Effect Of Casting Rate On The Development Of Polysulfone Flat Sheet Ultrafiltration Membrane For The Aluminium Removal

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ABSTRACT

This paper focused on the performance of flat sheet ultrafiltration membrane by various casting rate on the aluminium removal. Aluminium potassium sulfate (alum) known as an agent that used in water treatment processes to flocculate suspended particles but it may leave a residue of aluminium in the finished water. The removal of these impurities is significant based on its effect to human and environment. Therefore, membrane separation had developed in order to improve the method for removing the aluminium contaminants. The formulation of multicomponent (Polysulfone/poly(vinylpyrolidone)-K30/N,N dimethylacetamide) flat sheet ultrafiltration membrane had developed using the dry/wet phase inversion technique. The membranes were produced at three different casting rate (11 m/min, 10 m/min, and 8.5 m/min) from controlled pressure of 90 psi, 70 psi and 50 psi. The performances of these membranes were tested by Salt (NaCl) rejection and also aluminium removal. Then, the morphology (skin layer and cross section) for each membrane was observed using Field Emission Scanning Electron Microscope (FESEM). From the experiments, it showed that casting rate directly influences both membrane morphology as well as membrane rejection performance. The highest percentage of sodium chloride (NaCl) rejection was observed from membrane fabricated at 11 m/min of casting rate with 42%. Moreover with the increment of casting rate, then the percentage aluminium removal also increased. As conclusion, from this study proved that casting rate influence significantly on the morphology, rejection and flux performance of flat sheet ultrafiltration membrane.

Key words : *aluminium removal, casting rate, morphology, ultrafiltration membrane, and wastewater.*

Introduction

Membrane probably has ability to treat wastewater effectively. However, it still has several factor in determining the membrane performance and morphology (McGhee, 1991). Casting rate is one of the factors that affecting the performance of the membranes either flat sheet or hollow fiber membrane. The increasing casting would enhance the shear stress that can effect the molecular orientation and gas separation performance of polysulfone. Therefore, the morphology of flat sheet UF membrane became important since related to the rejection performance of membrane. Aptel et al., (1985) confirmed that increasing casting rate would enhance the shear stress during fabrication stage and subsequently produce greater molecular orientation of membranes. He found that the spinning conditions have a pronounced effect on the ultrafiltration characteristics. As extrusion rate was decreased from 8 cm/sec to 1.6 cm/sec, the water flux inside the nascent fiber increased from 4 X 10^{-2} to 6 X 10^{-2} cm^3/sec, while rejection for polyvinylpyrrolidone ($\overline{M}_w \cong 10{,}000$) decreased from 0.8 to 0.4. In contrast, Chung et al., (2000) stated that a higher casting rate apparently resulted in a hollow fiber UF membrane with a thicker and/or a denser skin due to a greater molecular orientation. As a consequence, he also stated that when casting rate increased would decrease the flux and membranes spun at a higher speed (shear rate) may show not only low separation performance but also a lower flux because the outer skin is thicker and highly oriented. Besides that, Ismail et al., (1997) has indicated that morphology of the membranes, such as the skin layer thickness and surface porosity influenced by casting rate and this parameter also important in the determination of membrane separation performance. Meanwhile, Ismail also stated that fabrication method does affect asymmetric polysulfone flat sheet UF membrane structure and performance.

Previous research and development of polysulfone hollow fiber by Tajuddin (2006) formulated and fabricated hollow fiber ultrafiltration (UF) membrane for pressurized and submerged membrane bioreactor to treat Palm Oil Mill Effluent (POME). She found that the pressure-normalized fluxes of assymmetric membrane were increased with increasing shear because of the decreased in the skin layer thickness and increased in size of macro voids finger-like structure. Besides that,it also reduce in the percentage rejection of sodium chloride solution. Then, she concluded that objective of her research was successful and stated that membrane morphology can be effected by the extrusion rate as well as membrane performance in hollow fiber ultrafiltration membrane. Therefore, by using the same formulation developed by Tajuddin (2006) this research focused on the determination of the morphology and performance of flat sheet ultrafiltration membrane for aluminium removal by various casting rate.

