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Plenary lecture

A Multiscale Approach to Design of Functionally Graded Piezocomposite Materials for Energy Harvesting

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This work addresses the optimal multiscale design of functionally graded piezocomposites for energy harvesting. In the optimization of a piezocomposite, the objective is to obtain an improvement in its performance characteristics, usually by changing the volume fraction of constituent materials, its properties, shape of inclusions, and the mechanical properties of the polymer matrix in the composite unit cell. The multiscale design can be achieved by combining topology optimization and homogenization techniques. The Functionally Graded Material (FGM) concept can be used to investigate the influence of small gradations between the constitutive materials in the performance of the piezocomposite and it can also help to redistribute stresses between the constitutive materials.

Thus, this work proposes a methodology based on topology optimization method and on homogenization method to design functionally graded piezocomposite materials that considers important aspects in the piezocomposite material design process, such as the influence of piezoelectric polarization directions and the influence of material gradation between the constituent materials in the unit cell. The polarization direction is analyzed using the Discrete Material Optimization (DMO) method, which combines gradients with mathematical programming to solve a discrete optimization problem. The homogenization method is implemented using the graded finite element concept which accounts for continuous gradation inside finite elements. The capability of the homogenization method in determining micro stress field shows that for piezocomposites, the effective stress level determined based on a macro dimensional scale might be very misleading for material selection and structure design. These effective values might be much lower than the actual maximum values occurring in the microstructure which may result in micro cracks.

From a computational point of view, polygonal elements are implemented to address the state equation and the optimization problem. In this context, Voronoi diagrams are used as a natural and effective means for generating unstructured polygonal meshes. Examples investigating piezocomposite designs demonstrate the validity of the overall approach.