Simulation of porous membrane boundary layer in a multi-phase fluid flow

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Abstract:

Membrane Technology has become one of the most effective methods for producing drinking water. Because of the high complexity of the interaction between the fluid flow and porous membrane, modeling such systems and its processes requires dealing with different types of partial differential equations for both subregions of the computational domain. The motivation for this work comes from a specific problem of the relationship between the size of boundary layer (in membrane vicinity) and fluid flow and membrane pore size distribution. This work focuses on fluid dynamics aspects of pure water and aims at investigating the possible modeling approaches for the physical description of the system. To avoid difficulties, a combined heterogeneous approach has been proposed using a universal strategy considering the Navier-Stokes equations in the whole domain and to correct them introducing a Darcy Factor number as a term that mimic the presence of porous membrane. In this paper, the applicability of one methodology to different ultrafiltration membrane scenarios and compared them numerically based on the size of boundary layer was discussed. Simulation results revealed that the impact of the parabolic velocity is in most of the cases is completely or partially untied when the fluid flow gets closer to membrane surface and there are no pores in the middle of 2D channel. The results clearly show that there is a strong relation between the end of fluid parabolic profile and the boundary layer size. It can be explained as a consequence of the y-velocity effect that becomes higher near to membrane pores. Ultrafiltration membranes have been simulated with a range of 5% - 10% and 100L/m²hbar – 1000L/m²hbar for porosity and permeability, respectively. The operating parameters such as initial pressure and permeability coefficient were defined accordingly to real conditions and validated in agreement.

Keywords: Modeling, boundary layer, ultrafiltration membrane, Navier-Stokes.