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# DEVELOPMENT OF FUNCTIONALLY GRADED FLEXTENSIONAL PIEZOELECTRIC DEVICES DESIGNED BY TOPOLOGY OPTIMIZATION

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Previous works have been shown several advantages in using functionally graded ceramics in the design of flextensional actuators, such as larger output displacements and lower coupled movements [1]. Furthermore, gains in reliability are also foreseen in functionally graded structures due to the reduction in stress concentrations [2]. Thus, in this work, the Functionally Graded Material (FGM) concept is explored in the design of graded piezoelectric devices by implementing the Topology Optimization Method (TOM). The goal in using this method is to determine topologies and gradations of the coupled structures of piezoelectric moonies, grippers and sensors in order to maximize its output displacements, for actuators, or its sensitivities, for sensors. The optimization procedure is based on the Solid Isotropic Material with Penalization (SIMP), extended to three materials case (“Void”, Copper and Nickel) by using two classes of pseudo-densities. The optimization problems are solved by the Sequential Linear Programming (SLP) algorithm. Foreseeing the subsequent manufacturing, layer constraints are imposed for gradation variables, obtaining numerical results with suitable distribution of material by layers sufficiently thick. The comparison between the optimal homogeneous and graded results shows relevant gains in objective functions, justifying the more laborious manufacturing process. Aiming to demonstrate the feasibility of designed devices, moonies and grippers with graded coupled structures are manufactured by using the Spark Plasma Sintering (SPS) and micromachining techniques, in order to be tested by using a laser Doppler vibrometer. Besides the experimental verification with a view to FGM devices viability, the technological path developed here lays the foundation for the manufacturing of integral piezoelectric devices [2]. These devices are made of a single piece, without bonding layers between the ceramic and the metallic coupled structure, and have potential to perform an important role in the expansion of the application of piezoelectric tools, by improving its accuracy and reliability.

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[2] CARBONARI, R. C.; SILVA, E. C. N.; PAULINO, G. H. Integral piezoactuator system with optimum placement of functionally graded material - a topology optimization paradigm. *Journal of Intelligent Material Systems and Structures*, v. 21, p. 1653–1668, 2010.