International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 4 Issue 3, March-2015, pp: (36-46), Impact Factor: 1.252, Available online at: www.erpublications.com

Calculation Heat Transfer Coefficient in Fluidized Bed

Ali Hasan Abdulla
Kirkuk University / College of Engineering - Petroleum Dept.

Abstract: In this research fluidized bed system was molded to estimate the fluidized bed heat transfer coefficient. The phases were used were particle solid has range diameter about (200,300,400 µm), and gas phase was air, the velocity is ranged (0.024 to 0.387 m/s). The heat transfer was estimated depending on unsteady state heat transfer coefficient. The heat transfer rate was calculated and was increasing with decreasing particle diameter by increasing velocity of particles or inlet gas.

Keywords: Fluidized bed, heat transfer in the fluidized, Heat coefficient in the bed.

1. INTRODUCTION

Many important industrial processes very upon intimate contact between a fluid (liquid or gas) and granular material. These processes vary from grain drying, to a wide range of chemical reaction including combustion. In early application the fluid flowed through a static bed of granules supported on a grid provided the material is suitable, great improvement in mixing and contact is achieved if the granules size is properly matched to the upward velocity of the fluid. If they are matched well, the particles of material will be supported by the drag force. When this occurs, the bed is said to be “fluidized”.[2] Gas fluidized bed may have the appearance of a boiling liquid. It has bubbles which rise and appear to burst. The bubbles result in vigorous mixing and generally horizontal free surface. The motion of the bed varies with the fluid flow rate. At high velocities, particle may become entrained and transported by the fluid.[2].The technique of the fluidization is related to operation first used commercially in the field of minimizing and metallic goal used as liquid setting sedimentation and density classification.

A bed of large particle offers resistance to the fluid flow through it, as the velocity of the fluid increase the drag force exerts on the particle increase if the fluid flowing down word thorough a bed particle it will be tended to compact it, if the fluid flow up wards the drag force will tend to cause the particles to rearrange them within the lid to offer less resistance to the fluid flow. Unless the bed composed of large particles the bed will expand. With the further increase in the upward velocity the expansion continues and stage will be ranched where the drag force exerted on the particles will be sufficient to supported the weight of the particles. In this state the fluid particles system legions to behave like a fluid and it will flow under a hydro-static head this point is called “incipient fluidization” the pressure drop will be equal to the weight.[1]

Although it is likely that this pressure drop will be exceeded just prior achievement of fluidization with gas fluidization system because the residual packing and inter touching of the particles within the bed must be broken down up to this point the system behave in similar way we then the fluidized liquid or gas, but at higher velocities or rate for liquid the bed continuous to expand as the velocity increase and it moisten it is uniform cheater this type of fluidization is called particle fluidization .While for gas uniform fluidization is obtained only at relatively low velocities at high velocities to separate phase are formed the continues phase which called the dues are emulsion phase and the discontinues are which called bubble phase the fluidization is then said aggregative .[3] The mechanism of heat transfer operation :

A. The presence of particle in fluidization system result in an increase of up to are component the teat transfer coefficient, as compared with value obtained with a gas alone at the same velocity .In a liquid fluidized system, the increase is so matter .

B. The main mechanism have been suggested for the improvement in the heat transfer coefficient brought about by the pieces of solid, first the particle where heat capacity per unit volume is many times greater than that of the gas, acting as heat transfer again, the second mechanism which has been suggested is the rising of the laminar sat layer the heat transfer surface by the particle and consequent in its effective thickness. The third mechanism is that packet at a particle move to the heat transfer surface and steady state heat transfer process takes place.[6]

2. GAS-SOLID HEAT TRANSFER

At although average fluid heat transfer coefficient based on the total particle are often not large. A fluidized bed particle cup able of exchange heat very effectively with the fluidized gas because of very large surface area exposed by particle (300-400)it would be that heat transfer occur by condition through a gas film surrounding the undivided particles. It is difficult to measure the solvent thermal driving force for fluid /particle heat transfer because of the large surface area involved and the very rabid approach to equilibrium between the gas of flow heat capacity and a bed of fine particles. Some worker based there determinations on the outlet gas temperature form unsteady seasonably dub bed and assumed that was measure of the solid temperature within the bulk of the bed.

3. EXPERIMENTIAL MODE

Two type of experiential determination of gas /partial heat transfer coefficient are passable. In one type of experimental the temperature of the interring gas (with is usually above that of the bed is controlled and measured. The gas exchanger heat with the fluidized bed with is cooled by internal heat exchange surface or by transfer of through walls. The gas tempters change rapidly in the entry zone of the bed. Making heat balance assuming plug flow of the gas and the particle with in the bed are well mixed.[7]

$$G\ Cg\ d\ Tg = hg\ \rho\ A(Tg-Tp)\ dz \quad (1)$$
$$Ln\ (Td-Tp/Tgi - Tp) = -(hg\ \rho\ A/Gg)\ Z \quad (2)$$

So plot of Ln(Td-Tp/Tgi-Tp) VS (Z) given measure of particle / gas heat transfer coefficient. The second type is the unsteady state measurement the inlet gas temperature is measured and main tend constant. The temperature change of the bed of the outlet gas is then followed as it changed with time these being no other source of heat supply or removed .

