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Mass Transfer Enhancement in GLS Fluidized Beds using Nanomaterials

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Abstract: ***Nanomaterial has unique physical property which made it important for many applications and that is why the use of nanomaterials rapidly increasing in the field of science and engineering.[1] This work focuses on mass transfer of solids into liquid in three phase fluidized beds in presence of nanomaterial. This include the study of effect of gas velocity, time and different concentration of nanomaterials on mass transfer coefficient in stagnant liquid column in three phase fluidized bed system. To measure coefficient of the mass transfer, known quantity of solid pellets ie benzoic acid and known amount of nanomaterial fraction ie Arachitol nano were charged in the test column of three phase fluidized bed system. At the beginning of each run, test section was partially filled with water which prevent breakage of particles. The experiments were conducted by sequentially varying gas velocity for different volumes of nanomaterial and measuring the rate of mass transfer by collecting samples directly from the outlet ports at the top subsequently analysed by volumetric titration method. The results show enhancement in mass transfer coefficient by addition of nanomaterials. Arachitol nano has been taken in different volumes ie 3ml, 7ml, 10ml and 20ml in (GLS) gas ,liquid and solid fluidized bed with air, water and benzoic acid pellets as three phases respectively in the system. The presence of nanomaterial increases the solid liquid mass transfer coefficient value with increasing fraction of nanomaterial, increasing gas velocity and increasing time although experimental run has been taken only for one hour.***

Keywords: ***Nanomaterial, three-phase fluidization, solid- liquid mass transfer, gas velocity, coefficient of mass transfer***

I. INTRODUCTION

In fluidized bed system, several techniques have been the key subject to enhance transfer of heat and mass processes and obtain better performance of multiphase system within the recent years[1]. Many workers have done study in the field of mass transfer in three phase fluidized beds. These studies were based on different measurement techniques which are generally classified into mechanical treatment such as the phases contact mode ,the chemical treatment such as additive adding and the fluid properties improvement [2].

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There are several research has been done on solid-liquid mass transfer in GLS fluidized beds by using experimental techniques including electrochemical reduction [4], [5],[6] ion exchange[7], [8] adsorption [9]. and dissolution of solids in liquid [10], [11], [12].Recently, nanofluids are known as one of the effective media for transfer of heat and mass. Fewer studies on mass transfer have been performed with nano particles, some are absorption process[13], [14] extraction[15] etc. A term nanofluid can be understood as a suspension in which size of solid particles is nano ie (diameter of particle d_p<100 nm) and these nano size particles are suspended uniformly in a base fluid[16]. In this research the effects of nanomaterial are investigated on mass transfer enhancement in dissolution of benzoic acid in water in three phase fluidized bed system. The aim of this research was to study the effect of nanomaterial on solid liquid mass transfer and the effect of liquid velocity , gas velocity, bed height, size and shape of solid material ie benzoic acid pellets in this case, on mass transfer coefficient with and without nanomaterials in the fluidized bed column.

II. MATERIALS AND METHODS

A. Experimental Setup

Fig 1. illustrates a schematic diagram of experimental set-up which consist of acrylic column of 90 mm id and 1350 mm total height. From the bottom of the bed the liquid and gas enters and passes through a gas liquid distributor. An umbrella type air sparger of 60 mm diameter having 79 orifice of 1mm has been fitted at the end of airline. For fluidization study a screen (16 mesh) is attached to the top of the column to prevent particle entrainment. The top section of the fluidizer is a cylindrical shape section (gas liquid disengagement section) has 300 mm and 250 mm diameter and height respectively assembled to the test section having 600 mm height which allows gas to escape. Liquid is filled in the test section only and not to be circulated

B. Experimental Procedure

The experiment was conducted using benzoic acid pellets as solid in stagnant liquid column with gas as a continuous phase. Arachitol nano is nanoparticles of Vit.D3, which is commercially available as (NDDS) novel drug delivery system of [17], [18] with a specific dosage was fed to the column and fully dispersed on the solid bed before liquid is charged into the column.

Different sets for fixed size (0.2cm dia and 0.4 cm height) of benzoic acid pellets with varying operating conditions of nanomaterial fractions (3ml, 5ml, 7ml, 10ml), gas velocity (0.011, 0.015, 0.020 metre per second) time(15, 30, 45, 60min) were used. By maintaining the gas phase flow rates constant for 15 min in stagnant liquid column by keeping the other parameters as constant, sample was collected from the top of column and analysed by volumetric titration method. The air flows were stopped at the end of the run and water was drained from the column in few sec. then all the solid pellets were removed from the test column and kept in desiccator and weighed [19] . The weight of the solid pellets which was actually lost, was measured.

Fig 1. Schematic diagram of the experimental setup

C. Determination of coefficient of mass transfer

The coefficient of mass transfer was calculated for solid pellets in water in GLS fluidized bed in the presence and in the absence of nanomaterial by using formula [3].

