Available online at www.elixirpublishers.com (Elixir International Journal)

Chemical Engineering

Elixir Chem. Engg. 100 (2016) 43410-43413

ISSN: 2229-712X

Comparative Study of Pervaporation Separation of IPA/water Mixture using Different Membranes

Nitin G. Kanse* and S.D. Dawande

Department of Chemical Engineering, Laxminarayan Institute of Technology, Nagpur(MS) India.

ARTICLE INFO

Article history:

Received: 28 September 2016;

Received in revised form: 02 November 2016;

Accepted: 06 November 2016;

Keywords

Pervaporation,

Flux,

PVA Membrane,

PVA-PES Membrane,

IPA/water mixture

ABSTRACT

PVA membrane and PVA-PES membrane were used for study of Pervaporation separation of IPA/water mixture. In present study experiments were carried out at different feed temperature (45-75 ^{0}C), feed concentration (6.28- 14.39 wt %.) and flow rates (6-18 LPH). The degree of swelling of the membranes studied at different concentration of water in feed. The experimental results of IPA/water system were presented and compared with regression analysis model data. It was observed that PVA-PES membrane has higher flux and lower separation factor than PVA membrane for separation of IPA/water mixture. The total permeation flux increased with increase in feed temperature and feed concentration. Increasing the feed flow rate had a positive effect on both permeation flux and selectivity due to elimination of concentration and temperature polarization. A permeation flux of 110.81 gm/m^2.hr with separation factor 124.93 was achieved for PVA membrane and permeation flux of 158.44 gm/m^2.hr with separation factor 25.24 was achieved for PVA-PES membrane. The Comparative results are presented in this work.

1. Introduction

In recent years Pervaporation is intensively studied for the separation method involving the breaking of azeotrope, dehydration of solvents, heat sensitive product and organic-organic solutions by partial vaporization through a dense membrane. Most of the chemical and electronic industries used High concentration of IPA in water as cleaning agent. After cleaning operations the waste IPA is required to recover and recycle from environmental as well as economic point of view. By Conventional method like distillation separation of IPA /water azeotropic mixture is difficult. The separation of IPA/water mixture by Pervaporation has also been reported by many researchers [1-3]. In most of Pervaporation (PV) works polyvinyl alcohol based membranes have been used [4-6].

In pervaporation, the flux and selectivity could be affected by operating parameters such as feed temperature, feed concentration and flow-rate [7–10]. Therefore, it is important to determine the effect of operating variables on flux of membrane and selectivity. Researchers generally study the Pervaporation separation performance by varying one operating parameter and other are constant, such as the feed temperature being varied while keeping the concentration and feed flow-rate constant. However, the effect of temperature, concentration and flow-rate may not be independent of each other and it is necessary to consider their interactions [9-10].

The objective of this work is to study Comparative investigate of Pervaporation separation of IPA/water mixture using different membranes. In this work comparative experimental results were presented by for PVA and PVA-PES composite membrane. The effect of operating parameters such as feed temperature, feed concentration and feed flow rate on the flux of membrane, selectivity, PSI and enrichment factor were presented for both the membranes.

This paper discusses the comparative study by using PVA and PVA-PES composite membrane for separation of IPA/water mixture. To determine the validity of regression model, the predicted results from the regression equation were compared to the experimental data.

2. Experimental

2.1 Materials

Poly vinyl alcohol (PVA) dense membrane and PVA-PES membrane was used in membrane test cell of Pervaporation setup (supplied by Shivom Membrane Pvt ltd. Ichalkaranji Sangali) for separation of IPA/water mixture. The membrane effective area is 0.026 m^2 and thickness of membrane is about 30 µm for PVA and 3 µm for PVA-PES membrane. All the comparative study on Pervaporation is done by using different performance parameters and above mentioned membranes.