$$Cg\ G\ d\ Tg = hg\ \rho\ A\ (Tg - Tp)\ dz = Cp\ (dTp/dt) \quad (3)$$

Assuming complete mixing then

$$Ln\ (Tgi-Tg/Tgi-Tgo) = -t\ hg\ f\ A\ Z\ Cg\ /\ Mp\ Cp\ (hg\ \rho\ A + Cg\ G) \quad (4)$$

The range of the experimental results are reviewed by Baker and Frantz which reduced to correlation as to weather temperature, where measured with suction of thermocouple or with above thermocouple they found the dependence of the 1.6th and 1.3th powers of Reynolds and Prandtle number effect and also attempted to shown that where as measurements were based on perfect gas mixing model are widely catteries and exhibit attend with bed height these following flow mode present a more consistent pattern which they correct by the equation :

$$Nup = 0.03\ Rep \quad (5)$$
$$Nup = 0.055Rep\ (\rho p\ /\ \rho go)^{0.2} \quad (6)$$

This relation predicts very low rate of (Nu) .

4. LIQUID / SOLID HEAT TRANSFER COEFFICIENT

It is if interest to draw attention to the very different situation encountered in liquid fluidized system. For such system solid and fluid have heat capacities and thermal conductivities of similar magnitudes, the fluidizing condition is generally particulate and the bed void intern more or less uniformly with increase in fluid flow rate. The heat transfer coefficient increase as the void increase and hence velocity increased and passes through maximum the void (ξ) max at which (h) max accrue becomes progressively greater as

viscosity of liquid increase. Many works have been corrected (Nup) in term of Pr, Re and the bed of void.

$$Nup = [0.033\ Rep + 1.88]\ Pr^{0.37} \quad (7)$$

An alternative form at correlation which was qually satisfactory involved Rep and the ratio of dp/dt

$$\xi\ Nup\ /Rep\ Pr^{0.922} = (0.088+0.2\ Rep^{-0.53})\ [dp/dt]^{0.5} \quad (8)$$

Where $Rep = U.cp\ /S\ \mu(1-\xi)$, $Rep=U\ cp.\rho\ d_P/\ \mu$

The maximum heat transfer coefficient could be get by differentiate with respect to void and putting the derivative equal to zero .[4]

5. BED / SURFACE HEAT TRANSFER COEFFICIENT

Many workers consider the heat transfer between fluidized bed and surface, they relate Nu many groups with certain powers. The power is different because of the results were by geometrical material arrangement and the quality of fluidization .

$$H\,dt/K = 0.55\,[dt\lambda]^{0.65}\,[dt/d_P]^{0.17}[(1-\xi)\rho_p\,Cp/\xi\,\rho\,Cg] \qquad (9)$$

Which related Nup to two groups are containing gas conductivity (KJ) with thermal and mechanical properties and the other is Re groups incorporation the fluidization parameter .

$$H = \text{const}\; g^{0.2}\,K_g^{0.6}\,(Cp\,\rho_p)^{0.4}\,[G.E/Mg\,R]^{0.36} \qquad (10)$$

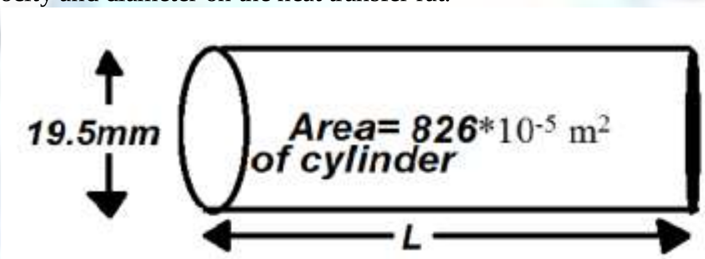
6. BED/WALL HEAT TRANSFER COEFFICIENT

There is arise in the observed heat transfer coefficient as the particles become mobile and circulate with in the bed under the influence of rising bubbles there is some coming increase with further increase in gas velocity until a maximum is reached which expends over average of flow values. Z gives an approximate correlation for the maximum particle convection coefficient. [8]

$$H_{mp} = 35.8\rho_p^{\;0.2}\,KJ^{0.6}\,d_P^{-0.36} \qquad (11)$$

7. HEAT TRANSFER CALCULATION

We will calculate the heat transfer coefficient for fluidized bed system, and study the most dominant effects on the heat transfer coefficient in fluidized bed. Velocity of the fluid will be varied also use various value of particles diameter to study the effect of both velocity and diameter on the heat transfer rat.



$q'' = h(T_S - T_F)$, T_S= Temperature element , T_F= Temperature of bed

$$h = q''/(T_S - T_F) \qquad (12)$$

$q = q'' * A$

$$q'' = q/A \qquad (13)$$

Area of cylinder =diameter *height* π

Area = $826*10^{-5}$ m^2 , diameter = 19.5 mm (from table)

