SIMULATION OF AN INDUSTRIAL PACKED COLUMN FOR REACTIVE ABSORPTION OF CO_2

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Abstract— **The steady-state simulation of a reactive absorption column is presented. The absorber is used in a large-scale ammonia plant to remove CO_2 from the process gas stream. To enhance the absorption process, high pressures and low temperatures are commonly used (T = 45-80 °C, P = 30-40 bar). At the outlet of the absorber, the CO_2 content in the process gas must be reduced to less than 500 ppm (dry basis) to avoid an excessive temperature rise in the methanation reactor (downstream of the absorption section). To represent the gas-liquid system, a rigorous mathematical model based on the two-film theory is considered. The heat effects are taken into account. The behaviour of different process variables for a reference operating condition is analyzed. The influence of changes in some operating variables is evaluated.**

Keywords–– **Reactive Absorption Of CO_2, Packed Columns, Ammonia Synthesis, MDEA**

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I. INTRODUCTION

Reactions of carbon dioxide with amines have been extensively studied during the last 20 years because of their industrial importance for the natural gas, petroleum chemical plants, and ammonia industries for removal of CO_2 from gas streams (Pintola et al., 1993). In an ammonia synthesis plant, the CO_2 must be removed from the process gas to avoid the poisoning of the ammonia synthesis catalyst. The CO_2 removal represents 10% of the capital and operating costs (Meissner III and Wagner, 1983).

The absorption in alkanolamine solutions is the commercially most important process for the removal of CO_2 from synthesis gas for ammonia production. A wide variety of chemical solvents are used, e.g. MEA (monoethanolamine), DEA (diethanolamine), MDEA (methyl diethanolamine), activated MDEA (mixture MDEA - piperazine), and recently AMP (2-amino-2-methyl-1-propanol) (Ko and Li, 2000).

The rigorous simulation of a packed column used industrially for reactive absorption of CO_2 using a MDEA solution is presented in this paper, aiming to obtain a useful tool for optimisation purposes.

Figure 1 shows a scheme of the industrial column. The CO_2 is removed from the process gas stream by counter-current absorption in two stages. In the lower part of the absorber, solution regenerated by flashing (semi-lean solution) is used for bulk CO_2 removal. In the upper part of the absorber, solution regenerated by stripping (lean solution) is used for scrubbing (Meissner III and Wagner, 1983).

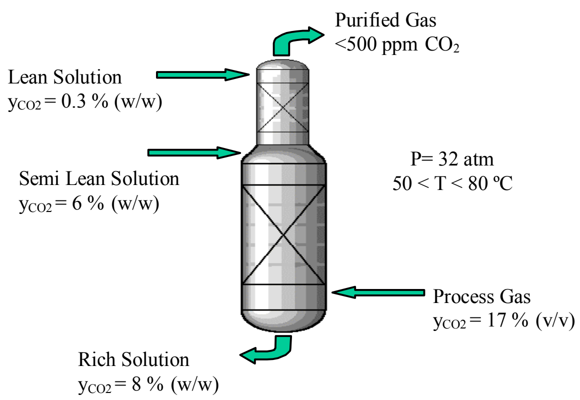

Figure 1. Scheme of the industrial absorption column

II. MATHEMATICAL MODEL

The two-film theory is adopted to represent the gas-liquid system (Froment and Bischoff, 1990, De Leye and Froment, 1986). The main chemical reactions are:

$$CO_2 + OH^- \xrightarrow{k_{OH}} HCO_3^- \quad (1)$$

$$CO_2 + R_3N + H_2O \xrightarrow{k_{MDEA}} HCO_3^- + R_3NH^+ \quad (2)$$

The most common situation is that the absorption of CO_2 in MDEA is accompanied by very fast reactions (Hatta Number > 3). Consequently, the reactions are assumed to be completed in the liquid film ($C^b_{CO_2}$ = 0).

The pseudo-first order kinetic expressions proposed by Ko and Li (2000) are adopted.

Steady-state conditions and plug flow is assumed for the gas phase, leading to a set of Ordinary Differential Equations (ODE's).