Institut für Verfahrenstechnik

JOHANNES KEPLER UNIVERSITY LINZ | JKU

CHARACTERIZATION OF MACROPOROUS HYDROPHOBIC MEMBRANES USED IN MEMBRANE DISTILLATION PROCESS

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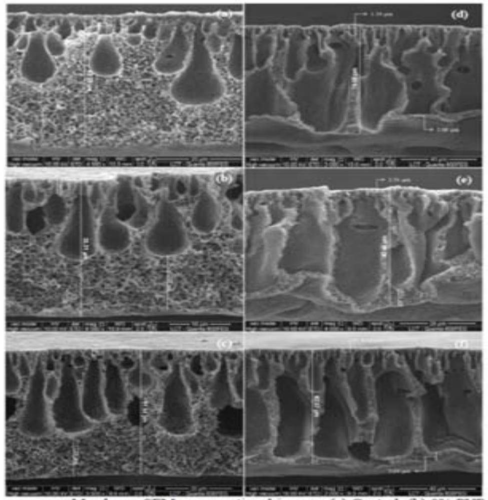
Outline

- Introduction (3W)
- Background (story)
- Theoretical
- Experimental (How)
- Results and discussions
- Summery

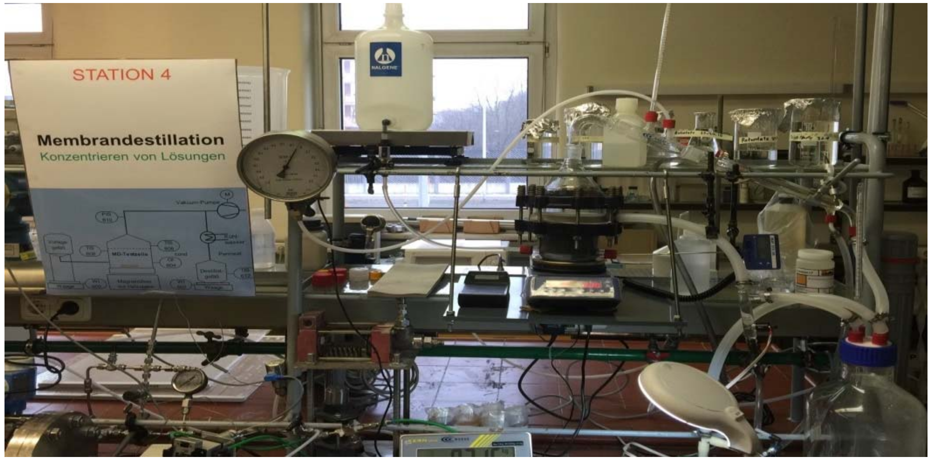
Introduction (3W)

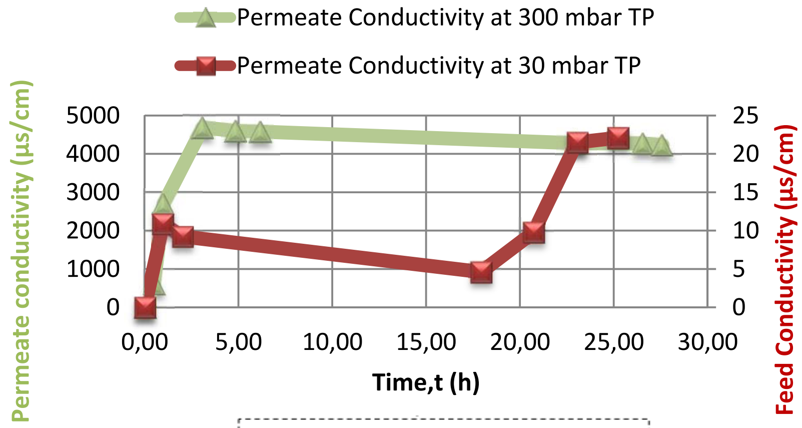
- What is characterization?
  - Morphological and physical properties
- Why characterization?
  - MD Performance ↔ Membrane morphology
  - Commercial MF membrane and manufacturer specification
- Which characters?
  - Mean Pore Size
  - Pore Size Distribution
  - Effective Porosity
  - Penetration Pressure

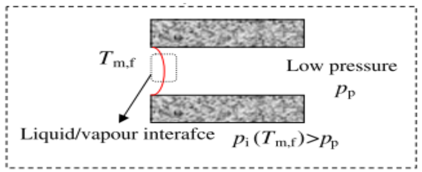


Membrane SEM cross-sectional images: (a) Control; (b) 0% PVP + 2% clay; (c) 0% PVP + 4% clay; (d) 1% PVP + 0% clay; (e) 1% PVP + 2% clay; (f) 1% PVP + 4% clay.

Background (story)







Understanding the membrane characteristcs is a prerequisite.