2.2 Pervaporation setup

The comparative study of separation performance of PVA and PVA-PES membrane were tested by Pervaporation for separation of IPA/water mixture. The membranes were tested for different feed concentration and temperature at permeate pressure kept at constant 760 mmHg. Fig.1. shows the schematic representation of Pervaporation setup. The Pervaporation has great potential for separation of azeotropic mixtures. Different membranes were used in PV cell to measure the performance for IPA-water separation. The heated feed mixture (at desired temperature) was continuously circulated over the membrane using circulating feed pump from the feed tank. A Vacuum was applied on permeate side less than 760 mmHg. by using vacuum pump. The permeate was collected at the permeate drain valve as shown in fig.1. The permeate was analyzed by Karl Fischer Titration.

In further analysis the membrane performance was evaluated by flux and separation factor of membrane

Tele: +919960835696

E-mail address: nitin_475@yahoo.co.in

which are defined as follows;

$$J = \frac{W}{A \times t} \qquad (1)$$

Where, W represent weight of the permeate (gm), A is the effective membrane area (m2) and t is the sample collection time (hr). While, the separation factor was calculated from the concentration ratio of permeate solution over feeding solution

$$\alpha_{w/IPA} = \frac{\left(y_w / y_{IPA} \right)_P}{\left(x_w / w_{IPA} \right)_F} \qquad (2)$$

Where y_w,y_{IPA}, x_w and x_{IPA} represent the weight fraction of water and IPA in permeate and feed.

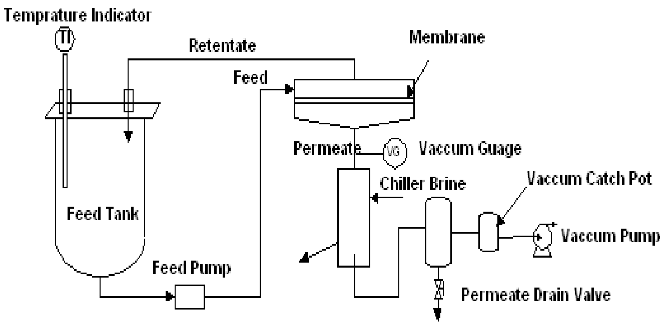
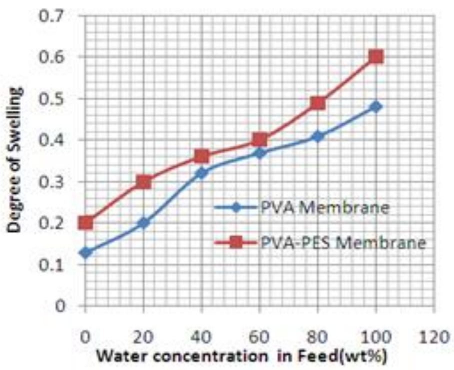


Fig 1. Schematic diagram of the apparatus for Pervaporation .

3.Results and Discussion

3.1 Degree of swelling of PVA and PVA-PES membrane in IPA/water mixture.

A comparative result of the degree of swelling in IPA/water mixture are presented in fig.2. degree of swelling was measured as a function of water concentration. In this work it was tried to determine the degree of swelling in all concentration (from pure IPA to pure water). According to the solubility parameter theory the component which has a solubility parameter (water) closer to that of membrane is more taken up into the membrane rather than other component (IPA). Result shows that amount of absorption enhance with increasing water concentration.



3.2 Effect of feed concentration and temperature

The performance of membrane could be expressed in terms of permeation flux and separation factor. Both the performance parameters are important in the separation process.

The separation factor decreases with increase in flux of membrane. Therefore, the extent of permeation of individual components could be determined by plotting the total flux of IPA/water compositions in the membrane with different temperature. Membrane separation is the ratio of water and IPA permeabilities, while the permeation flux complies with the water content in the feed. For hydrophilic membrane, water has better affinity as compared to IPA. In addition to the strong interaction, the smaller water molecule than IPA molecule make a diffusion of water easier than IPA. For concentration of component relatively low then Pervaporation is especially attractive for separating that component.

