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MASS TRANSFER PERFORMANCE OF Al_2O_3 NANOFLUIDS FOR CO_2 ABSORPTION IN A WETTED WALL COLUMN

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Abstract - *In the present work, the mass transfer performance of mixture of Al_2O_3 nanoparticles in water (nanofluid) on absorption of CO_2 in a wetted wall column was studied. The effects of concentration of nanoparticle on the molar flux were investigated by varying the gas flow rate. The wetted wall column was used to study gas liquid counter-current flow. 30, 40 and 50 LPH of gas flow rate used and 0.2, 0.4, 0.6, 0.8 and 1.0 volume.% (vol.%) of Al_2O_3 nanofluids were prepared and used in the study. It was revealed from the study that the addition of nanoparticle increased the molar flux and the results indicated that the maximum enhancement was obtained at 0.6 vol% of Al_2O_3 nanofluid concentration at all the gas flow rates..*

Key Words: CO_2 Absorption, Nanofluids, Wetted wall column

1. INTRODUCTION

Significant consequences for life on earth caused because of Global warming. CO_2 emission is the principle reason of the green house effect [1]. Hence, reduction of CO_2 content in gas streams has become mandatory in recent years. For this purpose, absorption methods such as chemical treatment, mechanical treatment, and application of nanotechnology [2] are widely used in many industries. In the case of chemical methods, the efficiency of the absorption processes has been significantly enhanced by the addition of surfactants to the base fluid. Addition of a small amount of nanoparticles causes interfacial turbulence by the Marangoni effect [3], which enhances the mass transfer performance. Nanofluid is a fluid, in which nanoparticles below 100nm are suspended in the base fluid.

The experimental study conducted by Komati et al., showed 92.8% enhancement in the CO2 absorption rate in amine solutions for a 0.39 volume fraction of ferro fluids [4]. In the study conducted in a bubble-type absorber, Kim et al. reported that the size of gas bubbles in a SiO_2 nanofluid were smaller than the size of bubbles in pure water and applied this phenomenon directly to a CO2 absorption process [5] and they concluded that the capacity coefficient of CO2 absorption in the nanofluid was four times higher than that of pure water. Heat and mass transfer study was conducted by Kim et al. [6] and they obtained 46.8% and 18% maximum enhancements of heat and mass transfer rate respectively. They have used SiO2 nanofluids and recommended an optimum concentration as 0.01 vol%.of SiO_2 nanofluids.

Pang et al. [7] prepared Ag nanoparticles and studied the NH_3/water bubble absorption performance and found that the absorption rate with 0.02 wt% Ag nanoparticles was improved 55% compared to that of the water. Lee et al.[8] reported the CO_2 absorption rate was enhanced up to 4.5% at 0.01 vol% of Al_2O_3 nanofluids at 20 °C in a bubble absorber. The study of CO_2 absorption in a tray column absorber was performed by Torres Pineda et al.[9] and they reported that 9.7% and 9.4% absorption rate enhancements for SiO_2 and for Al_2O_3 nanoparticles respectively. The effect of Al_2O_3 and SiO_2 nanoparticles on CO_2 absorption in a bubble column with methanol based fluids was performed by Lee et al.[10].Their study revealed that there are optimal values for nanoparticles and the maximum absorption of CO_2 for Al_2O_3 and SiO_2 nanoparticles (compared to the pure methanol) are 4.5% and 5.6% at 0.01 vol%, respectively.

From the literature it was noted that many studies have been conducted related to heat transfer enhancement in the nanofluids, however there are only a few publications dealing with the mass transfer studies [11]. In the current work, the mass transfer performance of Al_2O_3/water nanofluids on absorption of CO_2 in a wetted wall column was studied. The effects of concentration of nanoparticle on the molar flux were investigated by varying the gas flow rate.

2. MATERIALS AND METHODS

2.1 Experimental set up:

Fig. 1 shows the schematic view of the experimental set up used to conduct gas absorption study.

