Mathematical Modelling of Membrane based Carbon Dioxide Removal from Natural Gas using Spiral Wound Membrane

by

Syazwani Balqis Bt Dilah

Dissertation submitted in partial fulfilment of
the requirement for the
Bachelor of Engineering (Hons)
(Chemical Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

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(Dr Nurhayati Mellon)

UNIVERSITI TEKNOLOGI PETRONAS
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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(Syazwani Balqis Bt Dilah)

ABSTRACT

This Dissertation covers the introduction, literature review, methodology, results, discussions and some recommendations for the project entitled "Mathematical Modelling of Membrane Based Carbon Dioxide Removal from Natural Gas using Spiral Wound Membrane". Recently, many modelling of membrane is carried out to improvise the current membrane used for separation of carbon dioxide from the raw natural gas but the recent research studies mostly focussed on the development and optimization of Hollow Fibre membrane for sweetening of natural gas instead of the traditional Spiral Wound membrane. Thus, this project aims to develop a mathematical model of Spiral Wound membrane for natural gas treatment with three parameters to analyse: feed temperature, feed pressure, and permeate pressure. Model is developed based in cross-flow model derived by Weller and Steiner for gas separation by using spiral wound membrane through MATLAB. The base operating condition used in for the model is according to literature review from various sources including journals and books. The model proves that feed and permeate pressure has great influence on the membrane performance. The influence of the operating conditions (feed pressure, permeate pressure and CO_2 composition in the feed stream) on the design parameters (membrane area, methane loss, methane recovery and concentration of CO_2 removed) has been studied. It is shown that increase in feed pressure and low permeate pressure leads to higher rate of permeation thus reducing membrane area, improving methane recovery, minimizing methane loss and more CO_2 is removed due to greater driving force across the membrane. Higher CO_2 content in the feed shows decline in membrane performance.
In conclusion, the mathematical modelling of spiral wound membrane using Weller and Steiner method has proven its ability to compute the desired performance modelling for the separation of CO_2 from natural gas.

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ABBREVIATIONS AND NOMENCLATURES

US	United States
CH_4	Methane
CO_2	Carbon Dioxide
H_2S	Hydrogen Sulphide
C_{3+}	Heavier Carbon
N_2	Nitrogen
He	Helium
H_2	Hydrogen
CO	Carbon Monoxide
ppm	Parts per million
Btu/scf	British unit per standard cubic feet
℃	Degree Celsius
ODE	Ordinary Differential Equation
FYP I	Final Year Project 1
FYP II	Final Year Project 2
L_f	Flowrate of feed stream (cm^3(STP)/s)
L_r	Flowrate of retentate stream (cm^3(STP)/s)
V_p	Flowrate of permeate stream (cm^3(STP)/s)
x_f	Composition of feed
x_r	Composition of retentate
y_p	Composition of permeate
p_h	Pressure of high pressure feed side (cmHg)
p_l	Pressure of low pressure permeate side (cmHg)
t	Thickness of membrane (cm)
α_{AB}	Ideal separation factor
P'_A	Permeability of A (cm^3(STP).cm/(s.cm^2.cmHg)
P'_B	Permeability of B (cm^3(STP).cm/(s.cm^2.cmHg)
θ	Total fraction of permeate

$\boldsymbol{\theta}^*$	Fraction of permeate up to value of x
$\boldsymbol{i}$	Fraction of stream composition
$\boldsymbol{i_f}$	Fraction of stream composition at the feed
$\boldsymbol{i_r}$	Fraction of stream composition at the retentate
$\boldsymbol{u_f}$	value of u at $i = i_f = \frac{x_f}{1-x_f}$
$\boldsymbol{A_m}$	Membrane area (cm^2)