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Application of CFD for simulation of a baffled tubular membrane

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ABSTRACT

Computational fluid dynamics (CFD) investigation of a tubular membrane channel containing a set of baffles was conducted for predicting turbulent flow. Simulation was performed using an array of baffles oriented either in the flow or in the reverse direction. A range of local parameters such as stream function, velocity, static pressure, wall shear stress, turbulent kinetic energy, and turbulent dissipation energy on the membrane surface was computed using CFD code FLUENT. The simulation results indicate that the presence of baffle can improve the local shear stress on the membrane surface and produces eddy activities which enhance the filtration performance. The observed flux enhancement can be attributed to the intense fluctuations of wall velocity and shear stress which can disrupt the growth of boundary layer on the membrane surface. The experimental evaluation was performed through cross flow microfiltration of titanium dioxide suspension which showed an acceptable agreement with the CFD predictions.

Keywords: Computational fluid dynamics; Simulation; Shear; Fouling; Membrane

1. Introduction

The application of pressure driven membrane processes in water and wastewater purification has gained wide attention due to their effectiveness over the conventional water treatment processes. The reduced number of unit operations, relatively low capital and operating cost, easy scale-up and low space requirement, made membrane filtration an attractive alternative for water treatment (Saffaj et al., 2004). Despite its potential in water treatment, the large-scale and continuous operation of membrane filtration systems has been stymied by certain limitations. One of the major limitations is the membrane fouling which reduces the filtration flux and process yield (Mohammadi et al., 2003; Li and Elimelech, 2004). In addition it also increases the cost by increasing energy consumption as well as the materials cost for backwashing and cleaning processes. Successful application of membrane technology, thus, requires efficient control of membrane fouling (Hong and Elimelech, 1997). During membrane filtration, the concentration polarization and fouling result in the decline of membrane performance in terms of permeate flux and quality which reduces its reliability (Ahmed et al., 2010). Concentration polarization often leads to the formation of a concentrated boundary layer near the membrane surface and may result in the formation of a gel layer over the membrane surface. This phenomenon significantly relies on system hydrodynamics, nature and size of solute molecules, membrane pore size (molecular weight cut off) and characteristics (hydrophobic, hydrophilic, surface charge etc.). The inadequate shear stress on the membrane surface expedites the formation of cake-layer and membrane fouling which limits the back diffusive transport of the solute to the main stream. Promoting turbulence by introducing internals such baffles is indicated to enhance the solute mass transfer in the membrane system. A substantial amount of research has been focused on the development of strategies for controlling of the build-up of these additional resistances during operation. Several approaches have been used to try and minimize the effect of fouling. Of the available approaches, the changing of hydrodynamics of the system, use of external body force and

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