Gas Permeation Through the Polymeric Membrane - Fluid Behavior in the Permeate Channel

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Abstract

For membrane gas separation modeling, some assumptions are made. One of the most typical approaches in such modeling is to assume a plug flow in the feed/retentate channel and ideal mixing conditions in the permeate channel. For membranes with high permeation, the permeate flux could be quite large. Then the Peclet number reaches high values, Pe >> 1. Such Pe values do not allow one to assume ideal mixing conditions in the permeate channel. This paper's aim is to calculate and to show the real behavior of fluid in the permeate channel, when Pe >> 1.

For the numerical simulation, the COMSOL Multiphysics® software package was used. Tubular membrane was modelled in the 2D axisymmetric geometry. Transport of Concentrated Species and Laminar Flow physics interfaces as well as Fick's permeation equation were applied to the calculations.
The results were obtained for the membrane's thickness 0.5 μm and the membrane's ideal selectivity factor 17. The feed pressure is 10 bar, the retentate pressure is 9.5 bar, while the permeate outflow is open to the atmosphere. The flow of the feed and the permeate is concurrent. The Peclet number in the permeate channel calculated for this case is Pe=890.

The obtained results clearly show that there is no ideal mixing in the permeate channel. There is the plug flow as in the feed channel. However, while the difference in molar fraction in the feed channel is 0.12, the difference in the permeate channel is only 0.0189. That is why many authors assume ideal mixing conditions in this channel. The most important conclusion is that in the permeate channel there are no ideal mixing conditions, there are only small differences between the extreme concentration values along the membrane length.

Reference

Pfister, M., Belaissaoui, B., & Favre, E. (2017). Membrane Gas Separation Processes from Wet Postcombustion Flue Gases for Carbon Capture and Use: A Critical Reassessment. Industrial & Engineering Chemistry Research, 56(2), 591-602.

Figures used in the abstract

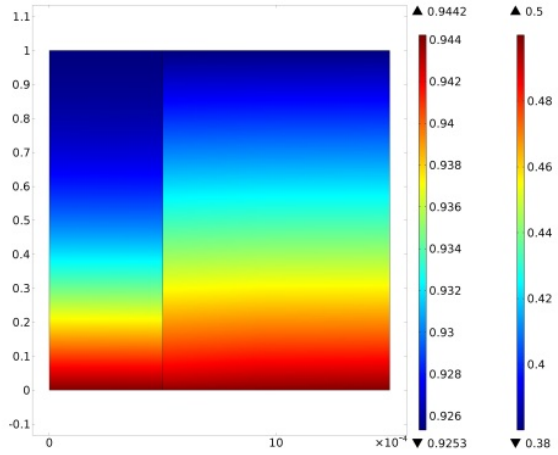

Figure 1: Molar fraction of selected species in feed and permeate channel.