Experimental

Materials

Asymmetric flat sheet membranes for ultrafiltration were fabricated using composition of polysulfone (PSF; nominal M.W. 75,000) as polymer, N,N-Dimethylacetamide (DMAc, 99% pure) as solvent and Polyvinylpyrrolidone (PVP, average M.W. 58,000; K-30) acts as a non-solvent additive that purchased from ACROS Organic, Geel, Belgium.

The weight ratio for this asymmetric membranes were consisted of 18wt. % PSF, 69wt. % DMAc, and 13wt. % PVP K-30 where the formulation of the dope solution obtained from past research by Tajuddin (2006).

Dope preparation

Materials that used in developing the dope solution were weighted based on the composition from past research formulation by Tajuddin, (2006). The dope solution was prepared in 1L for each mixing. Then, the dope solution was mixed in a round bottom reaction vessel stirred at constant value of 200 rpm by motor driven stirrer in heating mantle under temperature of 35°C for about 8 h until the solution become homogenous.

Fabrication of flat sheet membrane

The flat sheet UF membrane was produced by a wet casting technique using SOLTEQ® Pneaumatically controlled Flat Sheet Membrane Casting Unit. The membranes were cast onto a glass plate at ambient temperature (27°C) with a casting knife notch settling of 150μm. The membranes were cast at three casting rate by adjusting the casting rate valve pressure and casting speed which can be measured using the digital Tachometer provided. The casting rate that obtained are 11 m/min, 10 m/min and 8.5 m/min when control valve pressure fixed at constant value of 90 psi, 70 psi and 50 psi respectively. UF flat sheet membranes were fabricated by using water as both the external and internal coagulants. The evaporation step is considered as essential for the formation of the asymmetric membrane and is critically importance in determining the membrane structure but long evaporation time will affect the membrane.

The membrane forming process consists of surface treatment and coagulation steps. The surface treatment step involve evaporating the membrane surface by allowing air being sucking out of the air hood which the process known as dry phase inversion in evaporation time in the range of 10 s to 15 s before coagulation process and air-dried for 1 day in room temperature.

Permeation test

The performance of membrane were measured based on the rejection and flux.

a) Rejection (***R***)
It can be defined as percentage of solute concentration reduction of permeate stream and can be calculated as below :-

$$R = \frac{Cf - Cp}{Cf}$$

Where R is the rejection (%) , Cf is the feed concentration (mg/L) and Cp is the permeate concentration (mg/L)

b) Flux (***F***)

Flux is the mass or volume transfer through the membrane surface. It can be calculated as below :-

$$F = \frac{Average\ Permeate\ (mL)}{A\ X\ t}\ X\ \frac{1L}{1000mL}$$

Where F is the permeate flux ($L/m^2.hr$), A is the crossflow surface area (m^2), and t is the time interval which permeate volume is taken (hr)

