Effect of Extended Fins on Heat Transfer in a Bubbling Fluidized Bed

S. Rasouli, Member IAENG, and M. Farzinpoor

Abstract— **Bubbling fluidized bed apparatus was designed and constructed to investigate heat transfer coefficient from rectangular, triangular and circular fins. The results show that the diameter of solid particles and inlet air flow rate to the apparatus are among the parameters affecting the heat transfer coefficient. Heat transfer coefficient in equal Reynolds particle Number is more in triangular, rectangular and circular fin shape respectively. Triangular fin shape, due to having sharp top surface compared to the other fins, has a higher heat transfer coefficient.**

Index Terms—
Bubbling fluidized bed, Rectangular fin, Triangular fin, Circular fin, Heat transfer.

I. INTRODUCTION

MANY studies have examined heat transfer coefficient in fluidized bubbles [1]. Busoul and Abuein [2] studied the effect of input gas speed, particle diameter, and environment angle on the circle, and particle type on heat transfer coefficient of immersed objects in bed. They observed that the increase in heat transfer coefficient has a direct relationship with input gas speed and decrease in particles, diameter. Rasouli and Golriz [3] studied the influence of circular fins on heat transfer coefficient between horizontal tube and fluidized clod bubble bed. They showed that heat transfer coefficient is decreased by adding fins, but total heat transfer is increased due to the increase in the surface. Hou et al. [4] studied the heat transfer in bubbling Fluidized Beds with Geldart A powder. Kim et al. [5] identified heat transfer coefficient of bubble and emulsion phase between horizontal tubes and fluid, showing that the average of heat transfer coefficient is reached a maximum point by speed increase and then it decreases, but the total amount of heat transfer is raised up due to the surface increase. Salwe et al. [6] investigated the effect of particle diameter and speed on heat transfer in fluidization in heat converter. They concluded that the Silica sand is suitable in fluidization and increasing the speed of solid particle will increase the heat transfer coefficient between heat tube and sand particle by 80-250 W/m^2K.

Miccio et al. [7] studied the heat transfer method between boiling fluid bed and immersed tubes in order to regain heat and force production. From obtained results it can be concluded that to increase the heat transfer amount in heat transfer units of fluid bed, it is suggested that small particles be used for solid material of the bed. Arai et al. [8] studied the effect of heat transfer coefficient in a shallow fluidized bed heat exchanger with a continuous flow of solid particles. Gupta [9] experimentally studied the effect of connecting fins on probes of heat transfer on heat transfer coefficient in a circular separator in CFB. He observed that heat transfer coefficient is somehow lower when fins are connected. Meanwhile heat transfer in those with fins is higher than surfaces without fins. By proposing a mathematical model Reddy and Nag [10] could predict heat transfer rate from surfaces with fins in circulating fluidized bed. Increase in heat transfer rate from bed to wall has a direct relationship with the increase in density of suspension, and by incease in the number of fins, heat transfer coefficient is lowered. They found that heat transfer coefficient of circular horizontal fin is less than that of horizontal tube with no fin, but by increasing the surface, the total heat transfer is increased. Also heat transfer in one tube (with and without fin) is a function of Reynolds and Prandtl number, an exponential function. Amritkar and Tafti [11] experimentally studied Heat transfer in fluidized bed- tube heat exchanger. The present study will study the effect of the fin shape as rectangular, triangular and circular on heat transfer coefficient in cold bubble bed. In order to examine the effect of geometry of fin on fluidized bubble beds.

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II. BUBBLING FLUIDIZEAD BED APPARATUS

Bubbling fluidized bed apparatus was set up. General components of the apparatus model are shown in Fig1.

Fig.1 Bubbling fluidized bed apparatus, set up at heat transfer laboratory in IAU, Khomeinishahr Branch

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The bubbling fluidized bed unit in which experiments were conducted comprised of a 90 mm inside-diameter and 260 mm- tall main columns, made up of Plexiglas to allow visual observation, Fig. 1. For determining heat transfer coefficient around a finned horizontal tube, a heat transfer probe (20 mm outside diameter × 60 mm long) was made of steel rod and insulated at the ends. A hole was drilled at the center of the rod to accommodate a resistance heater (6.5 mm outside diameter × 42 mm long), Fig. 2. The finned heat transfer probe was made of steel rod (20 mm outside diameter × 60 mm long) with three types of shape fins (1 mm thick), with equal area of 1.25 cm2 in three shapes of fins includes rectangular, triangular and circular geometries, Fig. 2. The power input to the heater was controlled by a variable direct current power supply. The supplied heat flux is determined by measuring voltage (V) and current (I). Because the temperature of the probe was higher than the bed temperature, heat was transferred from the probe to the bed, i.e. in the opposite direction to that in a real fluidized bed heat exchanger.