$826*10^{-5} = 3.14 * (19.5/1000)*L$

L= 0.1349m L= 13.49 cm

From table D-1 dp 200µm , q=40 W

$q'' = q/A$

$q'' = 40/(826*10^{-5})$, $q'' = 4842$ W

u=0.024 m/s

$h = q''/(T_S - T_F)$

h=40.34 $w/m^2.k$

(Table 1): Surface Temperature of Heating elements for different power supplies

dp(μm)	q u (m/s)	Dh =19.5mm		
		40W	60W	80W
200	0.024	160.5	221.5	275
	0.031	124	135.6	164.3
	0.036	112	118.5	140
	0.048	98.3	109.5	125.9
	0.06	75.6	95.3	111.3
	0.078	71.6	87.8	102
	0.09	66	82.1	94.4
	0.102	62.1	74.5	87.1
300	0.054	153	190.6	239.7
	0.069	126.3	172.3	212.3
	0.083	101.3	116.6	132.7
	0.108	71.8	86.2	100.7
	0.132	64.6	76	86.1
	0.156	61	71.7	79.8
	0.18	57.5	67.2	76.2
	0.224	55.3	64.3	72.8
400	0.102	125.6	169.6	209.8
	0.12	107	139.5	169.5
	0.15	72	89.6	108
	0.18	63.2	76	87.7
	0.21	60	70.5	80
	0.255	58.8	68	77
	0.306	57.2	65	73
	0.387	56	62.7	70.7

Table 2): Radial and Axial Bed Temperature Profile, Dh=19.5mm.

dp(μm)	r/R u(m/s)	z=100mm (Q=40 W)	z=100mm (Q=60W)	z=100mm (Q=80W)
		0	0	0
200	0.024	40.48	47.6	37.82
	0.031	45.88	58.57	67.31
	0.036	48.94	62.13	66.99
	0.048	51.62	62.55	65.53
	0.06	49.59	57.4	62.64
	0.078	48.54	56.93	61.53
	0.09	47.47	54.98	59.54
	0.102	46.52	52.79	59.07

300	0.054	38.04	42.21	40.88
	0.069	38.55	43.55	41.63
	0.083	46.61	53.6	60.25
	0.108	46.14	50.41	54.76
	0.132	45.63	49.25	53.28
	0.156	43.99	48.08	51.79
	0.18	43.52	46.75	50.17
	0.224	42.3	45.12	48.33
400	0.102	37.52	40.06	39.58
	0.12	46.99	46.2	49.17
	0.15	43.8	48.31	52.93
	0.18	43.53	46.92	49.87
	0.21	43.13	45.64	47.68
	0.255	42.68	44.48	46.53
	0.306	42.38	43.18	45.07
	0.387	42.03	41.94	43.64

By Appling the a above equation we will get the following tables:

q=40 W , dp=200µm	
(q and dp are constant)	
velocity m/s	h (w/m^2.k)
0.024	40.34
0.031	61.98
0.036	76.78
0.048	103.72
0.06	186.15
0.078	209.97
0.09	261.3
0.102	310.78

Table (3)

q=60 W , dp=200µm	
(q and dp are constant)	
velocity m/s	h (w/m^2.k)
0.024	41.76
0.031	88.54
0.036	128.84
0.048	154.69
0.06	191.63
0.078	235.27
0.09	267.8
0.102	334.54

Table (4)

q=80 W , dp=200µm	
(q and dp are constant)	
velocity m/s	h (w/m^2.k)
0.024	40.83
0.031	99.85
0.036	132.65
0.048	160.42
0.06	199.03
0.078	239.31
0.09	277.82
0.102	345.52

Table (5)

q=40 W , dp=300µm	
(q and dp are constant)	
velocity m/s	h (w/m^2.k)
0.054	43.03
0.069	60.2
0.083	92.47
0.0108	239.94
0.132	322.58
0.156	388.6
0.18	482.75
0.224	511.47

Table(6)

q=60 W , dp=300µm	
(q and dp are constant)	
velocity m/s	h (w/m^2.k)
0.054	48.94
0.069	56.41
0.083	115.28
0.0108	212.59
0.132	271.51
0.156	307.49
0.18	355.15
0.224	378.67

Table(7)

q=80 W , dp=300µm	
(q and dp are constant)	
velocity m/s	h (w/m^2.k)
0.054	48.71
0.069	56.74
0.083	133.67
0.0108	210.81
0.132	295.09
0.156	345.76
0.18	372.07
0.224	395.79

Table(8)

q=40 W , dp=400µm	
(q and dp are constant)	
velocity m/s	h (w/m^2.k)
0.102	54.97
0.12	80.68
0.15	171.7
0.18	246.16
0.21	287.03
0.225	300.37
0.306	326.72
0.387	346.59

Table(9)

q=60 W , dp=400µm	
(q and dp are constant)	
velocity m/s	h (w/m^2.k)
0.102	56.06
0.12	77.84
0.15	175.9
0.18	249.75
0.21	292.15
0.225	308.8
0.306	332.85
0.387	349.85

Table(10)

q=80 W , dp=400µm	
(q and dp are constant)	
velocity m/s	h (w/m^2.k)
0.102	56.89
0.12	80.48
0.15	175.86
0.18	256.01
0.21	299.65
0.225	317.85
0.306	346.75
0.387	357.9

Table(11)

