OPERATIONS OF DIRECT CONTACT MEMBRANE DISTILLATION AND VACUUM MEMBRANE DISTILLATION ON SEAWATER DESALINATION

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ABSTRACT

The performances of DCMD and VMD in seawater desalination were studied in this work. The operating parameters included temperature difference, feed flow rate, and module inclination angle. The various channel design in the feed side was also investigated. The experimental results show that increasing the temperature difference will increase the distillate flux, but also heighten the polarization phenomena. The enhancement in distillate flux by increasing the feed flow was higher in DCMD operation than that in the VMD system. In DCMD system, the distillate flux increased as the module inclination angle increased, and reached a maximum at about 45°. Aeration in DCMD system also enhanced the flux. It is notable that the convex design in the feed channel could effectively reduce the polarization phenomena, and thus increase the distillate flux.

INTRODUCTION

Membrane distillation (MD) is a thermal driven process that is a combination of membrane technology and distillation. The applications of MD include the production of ultrapure water from salt solutions, concentration of solutions, purification of wastewater, etc. [1-8]. In the process, two streams with different temperatures are separated by a hydrophobic membrane. The vapor molecules transport from the side of higher temperature through the micro-sized pores of membrane, and then condense at the cooler side as the collected permeate. The permeate side has various operation modes, thus MD can be divided into direct contact membrane distillation (DCMD), vacuum membrane distillation (VMD), sweeping gas membrane distillation (SGMD), and air gap membrane distillation (AGMD).

The performance of MD is mainly related to the membrane properties, operating parameters and the module design [9-16]. In present work, the performances of DCMD and VMD will be investigated under various operating parameters, such as feed flow rate, feed temperature, gas addition and membrane inclination. And, the module with convex design in the flow channel will be also studied.

EXPERIMENTAL

The schematic flow diagrams of DCMD and VMD experimental setup are presented in Figs. 1 and 2, respectively. The seawater from the coast of Tamsui, Taiwan was prepared as the feed. The flat sheet of PTFE membrane (0.2 μm pore size, ADVANTEC) was adopted for the desalination operations. The operating parameters include feed temperature (313 – 343 K), feed flow rate (0.3 – 0.7 l/min) with addition of air flow rate (0.05 l/min) and the module inclination angle (0 – 90 degree).
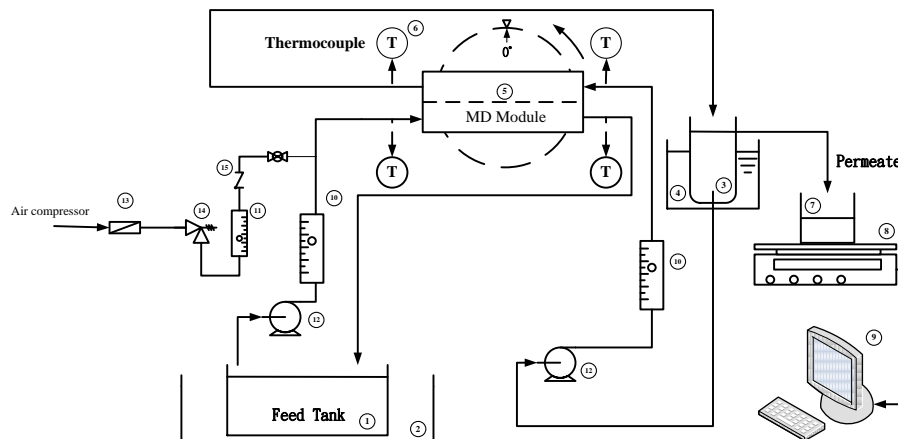

Fig. 1 Flow diagram of DCMD experimental setup.