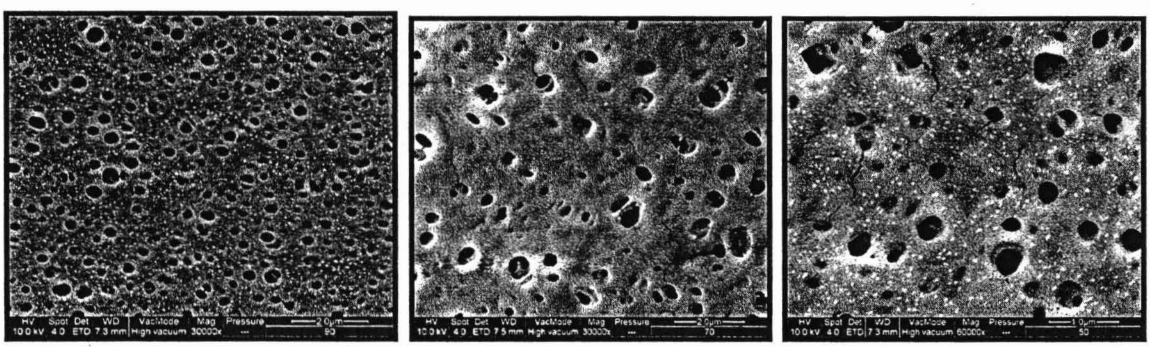
Morphology study by SEM

The surface and cross section which illustrate morphology of the fibers and porous substructure as well as others aspects of three various casting rate of flat sheet UF membranes were determined by using a Field Emission Scanning Electron Microscopic (FESEM) technique.

Results and discussion

Effect of casting rate on membrane morphology

According to the experimental result, it shown that the casting rate was effect the morphology of the membrane. The increasing casting rate can enhance the shear rate stress. As result, it can effect the molecular orientation and gas separation performance of polysulfone. Their FESEM pictures of skin layer and cross section of the flat sheet UF in three various casting rate were shown in Fig. 1 (a) to (c) below. Fig. 1(a) shows that the skin layer of flat sheet UF membrane for casting rate 11 m/min seems to be align and microporous structure closed together and skin pores more smaller compare than casting rate of others, 10 m/min and 8.5 m/min as shown in Fig.1 (b) and (c), respectively. Skin layer of casting rate 11 m/min had smaller pores than others casting rate but quantity of distribution of skin pores was much more thus produce a larger area of skin pores that produce higher permeability rate or flux. The reason for that case may be the membrane solution or molecular had enough time to build up together during casting stage on the slow casting rate compare to high casting rate (Ali et al., 2010).



(a) Casting Rate of 11 m/min (b) Casting Rate of 10m/min (c) Casting Rate of 8.5m/min

Figure 1: (a), (b) and (c) show the Skin Layer of Flat Sheet UF Membrane for different Casting Rate.

Effect of casting rate on membrane performance

For this study, the rejection performance of membrane believed related to the morphology of flat sheet UF membrane. Fig. 2 shown that, the flux decreased with a increased in casting rate. In high casting rate region, the decrease in selectivity with increasing shear rate from the better molecular orientation and chain-packing induced by shear. On the contrary, in the low casting rate region, the decrease in volume of flux was believed to be attributed by decreased in porous skins and fracture.

For the retention due to the performance of natrium chloride by this flat sheet UF membrane, Fig. 3, shown that the rejections increased with an increased of casting rate. Casting rate of 8.5 m/min rejected about 16%. On the other hand for casting rate of 10 m/min and 11 m/min produced of 21 % and 42% respectively. The performance of this membrane may caused by the electrostatic interaction of ions in aqueous solution and the charges of the membrane. As result, with the decreased in casting rate, then the rejection of sodium chloride also decreased (Ali et al., 2010). Fig. 4 also shown that, fromdifferent concentration of aluminium, with the high casting rate, the percentage removal of aluminium also increased.

