Some approaches to homogenization of porous piezoceramic materials: microscale, nanoscale and local heterogeneities near pores

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Porous piezoceramic materials are widely used in modern ultrasonic technology. Their effectiveness is determined by the fact that, in comparison with dense piezoceramics, they have smaller acoustic impedance, but almost the same thickness piezomodulus and higher piezosensitivity. Various technologies permit to obtain porous piezoceramics with both micrometer pore sizes and nanometer pores. In addition, porosity usually has a stochastic structure, it can be both closed and open, and can reach 70 or more percent. Recently, nanoparticle transport methods have also been developed. These technologies allow producing porous micro- and nanostructured piezoceramic materials with modified properties near pore boundaries.

In this research for the homogenization of porous piezoelectric materials we use the effective moduli method and the finite element technologies to solve static comparison problems in representative volumes. Three cases of porous materials were considered: 1) conventional porous piezoceramics; 2) porous piezoceramics with nanosized pores; 3) porous piezoceramics with pores covered with metal particles.

For all cases of porous composites we develop mathematical approaches to the determination of effective moduli for piezoelectric materials of any possible class of anisotropy, including taking into account electromechanically coupled and uncoupled surface effects.

The representative volumes of conventional porous piezoceramic were generated in the form of cubes uniformly divided into cubic finite elements with the properties either of solid piezoceramic or pore. Pore elements were selected either by a sample random algorithm or by a special algorithm supporting the connectivity of the skeleton. To simulate the nanosized pores in accordance with the Gurtin-Murdoch model, the pore boundaries were covered by the shell elements with special surface properties. Finally, for porous piezoceramic obtained by the transport of metal-containing particles, the pore boundaries were completely or partially covered by elastic shell elements, and these boundaries were considered as free electrodes.

We have studied some examples of the effective moduli calculation and analyzed them depending on the model choice, pore sizes and other factors.

Acknowledgements. The work was supported by the Ministry of Education and Science of Russia, competitive part of state assignment, No. 9.1001.2017/PCh.