

Two-Phase Particulate Flows in U-Bend and Helical Tubes

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Extended Abstract

Dean instabilities can significantly enhance performance of curved membrane filtration modules. Typically, industrial filtration operations involve particle/liquid slurries; hence, it is important to understand particle distribution in curved-geometry tubes and channels.

The efficiency of Dean vortices in several membrane applications (water oxygenation, pervaporation, ultrafiltration and microfiltration), and the presence of secondary flows in coiled (helical, toroidal, woven and U-tube) membranes, have been clearly demonstrated before. Both experimental and numerical evidence of this phenomenon is available in the literature [1,2,3]. However, most research so far has been focused on understanding single phase (mainly water) fluid flow phenomena, whereas most industrial applications used in membrane separation processes are solutes which may contain a significant amount of suspended particulate matter. In fact, one of the crucial industrial problems is concerned with membrane fouling due to these particulate matters. To better understand the root cause for these problems, carefully validated advanced computational models of two-phase flow are clearly needed.

The objectives of this paper are two-fold. The first objective is to develop a consistent numerical method of tracking details of a multidimensional single flow field in U-bend and helical geometries, and to demonstrate the accuracy of results. The second objective is to extend the liquid-only results to liquid-particle two-phase flows in similar geometrical configurations, and to investigate the effect of geometry and flow conditions on local particle concentration.

The multidimensional phenomena governing liquid/particle flows phenomena are modeled using the multifield model. In this model, the governing conservation equations for individual fields are determined with respect to common physical and computational domains, and include various interfacial effects between the fields. The consistency and accuracy of the multifield model's predictions strongly depend on the degree to which the closure laws, determined in terms of ensemble-averaged state variables, are capable of capturing the dominant local mass and momentum transfer phenomena. This is particularly important since the averaging procedure normally introduces several constraints on the formulation of individual models [4,5].

Because of the elliptic nature of the Navier-Stokes type of equations, the associated boundary conditions must be defined at all domain boundaries. For the geometries analyzed in this paper, the boundaries include the inlet and outlet of the module (for pressure, velocity, and concentration) and the tube wall. Typically, a reference pressure is assigned at the exit boundary, either uniform (if there is no effect of gravity across the flow) or given by a hydrostatic pressure distribution according to the orientation of the outlet area. At the inlet, a section of straight pipe is included to allow the flow to develop before entering the curved geometry. Since for all the cases investigated here, the Reynolds number was well below 2300, the flow was treated as laminar.