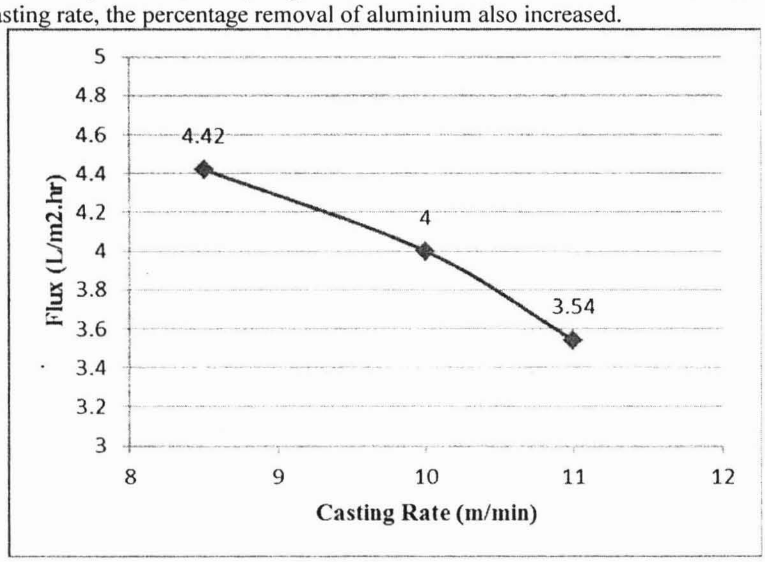


Figure 2 : Graph of Flux Performance.

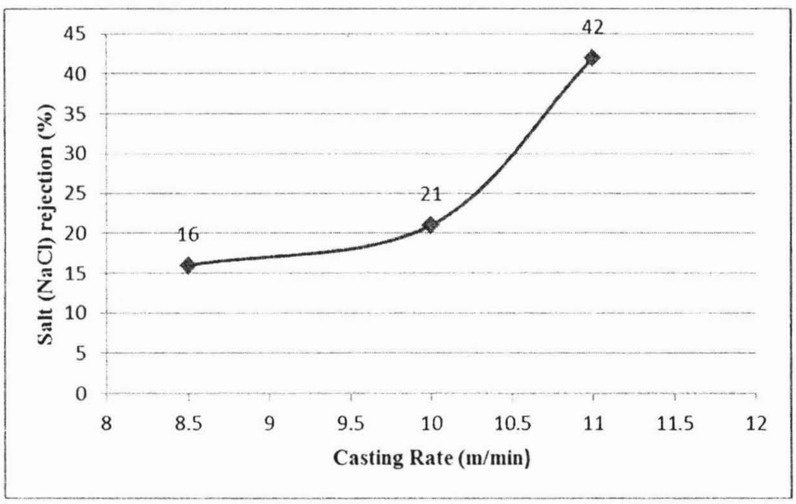


Figure 3 : Graph of Salt (NaCl) Rejection.

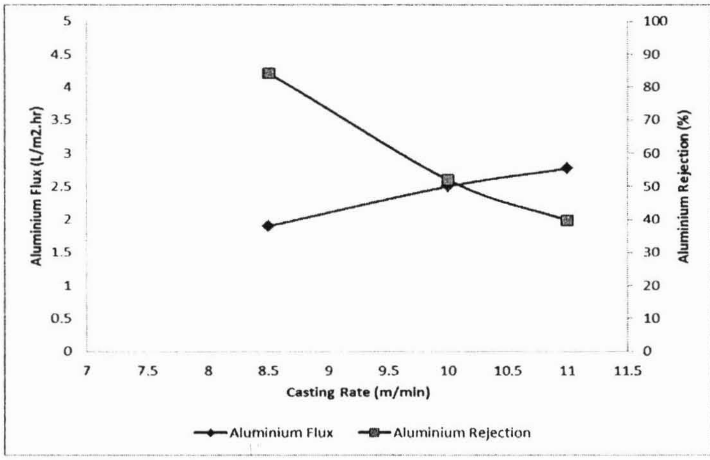


Figure 4 : Performance of Aluminium Removal.

Conclusion

Casting rate has a significant effect on the performance of permeability and selectivity of ultrafiltration flat sheet membrane. It is belived that casting rate that effected by shear, affects the phase inversion dynamics of membrane precipitation as well as the orientation of polymer molecules in the active layer. It caused a changes in the percentage rejection of sodium chloride solution. It was found that the pressure-normalized fluxes of assymmetric membrane were increased with increasing casting rate because of the reduction in the skin layer thickness and the increase in size of structure. Thus it can be concluded that casting rate can affect membrane morphology as well as membrane performance in this flat sheet ultrafiltration membrane.

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