Efficient simulations of fluid flow coupled with poroelastic deformations in pleated filters

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ABSTRACT

Pleated filters are broadly used for various applications. In certain cases, especially in solid-liquid separation case, the filtering media may get deflected and that may change the overall performance characteristics of the filter. From the modeling point of view, this is a challenging multiphysics problem, namely the interaction of the fluid with a so-called poroelastic structure. This work focuses on the development of an algorithm for the simulation of the Fluid Porous Structure Interaction (FPSI) problem in the case of pleated filtering media.

The first part of the work is concerned with the development of a robust and accurate numerical method for solving the Stokes-Brinkman system of equations on quadrilateral grids. The mathematical model describes a free fluid flow coupled with a flow in porous media in a domain that contains the filtering media. To discretize the complex computational domain we use quadrilateral boundary fitted grids which resolve porous-fluid interfaces. The Stokes-Brinkman system of equations is discretized here using a sophisticated finite volume method, namely multi-point flux approximation (MPFA) O-method. MPFA is widely used, e.g., in solving scalar elliptic equations with full tensor and highly varying coefficients and/or solving on heterogeneous non-orthogonal grids. Up to the authors' knowledge, there was no investigation of MPFA discretization for Stokes-Brinkman problems, and this study aims to fill this gap. Some numerical experiments are presented in order to demonstrate the robustness of the proposed numerical algorithm [1].

The second part of this study focuses on the coupling of the flow model with the deflection of the filtering media. For the consideration of the FPSI problem in 3D, the classical Biot system describes coupled flow and deformations in a porous body due to difference in the upstream and downstream pressures. Solving the Biot system of equations is complicated and requires a significant amount of computational time. In many pleated industrial filters, the thickness of the filtering media is small compared to the longitudinal dimensions and therefore the porous structure can be modeled as poroelastic plate [2] or poroelastic shell. We use a poroelastic shell model for linear elasticity to resolve the U-shaped pleated filters. Our numerical studies show that in many cases this approach gives accurate results. The so-called weak coupling approach is used to simulate the interaction between the flow and the elasticity problem.

REFERENCES

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