Mathematical Modeling of Membrane Filtration

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Abstract

The purpose of this talk is to formulate and investigate new mathematical models for membrane filtration. The work presented is divided into three parts. In the first part, a new mathematical model for flow and fouling in a pleated membrane filter is presented. Pleated membrane filters are widely used in many applications, and offer significantly better surface area to volume ratios than equal area unpleated membrane filters. However, their filtration characteristics are markedly inferior to those of equivalent unpleated membrane filters in dead-end filtration. While several hypotheses have been advanced for this poor performance, one possibility is that the flow field induced by the pleating leads to spatially nonuniform fouling of the filter, which in turn affects performance. In this talk we investigate this hypothesis by developing a simplified model for the flow and fouling within a pleated membrane filter. Our model accounts for the pleated membrane geometry (which affects the flow), for porous support layers surrounding the membrane, and for two membrane fouling mechanisms: (i) adsorption of very small particles within membrane pores; and (ii) blocking of entire pores by large particles. We use asymptotic techniques based on the small pleat aspect ratio to solve the model, and we compare solutions to those for the closest-equivalent unpleated filter.

In the second part we propose mathematical models to describe the effects of filter membrane morphology on filtration efficiency. The type of membrane used can vary widely depending on the particular application, but broadly speaking the requirements are to achieve fine control of separation, with low power consumption. The answer to this problem might seem obvious: select the membrane with the largest pore size and void fraction consistent with the separation requirements. However, membrane fouling (an inevitable consequence of successful filtration) is a complicated process, which depends on many parameters other than membrane pore size and void fraction; and which itself greatly affects the filtration process and membrane functionality. The challenge posed here is to devise mathematical models that can (i) account for the membrane internal morphology (internal structure, pore size and shape, etc.); and (ii) describe the fouling and separation. The proposed models here consider various types of fouling mechanisms such as adsorption, blocking by large particles.

Finally, in the third part of the talk we discuss the future work that will be required to complete the research.