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Performance of a rotating membrane emulsifier for production of coarse droplets

Nita Aryanti [a,b], Ruozhou Hou [a,*], Richard A. Williams [a]

[a] Institute of Particle Science & Engineering, School of Process, Environmental and Materials Engineering, University of Leeds, Leeds LS2 9JT, UK
[b] Department of Chemical Engineering, Diponegoro University, Semarang 50278, Indonesia

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ABSTRACT

A versatile and high capacity membrane emulsification system which utilises a rotating membrane for the precision manufacture of oil-in-water (o/w) emulsions is investigated. The o/w emulsions produced used a low viscosity paraffin wax as the dispersed phase, Tween 20 or sodium dodecyl sulphate (SDS) as the emulsifier and carbomer as the stabiliser, respectively. The ability to generate coarse monodisperse emulsions was demonstrated with droplets of average diameter 80–570 μm and coefficient of variation ranging from 9.8% to 33.6%. The effects of key process parameters on the droplet size and distribution are discussed, including requirements for future developments of the membrane.

1. Introduction

Emulsions can be defined as a heterogeneous system involving at least two immiscible phases, with one of the phases being dispersed in the other as drops of macroscopic or colloidal sizes. An emulsion typically consists of three essential ingredients, the dispersed phase, continuous phase, and surfactants. Surfactants are used to facilitate the emulsion formation and stabilisation through interfacial reactions. Depending on whether an oil or aqueous solution is used as the dispersed phase, emulsions can be broadly classified into oil-in-water (o/w) or water-in-oil (w/o) two major groups. Multiphase emulsions are also encountered in many applications, in which case the dispersed phase itself is an o/w or w/o emulsion. They may subsequently be further classified into water-in-oil-in-water (w/o/w) or oil-in-water-in-oil (o/w/o) emulsions [1].

Emulsions play an important role in product formulation in a wide range of industries, such as the chemical engineering, paint, food, pharmaceutical and cosmetic sectors. Typical emulsification methods include high-pressure homogenisation, ultrasound homogenisation, and various rotor–stator systems (e.g. stirring vessels, colloid mills and tooth disc dispersing machines) [1]. In these methods, droplet breakage is mainly initiated through shear induced mechanisms. The processes normally suffer from low energy efficiencies, poor control on droplet size and distribution characteristics, significant unwanted temperature rises, and deteriorating scale-up performances [2,3].

Membrane emulsification is a technique which utilises a novel concept of generating droplets 'drop by drop' to produce emulsions [2]. In this method, a pressure is applied to force the dispersed phase to permeate through a porous membrane into the continuous phase, and the thus formed droplets can then be disengaged from the membrane surface through the relative shear motion between the continuous phase and membrane surface. For example the cross-flow membrane emulsification (XME) system, as depicted in Fig. 1. One of the distinguishing features of membrane emulsification technology over the conventional emulsification process is that in this system, the droplet breakage is mainly initiated by a combination of factors requiring judicious selection of an appropriate porous membrane, efflux rate of the discontinuous phase, and the nature of any shearing motion between the continuous phase and the membrane surface [3]. The method enables droplets of much narrower size distributions to be produced, leading to a populations greater degree of control over product properties and characteristics. Moreover, the process throughput in a membrane emulsification system is readily scaled up or down by simply increasing/decreasing the membrane area which produces droplets, while keeping all the other essential process settings the same [4].

To date, membrane emulsification has been successfully applied to the precision manufacture of a variety of coherent and structured liquid/solid products, including single and multiple phase emulsions [5], microspheres [6], microcapsules [7,8] and even metal solder particles [9]. Fig. 2 summarises various methodologies

* Corresponding author. Tel.: +44 113 343 7809; fax: +44 113 343 2781.
E-mail address: r.a.williams@leeds.ac.uk (R.A. Williams).

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