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An experimental study for H_2S and CO_2 removal via caustic scrubbing system

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A B S T R A C T

In this study, removal of hydrogen sulfide (H_2S) and carbon dioxide (CO_2) from simulated syngas has been studied on one column scrubbing system. Gas flow rate as a measure of gas residence time and superficial gas velocity, gas composition, inlet H_2S load, flow modes (countercurrent and cocurrent) and packing geometry were the parameters in the design and/or operation of an acid gas scrubber system. Better H_2S scrubbing efficiencies have been obtained in countercurrent flow mode than that of cocurrent flow mode. When accordingly designed, static mixer with its superior performance on H_2S removal overweighed to structured packings. The coexistence of CO_2 and H_2S has been shown to increase the sodium hydroxide (NaOH) consumption along the scrubber column thereby decreasing the H_2S removal efficiency at higher H_2S loads. The gas residence time as changing with the gas velocity was found to be more dominant on acid gas removal efficiency than the effect of superficial gas velocity within the experimented range. A gas residence times of equal or above 3 s were seemed to be closer to the optimum point.

Keywords: Gas clean up; Packed bed gas scrubbers; Hydrogen sulfide removal; CO_2 removal; NaOH; Static mixer

1. Introduction

Particulate, ammonia (NH_3) and hydrogen sulfide (H_2S) comprise the main impurities of synthetic raw gas produced by coal gasification. Removal of these contaminants is an essential step in coal and biomass gasification process to avoid its detrimental effects on materials and environment. Hydrogen sulfide and ammonia can cause corrosion in pipelines and thus limit plant lifetime. These are also a well-known catalyst poisoner. Therefore, utilization of gasification products either as a fuel for gas turbines, gas engines or fuel cells or as a syngas for Fischer–Tropsch fuel, ammonia or methanol productions requires an effective gas clean-up technology (Chen et al., 2001; Moussavi et al., 2008; Panza and Belgiorno, 2010).

For the abatement of H_2S and NH_3, packed towers are widely used for chemical and physical scrubbing. The choice of the solution is critical in determining dissolution or chemical reaction rate of pollutant in the liquid. In physical scrubbing, the pollutants in basic nature can be passivated by the acidic solutions and vica-versa. Currently, the processes of choice in the commercial integrated gasification combined cycle (IGCC) facilities for the removal of acid gases are both the chemical solvent acid gas removal processes based on aqueous methyldiethanolamine (MDEA) and the physical solvent-based Selexol process which uses mixtures of dimethyl ethers and polyethylene glycol (Couvert et al., 2008; Turpin et al., 2008; Ohtsuka et al., 2009; Wang et al., 2004; Wallin and Olausson, 1993).

Alkaline hypochlorite, hydrogen peroxide or caustic solutions are economicaly alternative solvents to be used in physical solvent-based processes and show good results for decades. Sodium hydroxide solution is a very effective, but non-regenerable absorbent for CO_2 and H_2S. Therefore the use of caustic is usually limited to the removal of trace amounts of

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these impurities. For the disposal of the spent caustic, different considerations are applied such as simple neutralization or its use in pulp and paper mills after some certain quality control analysis (Couvert et al., 2006; Miltner et al., 2012; Mamrosh et al., 2008; Bontozoglou and Karabelas, 1991).

For the improvement of scrubbing efficiencies, design of the scrubber system is as important as the choice of the solvent. Multiple gas sorption columns packed with structured materials are used in order to increase the active surface area and residence time for an efficient gas–liquid interaction. High efficiencies of commercial structured packing materials for H_2S removal with an alkaline washing solution was attributed to a high contact area existing between the gas and the liquid phases. The major drawback in the use of structured packing is their excessive price per volume unit. Static mixers, if properly designed, can be acceptable in terms of investment costs and have higher resistance to pluggings. Nevertheless, high mass transfer performances cannot be reached by static mixers as structured packing materials can be. Hence, the design of a static mixer has crucial importance in generating high interfacial areas and improving mass transfer rates (Couvert et al., 2008; Mamrosh et al., 2008; Godini and Mowla, 2008).

Basic design parameters of the structured packing columns are hydrodynamic flow characteristics and packing surface area as determined by the packing material geometry, residence time, liquid to gas ratio, pH and reactivity of the solution. To avoid high investment and operation costs, the scrubber system should be designed by taking into consideration of these parameters (Bhave et al., 2008; Biard et al., 2010).