$K = \Delta M/\Delta t\ A\Delta c_m$

Where ΔM is the total mass variation of solid particles, A is effective mass transfer area and Δc_m is the mean driving force [20]. Then the effective ratio was determined to analyse the effect of nanofluid on the rate of mass transfer from the equation [16]

$R_{eff} = \frac{(k)nanofluid}{(k)water}$

The effective ratio can be define as a ratio is that to enhance the mass transfer coefficient how effective nanofluid is. The value of R_{eff} show how much mass transfer coefficient value is increased in the presence of nanomaterial .

III. RESULTS AND DISCUSSIONS

A. Effect of nanomaterial on mass transfer

The coefficient of mass transfer was calculated using the experimental data. Fig 2- 4 display that experimental data of mass transfer of benzoic acid as solid in water as liquid with time in three phase fluidized bed in different proportion of nanoparticle. It is observed that there is increase in coefficient of mass transfer with volume fraction of nanoparticles sharply although experimental run has been taken only up to 60 minutes. From above mentioned figures it can be understood that maximum volume fraction ie 20 ml Arachitol nano maximises the mass transfer of benzoic acid pellets in water. This nanofluid enhances mass transfer of benzoic acid in water in three phase fluidized bed up to 60%. Due to Brownian motion of nano size material, it causes micro convection in liquid phase. This phenomenon improves the mass transfer in the nanofluid.

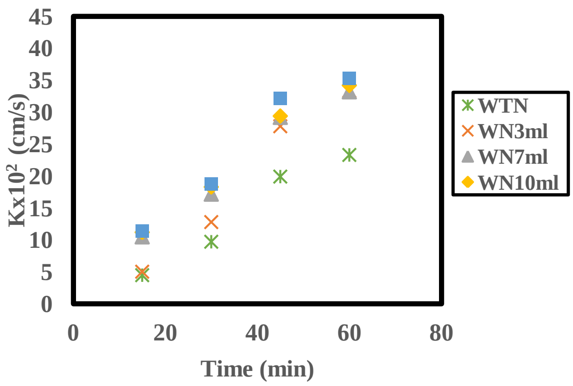

Fig 2. Mass Transfer coefficient vs Time at 4lpm gas velocity

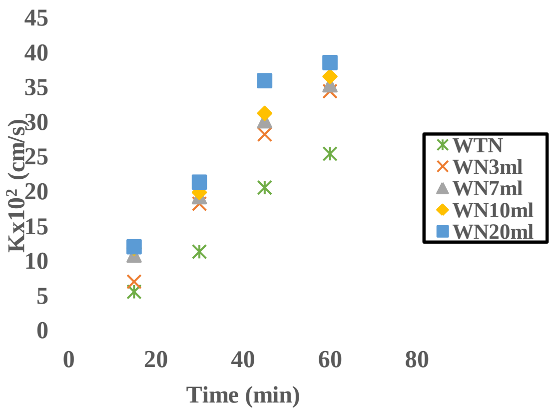

Fig 3. Mass Transfer coefficient vs Time at 6lpm gas velocity

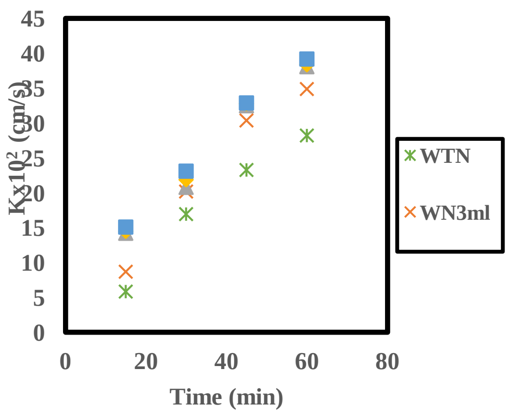

Fig 4. Mass Transfer coefficient vs Time at 8lpm gas velocity

B. Effect of volume fraction of nanomaterial on mass transfer coefficient

From the calculated value of R_{eff} it is observed that effective ratio of all nanofluids are higher than one (ref Fig 5.) so it can be concluded that nanofluid improve the phenomenon of mass transfer in GLS- fluidized bed so enhances the coefficient of mass transfer. It also can be inferred that there is increase in effective ratio with nanomaterial fraction increase. The maximum value of effective ratio is 2.58 ie case of 20 ml Arachitol nano.

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Fan et al [21] compared gas hold up in water & nanofluid and concluded that value of gas hold up is higher in nanofluids at same gas flow rate. Gas hold up helps in uniform distribution of solid in liquid that may be the one reason od mass transfer enhancement in nanofluids.

C. Effect of superficial gas velocity on mass transfer coefficient

Superficial gas velocity is an another very important factor affecting the column operation in three phase fluidization. The mass transfer coefficient increases with superficial gas velocity (ref Fig 6.). The gas flow rates were adjusted to 4, 6, 8 litre per minute, which results to superficial gas velocities of 0.011, 0.015, 0.020 metre per second. Experimental data shows that mass transfer rate is increased in both the cases. Difference in effect of superficial gas velocity on mass transfer is not very significant for with and without nanomaterial.

