Energy Efficient Design of Membrane Processes by use of Entropy Production Minimization

Elisa Magnanelli [C]
Department of Chemistry, Norwegian University of Science and Technology, Trondheim, Norway
elisa.magnanelli@ntnu.no

Øivind Wilhelmsen
Department of Energy and Process Engineering, Norwegian University of Science and Technology, Trondheim, Norway

Signe Kjelstrup[S]
Department of Chemistry, Norwegian University of Science and Technology, Trondheim, Norway

To minimize entropy production means to reduce the useful work which is lost in a process, and, therefore, to contribute to the optimal use of energy resources. Membranes for separation of CO_2 from natural gas are a promising technology. However, due to the need for re-compression of the permeate stream, membrane separation units might require very large amounts of electrical power. We show how this power requirement can be reduced by controlling the permeation process so that the entropy production is minimum. In the present work, we use optimal control theory to minimize the total entropy production of a membrane unit for separation of CO_2 from natural gas, by control of the partial and total pressures on the permeate side. We find that by controlling the permeate partial pressures, the total entropy production can be significantly reduced (circa 38 %), while the reduction is lower when only the total permeate pressure is controlled (circa 6.4 %). The continuous optimal results can serve as an ideal limit useful to formulate guidelines for the practical design [1]. A three-step permeate pressure that approximates the optimum reduces the entropy production by 5.3 %. This corresponds to a reduction of the compressor power of 3.8 %, when the permeate gas is re-compressed to be further processed.

References:

[1] Kjelstrup S, Bedeaux D, Johannessen E, Gross J. Non-Equilibrium Thermodynamics for Engineers. World Scientific Publishing Co (2017) p.215