EXPERIMENTAL EQUIPMENTS USED IN THE STUDY OF CARBON DIOXIDE ABSORPTION (II)

BY

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Abstract. Carbon dioxide is a component of industrial gaseous fluxes and is frequently removed to improve gas quality or to prevent catalyst poisoning. It is obvious that CO₂ emissions play a primary role in global warming. There are several ways to remove CO₂ - absorption, adsorption, cryogenic separation, permeation through membranes and chemical conversion. The industrial plant for absorption consists of the absorption unit, the regeneration unit and auxiliary equipment. Over time, the absorption process investigations were carried out using innovative equipment, which would improve the performance of this process.

Keywords: absorption; carbon dioxide; experimental devices; solvents.

1. Introduction

Every combustion process of fossil fuels and several different industrial processes produces flue gases, which are a mixture of carbon dioxide (CO₂), water vapour and other gases. In order to avoid CO₂ emissions to the atmosphere, CO₂ must be separated from the other gases. Absorption processes

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with chemical solvents are currently the most used technology for post-combustion CO₂ capture, because are the most efficient systems compared to other post-combustion capture processes (Mangalapally and Hasse, 2011; Hu et al., 2018).

The absorption installation is based on the use of two columns: one absorption column, to separate the CO₂ with a solvent and a regeneration column for recovering CO₂ in gaseous form and regenerate the solvent (Mangalapally and Hasse, 2011; Tătaru-Fârmuș and Harja, 2017; Liang et al., 2016). Removal performances for gas absorbers depend on each gas - solvent system and with the type of absorber used. Most absorbers have removal efficiencies up than 90%. Industrial equipments used frequently in industrial absorption processes include packed towers, plate columns, venturi scrubbers, spray chambers, etc.

2. Experimental Equipments

Over time, original laboratory equipment has been developed to measure the rate of carbon dioxide absorption at different temperatures, using various solvents. Chronologically, the experimental devices are as follows:

2002.

⇒ Liao (Liao and Li, 2002) investigated the kinetics of the absorption of CO₂ into monoethanolamine + N – methyl diethanolamine aqueous solutions, using a laboratory wetted wall column. The liquid flowed through an annular distributor cap and distributed uniformly as a thin film on the outside of the cylinder. The gas flow rate was measured by a soap film meter. The CO₂ absorption rate was measured from the product of the liquid flow rate. The apparatus and the experimental procedure are the same as those described by Shen (Shen et al., 1991).

⇒ A wetted-wall column, presented in Fig. 1, was used by Cullinane and Rochelle (Cullinane and Rochelle, 2004) as the gas–liquid contactor to study the equilibrium and rate experiments for carbon dioxide absorption with aqueous potassium carbonate promoted by piperazine The contactor is the same equipment used in the work of Bishnoi (Bishnoi, 2000) and Dang (Dang and Rochelle, 2001). The wet wall is a tube, which connects the liquid supply line with the column housing. The solvent solution is introduced through the inside of the tube, and is distributed on the outer surface of the tube. The liquid, collected at the base of the column, is pumped back into a liquid reservoir. The gas enters at the base of the column, flowing counter current with the fluid. The gas-liquid contact surface is closed by a thick-walled glass tube. The outer region of the column is the circulating bath of paraffin oil.
A laminar jet apparatus (Fig. 2) was used by Aboudheir (Aboudheir et al., 2003) to generate kinetics data for the absorption of CO$_2$ into high CO$_2$-loaded and concentrated solutions of monoethanolamine.

A jet of liquid from a circular nozzle circulates downward and is collected in a capillary hole. To measure the length and the diameter of the liquid jet, a two-dimensional microscope was used. The fluid flow rate was determined by weighing the liquid collected in a timed interval during each experiment. The volumetric technique was used to measure the gas absorption rates in the liquid.
A schematic diagram of experimental apparatus used by Yoon (Yoon et al., 2003) is shown in Fig. 3. The kinetics of CO$_2$ absorption in aqueous 2-amino-2-methyl-1, 3-propanediol (APMD) solutions was measured using a wetted-wall column absorber. The APMD solution is distributed uniformly as a thin film on the outside of the cylinder and the gas absorption rates were measured. The composition of the output gas was determined by a gas chromatograph. Absorption rates of CO$_2$ was measured by a soap-film meter.

Mandal (Mandal et al., 2003) studied the absorption of pure CO$_2$ into aqueous blends of diethanolamine (DEA) and 2-amino-2-methyl-1-propanol (AMP) using a wetted wall contactor. The wetted wall contactor used was similar to the one used by Saha et al. (1995).