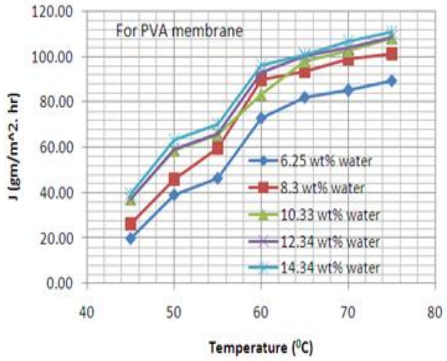


Fig 3. Effect of temperature and concentration on flux of PVA membrane

Fig 3 shows the effect of temperature and concentration on flux of PVA membrane. From the plot it shows that flux of membrane increases with increase in temperature and water concentration in feed. The higher flux 110.81 gm/m^2.hr is obtained at temperature 75 ^{0}C and water concentration 14.34 wt%.

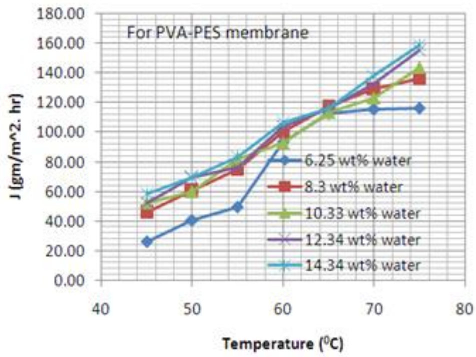


Fig 4. Effect of temperature and concentration on flux of PVA-PES membrane

Fig 4 shows the effect of temperature and concentration on flux of PVA-PES membrane. In this study we get maximum flux up to 158.43 gm/m^2.hr at same condition as that of PVA membrane. From the plot shown in fig 3 and 4 shows that PVA-PES membrane has higher flux than PVA membrane.

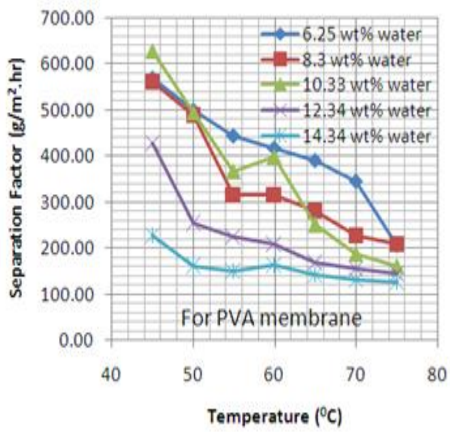


Fig 5. Effect of temperature and feed concentration on separation factor for PVA membrane.

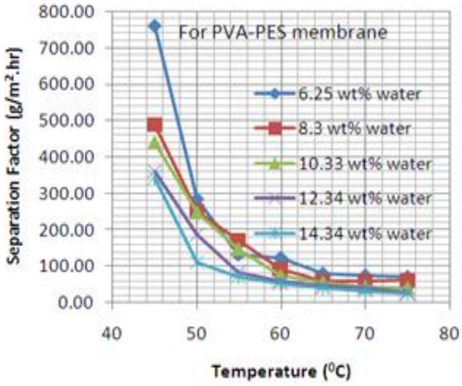


Fig 6. Effect of temperature and feed concentration on separation factor for PVA-PES membrane.

It's observed that in fig.5 and 6 the separation factor decreases with increase in temperature and feed concentration. For PVA membrane higher separation factor is 570 while as for PVA-PES membrane is 760 were obtained. These separation factor values were obtained at lower temperature 45^0C and lower water content in feed as 6.25 wt%. It shows that, PVA-PES membrane has higher separation factor than PVA membrane. The experimental results are good agreement with other researchers. The overall results showed that membrane flux increased with increase in temperature while separation factor decreased from temperature range 45 ^{0}C to 75 ^{0}C.

