11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

DESIGN OF PIEZOCOMPOSITE ENERGY HARVESTING DEVICES USING TOPOLOGY OPTIMIZATION METHOD CONSIDERING STRESS CONSTRAINTS

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Key Words: *piezocomposite, energy harvesting, topology optimization, stress constraints.*

Energy harvesting devices are smart structures capable of converting the mechanical energy (generally vibrations) that would be wasted in the environment into usable electrical energy. Laminated piezocomposite shell structures have been largely used in the design of these devices because of their large generation areas and their possibility of changing the displacement field by properly orienting the composite fibers [1].

The design of energy harvesting devices is complex and they can be efficiently designed by using topology optimization (TO) [1]. In this work, the energy conversion can be improved by maximizing the electric power generated by the piezoelectric material subjected to a harmonic excitation [1]. The effective electric power is measured at a coupled electric resistor. However, harmonic vibrations generate mechanical stress distribution that, depending on the frequency and the amplitude of vibration, may lead into piezoceramic failure [2].

This work suggests including a global stress constraint, which accounts for different failure criteria for different types of materials (isotropic, piezoelectric and orthotropic). Thus, the electric power is maximized by optimally distributing piezoelectric material, choosing its polarization sign, and properly choosing the fiber angles of composite materials [3], satisfying the global stress constraint.

In the TO formulation, the PEMAP-P (Piezoelectric Material with Penalization and Polarization) material model is applied to distribute piezoelectric material and to choose its polarization sign, and the Discrete Material Optimization (DMO) method is applied to optimize the composite fiber orientation [3]. The finite element method (FEM) is adopted to model the structures, where the piezoelectric multi-layered shell element is used. Numerical examples are presented to illustrate the proposed methodology.

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