The convex design in the feed channel was also investigated in this work. Four types of convex design, as shown in Fig. 3, were used to study the effect of convex on the performance of membrane distillation.
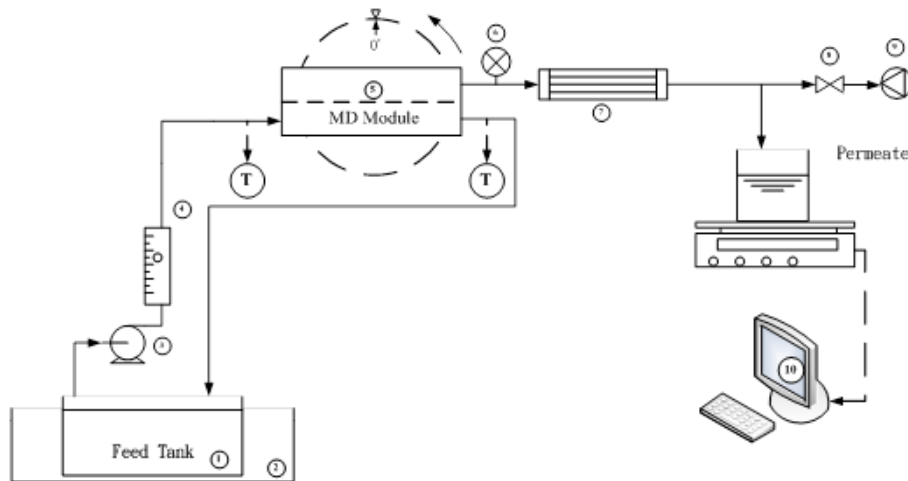
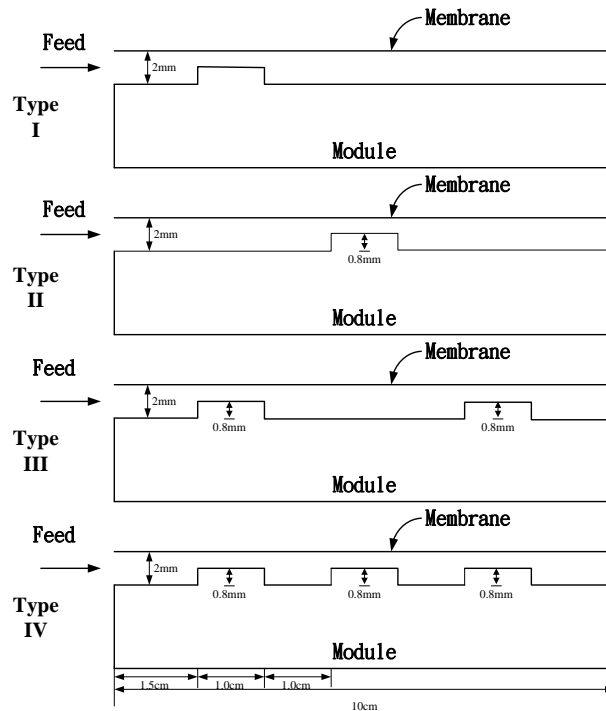Fig. 2 Flow diagram of VMD experimental setup.

Fig. 3 Various convex designs in the feed channel of membrane distillation.

RESULTS AND DISCUSSION

The permeate fluxes of DCMD and VMD operated at various feed temperature and feed flow rate are shown in Fig. 4. The flux increases with increasing the feed flow rate as well as the feed temperature. It is noted that the effect of temperature increment on the permeate flux is significant due to the increase of driving force by heightening the feed temperature. In addition, the permeate flux of VMD is larger than that of DCMD. The install of vacuum operation in the permeate side is benefit to the flux though the operating cost relatively increases.
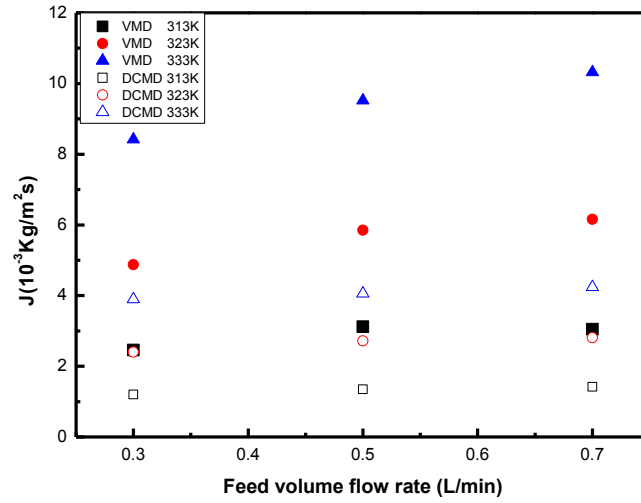
Fig. 4 Permeate fluxes of DCMD and VMD under various feed temperatures and flow rates.

