonlinear resonating attachment (shunt circuit).

Figure 2

please see the manuscript file for the full caption

Figure 3

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Figure 4

Free-free chain of NPUCs.

Figure 5

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Figure 6

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Figure 10

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Figure 11

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Figure 12

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Figure 13

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