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LIQUID HOLDUP IN TURBULENT CONTACT ABSORBER

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Dynamic liquid holdup in a turbulent contact absorber was obtained through quick shut off valves technique. Experiments were carried out in a Perspex column. Effects of liquid velocity, gas velocity, packing diameter packing density and packing height on dynamic liquid holdup were studied. Hollow spherical high density polyethylene (HDPE) balls were used as inert fluidized packing. Experiments were performed at practical range of liquid and gas velocities. Holdup was calculated on the basis of static bed height. Liquid holdup increases with increasing both liquid and gas velocities both for type 1 and type2 modes of fluidization. . Liquid holdup increases with packing density. No effect of dia was observed on liquid holdup.

Keywords: Liquid hold up, Turbulent contact absorber (TCA)

1. Introduction

Turbulent contact absorber (TCA) is countercurrent gas liquid mass transfer equipment in which gas enters through bottom of the column below supporting grid. Gas serves as continuous and liquid as dispersed phase in the equipment. Low density inert packing, normally spherical balls are used in TCA which are fluidized by gas above minimum fluidization velocity. Vigorous motion of the fluidized particles increases interfacial area and hence mass transfer in TCA. It has advantage of non choking, high gas and liquid flow rates hence low capital cost of equipment and high mass transfer coefficients over conventional packed towers. Particulates are also collected in this equipment and this is used for simultaneously particulate collection and mass transfer in scrubbing industry [1]. TCA is used in particulate removal, air cooling, humidification, dehumidi-fication, absorption, desorption, and flue gas desulphurization. There are also some disadvantages of TCA i.e back mixing in liquid phase, breakage of packing and bed pulsations particularly in deep beds.

Liquid holdup in TCA determines interfacial area and pressure drop which are key parameters for design of any mass transfer equipment. A number of correlations for liquid hold up have been given in literature [2-5] but most of the work done in literature is for small dia columns i.e upto 15 cm dia and those correlations were specific to the systems studied. Due to wall effects, scale up from available correlations does not give satisfactory results e.g holdup by Bruce et al[6] is about three times than the present study . So in present study, liquid holdup in a large scale column of dia 44.7 cm was studied so that the study may be more useful for designing industrial columns.

Two regimes of operation of TCA have been discussed in literature [7]. In type 1, fluidization starts before flooding in the column and in type 2, fluidization starts after flooding in the column. Vanjak [2] developed a chart for demarcation of type 1 and type 2 regimes. Increase in density of packing and liquid flow and decrease in packing dia shifts the regime from type 1 towards into type 2.

Different correlations for type 1 and type 2 fluidization have been given in literature [2-5].

Mathematical models have also been developed in literature for hydrodynamic and mass transfer in TCA[8, 9]. Liquid holdup in TCA with downcomer has also been studied by some authors [10-12]

There are different techniques for measuring liquid holdup i.e by tracer method, from pressure drop and by quick closing of liquid and gas valves. Quick shut off valve technique which was used in present study is most accurate one as liquid holdup is measured directly from liquid collected.

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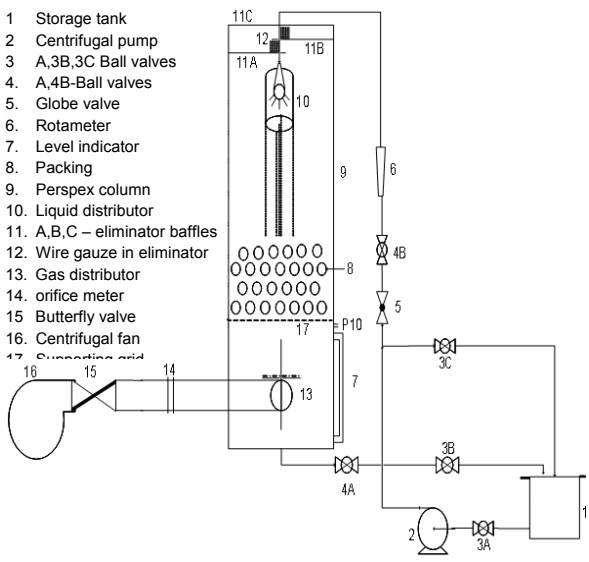

Figure 1. Schematic diagram of experimental setup.

