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ULTRAFILTRATION OF OIL-IN-WATER EMULSION: FLUX ENHANCEMENT WITH STATIC MIXER

Conventional methods of oily emulsion separation are not effective in removing small oil droplets and emulsions, especially if the emulsion is stable and the oil concentration is low. This paper deals with the oil removal from oil-in-water emulsion by an ultrafiltration membrane under different operating conditions of a novel flux enhancement method. Separation of oily water and wastewater by membrane filtration is a well-known process. Generally, because of heavy concentration polarization and membrane fouling, a single-stage membrane process is not economical and usually does not provide satisfying results in retention. In our experiments, 20 nm pore size ceramic tubular membranes were used. In order to reduce concentration polarization and membrane fouling, the use of static turbulence promoters, such as rods, differently shaped inserts and static mixers, has been considered during cross-flow ultrafiltration and microfiltration with different fluids. Helix-like plastic static turbulence promoter was installed in the experimental apparatus

Keywords: *oil-in-water emulsion, membrane separation, ultrafiltration, flux enhancement, concentration-polarization reduction, static mixer*

1. INTRODUCTION

Conventional methods of oily emulsion separation are not effective in removing small oil droplets of emulsions, especially if the emulsion is stable and the oil concentration is low. Separation of oily water and wastewater by membrane filtration is a well-known process. Generally, because of heavy concentration polarization and membrane fouling, a single-stage membrane process is not economical and usually does not provide satisfying results in retention. There are coupled membrane-filtration

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methods mentioned in the literature (UF-RO, UF-NF), but in these cases both investment costs and operating costs must be high [1], [2]. In some papers, their authors report that flow relations must be changed above the membrane surface to reduce concentration polarization and fouling [3], [4]. This can be done by choosing the optimal flow rate of retentate and transmembrane pressure which is in agreement with the literature [5]. To reduce the concentration polarization and membrane fouling the use of static turbulence promoters, such as rods, differently shaped inserts and static mixers, has been considered during cross-flow ultrafiltration and microfiltration with different fluids [6]. In this paper, static mixer was applied as turbulence promoter in the ultrafiltration process, so higher permeate fluxes were observed than those obtained with non-static mixer producing great retention even at low transmembrane pressure and recycled flow rates. Membrane fouling was not serious either. Our research revealed that no complex membrane process was necessary to separate oil from water, only a single-step membrane filtration at low recycled flow rate and low pressure can be applied, thus both investment costs and operating costs could be reduced.

2. MATERIALS AND METHODS

Membrane filtration experiments were conducted at different transmembrane pressures (TMP, 20–200 kPa), and at different retentate flow rates (RFR, 50–200 dm^3/h). During the experiments T1-70-20-Z (Pall) ultrafiltration ceramic tube membrane was applied. The physical properties of the membrane are as follows:

- ZrO_2 active layer; Al_2O_3 support;
- inner diameter of 6.8 mm; length of 250 mm;
- active membrane area of $4.62\times10^{-3} m^2$ (mean membrane pore size of 20 nm).

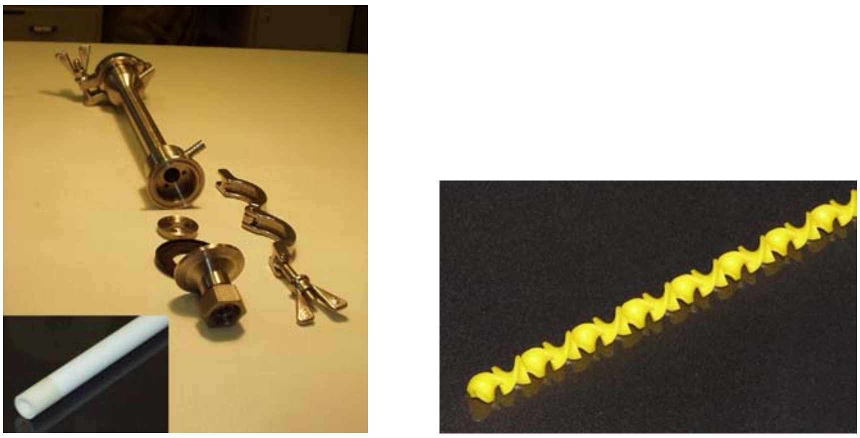

Fig. 1. The membrane with its housing and the static mixer

To generate a stable oil-in-water emulsion, MOL Unisol mineral micro-emulsion oil was used, feed concentration was 5 w/w%. The oil concentrations in the permeate and the feed were determined by spectrophotometric method. The membrane apparatus and method of permeate flux measurement are detailed in our previous publication [3].

The characteristic parameters of the static mixer used during the experiments are as follows:

- Kenics FMX8124-AC, Omega, USA; material: polyacetal;
- 6.35 mm diameter; 152.4 mm length;
- number of mixing elements: 24.

The membrane and the static mixer are shown in figure 1.

3. RESULTS

When the membrane worked in conventional mode (without static mixer) serious membrane fouling was observed due to the concentration polarization phenomena. The permeate flux increased minimally with an increase in TMP. Operating at higher RFR also resulted in higher flux (figure 2).

