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Separation of Ethanol/Water (Azeotropic mixture) by Pervaporation using PVA Membrane

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Abstract

In present work Poly vinyl alcohol (PVA) membrane was used for separation of ethanol-water mixture. Pervaporation has significant advantages and great potential for separation of azeotropic mixtures where traditional distillation can recover pure solvents with the use of entrainers, which then must be removed using an additional separation step. In present study, experiment were conducted over a wide range of temperature (45-75 ^{0}C) and water concentration (6.25-14.34 wt %). In this study it is observed that there is good separation of ethanol-water is possible with this membrane. The Effects of temperature, Solution concentration on flux selectivity, Permeation separation factor (PSI) and enrichment factor are investigated via experiments and model prediction

Keywords: Flux; Selectivity; PVA Membrane; Ethanol-Water Mixture.

1. Introduction

Pervaporation is recognized as an effective process for separating azeotropic mixtures, close boiling point compounds, and mixtures consisting of heat sensitive compounds. In recent years, numerous investigations have been carried out regarding the Pervaporation of ethanol–water mixtures through polymeric membranes. Hydrophilic membranes such as polyvinyl alcohol (PVA) and chitosan (CS) are required for dehydration purpose [1,2]. The

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separation of azeotropes by distillation poses a challenging problem as the vapor distils over without change in the composition irrespective of the change in temperature or pressure. [3]. A good Pervaporation membrane material should have high permeation flux and separation factor for the Pervaporation dehydration of alcohol.[4-5]. Many researchers explained the diffusion coefficient and Pervaporation results on the basis of solution-diffusion principles [6-8]. The key to the success of Pervaporation process is depends on membranes yielding high permeability, good selectivity and sufficient mechanical strength [9]. In present work we used PVA membrane for separation of ethanol-water mixture by Pervaporation. The experimental work explores the effect of varying water concentration in the feed mixture on membrane flux, selectivity, permeate separation index (PSI) and enrichment factor. The experimental results have been compared with model data.

2. Experimental

2.1 Membrane

Poly vinyl alcohol (PVA) dense membrane was used in membrane test cell of Pervaporation setup (supplied by Shivom Membrane Pvt ltd. Ichalkaranji Sangali). The membrane effective area is 0.026 m^2 and thickness of membrane is about 30 μm. All the experimental runs are performed on the PVA membrane.

2.2 Pervaporation setup

The experiments were carried out for separation of ethanol-water mixture on a Pervaporation apparatus as shown in fig. 1. PVA dense membrane was used in PV cell to measure the performance for ethanol-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 600 Pa. 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. The membrane performance was evaluated by flux and separation factor of membrane which were calculated by following equations;

$$J = \frac{W}{Am \times time} \tag{1}$$

Where, W represent weight of the permeate (kg), Am is the effective membrane area (m^2)

$$\alpha = \frac{\left(yw / yE \right)_p}{\left(xw / wE \right)_F} \tag{2}$$

Where yw,yE, xw and xE represent the weight fraction of water and ethanol in permeate and feed.

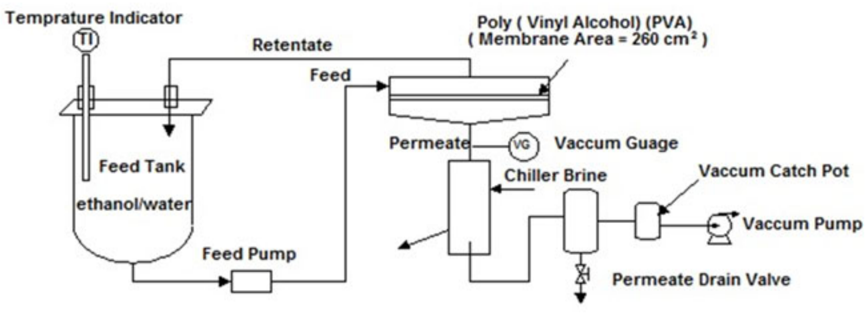
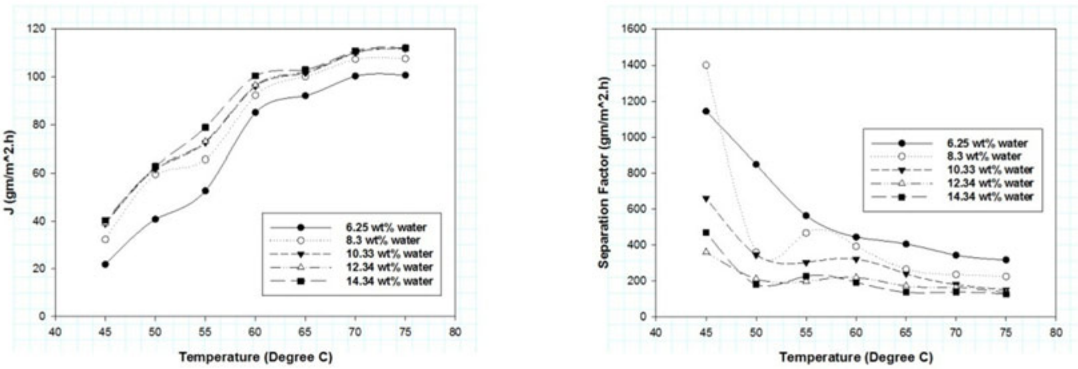


Fig.1. Schematic diagram of the Pervaporation set up.

