Elaboration and characterization of Ni/$BaTiO_3$ Functionally Graded Piezoelectric Material for active vibration control applications

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Abstract

In active vibration control, the classical smart structures are composites with piezoelectric devices adhesively bound to the host metallic structure. To overcome the risks of cracks in the adhesive layers, an original FGPM has been developed, made of a mixture between piezoelectric ceramic and metal, so that its composition varies symmetrically and continuously from metal at the mid surface to piezoelectric at the top and bottom surfaces. The numerical active control simulations of FGPM show the effectiveness of this concept [1], [2]. However, in these simulations, the materials properties P (Young modulus, density, …) are set so that P varies continuously throughout the thickness direction (z direction axis) (1) according to the volume fraction of constituents V defined by a same power-law and depending of the fraction index k (2):

$$P = \left(P^{(m)} - P^{(p)}\right) V^{(m)} + P^{(p)} \qquad (1)$$

$$V^{(m)}(z) = \left(1 - \frac{2\,|\,z\,|}{h}\right)^{k} \quad , z \in \left[\frac{-h}{2}, \frac{h}{2}\right] \qquad (2)$$

where *h* is the thickness of the structure.

This assumption is widely held in many theoretical papers [3], [4], but there is a lack of experimental validations.

In this way, a FGPM Ni/$BaTiO_3$ pellet has been elaborated by the Spark Plasma Sintering technique from $BaTiO_3$ and Ni powders to experimentally characterize the FGPM's physical properties and their evolution throughout the thickness direction. A first study is conducted to define the thermal and mechanical properties P. Five powder mixtures have been used (in vol%): 100% Ni, 75%Ni/25%$BaTiO_3$, 50%Ni/50%$BaTiO_3$, 25%Ni/75%$BaTiO_3$ and 100% $BaTiO_3$, in order to characterize independently and model the continuous nature of a smart FGPM. The thermal conductivity was investigated as a function of the microstructure by the transient plane source (TPS) technique, with a TPS 2500 Hot Disk thermal analyzer [5]. The Young's modulus was also characterized for each mixture by using compression tests.

The first experimental results show in one hand that the use of equation (1) seems to be adequate, and in the other hand that the fraction index k (2) is not a constant value and depends on the nature of the measured property P.

Recent Publications

1. J. Maruani, I. Bruant, F. Pablo, L. Gallimard (2017) A numerical efficiency study on the active vibration control for a FGPM beam', Composite Structures, pp 478-486, Vol. 182
2. J. Maruani, I. Bruant, F. Pablo, L. Gallimard (2019) Active vibration control of a smart FGPM plate using an adaptive fuzzy controller strategy', Journal of Intelligent Materials Systems and Structures, DOI: 10.1177/1045389X19853628
3. A. Sharma, A. Kumar, R. Kumar, R. Vaish, VS Chauhan (2015) Finite element analysis on active vibration control using lead zirconatetitanate--pt—based functionally graded piezoelectric material, Journal of Intelligent Material Systems and Structures} 27(4): 490-499.
4. C. Susheel, R. Kumar, VS Chauhan (2016) Active shape and vibration control of functionally graded thin plate using functionally graded piezoelectric material, Journal of Intelligent Material Systems and Structures.
5. D. Bregiroux, J. Cedelle, I. Ranc, C. Barreteau, G.Osoro, G. Wallez (2017) Effect of the sintering method on microstructure and thermal and mechanical properties of zirconium oxophosphate ceramics $Zr_2O(PO_4)_2$, Journal of Physics and Chemistry of Solids, Volume 111,pages 304-310.