A Metamaterial Concept using the Hybrid Position Feedback Control Method and Bistable Structural Elements

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Abstract. A new multi degree of freedom metamaterial concept that utilizes a hybrid position feedback controller is introduced and its characteristics are demonstrated. The concept is based on bistable element and associated controllers that are unstable-then-stable position feedback controllers. An arbitrary number of bistable segments or so-called "material elements" are attached to each other in a serial (or parallel) manner to generate a "distributed" multi-stable structure. This new metamaterial inherits the multiple bistable positions that its building blocks have; hence, the metamaterial becomes multi-stable. It can hold multiple positions without consuming power and has the capability of achieving many shapes. The proposed metamaterial concept can be used in various applications: locomotion in bioinspired systems, undulatory motion, morphing aerodynamic surfaces, wave guiding, and vibration attenuation.

Introduction

A bistable system has two stable configurations and one unstable equilibrium which can be exploited to design a functional metamaterial. The control of bistable structures using piezoelectric actuators has received significant attention recently. Arrieta et al. [1] and Bilgen et al. [2] introduced resonant control with a surface bonded piezoelectric device. Simsek et al. [3, 4] demonstrated an automated method for bidirectional state transfer on a wing-like cross-ply bistable plate using the hybrid control strategy and a piezocomposite actuator. Simsek et al. [5] demonstrated a piezoelectric-material induced monotonic snap-through without possibility of triggering cross-well oscillations or chaotic response. Simsek et al. [6] introduced an HPF controlled bistable metamaterial concept. In this paper, the concept will be extended to multi-DOF model to demonstrate full capacity.

Results and discussion

A parametric analysis is carried out for four different scenarios which are: (1) all forward (from stable state 1 to stable state 2), (2) DOF1 forward while DOF2 backward, (3) DOF1 backward while DOF2 forwards, (4) all backward. Figure 1 demonstrates behavior of a two degrees of freedom (2DOF) system where the elements are in series configuration. The green color indicates the controller parameters that achieve convergence to the desired state for predefined scenarios. The other colors in the figure are undesirable with the number of unsatisfied case(s) indicated in the legend. The results show that the concept is working for a 2DOF system; however, it needs to be extended to multi DOF models to realize the full functionality of metamaterial concept. This will be one of the contributions of the full paper.

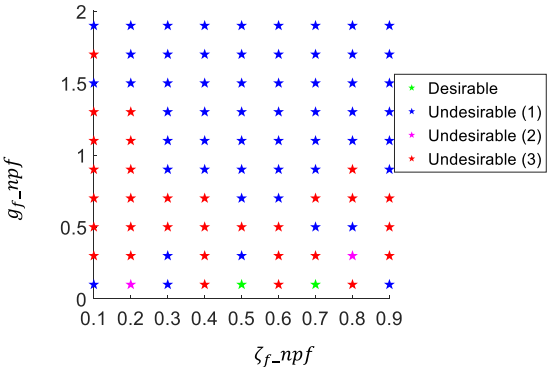

Figure 1: Parametric analysis for the 2DOF bistable Duffing-Holmes system with the hybrid controller in series configuration.

References

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