Amplitude dependent band gap characteristic of elastic wave propagating in pre-compressed periodic bistable elastic mechanical chain

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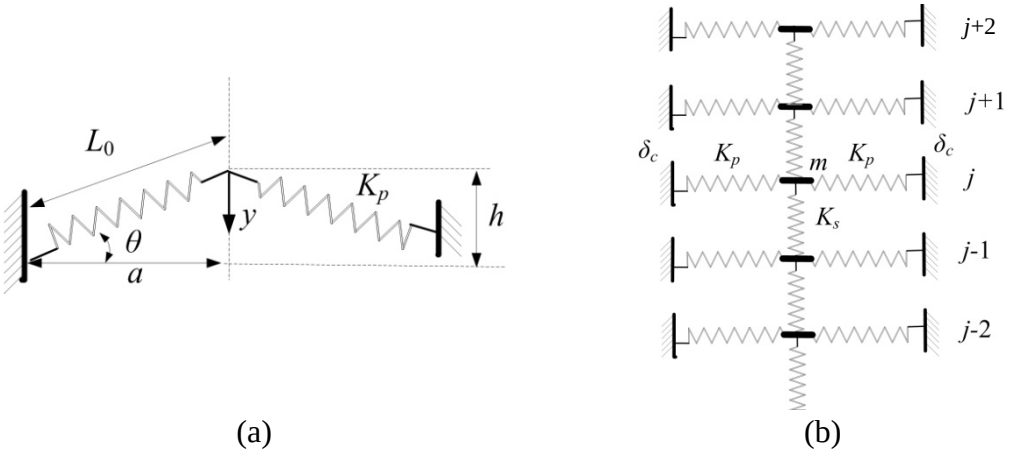
Abstract

Specific band gap characteristic can be designed artificially in periodic materials, which greatly enriches their potential applications such as waveguides, filters, lenses, diodes and sensors, thus attracting enormous attention from worldwide researchers. Unfortunately, most of the existed work is limited to linear elastic wave neglecting the nonlinear elastic wave propagation exhibiting rich and interesting physical phenomenon and properties such as amplitude dependent tunable band-gap character. To the best knowledge of the authors, very few researches related to nonlinear band gap design have been reported [1-5]. In this paper, the nonlinear amplitude dependent band gap characteristic of the pre-compressed periodic bistable elastic mechanical chain was theoretically analyzed. A mass-spring model for strongly nonlinear response of a chain of initial buckling bistable mechanical elements is established as shown in figure 1, and the corresponding force-displacement relation and potential curve is shown in figure 2. Analytical dispersion relation including structural configuration, pre-compression, and amplitude of elastic wave is built. Ultralow band gap is found when amplitude of elastic wave is large. The analytical solution is confirmed by numerical examples. Each mass in the bistable chain will vibrate around the one of the stable position when the amplitude of propagating elastic wave is small, and vibration experiencing snap-through between two stable positions will happen when the amplitude of propagating elastic wave is large. It is demonstrated that the energy in low frequency band gap for large amplitude elastic wave is transform to higher frequency range due to superharmonic nonlinear vibration. The investigation of the amplitude dependent nonlinear tunable band-gap properties offers a theoretical guidance for the design of novel ultra-low frequency vibration isolators and amplitude dependent band-gap acoustic filters.



(a) (b)

Figure 1. (a) mass-spring model of periodic initial buckling mechanical chain (b) Initial uncompressed position

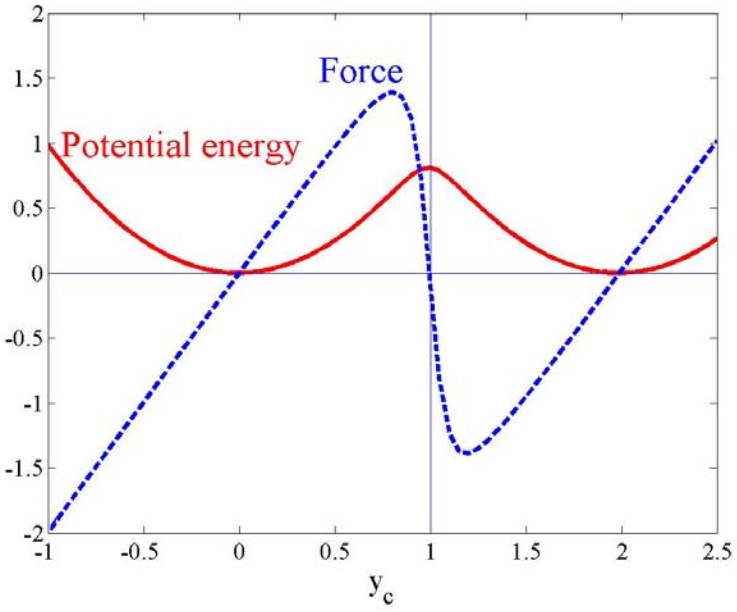


Figure 2 Force and displacement relationship and potential curve of bistable mechanism

Keywords: Bistable mechanical chain, Amplitude dependent band gap, Negative stiffness, Nonlinear elastic wave

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