3. Results and Discussion

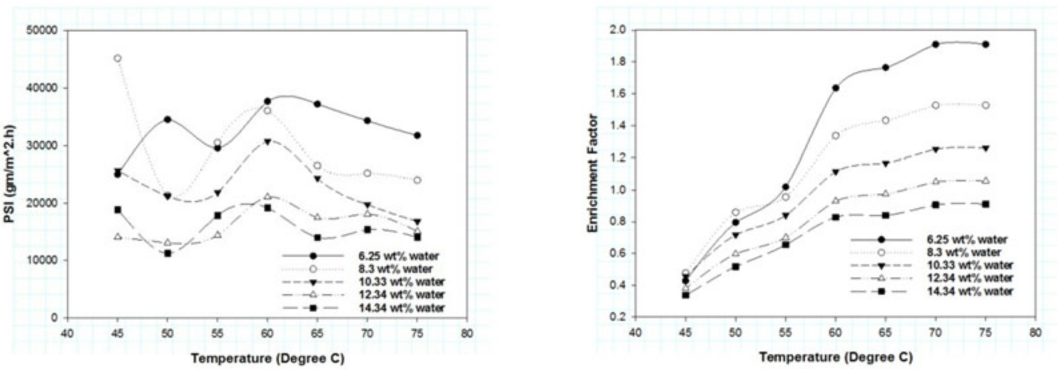
The Experimental work for separation of ethanol-water was carried out in a laboratory scale Pervaporation setup. For most of the polymeric Pervaporation membranes, permeation flux increase with increase in feed temperature. It is well accepted that increased feed temperature enhances the thermal mobility of the polymeric chain, thus the diffusion rate of the permeating molecules is significantly increased. It means the driving force of the Pervaporation process, the chemical potential difference in terms of the temperature difference increases which leads to increase the membrane flux. The experimental results are very much in agreement with other researchers as well as the permeation flux increase with an increase of the feed solution and temperature.



(a) (b)

Fig. 2. (a) Effect of temperature on flux of membrane; (b) Effect of temperature on separation factor

Different concentration of water and temperatures was chosen to determine the performance of Pervaporation process for separation of ethanol-water mixture. In view of this the feed weight percentage of water was varied from 6.25 to 14.34 and temperature from 45 ^{0}C to 75 ^{0}C. The result shows that the flux increased with temperature while the separation factor decreased as shown in fig. 2 (a) & (b) respectively



(a) (b)

Fig.3. (a) Effect of temperature on PSI; (b) Effect of temperature on Enrichment Factor

Fig.3 (a) & (b) shows that the composite parameter such as permeate separation Index (PSI) and enrichment factor changes with respect to temperature and feed concentration. As the operating temperature increased enrichment factor increases but permeate separation index (PSI) initially decreases and increases from temperature 45 ^{0}C to 60 ^{0}C, after that it decreases for all ethanol-water feed concentration range.

The experimental and model results for flux of membrane changes with respect to temperature and feed concentration were presented in Fig. 4. A good agreement was shown with experimental flux and model flux. At temperature 75 ^{0}C and 14.34 wt% of water in feed we got higher flux of membrane.

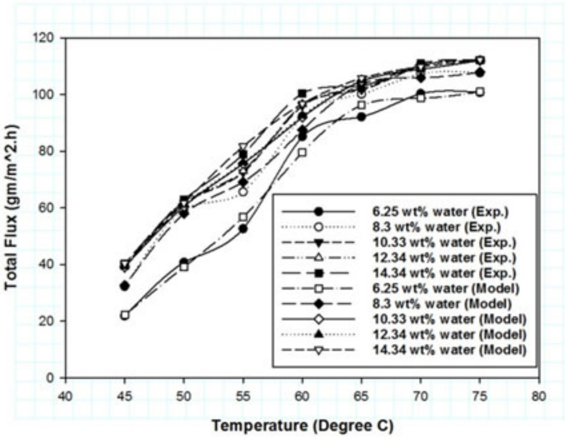


Fig.4. Comparison of experimental flux vs model flux with different wt% of water

4. Conclusion

The separation of ethanol-water (azeotropic mixture) mixture using PVA in Pervaporation was studied. The performance of Pervaporation membrane was analyzed by studying various parameters such as temperature, solution concentration. The effect of operating parameter like feed concentration and feed temperature on total flux of membrane, selectivity, permeate separation index (PSI) and enrichment factor were investigated. Effects of feed concentration and temperature on the membrane performance were found to be almost similar. Increasing wt % of water in feed and temperature increases total permeation flux, while decreases the membrane selectivity. This showed that PVA membrane have better affinity with water than ethanol. A good agreement showed between experimental and model data.

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