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Performance of slotted pores in particle manufacture using rotating membrane emulsification

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Abstract

This paper addresses the use of different slotted pores in rotating membrane emulsification technology. Pores of square and rectangular shapes were studied to understand the effect of aspect ratio (1–3.5) and their orientation on oil droplet formation. Increasing the membrane rotation speed decreased the droplet size, and the oil droplets produced were more uniform using slotted pores as compared to circular geometry. At a given rotation speed, the droplet size was mainly determined by the pore size and the fluid velocity of oil through the pore (pore fluid velocity). The ratio of droplet diameter to the equivalent diameter of the slotted pore increased with the pore fluid velocity. At a given pore fluid velocity and rotation speed, pore orientation significantly influences the droplet formation rate: horizontally disposed pores (with their longer side perpendicular to the membrane axis) generate droplets at double the rate of vertically disposed pores. This work indicates practical benefits in the use of slotted membranes over conventional methods.

Keywords: Membrane emulsification; Slotted pore; Tubular membrane; Rotating emulsification; Size control; High throughput

1. Introduction

Membrane emulsification has been developed to manufacture precisely size-controlled particulates through a droplet formation mechanism of drop-by-drop in the past 20 years (Nakashima & Shimizu, 1986; Nakashima, Shimizu, & Kukizaki, 1991; Omi, 1996; Vladisavljević & Williams, 2005; Williams, 2001). In general, the disperse phase is forced to penetrate through the micropore (of well-controlled sizes) from one side of the membrane, to form individual droplets on the other side in the continuous phase. Methods such as microfluidic (Husny & Cooper-White, 2006; Nisisako, Torri, & Higuchi, 2004; Sugiura, Nakajima, Tong, Nabetani, & Seki, 2000), crossflow (Schröder, Behrend, & Schubert, 1998; Williams et al., 1998), stirring (Micropore Technologies, 2008; SPG Technology, 2008), rotating (Schadler & Windhab, 2006; Vladisavljević & Williams, 2006) and vibration (Hatate, Ohta, Uemura, Ijichi, & Yoshizawa, 1997) emulsification have been developed using imbalanced Laplace pressure and/or flowing continuous phase and/or moving membranes to generate the major detachment force. These methods have advantages over conventional high shear force methods not only in precise droplet size control and high reproducibility, but also in high-energy efficiency and intensified environmentally friendly production (Schubert & Armbruster, 1992; Schubert, 2000).

Pore geometry plays an important role in the control of droplet uniformity and productivity. So far, random, round, square and rectangle pores have been applied in droplet preparation. Random and round pores have been used in crossflow, stirring and vibration technologies as both flat and tubular membranes. Square and rectangle geometries only demonstrated on flat membrane in a crossflow technique (Kobayashi et al., 2002a; Kobayashi, Nakajima, Chun, Kikuchi, & Fujita, 2002b; Kobayashi & Nakajima, 2002; Micropore Technologies, 2008).

When random-shaped/round pore membranes are employed in crossflow technologies, a significant external shear force is required to achieve the best control over droplet size distribution (Schröder et al., 1998; Williams et al., 1998; Yuan et al., 2008). In the case of tubular ceramic membrane and crossflow technology, the tube Reynolds number was required to be in the range from transient (2300 < Re < 4000) to turbulent region (Re > 4000) (Williams et al., 1998). When rotational membranes

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