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Research Article

The investigation of sulfur absorption from sour gas in packed bed with carbon nano fluid

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Abstract: Many different processes are used to treat raw natural gas to pipeline quality. Sulfur is commonly present as an impurity in fossil fuels. The mechanism of sulfur absorption by nano fluid in a packed bed under the magnetic field is considered, in this study. The experimental and theoretical investigation is done to obtain the outlet amount of sulfur in gas stream. The experimental results show the effect of gas flow rate and initial concentration of hydrogen sulfide on values of mass transfer flow rate. The increase in amount of gas flow rate increases the value of mass flow rate.
Keywords: Absorption; Gas; Packed bed; Carbon nano fluid; Sulfur.

INTRODUCTION

Burning fuels, the sulfur is released as sulfur dioxide—an air pollutant responsible for respiratory problems and acid rain [1-6]. Environmental regulations have increasingly restricted sulfur dioxide emissions, forcing fuel processors to remove the sulfur from both fuels and exhaust gases. The cost of removing sulfur from natural gas and petroleum in the United States was about $1.25 billion in 2008. In natural gas, sulfur is present mainly as hydrogen sulfide gas (H_2S), while in crude oil it is present in sulfur-containing organic compounds which are converted into hydrocarbons and H_2S during the hydro desulphurization [7-9]. In both cases, corrosive, highly-toxic H_2S gas must be converted into elemental sulfur and removed for sale or safe disposal [10-12]. Formation fluids that contain Hydrogen Sulfide-By-product from anaerobic bacterial action on sulfur compounds present in the mud (i.e. Sodium Sulfite)- Thermal degradation of mud additives containing sulfur (i.e. Lignosulfonates)-Chemical reactions with tool joint lubricants containing sulfur [13-15].

H_2S is a weak acid that can go through the following 2 stages when dissolved in water or water based mud: 1. H2S ↔ H+ + HS- - both steps (1 and 2) can go back and forth depending on the pH. 2. HS- + OH- ↔ S= + H2O

MATERIALS AND METHOD

The process temperature in vessel is adjusted by gas flow temperature and heat loss can be ignored since of the insulated Stainless Steel vessel. One polymeric weir with mesh size of 0.02 cm is on the top of vessel as a holder to let the only treated gas stream.

$H_2S+1/2O_2 \rightarrow 1/xS_x+H_2O$	1

Bed porosity, e, changes when the number of ball changes, Equation 2 shows the porosity evaluation. V_{nb} is nanoball volume and V is efficient volume of bed.

$e= 1-V_{nb.}/V$.	2

Water is applied to enhance the amount of absorbed H_2S in to the nano fluid. A Nano carbon tube with 3% wt is mixed with pure water for 180 min and 4000 Watt. This time is considered for stability of nano carbon into the pure water. This step is an exothermic process. Water helps oxidation of H_2S and also increases the nano carbon capacity for H_2S absorption. Equation 3, 4, 5, 6 and 7 show the related mechanisms in H_2S adsorption.

$H_2S(g) \rightarrow H_2S(aqua.)$	3

$H_2S(aqu.) \rightarrow H_2S(aqua\text{-}absorp.)$	4
$H_2S(aqua\text{-}absorp.) \rightarrow HS^-(ads.) + H^+$	5
$HS^-(ads.) + O(ads.) \rightarrow S\ (ads.) + OH^-$	6
$HS^-(ads.) + 3O(ads.) \rightarrow SO_2\ (ads.) + OH^-$	7

After absorption of H_2S into the carbon nano fluid, the increase in the outlet gas temperature is observed. Also, the increase in temperature is obtained using magnetic fields. Since of some safety limitations, lower appropriate ranges of feed temperature, below 40 C, are chosen beside the application of magnetic field.

MATHEMATICAL MODELING

For laminar flow, where only viscous drag forces come into play, □NRe,p □20□, experimental data may be correlated by means of the Kozeny-Carman equation, Equation 8 [1]:

$$f_b = \frac{150\ (1-\varepsilon)}{N_{Re,\ p}\ \phi_s} \qquad 8$$

Mass transfer rate

Mass transfer rate can be defined a function of mass transfer coefficient and concentration difference as driving force.

RESULTS AND DISCUSSION

Bed porosity, inlet gas temperature, inlet concentration of H_2S, magnetic field which influences the mass transfer area, mass transfer coefficient and rate of reaction are considered here.

The effect of bed porosity on sulfur elimination

Three different amounts of porosity are achieved by three groups of packing's. In this case higher porosity presents lower amount of packing's and also lower amount of mass transfer surface area. In the packed bed the channeling malfunction is occurred. So, the increase trend of C is predicted by increase in the amount of porosity. Outlet concentration below 4 ppm is acceptable result due to commercial rules. Experimental data are in higher values of hydrogen sulfide comparing with ones from modeling data.

