Technical Performance Assessment of Intensified Post-combustion Capture Process based on RPB technology through Modelling and Simulation

Atuman S. Joel, *Meihong Wang
Process/Energy Systems Engineering Group, School of Engineering,
University of Hull, HU6 7RX, UK

Abstract

Global climate change has been linked to anthropogenic gas emissions. Recent study by International Energy Agency (IEA) indicates that energy sector generate 68 % of the world anthropogenic gas and out of this percentage CO_2 emission accounts for 90% of all the anthropogenic gases emitted (IEA, 2015). The major sources of CO_2 emission comes from fossil fuel-fired power plants, therefore capturing CO_2 from such sources is necessary if the projected future danger in climate conditions is to be avoided. The suitability of post-combustion carbon capture (PCC) based on chemical absorption technology for fossil fuel-fired power plants has been highlighted by many researchers being the most matured with already large scale projects operational in Canada. Despite the success in the use of PCC for power plant, it has challenges such as huge sizes of the Absorber and Stripper, leading to high capital cost (Lawal et al., 2012, Agbonghae et al., 2014). Process intensification (PI) using rotating packed bed (RPB) is the technology that has the potential to reduce the size of a column by order of magnitude without compromising the performance of the columns (Ramshaw, 1995).

This work models and simulates standalone intensified absorber and stripper, then linked the two validated models to form a closed loop intensified PCC process. Four different correlations suitable for RPB were implemented in Aspen Plus rate-based model to replace the default correlations. These correlations are written in visual FORTRAN and then dynamically linked with Aspen Plus rate-based model. The model now represents intensified Absorber/Stripper. These four new correlations are for liquid and gas mass transfer coefficient, liquid hold-up and interfacial area. Pressure drop correlation suitable for RPB was also included. Heat transfer correlation given by Chilton and Colburn analogy was used.

The standalone models developed in Aspen Plus and Fortran were validated based on the experiment data presented in Jassim et al. (2007) and Cheng et al. (2013). Previous study by Joel et al. (2014) shows that standalone intensified absorber is 12 times smaller than conventional packed tower. In this paper, study on standalone intensified stripper compared to conventional stripper using MEA solvent shows a 10 times reduction in size. The impact of solvent concentration, liquid to gas (L/G) ratio and lean-MEA loading on closed loop intensified PCC process performance is also studied.

Impact of high MEA concentration in reducing solvent recirculating rate is studied. The cost implication of concentrated amine compared to lower MEA concentration solvent for capture process were analysed. Also the energy contribution of motors used in driving the RPB absorber and stripper is included in the regeneration energy calculations. Finally, after looking at the efficiency improvement and cost implication for intensified PCC process compared to conventional packed columns using solvent, it is concluded that PI has great potential for use in carbon capture application.

Keywords: Post-combustion CO_2 capture, Chemical Absorption, MEA solvent, Process Intensification (PI), Rotating Packed Bed (RPB), Process simulation

Acknowledgement: The authors would like to acknowledge financial support from EPSRC Research Challenges in Carbon Capture for CCS (Ref: EP/M001458/1) and EU FP7 International Staff Research Exchange Scheme on power plant and carbon capture (Ref: PIRSES-GA-2013-612230).

* *Corresponding author:*
Email address: Meihong.Wang@hull.ac.uk
Tel: +44 (0)1482 466688; Fax: +44 (0)1482 466664

Reference

Agbonghae, E.O., Hughes, K.J., Ingham, D.B., Ma, L. & Pourkashanian, M. (2014) Optimal Process Design of Commercial-Scale Amine-Based CO_2 Capture Plants. *Industrial & Engineering Chemistry Research,* 53 (38), 14815-14829.

Cheng, H., Lai, C. & Tan, C. (2013) Thermal regeneration of alkanolamine solutions in a rotating packed bed. *International Journal of Greenhouse Gas Control,* 16 206-216.

IEA (2015) CO_2 Emissions from Fuel Combustion IEA Statistics Highlights. *Available at: Https://Www.Iea.Org/Publications/Freepublications/Publication/CO2EmissionsFromFuelCombustionHighlights2015.Pdf (Accessed January, 2016),* .

Jassim, M.S., Rochelle, G., Eimer, D. & Ramshaw, C. (2007) Carbon dioxide absorption and desorption in aqueous monoethanolamine solutions in a rotating packed bed. *Industrial & Engineering Chemistry Research,* 46 (9), 2823-2833.

Joel, A.S., Wang, M., Ramshaw, C. & Oko, E. (2014) Process analysis of intensified absorber for post-combustion CO_2 capture through modelling and simulation. *International Journal of Greenhouse Gas Control,* 21 (0), 91-100.

Lawal, A., Wang, M., Stephenson, P. & Obi, O. (2012) Demonstrating full-scale post-combustion CO_2 capture for coal-fired power plants through dynamic modelling and simulation. *Fuel,* 101 (0), 115-128.

Ramshaw, C. (1995) The incentive for process intensification. *Proceedings of the first international conference on process intensification for the chemical industry.* BHR Group, London.