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An extended numerical homogenization technique for piezoelectric composites with arbitrary fiber arrangements

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Summary

Piezoelectric materials have the property of converting electrical energy into mechanical energy and vice versa. This reciprocity in the energy conversion makes piezoelectric ceramics very attractive for use as sensors and actuators. By combining piezoelectric fibers with passive non-piezoelectric polymer composites with superior properties can be created. But for design of such smart micro-macro structures homogenization techniques are necessary to describe the overall behavior of piezocomposites expressed by effective material coefficients.

A number of numerical and analytical methods have been developed to estimate the effective coefficients. Although analytical homogenization methods provide excellent results it is difficult to extend them to composites with more complex distribution of fibers.

In this paper a numerical technique for calculating effective properties of piezoelectric fiber composites with arbitrary fiber distribution is introduced. The method is based on finite element modeling of a unit cell. Due to the involved systematic scheme of appropriate boundary conditions and loads for ensuring periodicity this technique can be applied to composites with various fiber volume fractions and fiber distributions, from square over hexagonal and rhombic to random arrangements (Figure 1). That means in contrast to many published approaches the developed technique allows the extension to composites with arbitrary geometrical inclusion configurations and provides a powerful tool for fast calculation of their effective material properties.

The geometrical generation of random distribution of fibers in the three dimensional unit cell is based on a modified random sequential adsorption (RSA) algorithm. By using the finite element code ANSYS with its included ANSYS Parametric Design Language (APDL) a high automation can be achieved for generating the model, applying the boundary conditions and calculating the full set of elastic, piezeoelectric and dielectric effective material coefficients.

For several test cases the results are compared and verified with analytical and other numerical solutions from literature and with experimental data.

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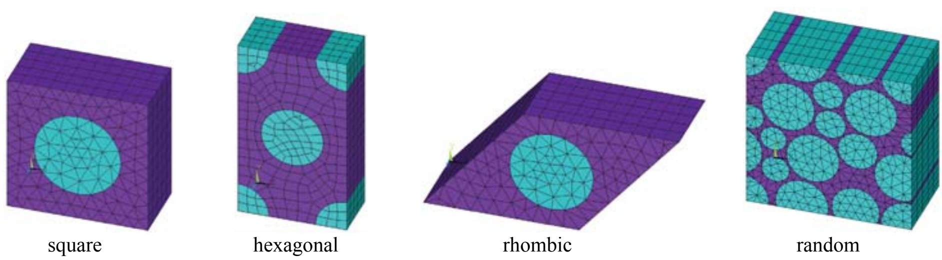

Figure 1: Unit cell models with different types of fiber distribution