THE EFFECT OF NONUNIFORM LIQUID DROPLETS CONCENTRATION DISTRIBUTION ON ABSORPTION OF SO2 IN AN ATOMIZING SCRUBBER

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ABSTRACT

Many investigators have predicted SO_2 absorption in a scrubber based on uniform concentration of liquid droplets concentration. In this study an investigation was carried out to determine the effect of actual liquid droplets concentration on SO_2 absorption in an atomizing scrubber. In this model liquid droplets are dispersed in the polluted gas stream from an area or line source depending on the method of liquid injection. Then the overall performance of the scrubber is obtained by solving the diffusion equation both for liquid droplets and gas absorption. The effect of various operating parameters such as liquid to gas ratio and scrubber size were obtained on cleaning performance of the scrubber. The results of mathematical predictions is compared with the data reported in the literature. The results of prediction with this model indicate a significant improvement compare to the prediction based on uniform liquid droplets concentration.

INTRODUCTION

Atomizing scrubbers are frequently used for absorption of SO_2 and some other gaseous pollutants. Gage and Rochelle (1992) have studied the use of this device in flue gas desulphurization processes. Also the capital cost and operating cost of a scrubber is given by Baasel (1988). In an atomizing scrubber the performance of gas absorption is a function of several parameters including, gas velocity, liquid to gas flow rate ratio, geometry, and the method of liquid injection. In designing a venturi scrubber the above parameters must be adjusted so that the liquid droplets are distributed as uniformly as possible. The purpose of this study was to study the effect of various operating parameters on liquid droplets concentration distribution in a scrubber. This in turn will improve the capability of various mathematical models in predicting gas absorption and particulate removal in a wet scrubber.

Several experimental and theoretical investigations for studying droplets concentration distribution in atomizing scrubbers have been reported in the literature. Taheri and Haines carried out an experimental work to study the effect of water injection on droplets distribution and SO_2 absorption in an atomizing scrubber. By photographing the throat of scrubber they showed that the water droplets are distributed nonuniformly across the cross section of scrubber. They also showed that the rate of SO_2 absorption and particle collection varied depending on method of water injection. Viswanathan et.al (1984) performed experimental work for determining water droplets distribution in the throat of a venturi scrubber. They showed that the droplets concentration distribution in the throat and down stream of point of water injection is a function of liquid to gas ratio. Calvert(1970) developed a mathematical model to predict particulate removal efficiency in a scrubber. He fitted the results of the experimental work by applying a correction factor in his model which included the non-uniformity effect of droplets distribution. Taheri and Shieh (1975) used a plume dispersion equation to predict water droplets concentration in an atomizing scrubber. They have shown that by considering nonuniform distribution of droplets the particulate removal efficiency are in close agreement with experimental data.

MATHEMATICAL MODEL

The detail of the mathematical model developed in this work is given by Talaei (1993). This model is based on a three dimensional dispersion of droplets and pollutants such as SO2 by convection and eddy diffusion. The gaseous pollutants are absorbed by liquid droplets while they are moving co-currently in the scrubber. The rate of gas absorption in the scrubber is influenced by distribution of droplets population. The steady state equation expressing material balance for droplets is as follows:

$$\frac{\partial(V_{d_x})}{\partial x} = E_d\left(\frac{\partial^2 C_d}{\partial y^2} + \frac{\partial^2 C_d}{\partial z^2}\right) + S \qquad (1)$$

In the above equation the droplets are convected in the x direction, while they are dispersed in y and z direction by eddy diffusion. In addition it is assumed that droplets are generated by a line or area source depending on method of water injection. This area source is located by an empirical correlation for calculating liquid jet penetration length which has been obtained by Viswanathan et.al (1984):

$$\frac{h^*}{d_j} = 0.1145\frac{V_j\rho_j}{V_g\rho_g} \times \left(\frac{P_j}{P_g}\right)^{1/2} \qquad (2)$$

The water droplets velocity V is adjusted to the ambient gas stream velocity according to the following equation:

$$\frac{dV_d}{dX} = \frac{3}{4}\frac{C_{D_f}}{D_d}\frac{\rho_g}{\rho_l}\frac{(V_g - V_d)^2}{V_d} \qquad (3)$$

The Transport equation for gaseous pollutant such as SO2 is as follows:

$$\frac{\partial(V_{g_x}C_g)}{\partial x} = E_g\left(\frac{\partial^2 C_g}{\partial y^2} + \frac{\partial^2 C_g}{\partial z^2}\right) - N_A\pi D_d^2 C_d \qquad (4)$$