Although design studies and commercial applications on structured packings were found in the literature extensively (Miltner et al., 2012; Godini and Mowla, 2008; Bhave et al., 2008; Aliabad and Mirzaei, 2009; Dang et al., 1998; Lu et al., 2006; Ballaguet et al., 2003) there were only a sufficient number of comparison studies differentiating the performances of both the static mixer and the structured packing for the acid gas removal. Static mixers have been known with their excellent gas–liquid contact due to a high turbulence rate inside and their potential on well mixed gas distribution giving high mass transfer rates (Couvert et al., 2008; Sanchez et al., 2008). Consequently, the objective of this study is to design a static mixer being able to generate high interfacial areas and improved mass transfer rates for acid gas alkali washing towers and compare the results with those of commercial packings. In order to elucidate the advantages of static mixers over structured packings, the removal of H_2S has been studied on one column scrubbing system on both of the designed static mixer and commercial structured packing. The effect of gas composition has been investigated by using H_2S in nitrogen and H_2S in simulated refinery gas mixtures. For these two different gas atmospheres, inlet H_2S concentration was increased in stepwise. The gas flow rate as a measure of gas residence time was changed to monitor the effect of superficial gas velocity and gas residence time. The scrubber has been operated in both countercurrent and cocurrent modes.

2. Materials and methods

2.1. *Experimental apparatus*

Fig. 1 illustrates the experimental set-up used in this study. The hydrogen sulfide (H_2S), carbon dioxide (CO_2), methane (CH_4) and nitrogen (N_2) inlet concentrations were adjusted by mass flow controllers (3) at the outlet of standard gas cylinders respectively, and mixed with a manifold (4) for preparing simulated refinery gas mixtures before entering to scrubber

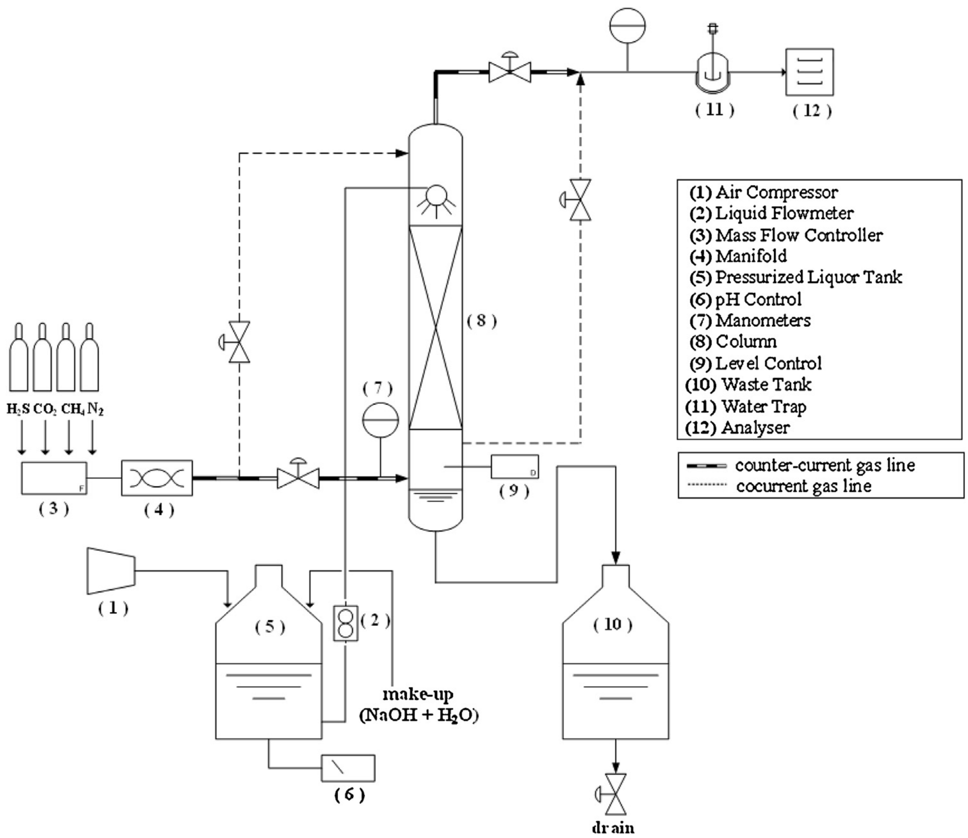

Fig. 1 – Scheme of the experimental set-up.