The estimation of concentration polarization layer resistance during salt solutions reverse osmosis

Serhii Huliienko[1], Olha Protsiuk[1]

1. Department of Machines and Apparatus of Chemical and Oil Refinery Productions, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", UKRAINE, Kyiv, Prosp. Peremohy, 37, 03056, E-mail: sergii.guliienko@gmail.com

Abstract – The experimental determination of the concentration polarization layer during salt solutions reverse osmosis. It was defined that assumption about linear dependence of concentration polarization layer resistance from applied pressure is reasonable not only for ultrafiltration but also for reverse osmosis.

Keywords – membrane, reverse osmosis, concetration polarization, resistance, pressure, mass tramsfer

Introduction

The concentration polarization phenomenon is one of the most significant problems in applications of pressure-driven membrane processes, which often lead to bigger problems such as fouling formation and irreversible drop of membrane units productivity. Taking into account these phenomena, according to [1] the transmembrane flux could be described by that equation:

$$J = \frac{\Delta p - \Delta \pi}{\mu \cdot (R_m + R_{cp} + R_f)} \qquad (1)$$

The methods for determination of membrane resistance (Rm) and fouling resistance (Rf) are described in works [1] and [2] but reliable dependencies for determination of concentration polarization layer (Rcp) was not found in the literature.

The most comprehensive research about the concentration polarization layer resistance was done in work [3]. In that work, the assumption about linear dependence between concentration polarization and applied pressure has been done. The proportional coefficient was determinated from experimental data approximation using the dependence obtained from transformation of Eq. (1):

$$\frac{1}{J} = \mu \cdot (R_m + R_f) \frac{1}{\Delta p} + \mu \cdot \psi \qquad (2)$$

However, the physical sense of proportional coefficient and extends of usability of that technique have been not described in work [3]. In our recent work [4] the attempt of determination of concentration polarization layer resistance and validate of the possibility of using such technique for reverse osmosis have been done, but the obtained results were not allowed to confirm mentioned assumption. However, the feasible reason for this problem was a big step of applied pressure variation. The purpose of present work is the evaluation of the concentration polarization layer and examination the assumption about linear dependence between the concentration polarization layer and applied pressure.

Materials and methods

The research was carried out on the experimental set-up of crossflow reverse osmosis with new (without fouling) membrane modules TFC-75. The NaCl solutions and deionized water were used as test solutions. The step of applied pressure variation was 0.02 MPa whereas in previous work it was 0.1 MPa [4]. The range of applied pressure variations was 0.2–0.6 MPa. The experiments were carried out under the temperature of the environment.

Results and dicussions

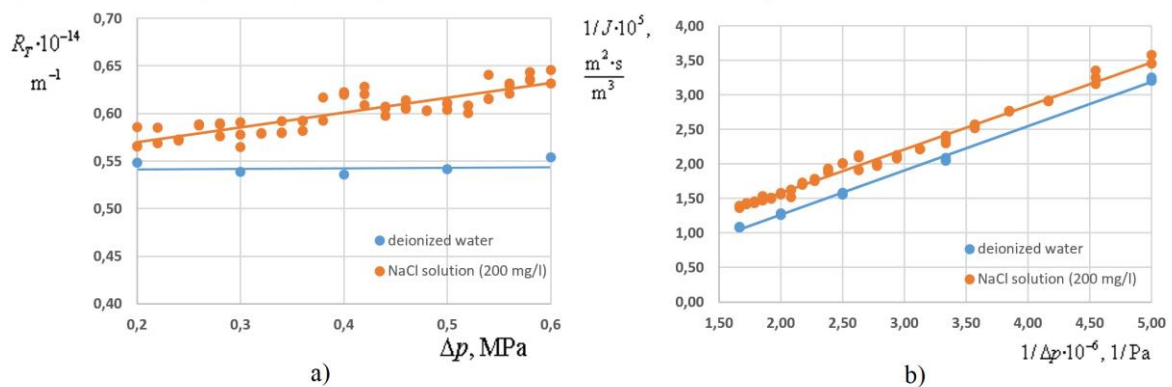The results of experimental research are shown on Fig. 1.

Fig. 1. The results of experiments: a) dependence of total resistance to mass transfer thorough the membrane from applied pressure b) dependence $1/J = f(1/\Delta p)$

From the dependence of total resistance from applied pressure (Fig. 1a) it could be seen that when deionized water is used as test solution the total resistance did not change with applied pressure with confirms the conclusions about absence change in membrane productivity due to compression obtained in previous work [4]. When the salt solutions were separated by reverse osmosis, the increasing of total resistance with applied pressure was observed which are close to linear. In considered conditions, the total resistance was the sum of membrane resistance and concentration polarization layer resistance, therefore, concentration polarization layer resistance also increases linearly. The reason of scattering of points is the deviation from isothermal condition during experiments. However, even in such conditions, the dependence of resistance from applied pressure could be approximated by a linear equation with the correlation coefficient of 0.85, which gives evidence that mentioned assumption is reasonable. Moreover, from Fig 1b, it could be seen that dependence $1/J=f(1/\Delta p)$ can be approximated by linear equation (correlation coefficient is 0.95) which confirmed that technique proposed in [3] is also suitable for reverse osmosis.

Conclusion

The assumption about linear dependence between concentration polarization layer resistance and the applied pressure is reasonable. The technique for data analysis of membrane productivity proposed in work [3] for ultrafiltration also can be used for reverse osmosis.`

References

[1] Shirazi S., Lin C.-J., Chen D., "Inorganic fouling of pressure-driven membrane processes – A critical review, " *Desalination*, vol. 250, no. 1, Jan., pp. 236-248, 2010

[2] Sioutopoulos D., Karabelas A., "The effect of permeation flux on the specific resistance of polysaccharide fouling layers developing during dead-end ultrafiltration," *Journal of Membrane Science*, vol. 473, Jan., pp. 292–301, 2015.

[3] Macedo A., Duarte E., Pinho M., "The role of concentration polarization in ultrafiltration of ovine cheese whey," *Journal of Membrane Science*, vol. 381, no. 1-2, Sep., pp. 34–40, 2011.

[4] Huliienko S., Leshchenko O., "Ekspery`mental`ne vy`znachennya oporu sharu koncentarcijnoyi polyary`zaciyi pry` zvorotnomu osmosi, " In Membranni procesy` ta obladnannya v xarchovy`x texnologiyax ta inzheneriyi, Kyiv, 2018, pp. 21.