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Fluid to Particle Mass Transfer Studies in Downers

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Abstract- Gases to particle mass transfer coefficients are measured in a downer.The effects of gas velocity, solid flux and particle size on Mass transfer coefficients are studied. The effect of downer diameter on Mass transfer coefficients was studied by plotting Mass transfer coefficients in terms of dimensionless parameters. Downers are down flow fluidized beds. They offer several advantages compared to risers. 1. Reduced gas and solid back mixing. 2. Reduced contact time between different phases 3.Better control over the reactions. These advantages become significant in several fields where down flow fluidized beds (downers) are used e.g. petroleum industry (FCC), glass industry, fertilizer industry, etc.Some studies have already been done on other parameters of downers like Heat transfer, Particle velocity profiles, etc. The present work reports experimental observation on fluid to particle mass transfer in downers.

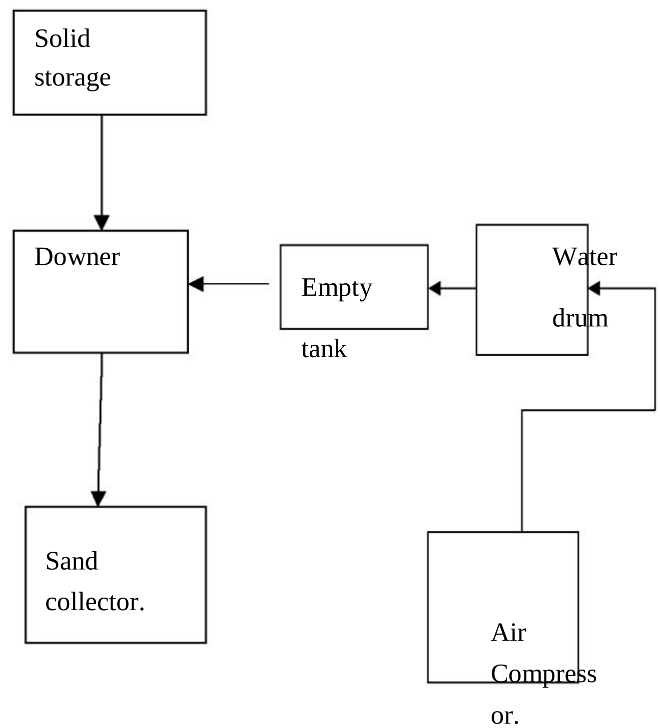
Keywords- Downers, FCC, Mass transfer coefficients, Solid flux

1. INTRODUCTION.

The key benefits of downers over risers are: reduced gas and solid backmixing near the wall region, reduced contact time between gas and solid phases, plug flow behavior and so on. These advantages become more significant in the fields of fluid catalytic cracking and combustion reactions. Some information is available in the literature on hydrodynamics of downers such as particle velocity profiles[3],axial and radial solid flux profiles[1], solid holdup and pressure gradient distributions[2],[4],[5],[8],reactor performance[6],[9], and heat transfer studies[11].

For gas- solid reactions in downers, in general, are fast and so can be limited by gas phase mass transfer to solid surface. In general mass transfer rates depend on mass transfer coefficient, gas velocity, and Particle size and so on. The present work reports experimental observations on to gas to particle mass transfer in downers.

EXPERIMENTAL SECTION



Experiments were conducted in downers of height (88cm) and internal diameters (5cm) made with Plexiglas. The experimental set up is as shown in fig. Washed and dried sand kept in solid storage tank few minutes before start of experiment. Air from compressor send into water drum (33cmID, 55cm height) to get saturated air. The exit air from water drum again send to an empty tank(37cmID,58cmheight) to avoid entrained water into the downer, this saturated air contacts with dry sand coming from solid storage tank, the gas solid mixture flows along the length of the downer.At the end the samples are collected in a beaker.Solid flow rate measured by collecting sand in a beaker at known time. Gas Velocity is measured by using a calibrated Rotameter.

Samples are collected at the exit of the downer and weighed immediately by using an electronic weighing machine. These samples kept in furnace at 120 ^{0} c for 12 hrs and again weighed and calculated the amount of moisture transferred from gas to particle. Particle used for the present study were sand with a mean diameter of 425 micrometer and a density of 1885kg/m$^{3.}$ The operating solid flux is up to 33kg/m^2 s ,the superficial gas velocity is 1.5m/s

GAS TO PARTICLE MASS TRANSFER.

Fig shows the graphical visualization of gas to particle mass transfer in a downer. Saturated air with moisture enters into a downer at velocity U_0 and fed with a flux of 'W'. Variation of solid holdup along the length of downer is shown in fig. Mass transfer takes place from gas to solid during the concurrent downward flow. Gas enters into the downer with saturated moisture concentration of c* and exits at C_e. Moisture concentration on particle changes from zero to c_p as shown in fig. It can also be expressed in terms of moisture fraction on particle,X, defined as 'kg 'of moisture per particle to maximum moisture adsorbed per particle(MPS).

By taking a mass balance over a differential length of 'dh'. At a length h from downer entrance. Consider moisture fraction on particle increased by an amount dX due to mass transfer from gas, concentration of moisture in gas is C and concentration of moisture on surface of particle is $c_{p.}$ By conservation of mass, mass of moisture on particle is equal to mass transfer from gas to particle.

$MPS(dX) = K_g S_p (C-C_p)$ - (1)

To use equation 1 for the calculation of mass transfer coefficient we need the value of C, C_p,(1-e) and maximum moisture per particle (MPS).

