Investigating the Influence of Buoyancy on Deposition and Shear-Induced Removal during the Cross-Flow Microfiltration of a Model Suspension

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ABSTRACT

Fouling phenomena in industrial microfiltration processes are often complex and difficult to predict. The presence of complex macromolecules, dissolved solids, and suspended particles can all lead to a loss of membrane performance through different mechanisms, namely standard, intermediate, and complete blocking; and cake filtration [1]. In this work, we investigate the growth and shear-induced depletion of irreversible foulant (cake) layers on a cellulosic microfiltration membrane, during the cross-flow filtration of a model suspension of spherical glass particles. The technique of fluid dynamic gauging (FDG) is used, which has proven effective for the study of cake fouling under a variety of conditions and with a number of different foulants [2-4]. One of the most promising aspects of this technique is that it facilitates the study of cake erosion by inducing controlled fluid shear forces to the surface of the cake whilst simultaneously indicating its thickness. As a result, the yield-stress of the cake (i.e. the tangential shear fluid shear required to remove particles from the surface) can be estimated at any given thickness as the cake is eroded.

The operating principles of FDG are detailed in earlier work [4]. A gauge, which consists of a tube and tapered nozzle, was mounted at a known distance above the surface of a membrane in a purpose-built, flat-sheet, cross-flow filtration module. A regenerated cellulose membrane of 0.6 μm nominal pore size and membrane resistance, R_m, of 2.9×10^9 m^{-1}, was installed such that it formed a permeable face on the bottom of the duct. Both neutrally buoyant and buoyant spherical glass particles (Sauter mean diameters of 12.6 and 15.5 μm, and densities of 1100 and 600 kgm^{-3} respectively) were employed as model foulants at a concentration of 0.2 vol%, and their fouling and removal behaviour was compared. The fluid shear imposed on the cake layer increased as the gauge was moved nearer, and erosion of the cake occurred when this overcome the forces due to convection (by cross-flow and permeate flow) keeping the particles attached to the cake and membrane. By moving in increments towards the membrane, the gauge was used to identify the relationship between cake thickness and applied fluid shear.

Membranes were fouled for 1 hour at a constant transmembrane pressure of 50 mbar, and cross-flow velocity wherein Re_{duct} was 1000, after which a near steady-state flux was reached and cake erosion using FDG was performed. For both types of particle, a small degree of erosion was observed at stresses < 5 Nm^{-2}, however the cake composed of the neutrally buoyant particles was ~ 400 μm thicker than for the buoyant particles. Cakes formed from neutrally buoyant particles showed greater resistance to fluid shear than their more buoyant counterparts. Significant cake erosion takes place at stresses > 21 Nm^{-2} for the buoyant particles and > 34 Nm^{-2} for the neutrally buoyant particles. In both cases the entire cake could be eroded at a shear stress ~ 35 Nm^{-2} higher than this and a linear relationship between thickness and shear stress is observed between these two points, showing that the resilience of the cake surface increases the closer it is to the membrane.

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