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Formation of dynamic membranes for oily water separation by crossflow filtration

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Abstract

This paper presents the results of a study of dynamic membranes for oily water separation. The formation of the dynamic membranes and their performance in oily water separation were investigated. The results showed that a magnesium hydroxide suspension, made by a simple reaction process with salt and sodium hydroxide, was a suitable material for dynamic membrane formation on the ceramic support. A dynamic membrane with a uniform and compact structure was formed using the crossflow filtration technique. The formed dynamic membranes were reproducible and gave good performance in separating oil from water using a model oil emulsion in an alkaline environment. The oil retention was more than 98% and the permeate flux was more than 100 L m^{-2} h^{-1} at 100 kPa in a batch concentration test.

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1. Introduction

Dynamic membranes (DM) are a specific type of membrane that can be formed in situ by filtering a solution containing either inorganic or organic materials through a porous support. The potential benefit of the dynamic membrane lies in the ability to be formed by a simple filtration process using inexpensive materials. Once the membrane is fouled, the deposited layer can be removed and a new dynamic layer can be deposited [1]. Dynamic membranes can be classified into two types: self-forming and pre-coated types [2]. Tanny [3] further characterized dynamic membranes into three classes. The main classification criterion was the geometric relationship of the membrane-forming colloid radius and the pore size of the support.

Dynamic membranes were first reported in 1965 by workers at the Oak Ridge National Laboratories [4]. Interest in dynamic membranes was initially centered on desalination applications. The best results were obtained with inorganic hydrous oxides, especially Zr(IV) oxide [5,6] and post-treated with polyacrylic acid (PAA). These membranes were mainly applied to the removal of salts because of their high water fluxes and medium salt retentions [7]. However, these membranes have not found widespread use for several reasons. These included: insufficient salt retention for practical desalting application; the membrane properties were difficult to control reproducibly and the flux tended to decline continuously with time after the membrane forming materials were removed [8]. Since the early 1980s, interest in dynamic membranes has been shifted to the research for UF applications, such as treatment of effluents from the textile industry [9] and recovery, and disposal of dyes [10]. Some researchers have tested dynamic membranes for protein retention [11–13]. High retentions have been achieved, but most of the membranes were formed on relatively expensive tubular substrates and suffered from unacceptably low permeabilities due to protein fouling. There have been

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some studies on these type of membranes for the purpose of microfiltration (MF) in wastewater treatment in recent years [14–17].

Many inorganic or polymeric materials have been used as supports for dynamic membranes, e.g., porous ceramic tubes [18–23], porous stainless steel tubes [14], polymeric membranes [11,24], woven fibers and non-woven fabric [8,16,17,25], and sintered polymer (PVC, PE, etc.) tube [15]. Wide ranges of colloidal materials have been used to form dynamic membranes by various workers. The most popular material used for dynamic membranes was hydrous zirconium oxide. Other inorganic hydrous oxides and organic polyelectrolytes have also been tested, such as MnO_2 [15–17,26] and clay [14,25,27]. Some substances being separated can also form the self-retention membrane with better separation performance on the porous support during operation [1,28].

Apart from the properties of the support and membrane materials, formation parameters including pressure, cross flow velocity and concentration of feed may also influence the properties of dynamic membranes. For example, for RO applications, the formation pressure adopted in many investigations was higher than 10 bars and some have reported up to 90 bars [29,30]. For ultrafiltration (UF) and microfiltration applications, the formation pressure was typically at a lower value of below 10 bars [31].

Oily water is a common waste stream in a wide range of industries, such as steel, aluminum, food, textile, leather, petrochemical and metal finishing. In recent years, considerable attention has been focused on the removal of oil from wastewater since it is an important aspect of pollution control in such industries [32]. Conventional methods such as gravity settling, dissolved air flotation, coalescence, centrifugation, flocculation and coagulation either fail to remove the oil cost-effectively to meet discharge standards or contaminate the oil so that it cannot be recycled. As a result there is a need to evaluate alternative technologies. Membrane separation is technically one of the most effective alternatives for oily water separation. Both microfiltration and ultrafiltration have been used for concentrated oils, as they can give high removals, do not require chemical additives and are potentially more economical than conventional separation techniques [33,34].

In this paper, the feasibility of using a dynamic membrane with a ceramic tube as support for treating oily water was investigated. Different dynamic membrane materials were compared and magnesium hydroxide was found to be particularly effective. The performance of this dynamic membrane is reported.

2. Experimental

2.1. Equipment

The experimental setup is shown schematically in Fig. 1. The recirculation loop consists of a feed tank, a diaphragm pump and a membrane module, a digital flowmeter, digital pressure gauges, valves and piping. A porous ceramic tube was fitted into the stainless steel membrane module. A magnetic stirrer was used in the feed tank to ensure that the suspension was well dispersed.

2.2. Materials

Al_2O_3 porous ceramic tubes (Jiangsu Jiusi High-Tech Co. Ltd., PR China) were used as supports in this work. The support specifications are: o.d. 1.2 cm, i.d. 0.8 cm, length 20 cm and average pore size about 5 μm. A SEM photograph of the inside surface of the support is shown in Fig. 2.

Various metal hydroxides, including ferric hydroxide $Fe(OH)_3$, manganese hydroxide $MnO_2 \cdot 2H_2O$ and magne-

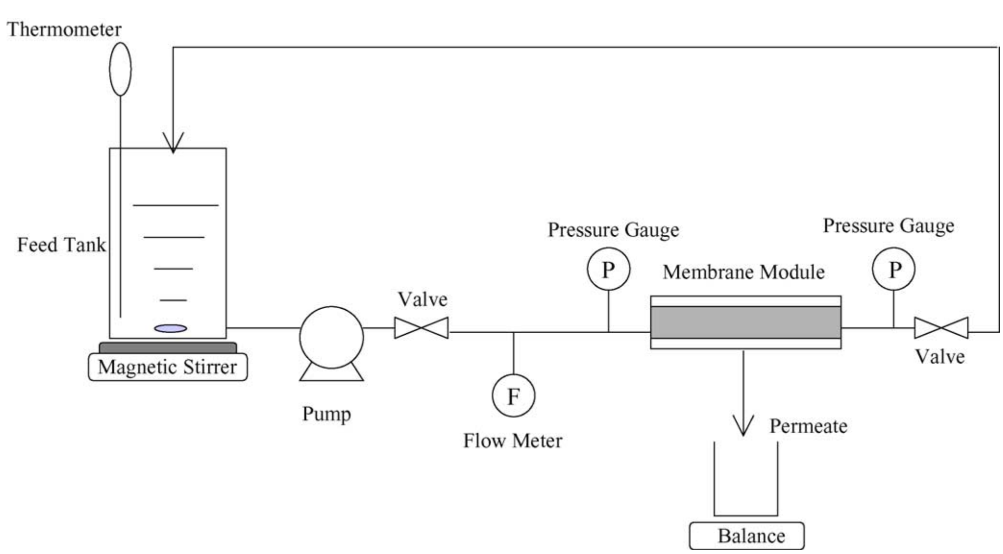

Fig. 1. Schematic diagram of crossflow filtration setup.

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