Dehydration of Nitric acid Solution by Membrane Distillation with Co-Current liquid flow regime

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INTRODUCTION:

Dehydration of nitric acid is a more complicated due to presence of azeotropic in the system at 68wt% nitric acid. The separation process is a hazardous in the chemical industry. Nitric acid was separating by adding the sulfuric acid in the system. This process is more capital and operating costs due to the separating the sulfuric acid water.

Membrane distillation is a separation process for liquid from liquid mixture by heating and evaporating the liquid and allowing the vapor to pass through a micro porous hydrophobic membrane and then condensed back into liquid by cooling in the other side of the membrane.

- It can perform below the boiling point of the liquid mixture.
- It can be use any form of low-grade heat energy from the industrial and solar system.
- It can have high selectivity of non-volatile solutes.

In this study, air gap membrane distillation was examined for separation of azeotropic mixture like, nitric acid - water mixture. The experiments were carried out by PTFE (Teflon) hydrophobic micro porous membrane. The effects of feed temperature, concentration, and flow rate were investigated under the steady state condition. The effect of Recirculation mode on dehydration of nitric acid – water mixture was also studied. The influence of the operating parameters on the permeate flux and selectivity of nitric acid was discussed.

EXPERIMENTAL:

The schematic diagram of the membrane distillation system was shown in the Figure 1. Membrane distillation system consists of three compartments: In the feed compartment, nitric acid solution where directly contact with membrane. Water was passed in the cooling compartment that is contact with condensing plate. Permeate was collect in the permeate compartment. The condensing plate was made of stainless steel. The feed and permeated were separated by hydrophobic micro porous (PTFE) membrane. The stainless steel grid was used as a membrane support to avoid membrane bending and wrinkling. The effective area of the membrane is 13.68 cm^2. The cooling water was maintained at 15°C and was recirculated. The effects of various operating parameters were studied under a non-recirculation feed solution and co-current (with cooling water) mode. Further, under a specific constant operating condition, feed solution was operated in a recycle mode.

Separation performance was evaluated in terms of permeate flux and selectivity. Selectivity represents the measure of the preferential transport of nitric acid based on the chemical analysis of permeate. A calibrated graduated cylinder was used to collect directly the permeate solution. The concentration of nitric acid in the permeate solution was obtained by titration (APHA 1998).

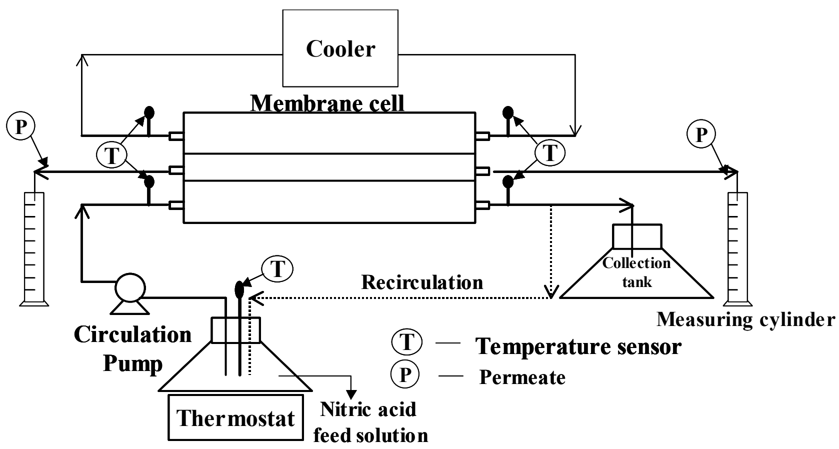

Figure 1. Schematic Diagram of Air Gap Membrane Distillation (AGMD).

RESULT AND DISCUSSION:

Effect of feed concentration:

The effects on the permeate flux and the selectivity of water was examined by varying feed concentration as shown in the figure 2. The permeate flux gradually decreases with increase the feed concentration of the nitric acid. The decrease of the flux up to azeotropic point, beyond the azeotropic point the flux will be increasing gradually. Above the azeotropic point the vapor containing rich in nitric acid but in the case of dilute nitric acid solution the vapor containing rich water. The selectivity of water was increased with increase the feed concentration. Above 25-wt% HNO_3, the selectivity of water decrease with increase of feed concentration due to decrease of activity of water in the feed. Wetting would have resulted in high fluxes and a drop in the selectivity as the pores filled with liquid and the feed solution passed into permeates. The selectivity of water and flux was decreased as the concentration increased.

