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Dynamic Behavior of a Clamped-Clamped Bi-Stable Laminate for Energy Harvesting

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ABSTRACT

Multi-stable laminates have many applications in morphing structures, energy harvesting devices, and metamaterials due to the specific characteristics attributed to the exhibited stable states. Changes between stable states allow for large deflections, on-demand variation of the stiffness of compliant structures embedded within these elements, and control of effective dynamic properties in periodic lattices. These changes in state can be accessed via a snap-through instability triggered by introducing a well-defined activation energy. The resulting oscillations could enable broadband energy harvesting via piezoelectric transduction and resistive circuits. In this paper, a clamped-clamped bi-stable laminate is studied to understand the behavior of the laminate at each stable state and determine energy harvesting capabilities. An FEA model is created to determine the frequency and shapes of resonant modes. Certain modal shapes have significant deformations near the clamp which are necessary for piezoelectric elements to generate a voltage. Small amplitude low frequency vibrations are used to excite the laminate at each stable state using a shaker. The laminate is then excited so that inter-well oscillations become present. The resonant characteristics of each stable state determined by the simulations are similar to the experimentally observed responses with some variation. The laminate shows inter-well dynamics at particular resonant frequencies and for a range of frequencies in which both sable states have similar modal characteristics. At higher excitations and a range of frequencies is observed causing chaotic and inter-well oscillations. This shows that the laminate exhibits vibrational dynamics which are capable of enabling broadband energy harvesting devices.

KEYWORDS

Energy, Harvesting, Bi-stable, Metamaterials, Vibrations, Nonlinear