

Multi-layers radical morphing: shape transitions and vibration

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Abstract. Shape-shifting materials is entering into many disciplines from engineering to medicine, where passive sensors are needed. The idea of making the material independent of configuring itself on the basis of the surrounding environment thanks to a preliminary training that does not lose its characteristics of the material, is innovative. This study, from an experimental point of view, is aimed at analyzing the morphing capabilities of a multilayer in a fixed temperature range following a preliminary training. A bi-material structure is considered in which one of the two layers is made up of polyethylene (PE) reinforced with polyethylene terephthalate (PET) fibers and the other is made up of a layer of Aluminum Foil. The capacity of this morphing material is to modify its shape configuration and the variation of the dynamic response is compensated by the contribution of the material and geometric variations due to the different configurations.

Introduction

The development of materials with multiple functionalities, as morphing materials, is becoming essential not only in various engineering fields to improve performance of the devices/structures but also to reduce environmental impact. Morphing materials have the intrinsic ability to adapt their shape due to different (even external) stimuli. [2] There are, in particular, some smart materials that can be programmed and transformed using external stimuli such as: the change of temperature, light, water, electricity and magnetic fields. Others that change in which the shape changes are triggered by geometric effects or by exploiting the material's homogeneity or non-homogeneity [7]. Among the existing morphing and smart materials, shape memory polymers (SMPs) are those capable of memorizing a temporary shape and recovering to the permanent shape upon the occurrence of an external stimuli. Although such a basic concept was known for half a century, recent progresses allowed to transfer the usage of such materials, especially in the case of thermo-responsive materials, for practical applications. The fundamental limitation of SMPs is that they are not able to provide cyclic shape changes and that their morphing response can only be achieved under specific and unchangeable inputs. Moreover, in most cases external devices/power are required to provide the relevant stimulus to achieve the desired morphing shape (such as sources of heat, light or humidity). The most intriguing approaches are seeking the spontaneous response of materials when the stimulus is directly provided by the surrounding environment. However, spontaneous cyclability and adaptability to different environmental conditions represents key challenges in the field. With this in mind, here a unique bi-material structure that is able to provide cyclic and indeed radical shape changes at the desired set triggering temperature, is presented together with the vibrational response of the corresponding morphing modes.

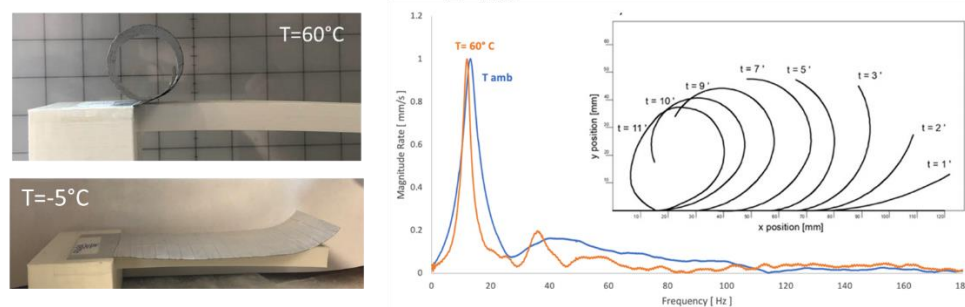


Figure 1: Images showing the designed bi-layer in its two programmed shapes activated by temperature. FFT of the bi-layer in its two configurations (flat and rolled). In the inset the shape changes are plotted at different time intervals.

Bi-layer design and the dynamic response of its morphed shapes

In this work it is shown that a bi-material structure formed by a fiber reinforced composite layer and an aluminum foil, has morphing ability when subjected to both positive and negative thermal gradients. This response can be associated with the opposite coefficients of thermal expansion and glass transition temperature between the forming layers as well as their stiffness variation with temperature and the multi-material plasticization during the “education” step. The vibrational analysis shows that the resonance frequency is just slightly affected by the configuration changes and this is due to the compensation of the loss in stiffness due to temperature with the increase in stiffness due to large-in-scale geometrical changes.

References

- [1] Athanasopoulos, N. , Siakavellas J. (2015) Programmable thermal emissivity structures based on bioinspired self-shape materials *Scientific Reports*, 5:17682
- [2] Athanasopoulos, N. (2018) Bioinspired Temperature-Responsive Multilayer Films and Their Performance under Thermal Fatigue *Biomimetics*, 3, 3, 20.