2. Experimental

The schematic diagram of experimental set up is shown in Figure1. It consists of 44.7 cm dia and 213 cm high perspex column. Below it was of same dia and 122 cm long SS cylinder for air seal, water collection for increase in level measurements and gas inlet and distribution. A novel type of gas distributor was installed in the lower cylinder called plenum to achieve acceptable gas distribution at the supporting grid situated between perspex and SS cylinders. Supporting grid was SS sieve having 74 % free area. At the top most section was mist eliminator to remove moisture entrained by air. Flow rate of air entering from bottom was measured by orifice meter installed at inlet gas pipe while flow rate of liquid entering from top was measured by rota meter. Initially solenoid valves were mounted for quick shut off. Since the inlet and outlet liquid lines were of diameters 1.5 in and 2 in respectively and solenoid valves available in market for these sizes were normally close. So for shut off, when power was turned off, there was a significant lag in closing the valves due to frictional drag. Since this lag was not constant so manual ball valves were installed at the inlet and outlet liquid pipes such that these could be closed simultaneously by a single person.

Liquid holdup was measured by collecting the liquid after closing simultaneously these valves and butterfly valve located at outlet of fan. The rise in level of water in plenum was measured from level glass. Water retained in inlet liquid pipe after closing the valve 4B was measured for each liquid flow by removing the pipe from column. and providing it same angle and height outside the column. Two hand holes were provided in Perspex column one above the supporting grid and other near the top of the column to change balls. Superficial air velocity in column ranged from 1.8-3.6 m/s while superficial liquid velocity ranged from 0.004 -0.012 m/s. Packing used was balls of dia 25 mm and 45 mm having apparent densities 354 kg/m3 and balls of dia 38 mm having apparent densities 180, 270, 354, 442 and 547 kg/m3. These were made by joining two threaded hollow hemispheres by local manufacturer. Most of the experiments were carried out at static bed height 25 cm. Experiments were also performed at static bed heights 15 cm, 35 cm and 45 cm for effect of static bed height on liquid holdup.

3. Results and Discussion

The liquid holdup based on static bed height was calculated using the following equation.

$$\varepsilon_{l,st} = \frac{V_l}{A_c H_o}$$

The liquid holdup based on expanded bed height can be calculated as

$$\varepsilon_l = \frac{V_l}{A_c H}$$

So the relation between liquid holdups based on static and expanded bed heights is

$$\varepsilon_{l,st} = \frac{H \varepsilon_l}{H_o}$$

Liquid holdup mentioned here stands for based on static bed height. Liquid holdup increases with increase in gas and liquid velocities as shown in fig. 2. Liquid holdup increases with liquid velocity since more liquid is present in column at high liquid velocities.

Some authors [2, 4, 13] mentioned that there was no effect of gas velocity on liquid holdup while from study of Rama [3] there is increase in liquid hold up with increase in gas velocity. However all agree that for type 2 fluidization, there is increase in liquid holdup until bed is fully fluidized.

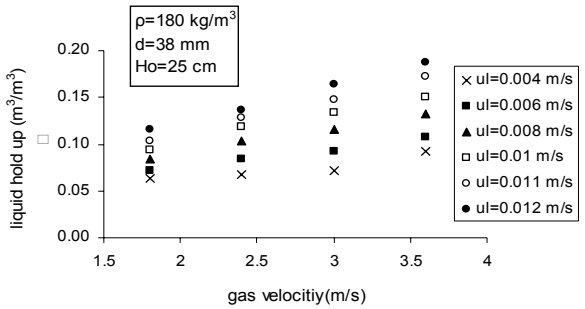

Figure 2. Effect of liquid and gas velocities on liquid hold up for type 1.

In the present study, only practical range of gas velocity is studied which is above fluidization at all densities of packing and liquid flow rates. Liquid holdup increases with increase in packing density (Fig 3) since high density packing exhibit more pressure drop in the column. Higher the pressure drop, more the liquid will retain in the column resulting more liquid holdup.