Theoretical - 1

- **Mean pore size and effective porosity by gas permeation test**
  - $B_g = \frac{2}{3}\left(\frac{2}{\pi MRT}\right)^{0.5} d_P \varepsilon_e + \frac{P_m}{16\mu RT} d_P^2 \varepsilon_e = I_0 + S_0 P_m$
  - $d_P = \frac{32}{3} \frac{S_0}{I_0} \left(\frac{8RT}{\pi M}\right)^{0.5} \mu$
  - $\varepsilon_e = \frac{32\mu RT}{d_P^2} S_0$

B_g = gas permeance (*mol m*$^{-2}$ *s*$^{-1}$ *Pa*$^{-1}$)
P_m = mean pressure (*Pa*)
I_0 = intercept of B_g vs. P_m plot
S_0 = slope of B_g vs. P_m plot
M = the molecular weight of the gas (*g mol*$^{-1}$)
R = the gas constant (*Pa m*^{3} *mol*$^{-1}$ *K*$^{-1}$)
T = absolute temperature (*K*)
d_P = pore diameter (*m*)
μ = gas viscosity (*Pa s*)
ε_e = effective porosity (*m*$^{-1}$)

Theoretical - 2

- **Maximum pore size, the mean pore size and the pore size distribution by liquid displacement method**
  - $n_a(j) = \sum_{K=1}^{j} n_d(k)$
  - $n_d(j) = K \frac{g_d(j)}{d_p(j)^2}$
  - $g_d(j) = \frac{g'_a(j+1) - g'_a(j-1)}{2}$
  - $g_a(j) = 1 - g'_a(j) = 1 - \frac{J_W(j)}{J_D(j)}$
  - $K = \frac{g_a(n)}{\sum_{j=1}^{n} g_d(j)/d_p(j)^2}$
  - $\frac{df(d_p)}{d(d_p)} = \frac{1}{d_p ln(\sigma_p (2\pi)^{0.5})} exp\left[-\frac{(\ln(d_p) - \ln(\mu_p))^2}{2(ln(\sigma_p))^2}\right]$

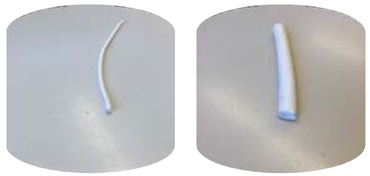
n_a = cumulative distribution of number of pores
$n_d(j)$ = number of the j^{th} pores (with size $d_p(j)$)
$g_d(j)$ = incremental flow rate ratio occurring in j^{th} pores
J_w = gas permeation rate through wet membrane
J_d = gas permeation rate through dry membrane
K = normalization factor
μ_p = mean pore size (50% of cumulative number of pores)
σ_p = geometric standard deviation (ratio of 84.13% of cumulative number of pores to that of 50%)

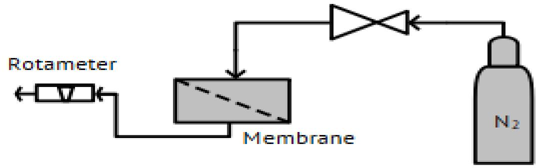
Experimental - 1

- **Materials**
  - — ACCUREL® PP V8/2HF and PP 150/330
- **Membrane characterization methods**

  1. **Gas permeation test**

  — $J = \frac{101{,}325}{\Delta P}\frac{1}{RT}\frac{1}{A}\frac{dV}{dt}$





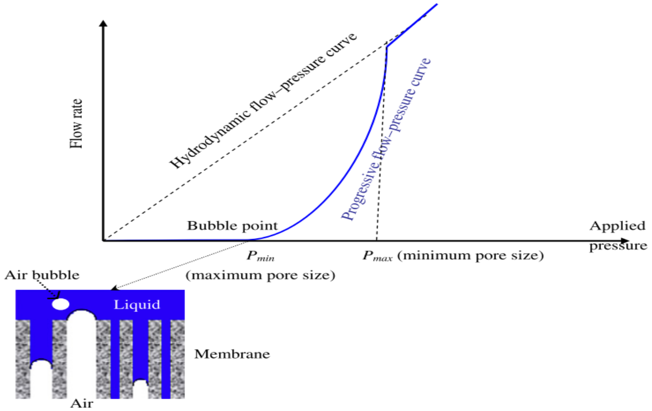
J = gas permeance (molm^{-2} Pa^{-1} s^{-1})
Δp = transmembrane pressure drop (Pa)
T = absolute temperature (K)
V = volume of gas permeated through the membrane (m3)

A = effective membrane area (m^2)
t = permeation time (s)
R = universal gas constant (8.314 J mol^{-1} K^{-1})
101,325 = atmospheric pressure in Pa

Experimental - 2

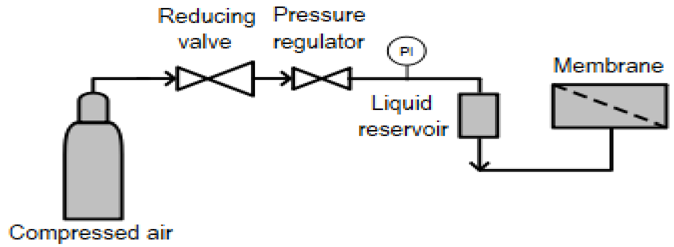
- **Membrane characterization methods (cont.)**