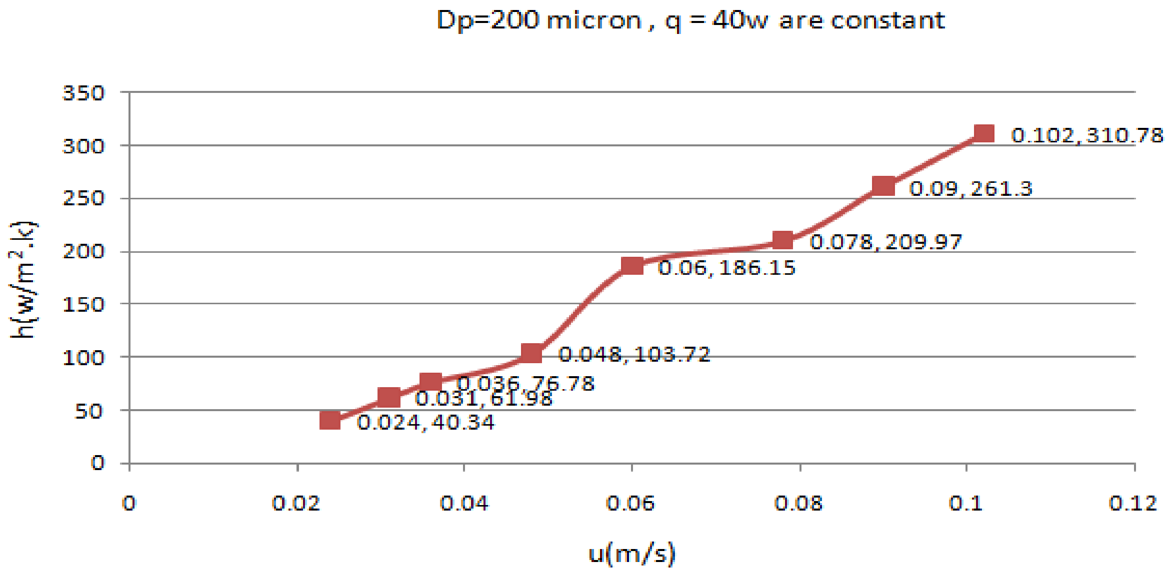


Fig: 1: Relation between velocity and heat transfer

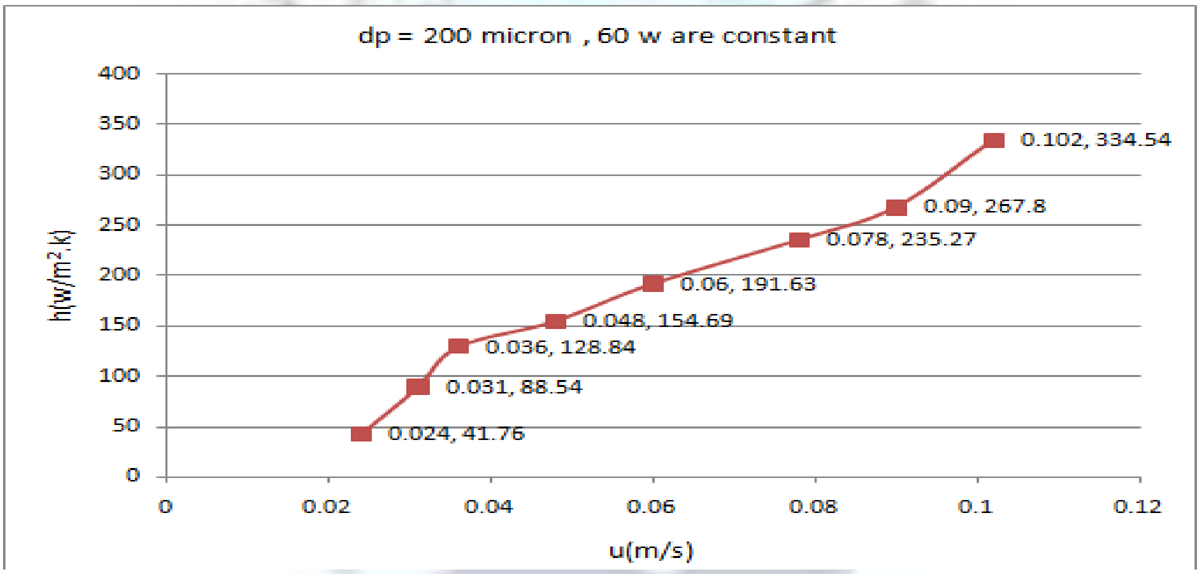


Fig: 2: Relation between velocity and heat transfer

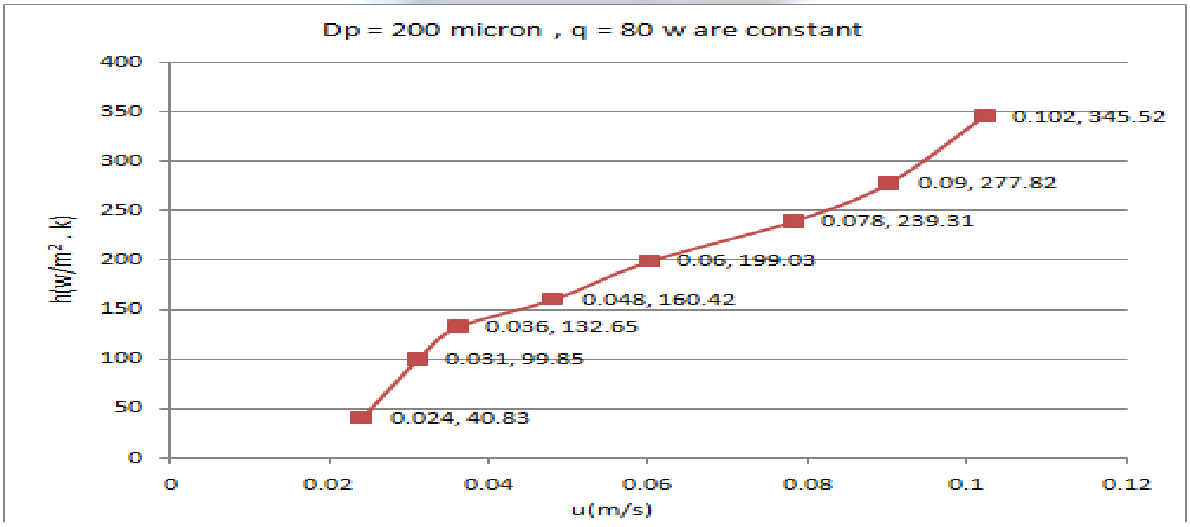


Fig: 3: Relation between velocity and heat transfer

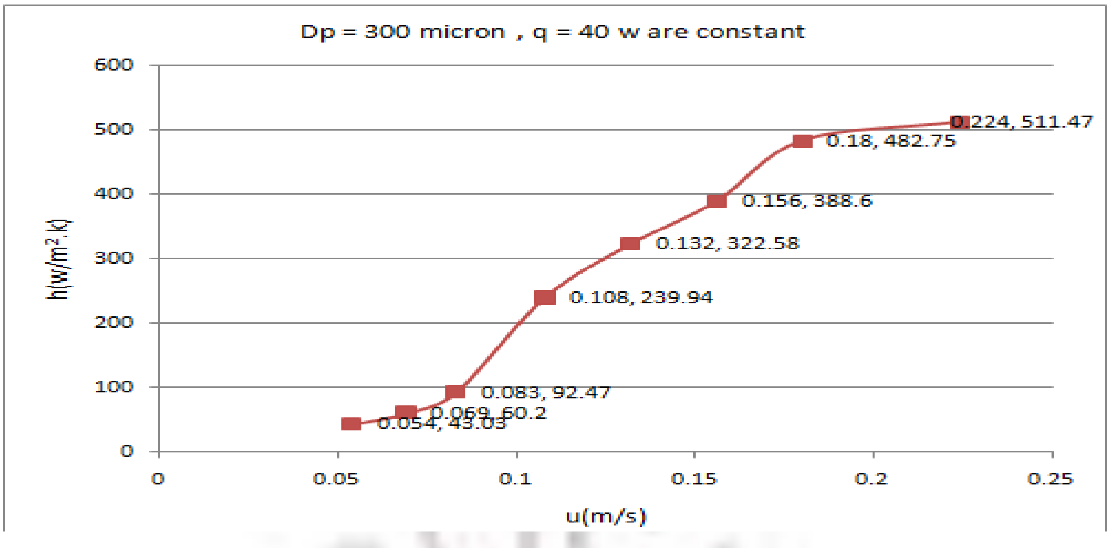