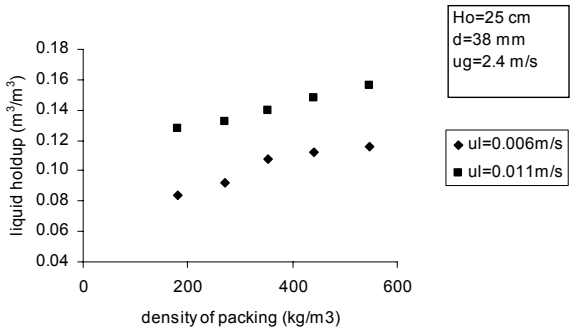

Figure 3. Effect of liquid and gas velocities on liquid hold up for type 1

It was investigated [2, 4, 13] that liquid holdup decreases with increasing particle size but in present study (Fig 4), no remarkable change in liquid holdup is observed. It might be due to the fact that earlier investigators worked on small dia columns. In small dia columns, balls with larger dia congregate along the walls of the column causing channeling for gas so less liquid holdup was observed for larger dia packing.

Pronounced effect of static bed height on liquid holdup (Figs. 5a &b) was observed both for type 1 and type 2 TCA operations. Liquid holdup decreases with increasing static bed height. No doubt volume of liquid held in column increases with increasing bed height but fractional holdup decreases since there is more space for liquid per unit static bed height for smaller bed heights. It can also be due to the reason that in present study, liquid holdup is calculated for the column including plenum. In the later study, effect of plenum will be incorporated and correlation will be developed for liquid holdup. If there is a significant holdup in plenum, there might be less or no decrease in holdup with increasing static bed heights. This additional liquid is being divided by these heights and for lower static bed height it will have more effect on liquid holdup.

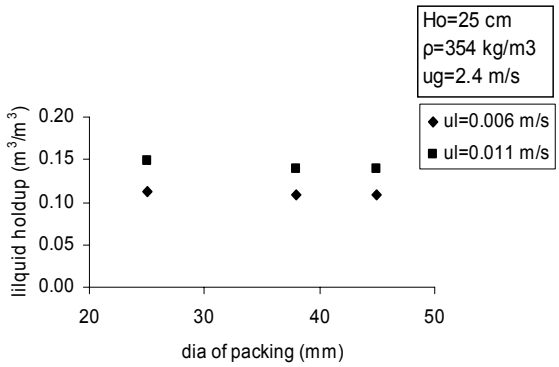

Figure 4. Effect of packing density on liquid holdup for type 2 fluidization.

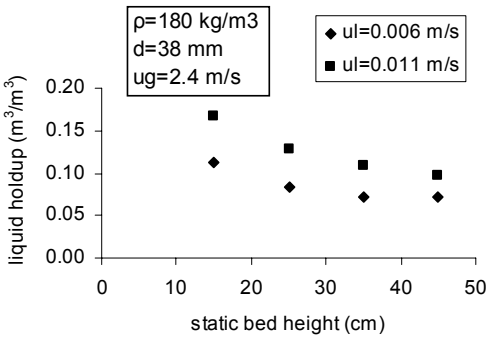

Figure 5a. Effect of static bed height on liquid holdup for type 1 fluidization

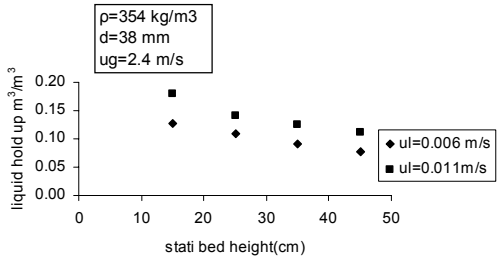

Figure 5b. Effect of static bed height on liquid holdup for type 2.

4. Conclusions

Effect of dia, static bed height and density of packing on liquid holdup was determined for

type 2 fluidization. Liquid holdup increases with decreasing static bed height and increasing density of packing. No significant effect of dia on liquid holdup was observed. For type1 fluidization, liquid holdup increases with increasing gas and liquid velocities. And decreases with increasing packing height.

Nomenclature

d = diameter of hollow spherical balls (mm)

D_c = diameter of column (m)

Ho = static bed height of packing (cm)

ε_l = liquid holdup based on expanded bed height (m^3/m^3)

$\varepsilon_{l,st}$ = liquid holdup based on expanded bed height (m^3/m^3)

Ul = superficial liquid velocity in column (m/s)

ug = superficial gas velocity in column (m/s)

A_c = area of empty column (m^2)

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