The eddy diffusivity E depends on the flow situation and is a function of the degree of mixing and turbulence. The gas stream eddy diffusion was obtained by using a Peclet number :

$$\frac{V_g D}{E_g} = N_{Pe} \qquad (5)$$

The value of Pecklet number was found to be 130 for a venturi scrubber. Droplets because of their inertia can not follow the random motion of gas stream. As a result their eddy diffusion is reduced. The effect of droplets inertia on eddy diffusivity was obtained by Talaie (1993):

$$\frac{E_d}{E_g} = \frac{l_d^2}{l_g^2} \qquad (6)$$

NUMERICAL SOLUTION

Equations (1),(2) and (3) are the main equations for the present model.Equation (3) is integrated analytically and the droplets velocity U is computed. With all the other parameters Known , the problem is then reduced to solving C,and C by a numerical technique.

RESULTS

The comparison between the result of simulation and Viswanathan

data for water droplets distribution is given in Figure (1). This Figure indicates a very good agreement between predicted value s and experimental data.
Figure (2) indicates the comparison between Calculated and experimental data performed by The Office of Air Program. These data are reported by Wen and Fan (1975). This figure indicates a very good agreement compare to applying a uniform water droplets concentration. The results indicate that water droplets concentration distribution plays an important role in scrubber performance and must be considered in any realistic model.

SUMMERY AND CONCLUSION

From the results of simulation the following conclusions can be drawn:
The factors which increases the uniformity of droplets distribution also increases removal efficiency.The highest uniformity of droplets distribution is attained in a scrubber for a jet penetration of 20 to 30% of scrubber width. Some of the factors which affects the uniformity of droplets distribution are as follows:
a) Increasing liquid to gas flow ratio, to some limit at constant gas velocity increases uniformity
b) When L/G and Vg are constant,increasing cross sectional area of the scrubber increases uniformity by increasing droplets eddy diffusivity.

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NOTATION

C	=	Droplets concentration	No./m^3
C	=	Gas concentration	gmole/m^3
D	=	Throat diameter of scrubber	m
D	=	Drop diameter	m
d	=	Nozzle diameter	m
E	=	Eddy Diffusivity	m^2/s
h	=	Penetration length	m
l	=	Mixing length	m
L/G	=	Liquid to gas flow rate ratio	m^3/1000 m^3
N	=	Overall mass transfer rate of component A	gmole/m^2.s
P	=	Pressure of liquid jet at injection point	(atm)
S	=	Source strength	No./m^2.s
V	=	Velocity	m/s
x	=	Rectangular coordinate in the direction of flow	m
y,z		Rectangular coordinate perpendicular to the direction of flow	m

Subscripts

d	=	Droplets
g	=	Gas
J	=	Jet

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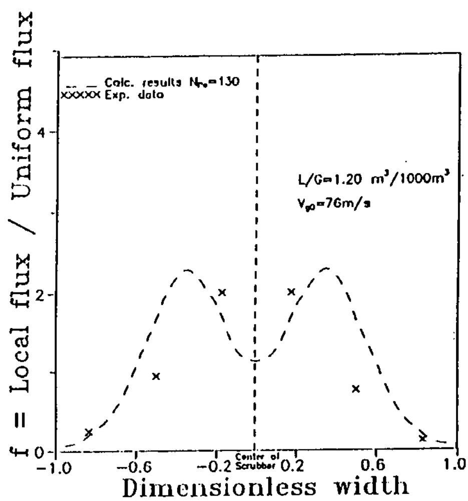

Figure 1 Variation of Normalized Flux With Dimensionless Width

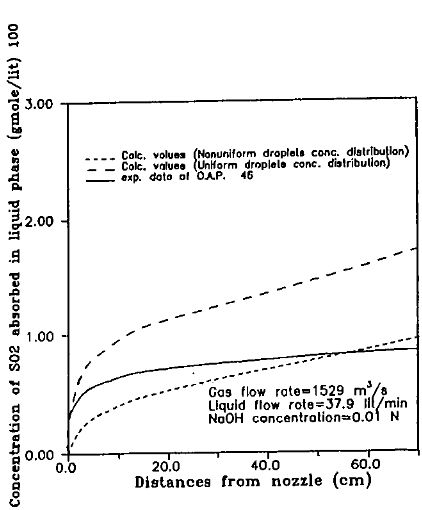

Figure 2. Variation of Liquid Phase Concentration Along the Scrubber for O.A.P. Data