Fig: 4: Relation between velocity and heat transfer

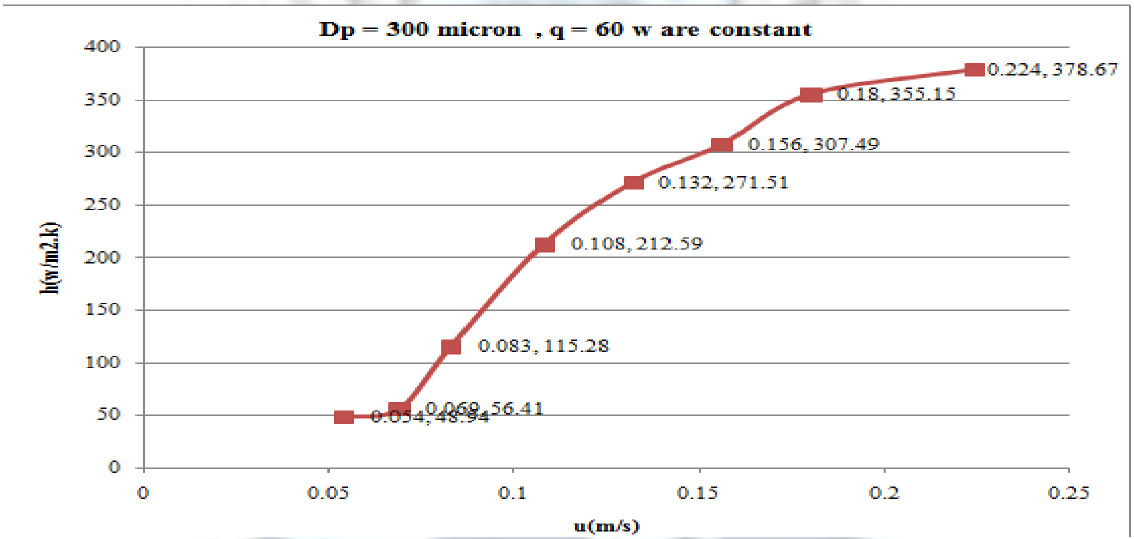


Fig. 5: Relation between velocity and heat transfer

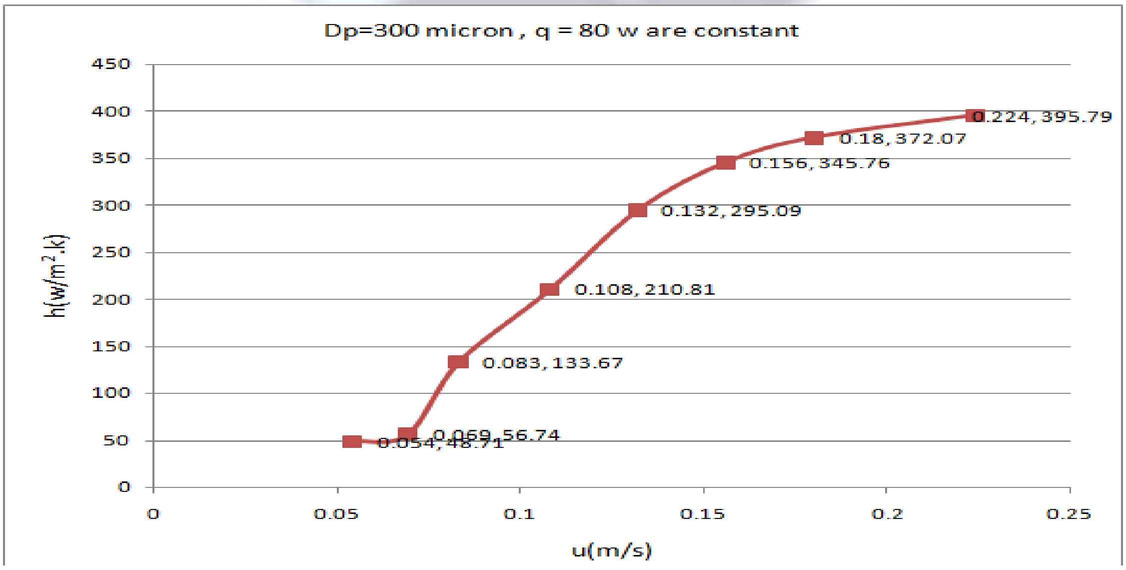


Fig: 6: Relation between velocity and heat transfer

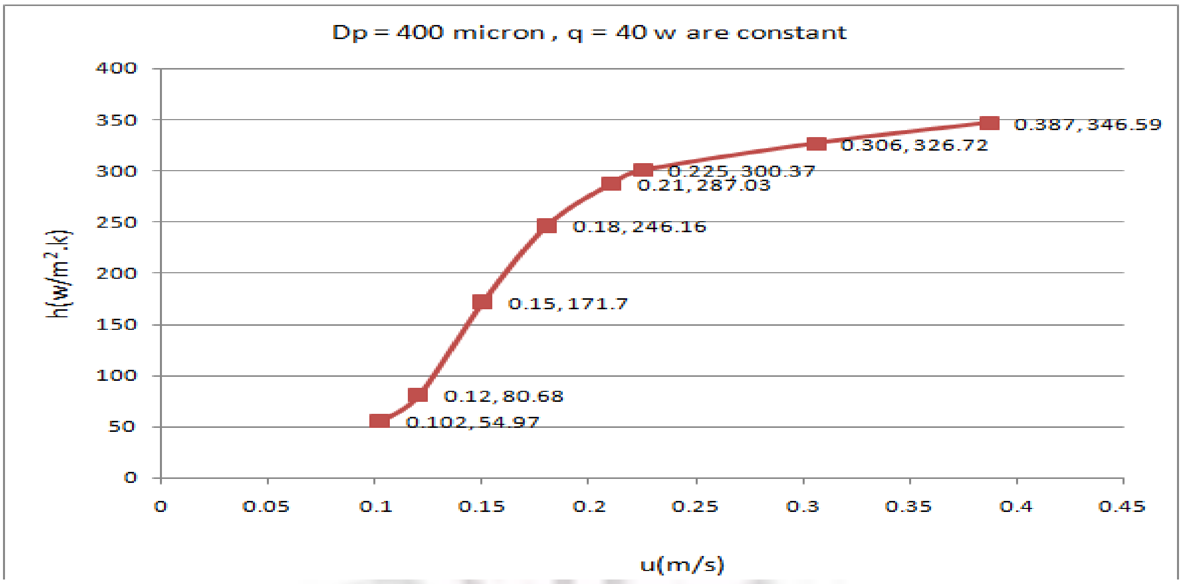