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\text{Mass flow controller} \quad \rightarrow \quad \text{Wetted wall column} \quad \rightarrow \quad \text{Soap film meter} \\
\text{CO}_2 \quad \rightarrow \quad \text{N}_2\text{O} \quad \rightarrow \quad \text{Gas chromatography} \\
\text{Water} \quad \rightarrow \quad \text{Amine solution} \quad \rightarrow \quad \text{Reservoir}
\]

Fig. 3 – The schematic experimental equipment used by Yoon (2003).

The rate of reaction between CO$_2$ and amine was measured by Ali (Ali, 2004) using a standard stopped-flow apparatus (Fig. 4). This principle of this method is to track the evolution of the conductivity of the blends in time. In each experiment, equals volumes of the solutions and carbon dioxide were mixed in the stopped-flow apparatus. A conductivity cell was used to monitor ion formation, as a function of time. Previous work of Ali (Ali et al., 2000; Ali et al., 2002) has validating this technique.
An innovative concept for the removal of CO₂ from gas was developed by Zhang (Zhang et al., 2005). First, they evaluate the effect of immobilised amines in the CO₂ absorption process with methyldiethanolamine (Schubert et al., 2001), using an aerated stirred tank reactor. In order to identify the limiting steps of the new system, experiments with a liquid medium in a fixed-bed reactor (Fig. 5) have been carried out. Two electric conductivity detectors are used before and after the fixed-bed for the rapid qualitative detection of CO₂ concentration variations.

Fig. 4 – Ali experimental apparatus
1 – thermostat; 2 – pneumatic plate; 3 – CO₂ solution; 4 – amine solution; 5 – mixer; 6 – waste; 7 – conductometer; 8 – computer.

2005.

Fig. 5 – Schematic diagram of the equipment (Zhang et al., 2005)
1 – CO₂ saturated water feed tank; 2 – amine tank; 3 – pump; 4 – fixed-bed reactor; 5 – electrical conductivity detector; 6 – sample collector.
In the same year, Siminiceanu (Siminiceanu et al., 2005) used a gas–liquid reactor to measure the absorption rate for carbon dioxide absorption, (Fig. 6). The device is composed of a Lewis cell with double jacket (which allows the circulation of a fluid, regulating in temperature inside the cell) provided with a Rushton turbine in its lower part (liquid phase), a propeller in its upper part (gas phase) and four PTFE counter blades to avoid deformation of the gas-liquid interface area by a vortex and also to maintain a stable horizontal ring. The experimental issue is the same used by Pani (Pani et al., 1997) and Cadours (Cadours et al., 1997; Cadours, 1998).

Fig. 6 – Gas – liquid reactor used by Siminiceanu (2005)
1 – central teflon cylinder; 2 – teflon ring; 3 – magnetic bars; 4 – propeller;
5 – Rushton turbine; 6 – baffles; 7 – upper flange; 8 – lower flange.

3. Conclusions

With the increasing number of disasters related to climate change, it is important to consolidate all available information to reduce CO$_2$ emissions into the atmosphere, to minimize the effect of global warming. Although new CO$_2$ elimination technologies are emerging, it is unanimously accepted and recognized that the absorption process is the most popular method of separating CO$_2$ from gas or natural gas streams.

The performance of the CO$_2$ absorption process is influenced by the type of reactor used. Currently, due to the research carried out, there are data needed to design and design a large number of types of gas - liquid contactors.

It was hoped that, with the studies conducted worldwide, the challenges related to the absorption process could be overcome and several CO$_2$ capture projects could be integrated and materialized in the industrial process.
REFERENCES


ECHIPAMENTE EXPERIMENTALE UTILIZATE ÎN STUDIUL ABSORBŢIEI DIOXIDULUI DE CARBON (II)

(Rezumat)

Dioxidul de carbon este o componentă a fluxurilor gazoase industriale și este îndepărtat frecvent pentru a îmbunătăți calitatea gazelor sau pentru a preveni otrăvirea catalizatorilor. Este evident, de asemenea, că emisiile de CO₂ joacă un rol primordial în încălzirea globală. Există mai multe moduri de a elimina absorbția CO₂ într-un solvent lichid, adsorbția, separarea criogenică, separarea prin membrane și transformarea în alți compuși. Instalația industrială de absorbție constă din unitatea de absorbție, unitatea de regenerare și toate echipamentele și utilajele auxiliare necesare. De-a lungul timpului, investigațiile procesului de absorbție au fost efectuate folosind echipamente inovatoare, care ar îmbunătăți performanța acestui proces. Această lucrare prezintă a doua parte a cronologiei experimentelor efectuate în studiul absorbției dioxidului de carbon, concentrându-se pe echipamentele experimentale dezvoltate în cercetările de laborator între anii 2000 și 2005.