Vibration Damping in Fiber-Reinforced Bistable Composites with Magnetic Particles

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Abstract. Today one of the greatest engineering challenges in smart materials is on the development of structural morphing materials. Multistable composites have the intrinsic ability to vary their shape but they have some weaknesses that limit their usage in structural applications. For instance, bistable composites lose rigidity while snapping from a configuration to the other and their transition to the new configuration is coupled with undesired vibrations. This paper focuses on solving such criticalities by inserting magnetic particles within the composite matrix. The exposure of such a bistable composite to a magnetic field, allows to dampen these vibrations and increase the overall composite stiffness.

Introduction

Multistable composite laminates have the uniqueness of being characterized by multiple equilibrium configurations, each with a different geometric shape. Shape changes in bistable composites need the actuation of an external force or proper actuation mechanisms [1]. The prediction of the stable shapes and the understanding of the snapping mechanism of asymmetric thin laminates has been carried out by many researchers [e.g. 2] by extending the Classic Laminate Theory while analytical models for predicting the snap-through forces and moments were developed by Dano and Hyer [3,4]. The models were based on Rayleigh–Ritz method also with higher order polynomials [5]. In general, morphing materials should transit smoothly and in a controlled manner from a shape to the other. Unfortunately, bistable composites are affected by undesired vibrations once the material has reached its alternate stable configuration. The most advanced damping approaches in the literature use nanoparticulates to activate exotic stick-slip mechanisms. Such approaches are intrinsically passive. Active solutions instead have the potential to be activated by means of external energy sources.

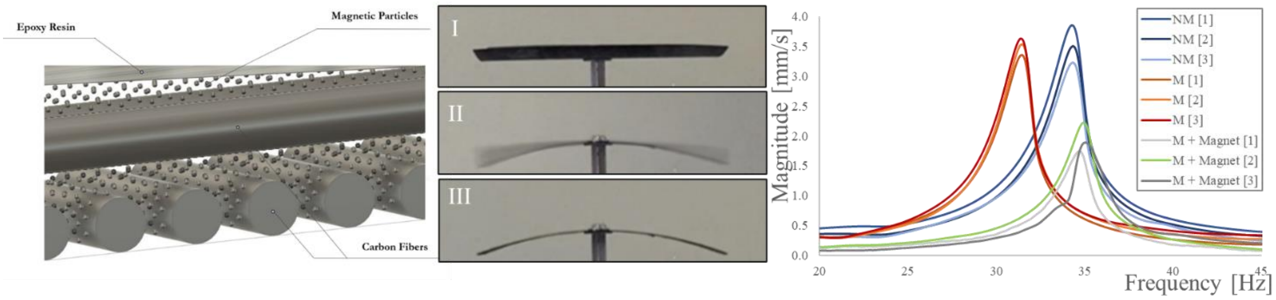

Figure 1: (Left) Schematic of the composite design; (Center) Experimental validation of the vibrations induced in a composite after shapping; (Right) Comparison of the FFT response of a non-magnetic composite (NM), of a micro-composite in its passive state (M) and of a micro-composite exposed to a magnetic field (M+magnet)

A bi-stable magnetic composite and its frequency tunability

This paper aims to investigate a novel bistable composite design in which carbon fibers are embedded in a magnetic micro-composite matrix (schematic in Figure 1). The addition of iron micro-particles allows to enhance the transition from an equilibrium state to the other by damping out vibrations through a passive and active (hybrid) approach. Magnetic particles can in fact work as passive and active fillers, in the latter case thanks to their interaction with an external field.

It is shown that the mass increase can indeed dominate with respect to pure passive stiffening which results in a reduction of resonance frequency, but at the same time the interaction with the magnetic field allows to control finely the material rigidity. It is also demonstrated that such interaction can control the undesired vibrations when a bistable composite snaps from a stable configuration to the other. This work paves the way to composites that can change shape and rigidity in a controlled manner.

References

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