Experimental study of CO\textsubscript{2} absorption in a diameter-varying spray tower

Xiaomei Wu\textsuperscript{1,2}, Yunsong Yu\textsuperscript{1}, Zhen Qin\textsuperscript{1,2}, Zaoxiao Zhang\textsuperscript{1,2,*}

1. School of Chemical Engineering and Technology, Xi’an Jiaotong University, No.28 Xianning West Road, Xi’an 710049, P.R. China

2. State Key Laboratory of Multiphase Flow in Power Engineering, Xi’an Jiaotong University, No.28 Xianning West Road, Xi’an 710049, P.R. China

* Corresponding author. Tel: +86-29-82660689 E-mail: zhangzx@mail.xjtu.edu.cn.

Abstract:

Greenhouse effect has become a huge challenge for the sustainable development of the world. It is well known that CO\textsubscript{2} is the major greenhouse gas that contributes to global warming more than 60%, resulting in the urgent demand to reduce the CO\textsubscript{2} emission. Currently, post-combustion CO\textsubscript{2} capture is a promising choice in the near-to middle-term, since it can be retrofitted to the existing power plants. Chemical absorption is generally recognized as the most mature technology for industrial application, and monoethanolamine (MEA) is the most widely used absorbent.

Conventional MEA absorption process suffers from high energy consumption due to its immense steam consumption in the regeneration process, leading to the extremely high operating cost for industrial application. To reduce the high cost of chemical absorption, researchers tried to improve the typical CO\textsubscript{2} absorption process in several aspects like exploring new absorbents, improving absorbing equipment and strengthening the process. Numerous studies have been carried out on the improvement of MEA absorption in packed columns and a vast number of meaningful conclusions have been obtained. But it is not yet fully developed for application and may not be economically competitive. Packed columns generally suffer from high gas-phase pressure drop, liquid channeling and flooding, deposition onto the packing material and so on. To avoid these problems, researchers proposed a type of spray towers with no solid packing material inside and the absorbing solution is sprayed as fine droplets for absorption. Since the spray towers are empty columns, there will be a lower pressure drop for the gas flow and a wider range of gas to liquid loading ratios compared to the traditional packed columns. In addition, with the simpler structure compared with typical packed columns, the spray towers cost less for construction and maintenance.

The application of spray towers for CO\textsubscript{2} capture is a development trend in recent years. However, most of the previous jobs were conducted in a cylindrical tower by using a single spray nozzle, whose configuration and performance is not good enough for industrial application. Furthermore,
droplets coalescence and wall flow would cause a rapid reduction of interfacial area leading to a low mass transfer rate. To solve this problem, the present work proposed a diameter-varying spray tower and a new spray mode of dual-nozzle opposed impinging spray to enhance the heat and mass transfer of CO$_2$ absorption process. Experiments were performed to investigate the mass transfer performance (in terms of the CO$_2$ removal rate ($\eta$) and absorption rate per volume ($\Phi$)) of the improved spray tower. The effects of operating parameters including liquid flow rate, MEA concentration, total gas flow rate, CO$_2$ inlet concentration, liquid to gas ratio and mole ratio of MEA to CO$_2$ were tested over a wide operating range. Experimental results showed that the liquid to gas ratio and mole ratio of MEA to CO$_2$ were major factors which affect the absorption performance. Under the experimental conditions, maximums of $\eta$ and $\Phi$ are 94.0% and 2.735 kmol $\cdot$ m$^{-3}$ $\cdot$ h$^{-1}$ respectively. Furthermore, compared with CO$_2$ absorption in a packed column, the diameter-varying dual-nozzle opposed impinging spray tower shows better performance, which demonstrates a great potential of using the improved spray tower in CO$_2$ capture system.