Fig: 7: Relation between velocity and heat transfer

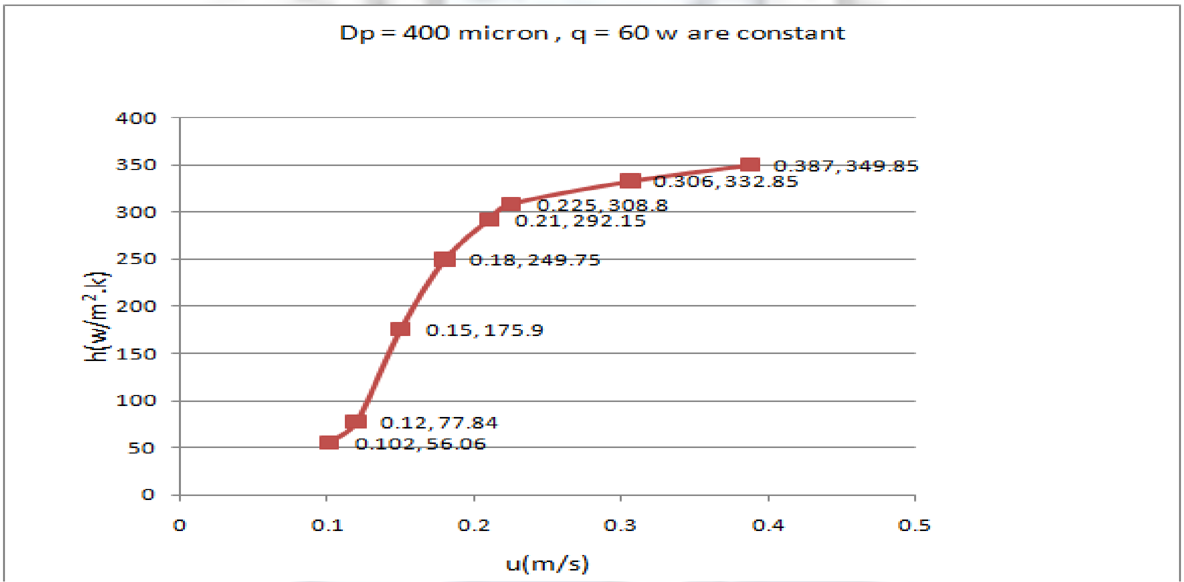


Fig: 8: Relation between velocity and heat transfer

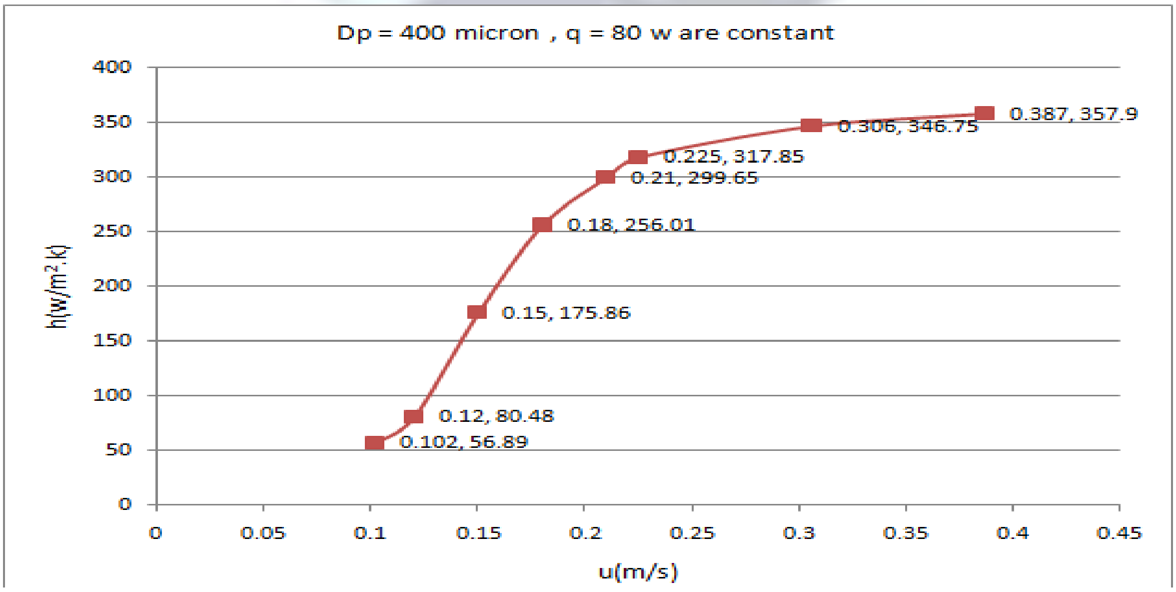


Fig: 9: Relation between velocity and heat transfer

International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 4 Issue 3, March-2015, pp: (36-46), Impact Factor: 1.252, Available online at: www.erpublications.com

u=0.1m/s , q=40 w are constant	
$h(w/m^2 . K)$	dp (micron)
316.3	200
238.6	300
51.76	400
27.55	500
13.26	600

Table (12)

u=0.1m/s , Dp=400 micron are constant	
$h(w/m^2 . K)$	q (w)
54.91	40
56.21	60
56.88	80
57.15	100
57.97	120

Table(13)

