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Review of design correlations for CO_2 absorption into MEA using structured packings

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ABSTRACT

A good knowledge of design correlations is essential to provide the best possible scale-up data in order to know and remove technical risks related to the design and operation of a full scale CO_2 capture plant. Hydrodynamics and mass transfer correlations for structured packed columns have been compared for two cases: absorption of CO_2 from gas-fired power plants and absorption of CO_2 from coal-fired plants to take account of the impact of operating conditions and hydraulics of a packed column in a large scale CO_2 capture plant. The study showed that there is a large uncertainty associated with applying the proposed correlations in a large scale of packed column. The uncertainty can be explained by three main factors: (i) the model which correlations developed is based on; (ii) the data for development and verification of the models, and (iii) the calculation approach which is related to mathematical expressions (complexity of the model).

1. Introduction

Anthropogenic emissions of carbon dioxide (CO_2) are the most significant contributor to the greenhouse gases and thereby to the global warning. One source of CO_2 emission is fossil fuelled power plants (gas-fired, coal-fired), and others are transportation and industries. A drastic reduction of CO_2 emissions from fossil fuels can be obtained by improving the efficiency of power plants and production processes, reducing the general energy requirement, and by applying carbon dioxide capture and storage (CCS), (Abu-Zahra et al., 2007). CCS is a technology which is based on capturing CO_2 from fossil-fuel power plants, compression, transportation and injection of CO_2 into deep geologic formations or abandoned gas reservoirs. Another way to reduce carbon dioxide emissions is to use carbon-free energy sources like solar power, wind power, geothermal energy, low-head hydropower, hydrokinetics (e.g., wave and tidal power), and nuclear power (Audus et al., 1996). Also, using low-carbon fuels such as natural gas instead of high-carbon fuels like coal and oil, will also lead to a reduction in carbon dioxide emissions.

There are three different approaches for scrubbing CO_2 emissions (José D. Figueroa et al., 2008):

a) In post-combustion: dilute CO_2 is separated from the flue gas steam coming from fossil-fuel power plants. This technique can be applied to new and existing coal or gas power plants (retrofit). Several methods for CO_2 capture are thinkable for post-combustion capture, like chemical absorption, physical absorption, membrane separation, adsorption, and cryogenic. However, only chemical absorption is presently a viable option for CO_2 post-combustion capture. The technology has already been in use for the capture of CO_2 from ammonia plants and other industrial applications. Although commercialized, the technique is not tested at full scale for power plants.
b) Pre-combustion capture involves removal of CO_2 after gasification or steam reforming the fuel to produce syngas. This produces CO_2 at relatively high partial pressure, 5–15 bar, and can be removed by many of the methods mentioned above. However, also for the method, absorption is the preferred method, although in this case physical solvents may be best.
c) In oxy-fuel combustion nitrogen is removed from air to produce more or less pure oxygen, and the fuel is burned in the oxygen. The advantage of oxy-fuel combustion is that the flue gas contains only water vapor and carbon dioxide, and CO_2 can in principle be separated out by condensation. In reality the final gas will contain significant quantities of inert gases making the CO_2 separation more involved.

An alternative oxy-fuel method which is under development is chemical looping combustion (CLC). The fuel is brought in contact

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