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OPTIMIZATION OF POROUS STRUCTURE EFFECTIVE ELASTIC PROPERTIES BY THE FAST MULTIPOLE BOUNDARY ELEMENT METHOD AND AN ARTIFICIAL IMMUNE SYSTEM

Jacek Ptaszny, Arkadiusz Poteralski

Silesian University of Technology, Institute of Computational Mechanics and Engineering, Poland
jacek.ptaszny@polsl.pl, arkadiusz.poteralski@polsl.pl

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Abstract: Porous structures include natural porous bodies (e.g. bones, wood, etc.) and artificial porous bodies. The latter group is a class of functional-structural materials with the optimal index of physical and mechanical properties due to their porous structure, including porous metals, porous ceramics and polymer foams. The paper presents an application of the fast multipole boundary element method (FMBEM) coupled with an artificial immune system (AIS) to the optimization of porous structure effective elastic properties. 3D representative volume elements (RVE) of linear elastic porous materials are modelled by the FMBEM, that only requires the discretization of the boundary. The FMBEM allows one to model complex geometries with much lower number of degrees of freedom in comparison to the finite element method that is usually applied in computational homogenization. Furthermore, the computational complexity of the FMBEM is reduced in relation to the conventional BEM. In the present research, 8-node Serendipity boundary elements with adaptive integration scheme are applied. The FMBEM code is parallelized by the OpenMP standard. On the RVE external boundary, displacement boundary conditions are applied, corresponding to a given strain state in the macro scale. Averaged stresses are calculated by the integration over the external boundary. Effective elastic constants of the material are calculated by using the averaged strains and stresses. Design variables considered in the optimization problem, with appropriate constraints, describe the pore geometry. The minimized objective function involves a metric that allows one to calculate the distance between two elasticity tensors: a current solution and a reference tensor that defines the desired properties. The optimization problem is solved by an AIS that is a computational adaptive system inspired by the principles, processes and mechanisms of biological immune systems. AIS algorithms use the ability of the immune systems to learn and detect pathogents in the solution of optimization problems in a computational manner. The AIS does not need any information on the objective function gradient and is suitable for multimodal problems. The algorithm is composed of the following stages: random generation of memory cells, memory cells proliferation and hypermutation, B-cell objective function evaluation, selection and crowding mechanism. Respective operations are performed iteratively until a stop condition is satisfied. Details of the methods and optimization problem will be described in the full paper.

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