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HOMOGENIZED CONVECTIVE HEAT TRANSFER: ANALYTICAL ANALYSIS AND INVERSE HOMOGENIZATION

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Abstract: The solution of the flow and heat transfer problem in a porous medium using traditional finite element methods requires considerable computational resources to both define the intricate fine scale geometry and to solve the large system of equations. In this work, we analyzed the heat transfer problem and argue that its physical and geometric nature makes it suitable for analysis through homogenization theory. We applied this mathematical method to the convection-conduction energy equation in a domain constituted by a periodic base cell. It provides an assessment that in a periodic medium, the solution of the convection-conduction energy equation is approximated by the solution of a heat equation. In this equation, a new term appears: a homogenized conductivity tensor that includes terms that account for convection. This equation can be used for the first time to: (i) study in great detail one single periodic cell of the microstructure and use its results to characterize the performance of the macroscale domain (ii) serve as a model for material engineering in heat transfer applications (iii) model problems in other fields that possess the same physical and geometric nature. Analytical examples are used to show that the homogenized conductivity tensor corresponds to a highly orthotropic material, with a great increase of homogenized thermal conductivity in the direction of the flow. A bidimensional inverse homogenization is used to determine the optimal topology of the periodic cell that maximizes the homogenized conductivity tensor. The numerical optimization was implemented using the method of moving asymptotes, and design sensitivities were obtained by means of the discrete adjoint method. Results converge to a waved walled structure, with a small obstacle in the center that separates and rejoins the flow.