Application of the MFS and the SPTF for determination of slip constant in the Beavers-Joseph boundary condition

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ABSTRACT

Free flow through porous walls can be commonly found in a variety of natural processes and industrial applications, such as groundwater flows, packed beds, arterial blood flows and cross-flow and dead-end filtration. In 1967 Beavers and Joseph [1] published the paper about the boundary condition between a porous and a free fluid region. They described experiments performed in a parallel-plate channel, one of the bounding walls was made of the porous material while the other one was impermeable. Identical axial pressure gradients were imposed on the channel and the porous medium, thereby giving rise to parallel axial flows. In interpretation these experiments they proposed the boundary conditions with "slip constant" obtained experimentally.

This paper presents a numerical simulation of the Beavers-Joseph's experiment for the fibrous porous media. The longitudinal laminar flow (the Poisseulle flow) in a parallel-plate conduit is considered. The first half of the considered region is a porous medium and the second one free fluid region. The porous medium is modelled as a bundle of parallel fibres arranged in a square array. The purpose of the present consideration is determination of the slip constant in the Beavers-Joseph boundary condition. But for do this the permeability of the porous medium is required. Then to determine the permeability the flow with the pressure gradient in unbounded porous medium was considered [2]. Numerical simulations are conducted using the method of fundamental solutions (MFS) [3] and the special purpose Trefftz functions (SPTF) [4]. The paper deals with both the Newtonian fluid and the generalized Newtonian fluid. Essential novelty of paper is numerical simulation of the Beavers-Joseph experiment for the generalized Newtonian fluid, namely the power law, the Sisco and the Cereau fluid. The influence of the volume fraction of the fibres and parameters of the generalized Newtonian fluid on value of the slip constant is investigated.

References

[1] G. S. Beavers and D. D. Joseph, Boundary conditions at a naturally permeable wall, J. Fluid Mech., 30, 197-207 (1967).
[2] J.A. Kolodziej, M. Mierzwiczak, M. Ciałkowski. Power law fluid flow through a bundle of regular fibers. Applied Mathematical Modelling 39 (2015) 6425–6437.
[3] G. Fairweather, A. Karageorghis: The method of fundamental solutions for elliptic boundary value problems. Advances in Computational Mathematics 9 (1998) 69–95.
[4] M. Mierzwiczak, J.A. Kolodziej: Comparison of different methods for choosing the collocation points in the boundary collocation method for 2D-harmonic problems with special purpose Trefftz functions, Engineering Analysis with Boundary Elements 36 (2012) 1883–1893.