Novel Vacuum Membrane Distillation Configuration for Water Vapor Flux Enhancement

Noreddine Ghaffour
A.S. Alsaadi, A. Alpatova, J.-G. Lee, L. Francis

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Membrane Distillation (MD)

Due to non-equilibrium conditions between the two sides, the most volatile species escape the meniscus formed at pores inlet and flow through the porous membrane in a vapor state to reach the permeate side and condense.
Parameters affecting the MD flux & energy efficiency

- **Process conditions**
  - ✓ Feed/coolant Temperatures
  - ✓ Feed water quality (salinity)
  - ✓ Flow velocity

- **Polarization**
  - ✓ Temperature polarization
  - ✓ Concentration polarization

- **Membrane**
  - ✓ Porosity
  - ✓ Pore size
  - ✓ Thickness
  - ✓ Tortuosity
  - ✓ Thermal conductivity

Heat transport through membrane Qm: HT due to flux Qn and HT due to conduction Qc (energy loss)

\[ EE = \frac{Q_N}{Q_m} = \frac{Q_N}{Q_N + Q_c} \]
Configurations

Direct Contact Membrane Distillation

Air Gap Membrane Distillation

Vacuum Membrane Distillation

Sweeping Gas Membrane Distillation

Water Gap, Material Gap, Conductive Gap Membrane Distillation
Temperature polarization effect is more significant than concentration polarization
Main controlling resistances in VMD

At low mass transfer resistance, the thermal separation process becomes heat transfer limited, and the opposite is true when the heat transfer resistance is lower.

\[ Q = h(T_b - T_i) = C_m(P_v - P_i) \]
Custom-made VMD module

A

- Vacuum port
- Pressure sensor
- Membrane
- Level indicator
- Inlet/outlet ports

B

- Applying vacuum
- Vacuum sensor
- Feed inlet
- Level indicator
- Feed outlet
Experimental set-up
Effect of TP on water vapor flux

After eliminating temperature polarization effect membrane distillation flux is controlled by the heat transfer coefficient.
Effect of TP on water vapor flux

Feed inlet temperature of 80 °C and 20 kPa

Cumulative water vapor weight (g)

Time (min)

- 119.5 kg/m²·hr
- 105 kg/m²·hr
- 90 kg/m²·hr
- 68 kg/m²·hr
- 40 kg/m²·hr
Temperature polarization can reduce membrane distillation feed temperature by as much as 10 °C at a membrane surface relative to the bulk feed temperature.
Membrane performance

Estimating water vapor flux at different $\Delta P$ for feed flow rate of 900 mL/min and at temperature of 70 °C after eliminating TP effect

Temperature polarization decreases the driving force by about 16.2 kPa
The coupling of heat and mass transfers in MD processes makes determining MD membrane MTC quite challenging due to the effect of TP. With our new concept:

- MD flux is controlled by the heat transfer coefficient.
- The currently available commercial membranes are good enough for scaling-up the process.
- TP can reduce MD feed temperature by as much as 10 °C at a membrane surface relative to the bulk feed temperature.
- Average water vapor fluxes of 9 kg/m².hr could be produced at ΔT of 5 °C.
Please find more details in:


Thank You

noredidine.ghaffour@kaust.edu.sa