The permeate fluxes of DCMD and VMD by varying the module inclination are shown in Fig. 5 where 0° means horizontal orientation while 90° is vertical position. It is known that the instability flow of natural convection can be induced by inclining the membrane. Though the effect of module inclination on these operations is not obvious, it is recommended that 45° is optimal for DCMD and 0° is the best for VMD.
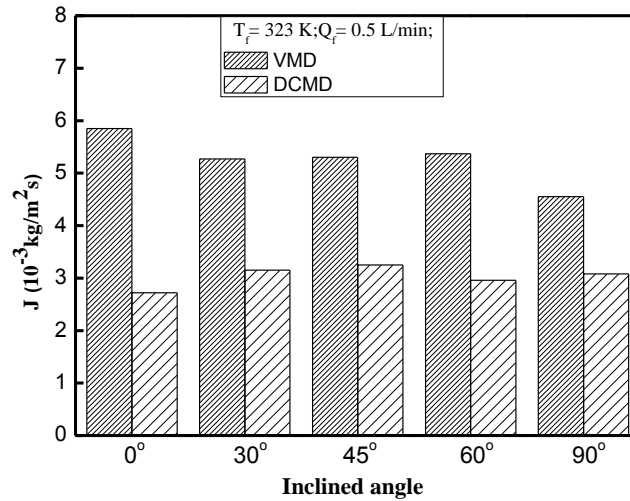

Fig. 5 Permeate fluxes of DCMD and VMD under various membrane inclinations.

The influence of aeration on the permeate flux of inclination operations is shown in Fig. 6. The introduction of air flow into the feed stream can create disturbances in the flow channel and potentially disturb the polarization layer near membrane surface. It shows that the effect of gas addition on the flux varies with the membrane orientation. In most inclinations of DCMD, the aeration does not aid to the flux improvement.
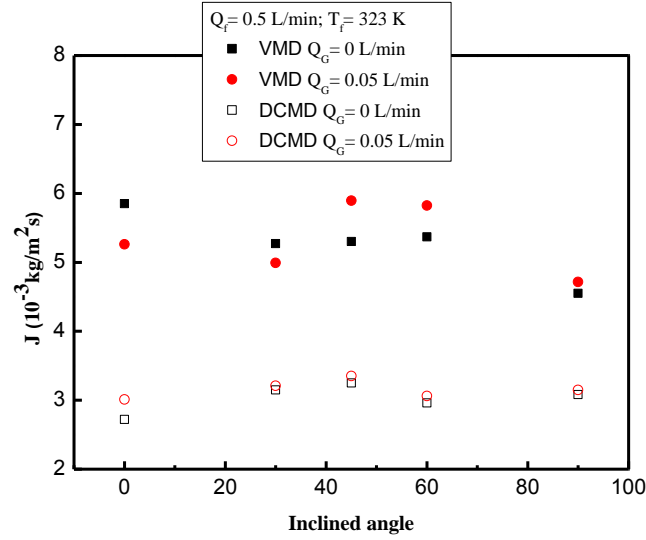
Fig. 6 Permeate fluxes of DCMD and VMD under inclination membrane with aeration.

The flux comparison between the original channel and convex type IV is shown in Fig. 7. At low feed flow rate (0.3 and 0.5 l/min), the design of type IV convex has a significant enhancement on flux for both the DCMD and VMD due to the disturbance on the membrane surface can be further improved by the convex design. However, the effect of this convex design becomes limited at the high flow rate (0.7 l/min).
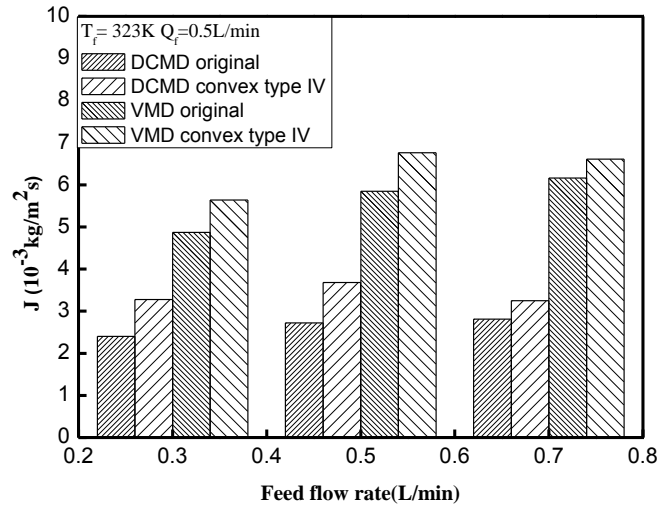

Fig. 7 Flux comparison between the original module and type IV convex module.