2. Liquid displacement method

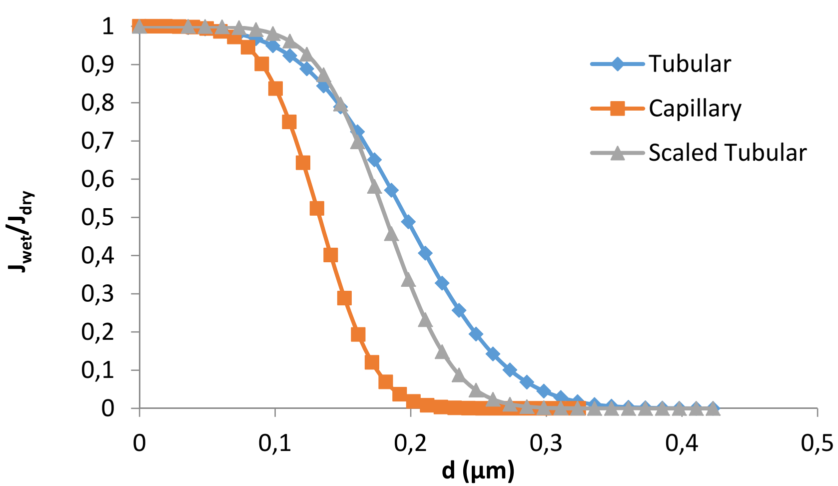


3. Liquid entry pressure measurement

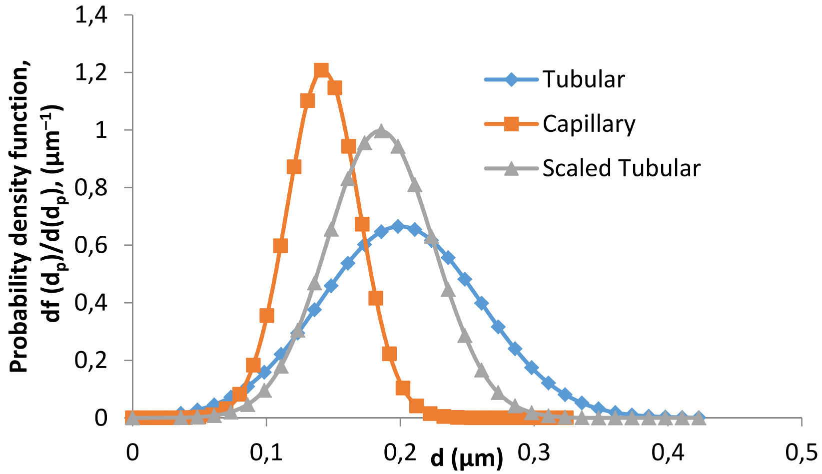
- Type of Alcohol
- Alcohol Concentration
- Membrane Type



Results and discussions - 1



Ratio of dried membrane gas permeance to wetted membrane gas permeance versus pore radius

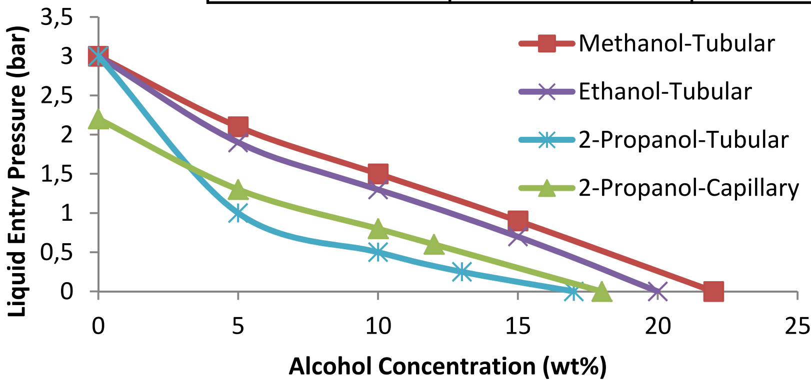


Pore size distributions

Results and discussions - 2

Pore diameter and effective porosity by gas permeation test

Membrane name	Material	Bubble point (bar)	Mean pore diameter (µm)	Effective porosity (m-1)
PP V8/2HF	Polypropylene	1.07	0.136	6572.12
PP 150/330	Polypropylene	1.1	0.195	6020.43



Liquid entry pressure as a function of alcohol concentration for different alcohols in aqueous solutions and effect of membrane type on LEP. Solid lines represent the fits of the experimental data

The length of the alcohol hydrocarbon chain ⇧ ⇨ LEP ⇩ ⇨ Wettability ⇧

The pore size ⇧ ⇨ LEP ⇩ ⇨ Wettability ⇧

Summery

- **Gas permeation test**
  — to measure the diameter of the large pores of the membrane
- **liquid displacement method**
  — to measure the diameter of the smaller pores of the membrane
- **Liquid entry pressure measurement**
  — to determine the minimum required pressure for wetting

Membrane morphology ↔ MD Performance

The application of MD (to ensure MD efficiency and to avoid pore wetting) is aided by knowing the membrane morphological parameters

Thank you for your attention!

The End!