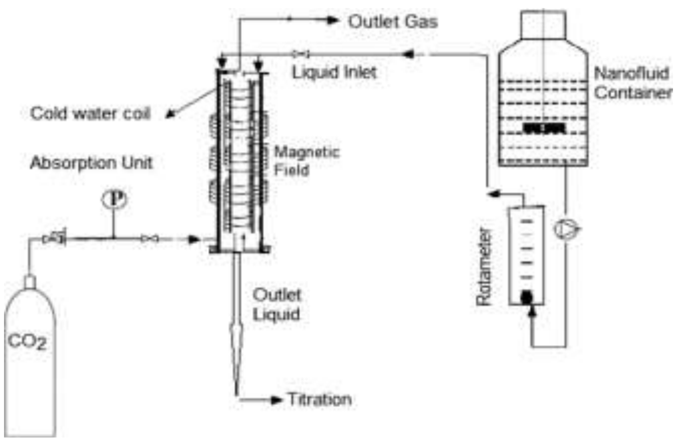

Fig -1: Schematic Diagram of Experimental set up

The experimental set up mainly consists of a wetted-wall column, solvent container, CO_2 vessel, liquid distributor, pump, and flow meters. The solvent flow rate varied in the range of 0.7–1.1 LPH and the gas flow rate was adjusted at 30, 60 and 90 LPH. CO_2 gas enters from the bottom of the instrument and the fluid enters from the top of the tower as shown in Fig. 1. After steady state condition is achieved, CO2 concentration in the liquid outlet is measured by the titration method and the molar flux was calculated [3,12].

2.2 Preparation of the nanofluids

The Al_2O_3/water nanofluids were prepared by dispersing 0.2, 0.4, 0.6, 0.8 and 1.0 vol% Al_2O_3 nanoparticles in water without the use of any surfactant Then, mechanical stirrers were used to stabilize nanoparticles in the fluid. Finally, the Solution was placed under ultrasonic oscillations for one hour. In order to avoid the sedimentation of Al_2O_3 nanoparticles in the water, the prepared Al_2O_3 /water nanofluid was used immediately to the absorption CO_2.

2.3 Experimental Procedure

The CO_2 gas and Al_2O_3/water nanofluid mixture is passed into a wetted wall column in a counter current way. The Al_2O_3/water nanofluid started to absorb CO_2. The absorbed CO_2 gas was titrated against sodium hydroxide (NaOH) and adding phenolphthalein as an indicator resulted the concentration of CO_2 absorbed. By varying the gas flow rates, the readings were taken with and without nanofluids. The photography of the experimental setup is shown in Fig.2.

Fig -2: photography of the experimental setup

3. RESULTS AND DISCUSSION

3.1 CO2 Absorption using Al_2O_3 Nanofluids at a gas flow rate of 30 LPH:

Experimental result on the influence of Al_2O_3 nanoparticle on the CO2 Absorption in terms of molar flux was reported in the Figure 3.The molar flux of nanofluids increased significantly at a gas flow rate of 30 LPH, however the maximum enhancement occurred at the nanofluid of 0.6 vol. %.

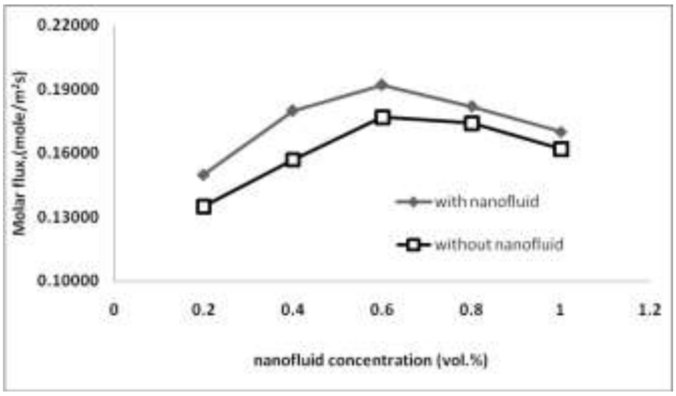

Fig -3: Effect of nanofluid concentration on molar flux at a gas flow rate of 30 LPH

3.2 CO2 Absorption for Al_2O_3 Nanofluids at a gas flow rate of 40 LPH:

Comparison between molar flux values of with and without nanofluid with respect to a gas flow rate of 40 LPH were plotted in Figure 4. It is evidenced from below figure that, at the variation of solvent gas flow rate, this nanofluid exhibits linear increase in molar flux with increasing concentration of Al_2O_3 nanoparticle.