Figure 8 shows the comparison of flux between various convex designs. It is noted that both the position and number of convex in the flow channel are contribution to the flux improvement. For VMD operation, one convex at medium position (type II) is enough to provide a satisfied flux enhancement though more convex is further better. However, in the DCMD operation, the increase of convex in the feed channel results in a negative influence on the permeate flux because the area of dead zone behind each convex may grow as the flow rate increases.
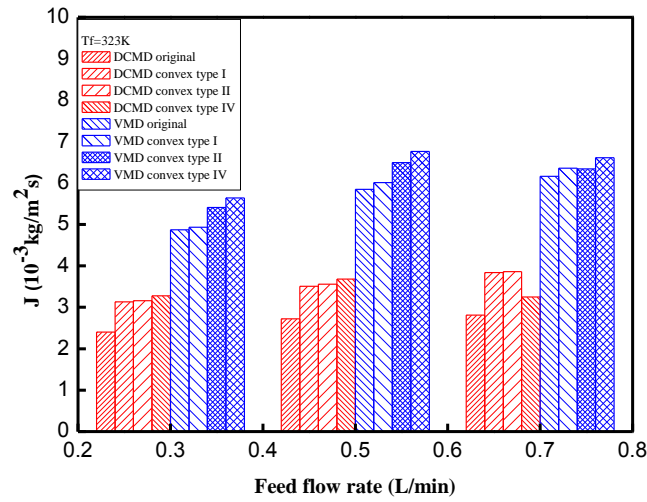
Fig. 8 Flux comparison between various convex designs.

The influence of the combination convex design with the addition of gas flow and membrane inclination on the permeate flux is shown in Fig. 9. It indicates that there are usually no multiple effects on flux enhancement with the addition of gas flow or membrane inclination. A proper convex design in flow channel is good enough to improve the MD performance.
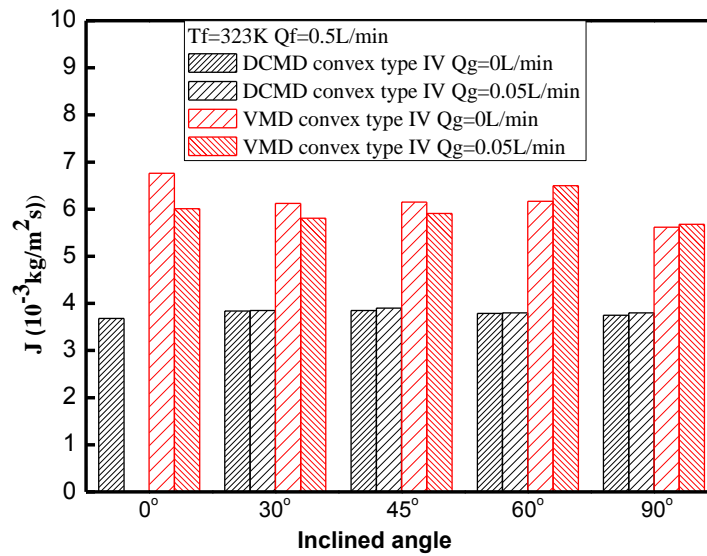

Fig. 9 Permeate fluxes under convex design combined with gas flow and membrane inclination.

CONCLUSIONS

The performances of DCMD and VMD were studied under various operating parameters, such as feed flow rate, feed temperature, gas addition, membrane inclination and convex design, in this work. The flux increases with the increase of feed flow rate and feed temperature, especially the effect of

temperature increment on the permeate flux is significant. The permeate flux of VMD is larger than that of DCMD though operation cost is higher for VMD. A proper convex design in flow channel is good enough to improve the MD performance. Both the position and number of convex in the flow channel are benefit to the flux improvement. For VMD operation, one convex at medium position (type II) is enough to provide a satisfied flux enhancement.

ACKNOWLEDGMENTS

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