3.3 Effect of feed flow rate

Fig 7 shows the effect of feed flow rate on flux of membrane. As feed flow rate increases with increase in flux of membrane. The highest flux in our case is measured as 185.59 gm/m^2.hr for PVA-PES membrane at highest temperature 80 ^{0}C. The comparative result is shown in fig. 7 for both the membranes. It can be seen that permeate flux increases with increase in feed flow rate.

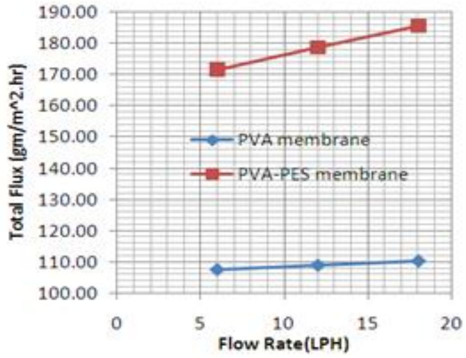


Fig 7. Effect of feed flow rate on flux of membrane.

Conclusion

In this study the membranes were used to separate the IPA/water mixture through Pervaporation. The effects of feed temperature, concentration and feed flow rate on Pervaporation performance of PVA and PVA-PES membrane were discussed. As feed temperature and concentration in the feed solution increases with increase in permeate flux of membrane while separation factor decreased. Also the feed flow rate has positive impact on permeate flux. Experimental results shows that as feed flow rate increases, permeate flux of membrane increase. The experimental flux and selectivity of PVA membrane compared with PVA-PES membrane. Under higher operating temperature and feed concentration results showed that the PVA-PES membrane exhibited a higher permeation flux and a lower selectivity. The model data is predicted by using regression analysis. The comparative experimental results are shown in table 1 and 2. It shows that good agreement with model data.

Table 1. Comparative result of experimental flux and model flux for PVA membrane .

Temp ^{0}C	Experimental data					Model data				
	Membrane used : PVA Membrane									
	Water in feed (wt%)					Water in feed (wt%)				
	6.25	8.3	10.33	12.34	14.34	6.25	8.3	10.33	12.34	14.34
	Experimental flux (gm/m^2.hr)					Model flux (gm/m^2.hr)				
75	89.38	101.19	108.11	108.24	110.81	89.57	101.45	108.14	108.45	111.06
70	84.94	98.77	102.61	103.89	106.56	83.83	97.23	102.42	102.63	105.05
65	81.87	93.27	98.15	100.18	100.83	84.65	97.12	98.63	103.34	104.60
60	73.03	89.56	83.17	92.77	96.32	69.32	84.43	82.53	88.56	91.29
55	46.38	59.71	65.61	66.12	69.98	49.16	63.56	66.09	69.28	73.75
50	38.97	45.88	58.70	59.30	63.16	37.86	44.34	58.51	58.04	61.65
45	19.73	26.14	37.04	37.14	39.47	19.92	26.40	37.07	37.35	39.72

Table 2. Comparative result of experimental flux and model flux for PVA-PES membrane.

Temp ^{0}C	Experimental data					Model data				
	Membrane used : PVA-PES Membrane									
	Water in feed (wt%)					Water in feed (wt%)				
	6.25	8.3	10.33	12.34	14.34	6.25	8.3	10.33	12.34	14.34
	Experimental flux (gm/m^2.hr)					Model flux (gm/m^2.hr)				
75	116.31	136.04	143.78	155.23	158.44	116.55	136.12	143.61	155.44	158.63
70	115.16	129.13	123.22	132.33	138.06	113.71	128.66	124.26	131.05	136.93
65	112.51	117.50	113.19	115.76	115.76	116.14	118.67	110.59	118.97	118.60
60	93.41	100.32	92.91	104.03	106.73	88.58	98.76	96.37	99.76	102.95
55	49.91	75.05	81.46	76.56	83.47	53.54	76.22	78.86	79.76	86.31
50	40.48	60.21	59.71	69.19	69.55	39.03	59.74	60.75	67.91	68.42
45	26.14	45.88	52.29	52.29	58.70	26.38	45.96	52.12	52.50	58.89

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