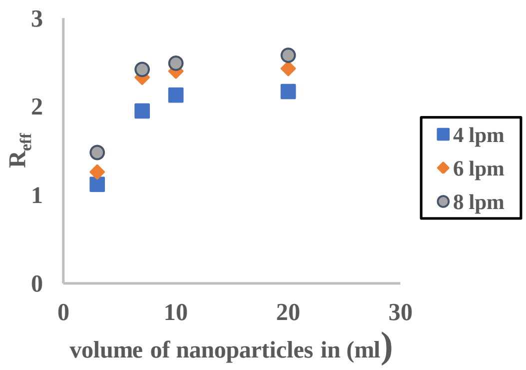

Fig 5. Comparative effect of nanomaterial on mass transfer coefficient

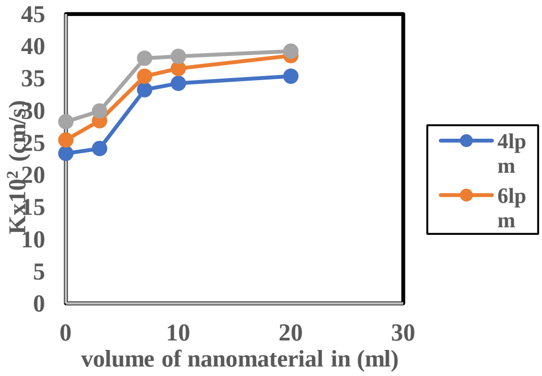

Fig 6. Effect of superficial gas velocity on mass transfer coefficient

D. Effect of superficial gas velocity on mass transfer amount

Fig 7., Fig 8., Fig 9. reveal the amount of mass transfer of benzoic acid in water with and without nanomaterial for different superficial gas velocities. Flowrates of air in three phase fluidized bed were adjusted to 4, 6, 8 L/min and volume fraction of nanomaterial were used 0.0007, 0.001, 0.002, 0.005 for each gas velocity. The experimental data show that slope of the curve which is the mass transfer rate is increased with increasing superficial gas velocity for each nanomaterial.

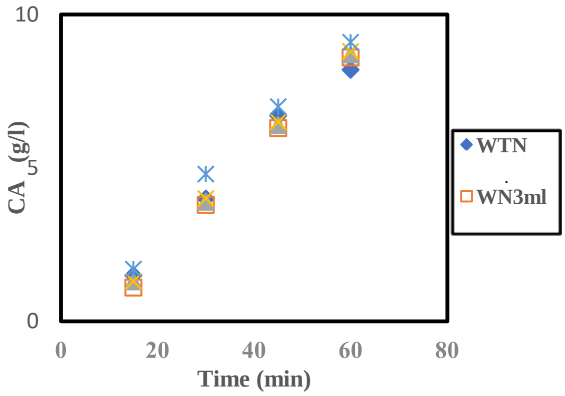

Fig 7.Variation of benzoic acid concentration in liquid phase with time for different dosage of nanomaterial at (4lpm)

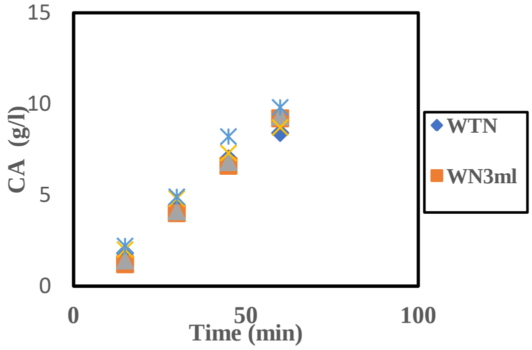

Fig 8. Variation of benzoic acid concentration in liquid phase with time for different dosage of nanomaterial at (6lpm)

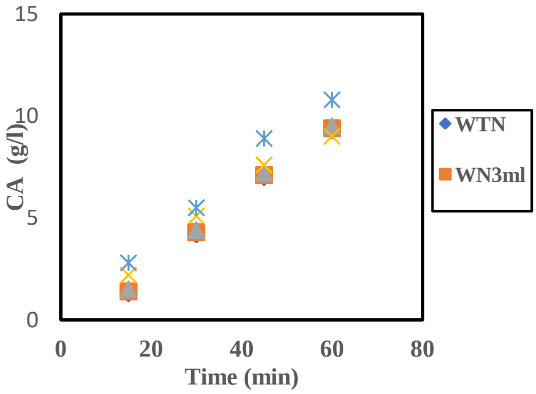

Fig 9. Variation of benzoic acid concentration in liquid phase with time for different dosage of nanomaterial at (8lpm).

IV. CONCLUSIONS

In the present study, addition of small volume fractions of nanomaterial in three phase fluidized bed and its comparison with in absence of nanomaterial was studied. The influence of volume fraction of nanomaterial on mass transfer coefficient was systematically investigated. Significant enhancement of mass transfer coefficient between benzoic acid pellets and water was achieved with increasing amount of volume fraction of nanomaterial.

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