Homogenization of the fluid-saturated piezoelectric porous metamaterials

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ABSTRACT

Design of new materials, or metamaterials is often motivated by construction of small purely mechanical, or electromechanical devices presented in a form of porous media serving for design of lightweight and/or intelligent structures. There are challenging applications in mechatronic structures, microfluidic devices, such as flow splitters, or resistors with passive, or piezo-assisted microvalves, peristaltic pumps based on controllable buckling of pores, thus, propelling the fluid.

The paper is devoted to the homogenization approach in modelling of porous media constituted by piezoelectric porous skeleton with pores saturated by viscous fluid, cf. [2]. Such materials are generated as periodically distributed micro-devices. Each microdevice is a copy of the representative volume element containing the piezoelectric solid part (the matrix) and the fluid saturated pore (the channels). Both the matrix and the channels form connected subdomains. The mathematical model describing the material behaviour at the microscopic scale involves the quasi-static equilibrium equation governing the solid piezoelectric skeleton, the Stokes model of the viscous fluid flow in the channels and the coupling interface conditions on the transmission interface.

The macroscopic model is derived using the unfolding method of homogenization, see [1] where the piezoelectric composites were treated. The obtained Biot model with the poroelastic coefficients modified by piezoelectric coupling effects can be extended beyond the scope of linear theory. For this, the approach reported in [2] can be pursued. Assuming the linear kinematics framework, the physical nonlinearity in the upscaled model is introduced in terms of the deformation-dependent material coefficients which are approximated as linear functions of the macroscopic response expressed by the deformation, fluid pressure and the electric field. For a given geometry of the porous structure, these functions are obtained by the sensitivity analysis, cf. [3], of the homogenized coefficients with respect to the macroscopic fields. Unlike the fully nonlinear case, the deformation-dependent material coefficients approximated in this way do not require any solving of additional local microscopic problems for updated configurations.

REFERENCES

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