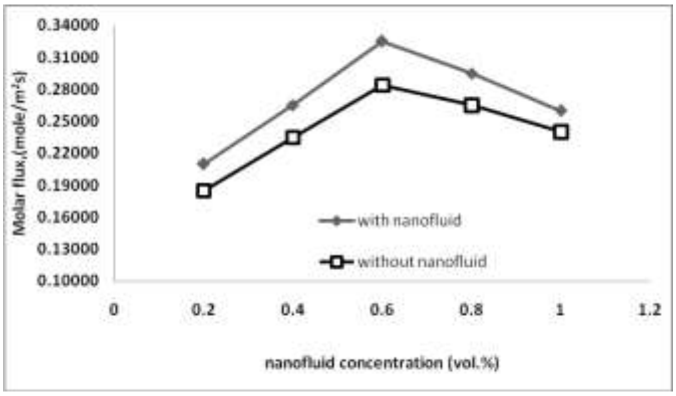

Fig -4: Effect of nanofluid concentration on molar flux at a gas flow rate of 40 LPH

3.3 CO2 Absorption for Al_2O_3 Nanofluids at a gas flow rate of 50 LPH:

Figure 5 shows the effect of Al_2O_3 nanofluid on molar flux of nanofluid at a gas flow rate of 50 LPH. For all the nano fluid concentrations, the molar flux increases with the increase in nanoparticle concentration similar to solvent flow rates of 30 and 40 LPH, however the magnitude may vary based on the nanoparticle and fluid physical properties.

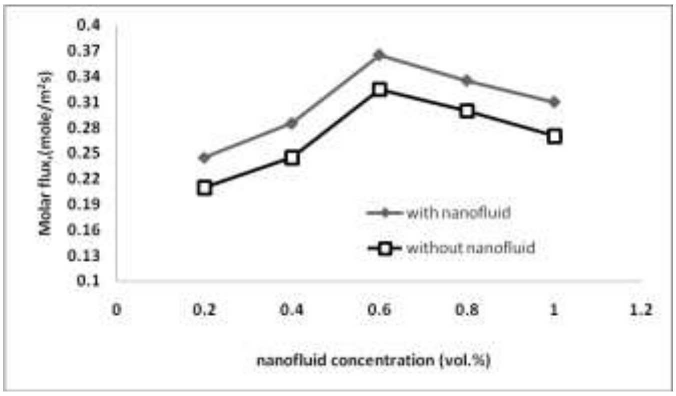

Fig -5: Effect of nanofluid concentration on molar flux at a gas flow rate of 50 LPH

4. CONCLUSIONS

The mass transfer performance of CO_2 absorption in a wetted-wall column using Al_2O_3/water nanofluid as solvents was investigated experimentally. The effects of gas flow rate, nanoparticle volume fraction, on mass transfer performance were examined and the results were compared for the absence of nano particles. The study reveals that the mass transfer performance of base fluid was improved by adding Al_2O_3 nanoparticles to the base fluid [13]. It is also observed that the performance enhanced with increasing nanoparticle concentration in the nanofluid.

The maximum enhancement in mass transfer for Al_2O_3 nanoparticle was occurred at the concentration of 0.6 vol%. It is noted that beyond 0.6 vol% , the increase in molar flux is reduced due to reduced diffusion coefficient and increased viscosity. The mass transfer enhancement in the nanofluids may be due to the Brownian motion of nanoparticles, and grazing effect.

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