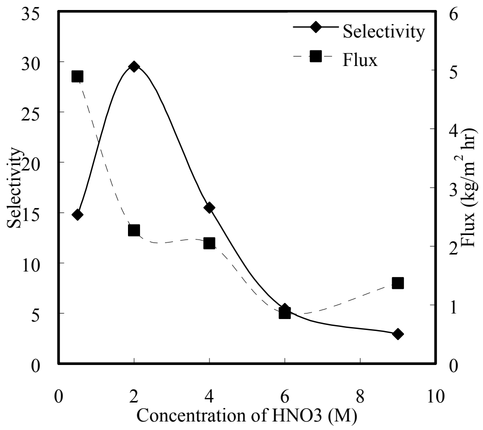

Figure 2. Effect of Feed Concentration on flux and selectivity of water.
(T_h = 80 ℃, q = 50 ml/min, T_c = 15 ℃)

Effect of feed temperature:

The experiments were studied the effect of flux and selectivity of water by means of changing the hot feed temperature Permeate flux was increased with increase temperature. The results were shown in the figure 3.The solid lines represent the best-fit lines to Arrhenius type expression that used in the literature when only one component is transported through the membrane. The selectivity of water was decreased with temperature until 80°C. After increasing the temperature selectivity of water was decreased marginally. This is due to the thermodynamic effect of temperature difference, combined with the kinetic effect and also effect of feed concentration, vapor pressure difference, activity coefficients on the partial pressures driving force.

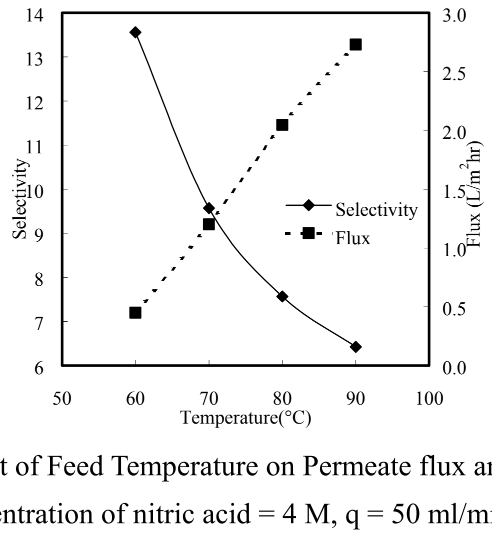

Figure 3. Effect of Feed Temperature on Permeate flux and selectivity of water.
(Concentration of nitric acid = 4 M, q = 50 ml/min, T_c = 15 ℃)

Effect of feed flow rate:

The effect of feed flow rate was studied on permeate flux and selectivity of water. The permeate flux was increased rapidly with feed flow rate. The permeate flux increase seems to reach maximum values asymptotically for higher feed flow rates. The selectivity of water was decreased with increasing the feed flow rate of the solution. This is due to the risk of membrane wetting increases at higher flow rate.

Recirculation of feed solution:

The effects of Recirculation mode on permeate flux, feed concentration and permeate concentration were studied. Initial volume of the feed solution was constant with varying initial concentration of feed solution. The inlet temperature of feed solution and inlet coolant temperature maintained constant throughout the experiment. The feed flow rate of nitric acid solution was 150ml/min. under the specific condition, the concentration of nitric acid was changed in permeate and feed solution during the experimental time. Both permeate and feed concentration was increased during experiment. Flux was decreased with increase in initial feed concentration of the solution.

CONCLUSION

The membrane distillation was examined to remove water from nitric acid solution using PTFE micro porous hydrophobic membrane. The effect of various parameters like feed temperature, concentration, and feed flow rate were studied to evaluate the selectivity of the membrane and permeate flux patterns. The experiments were conducted in a co-current liquid flow pattern. The effect of separation was also studied under feed recirculation mode. The selectivity of water and flux decreased with the increase in the feed concentration. Water and nitric acid was successfully separated by means of air gap membrane distillation.

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REFERENCE

1. Ames, L., Douglas Way, J., Bluhm, A., "Dehydration of nitric acid using perfluoro carboxylate ionomer membranes," *J. Membrane Sci.*, **249**, 65 (2005).
2. Kim, J., Kim, T.S., Jenog, D.Y., Ko, K.H., "Isotropic Water Separation using AGMD and VEMD," *NUKLEONIKA*, **49**, 4, 137 (2004).
3. Tomaszewska, M., Gryta, M., Morawski, A.W., "Study on the concentration of acids by membrane distillation," *J. Membrane Sci.*, **102**, 113 (1995).
4. Gostoli, C., sarti G.C., "Separation of liquid mixtures by membrane distillation," *J. Membrane Sci.*, **41**, 211 (1989).