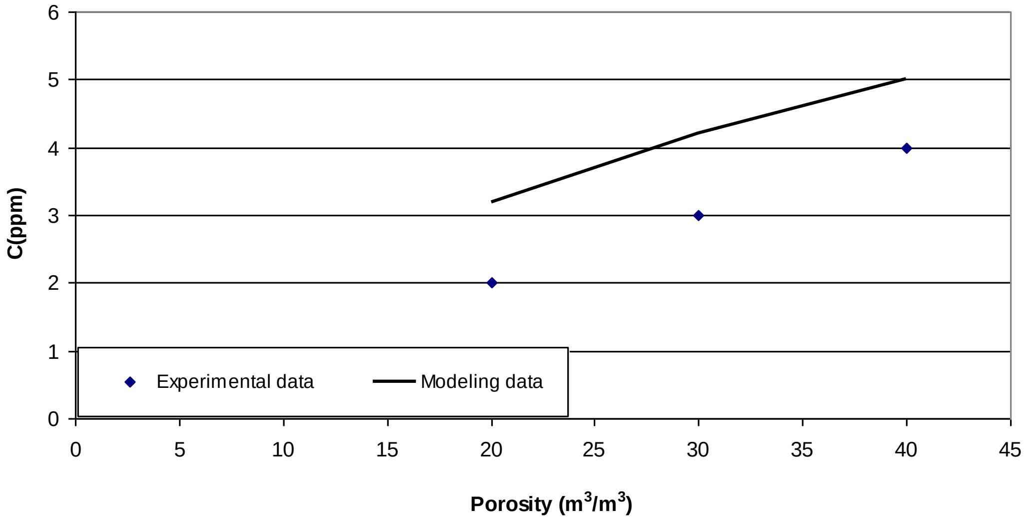

Fig-1: The effect of porosity on outlet hydrogen sulfide.

Figure 1 shows the trend of outlet hydrogen sulfide concentration with bed porosity, V_{void}/V. In this experiment, the amounts of hydrogen sulfide catch from branch line defined the process performance. Inlet sour gas contains 3.4 ppm H2S, temperature of 33 C is fed into the packed bed with 20m3/m3, 30m3/m3 and 40m3/m3 porosity and also, magnetic field occurred with current of 1 Ampere.

The effect of initial concentration and gas flow rate

Gas phase is not pure so gas, liquid and solid resistance should be considered in mass transfer rate. H2S absorption into the nano fluid is considered physically and chemically. Both mechanisms are dependent on mass transfer film of nano fluid. The effect of gas flow rate on mass transfer rate and mass transfer coefficient is studied here. The increase in initial amount of hydrogen sulfide decreases the gas phase resistance and facilitates the total mass transfer rate. The increase in flow rate with the fixed surface area increases the gas superficial velocity and turbulency of gas phase. This also increases the solubility of H_2S into the nano fluid bulk.

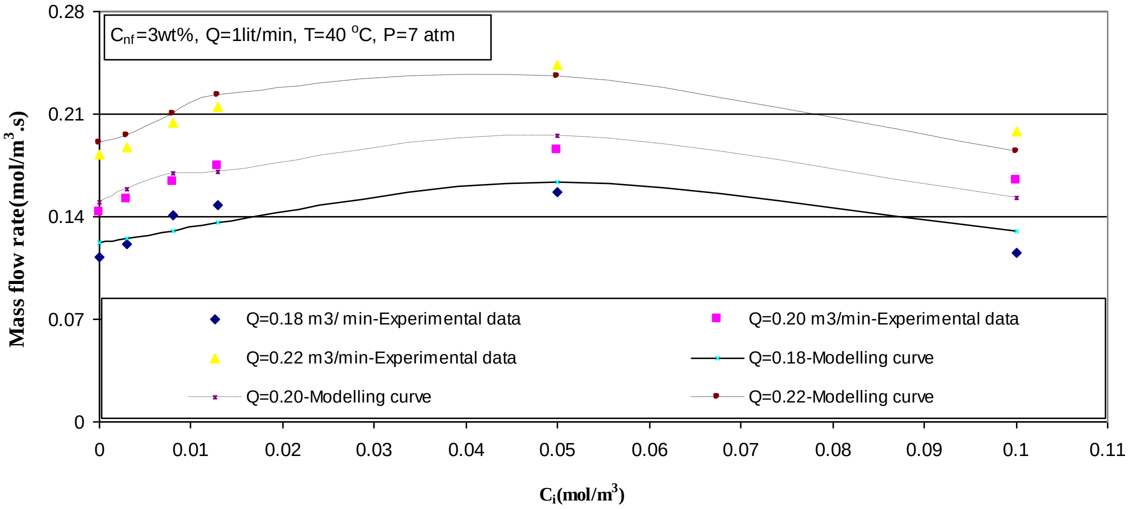

Fig-2: Mass flow rate versus inlet hydrogen sulfide and gas velocity.

Figure 2 shows the effect of gas flow rate and initial concentration of hydrogen sulfide on values of mass transfer flow rate. The increase in amount of gas flow rate increases the value of mass flow rate. This may indicate on the high absorption capacity of nano fluid and high surface area in packed bed. At 0.18 m3/min value of gas flow rate the increase in amount of initial hydrogen sulfur (0 to 0.05 mol/m^3) increases the mass flow rate initially and then the relatively decrease trend in flow rate is observed. This trend is similar for both 0.20 m3/min and 0.22 m3/min and the peak of graph happens in the 0.05 mole per liter as concentration of hydrogen sulfide in the gas stream. This shows the limited value of carbon nano fluid capacity. Also, the positive effect of turbulency on decreasing the gas phase resistance is observed. The higher value of driving force doesn't show the significant effect on increase of mass transfer rate when the capacity of nano carbon is limited.

CONCLUSION

Combination of absorption mechanism and magnetic field are used to remove hydrogen sulfide from sour natural gas. Mass transfer rate and mass transfer coefficient is measured and calculated experimentally and theoretically. The experimental results show the effect of gas flow rate and initial concentration of hydrogen sulfide on values of mass transfer flow rate. The increase in amount of gas flow rate increases the value of mass flow rate. In addition, the obtained results show the trend of outlet hydrogen sulfide concentration with bed porosity, V_{void}/V. In this experiment, the amounts of hydrogen sulfide catch from branch line defined the process performance. Inlet sour gas contains 3.4 ppm H2S, temperature of 33 C is fed into the packed bed with 20m3/m3, 30m3/m3 and 40m3/m3 porosity and also, magnetic field occurred with current of 1 Ampere.

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