DETERMINATION OF MAXIMUM MOISTURE PER PARTICLE

A simple set up of batch fluidized bed used to determine the maximum moisture per particle. Air from blower is send into a water drum (33cmID and 55cmheight) for getting saturated air. Saturated air from drum enters into the batch fluidized bed where it contacts with a known amount of sand(50gm) of sand till the sand particle get saturated. The saturated sand removed from batch fluidized bed and weighed immediately and kept in furnace at 120 ^{0}c for 12 hrs. Saturation point can be found by measuring sand and water temperatures. From previous experiments the maximum moisture adsorbed per particle for 159micrometer is 8.4x10^{-11}kg/ particle and for 319micrometre particle is 1.88x10^{-10} kg/ particle.For 425 µm the MPS was found to be 2.5x10^{-10}.

SATURATION CONCENTRATION OF MOISTURE IN AIR (C).

Saturation concentration of moisture in air is calculated by using wet and dry bulb temperature of inlet air to downer. Wet and dry bulb temperatures of air are measured using laboratory thermometers.

If air entered into the downer is saturated then C=C*.

Concentration of moisture on surface of particle (C_P) can be calculated by assuming as

$C_p = XC^*$ (2)

By rearranging equation for mass transfer coefficient gives as:

$K_g = (MPS)(dX)/(S_p C^*(1-X))$.

RESULTS AND DISCUSSION

The following results are obtained.

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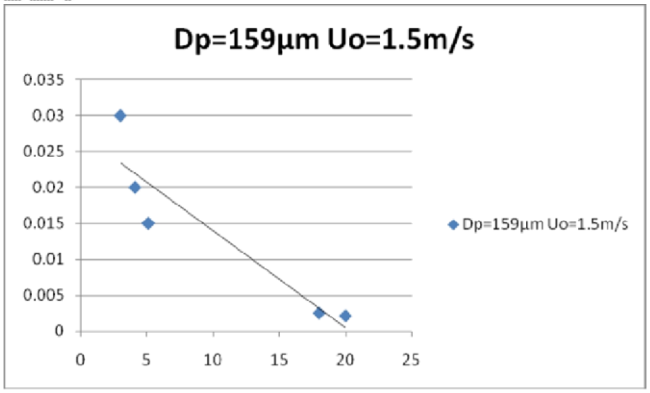

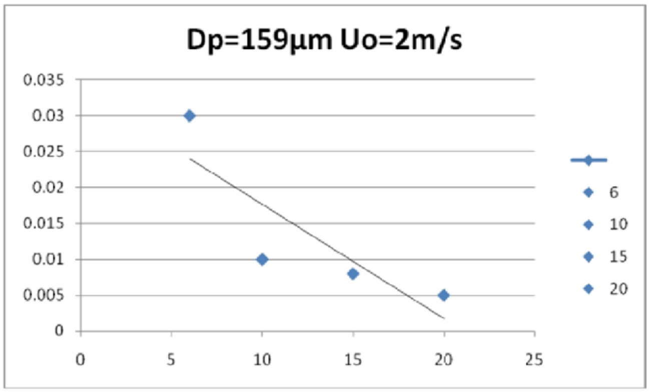

From this graph we observe that increasing gas velocity mass transfer coeffcient increases.Increasing solid flux decreses mass transfer coefficient at constant gas velocity.Also smaller particles give higher mass transfer coefficient than larger particles at constant velocity and solid flux.The last graph is plotted with the logarithm values, due to very low value of mass transfer coefficients.

CONCLUSION

From this study the following conclusions can be listed as follows.

1. With increasing gas velocity mass transfer coefficient increases at certain solid flux.
2. With increasing solid flux mass transfer coefficient decreases at constant gas velocity
3. With increasing particle diameter mass transfer coefficient decreases at constant gas velocity and solid flux.

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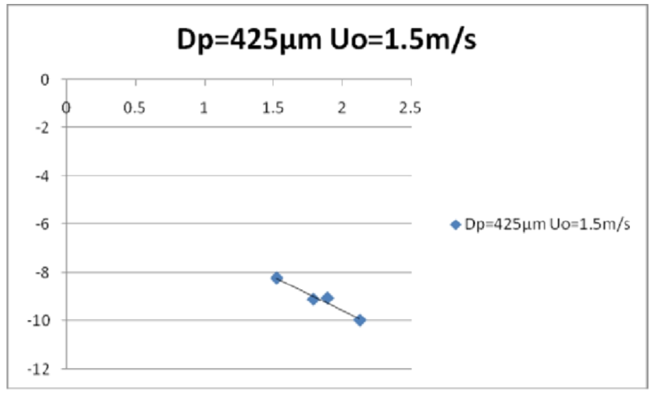
NOTATION



A_t downer diameter,m^2

C Moisture conc in air kg/m^3

C* Saturation moisture conc in air , kg/m^3

Cp moisture conc on particle, kg/m^3
g gravitational constant , m^2/s

h downer height,m

K_g gas to particle mass transfer coefficient.m/s

MPS maximum moisture per particle

M_w Molecular weight of water

S_p Surface area of particle,m^2

V local velocity of particles,m/s

V_p volume of particle,m^3

W solid flux kg/m^2s

X fractional value of moisture adsorbed per particle

d_p Density of particle,kg/m^3

e Voidage.

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