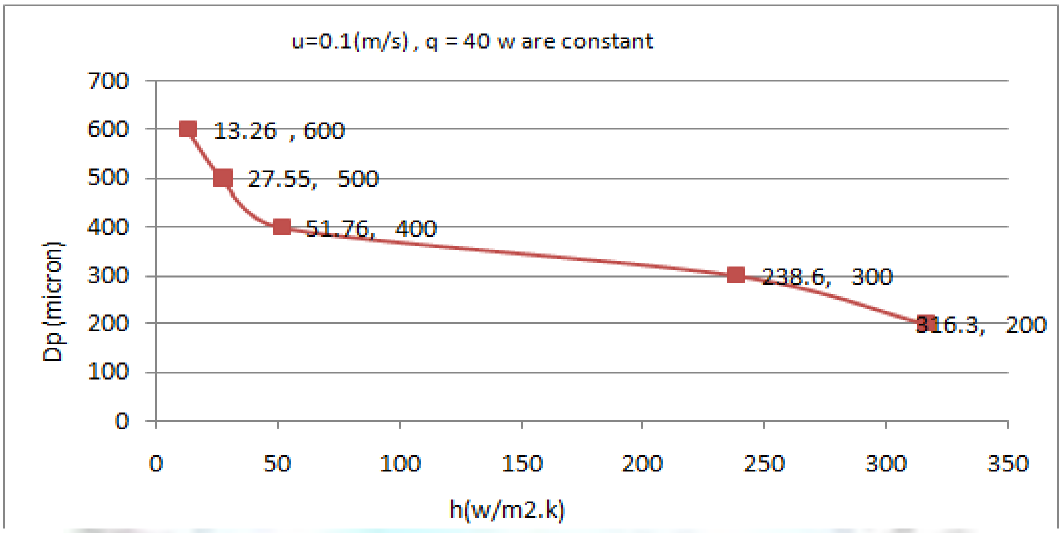


Fig: 10: Relation between diameter and heat transfer

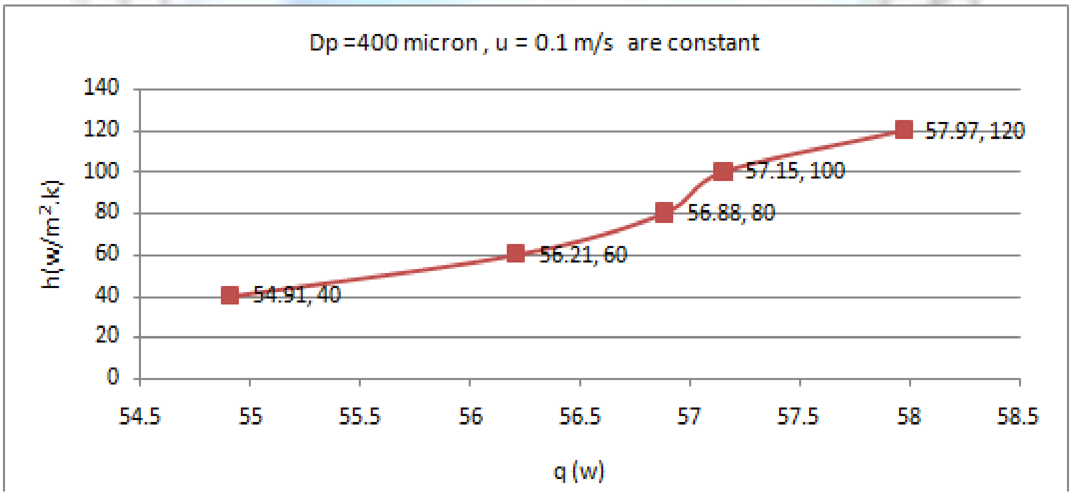


Fig: 11: Relation between heat capacity and heat transfer

8. CONCLUSIONS

From figures.(1) to (9)(Table from 3 to 11), it can be observed that heat transfer coefficient increase by increasing velocity of the gas, where various type of particle diameter used in each run of the experiment.

From figure (10)(Table 12), it can be seen that the heat transfer coefficient decrease with increasing particle diameter, (m) where these experiment are carried out at a gas velocity (0.1 m/s) and heat transfer rat (q) equal (40 w).
From figure (11)(Table 13), we can see that heat transfer coefficient increasing with increases heat transfer rat linearly band these result complied with the theoretical result of Newton law.

NOMENCLATURE

G : mass flow rate (kg/sec)
Cg : drag coefficient
Tg : Temperature of gas
hg : Heat transfer coefficient
ρ : Density of fluid(kg/m^3)
A : Area of cylinder (m^2)
Tg : Temperature of gas (k)
Tp : Temperature of particle (k)
Z : Volume of zone (m^3)
d : Diameter of cylinder(m)
D_p :Diameter of particle.(m)
Tgi : Temperature of inlet gas
P : Pressure in cylinder(psi)
ρgo = density of gas at atmospheric pressure(psi)
Pa : Area of particle(m^2)
Cp : Specific heat capacity
Tgo : Temperature of outlet gas
T : Temperature (k)
Mp : Mass of particle (kg)
Nup : Particle nuss
Rep : Renolds number
ρ_p : Density of particle
Pg = density of working pressure
Pgo : Pressure outlet gas
Pg : pressure of gas
Pr : Prandtle number
U : Velocity (m/s)
ξ :. Void of bed
(1-ξ) : Void fraction
Nup : Nusselt number of paeticle
S : Surface of particle(m^2)
Z : Zone of particle
μ : dynamic viscocity
K : Thermal conductivity of fluid, (W/mK)
λ : Ratio of total surface in the bed
E : Fluidization efficiency
Mg : Molecular weight of gas.
R : Radiation
Kg ; Conductivity of gas.
d_p : Diameter of particle(m).

REFERENCES

[1]. Bearg, K. and gashler C, F 28 (1950).
[2]. Barker, Ind, Eng, chem., 57, (1965).
[3]. Baskakove and suprun, Int, chem.., eng, 342, (1972).
[4]. Coulson and Richardson (Chemical engineering). , vol.(2) (1978) .
[5]. Davies, (heat transfer in liquid solid fluidized bed). Ph.D.Thesis, University of wales.
[6]. Dow and Jacob, Chem. Eng. 48, (1951).
[7]. Ergum, chem.. eng. Progr.48, (89-94), (1952).
[8]. Kuniri and Levenspiel, (Fluidization Engineering), Wiley (1996).
[9]. Lemlich and Calolas, D.7 .chem.eng. 14, 376, (1998).
[10]. Levespiel and Walton, chem.. eng. Progr. Symp. Series.so.(1995).
[11]. Millry and Logwinuk, Ind. Eng. Chem., 43, 220, (1988).
[12]. Zabrodsky, S.S. (Hydrogynemic and heat transfer in fluidized bed), (1996).

AUTHOR

B.Sc. University of Technology – Baghdad / Chemical. Engg. – 2006
MsD. Azerbaijan state oil academy (Baku) / Azerbaijan – 2010
Specialist: Refinery of petroleum and gas
Lecturer in College of Engineering / Kirkuk University

ALI HASAN ABDULLA