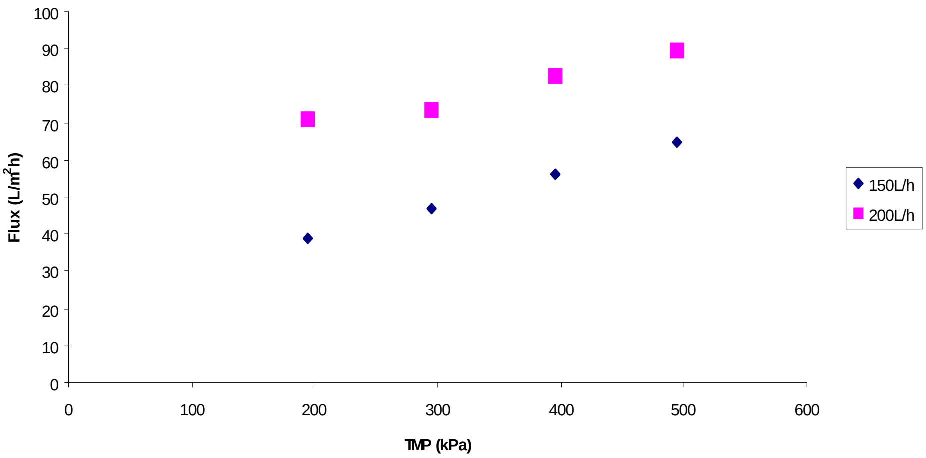

Fig. 2. Permeate flux versus transmembrane pressure for the membrane working in conventional mode without static mixer

Figure 3 shows the effect of the static mixer on the process efficiency. The flux is tree times as high as that without the static mixer (150 $dm^3 \cdot h^{-1}$). A large flux improvement can be explained by the turbulence promotion and by a characteristics of the flow field created by the static mixer. The enhanced scouring in the static mixing mode operation reduces the thickness of the oil drop deposit on the membrane surface, leading to a large improvement of the permeate flux. Inserting a static mixer turbulence promoter into a tubular membrane module causes an increase in flow rate and pressure drop at the same flow rate. The hydraulic dissipated power or power required for circulating the fluid increases because of the increase in pressure drop along the module leading to large energy consumption. This observation is similar at each cross-flow velocity. Therefore, the improvement of performance by using the static mixer should be verified taking account of energy consumption.

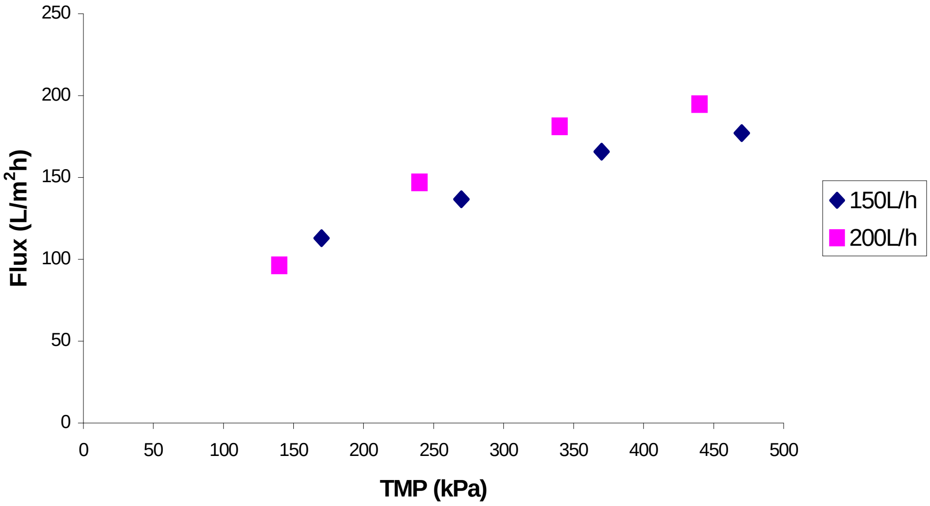

Fig. 3. Permeate flux versus transmembrane pressure for the membrane working with static mixer

Oil retention by the membrane determined by spectrophotometric method is shown in the table (without and with static mixer) for the experiments at 150 dm^3/h and 200 dm^3/h.

Table

Oil retention

TMP	Without static mixer		With static mixer	
	Retention % RFR = 150 dm^3/h	Retention % RFR = 200 dm^3/h	Retention % RFR = 150 dm^3/h	Retention % RFR = 200 dm^3/h
200 kPa	99.0	99.9	99.2	99.8
500 kPa	95.2	96	99.9	99.8

It can be seen that at TMP = 200 kPa the concentration of the oil in the samples is low contrary to the concentration of the oil at 500 kPa without static mixing of emulsion. The filtration gives satisfying results at 200 kPa independently of using the static mixer. When the mixer was installed retention at higher TMP improved. However this method shall be energy efficient only at low TMP and RFR.

4. CONCLUSIONS

By using static mixer, essential flux improvement can be obtained with efficient separation. Considering the *resistance-in-series* model, permeate flux can be enhanced besides an increase in the pressure and CFV by the reduction of the resistance of filtration. The resistance of the boundary layer and the gel layer decreased by changing the flow relations above the membrane surface and caused rise in the permeate flux. The statement that the installation of static turbulence promoters advantageously affects the process is not possible before examining the cost effect. The phenomena of energy consumption and retention improvement should be considered and discussed. Separation of stable, low concentration oil-in-water emulsions in a single step cross-flow ultrafiltration process is possible which means reduced costs compared to complex treatment methods.

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