Air velocity was varied from minimum fluidization velocity, umf, to near 3×umf, and two different silica sand diameters were used as shown in Table I. These particles have different diameters equal to 215 microns and 360 microns.

For each of the sand particles the heat transfer coefficients were determined for 8 to 10 different gas velocities, and for each of the velocities the measurements were repeated 4 to 6 times.

TABLE I
PROPERTIES OF SILICA SAND PARTICLES

ρ (Kg/m^3)	C_p(J/Kg K)	K(W/mK)
1800	800	0.27

III. CALCULATING HEAT TRANSFER COEFFICIENT

In general, the heat transfer process in fluidized bed combustor in gas-fluidized beds consists of particle convection/conduction, gas convection and radiation.

However, in this work because of low temperature difference between the immersed surface and the bed material the radiation has been neglected. For the mathematical modeling despite of two components of heat transfer, particle convection and gas convection, an average value has been assumed [12].

Heat transfer coefficient was obtained for each finned tube [3, 13]. Heat power output from immersed tube with rectangular fin which is insulated on the top is obtained by:

$$V.I = \left[\sqrt{hpkA}(T_0 - T_\infty)\tanh(ml)\right] \times n + hA(T_s - T_\infty) \quad (1)$$

In which: $m = \sqrt{\frac{hp}{kA}}$

Heat power output from immersed tube with triangular fin which is insulated on the top is obtained by:

$$V.\text{I}= \left[(Z\sqrt{2hk\delta}\,\frac{I_1(2\alpha\sqrt{L})}{I_0(2\alpha\sqrt{L})}(T_0 - T_\infty)\right] \times n + hA(T_s - T_\infty) \quad (2)$$

In which: $\alpha = \sqrt{\frac{2hL}{k\delta}}$

Heat power output from immersed tube with circular fin which is insulated on the top is obtained by:

$$V.\text{I}= [K2\pi r_1\delta(C_1 I_1(mr_1) - C_2 K_1(mr_1)) \times n + hA(T_s - T_\infty) \quad (3)$$

In which: $\text{m} = \sqrt{\frac{2hL}{k\delta}}$,and:

$$C_1 = \frac{T_0 K_0(mr_2) - T_{top}K_0(mr_1)}{k_0(mr_2)I_0(mr_1) - I_0(mr_2)k_0(mr_1)}$$
$$C_2 = \frac{T_0 I_0(mr_2) - T_{top}I_0(mr_1)}{k_0(mr_1)I_0(mr_2) - k_0(mr_2)I_0(mr_1)} \quad (4)$$

All experiments were conducted with the same heat transfer (V. I= 10.6 W).

Reynolds particle Number is calculated as below:

$$Re_p = \frac{\rho v D_p}{\mu} \quad (5)$$

Nusselt Number is calculated as below:

$$\text{Nu} = \frac{hD_p}{k} \quad (6)$$

IV. RESULTS

For three different fin geometries, rectangular, triangular and circular shape with the same surface area, (1.25 cm^2),and for two type of silica sand particles with 215 and 360 microns particle diameters with variation of Reynolds particle Number from 2.22 to 5.1, the heat transfer coefficient and Nusselt number is calculated.

The results show in Fig. 3 and Fig. 4.

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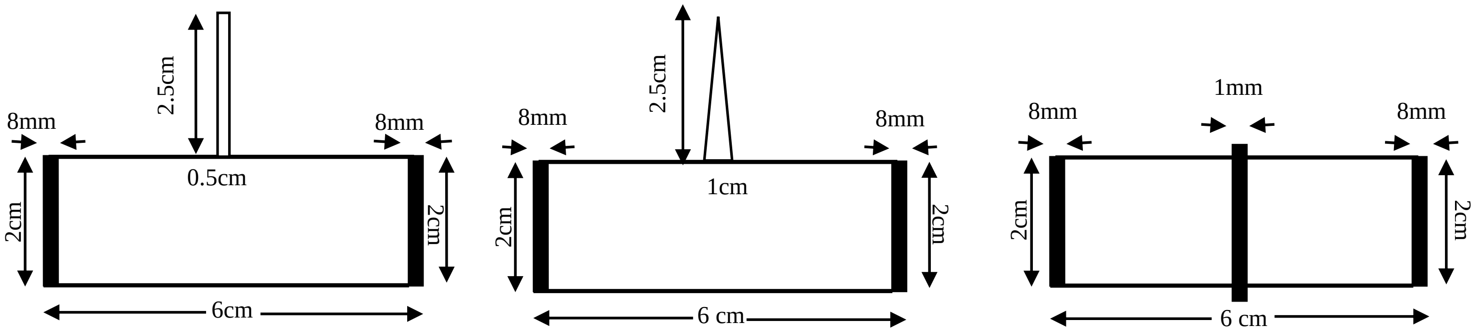

Fig. 2. Geometrical installation of the fins on immersed tube

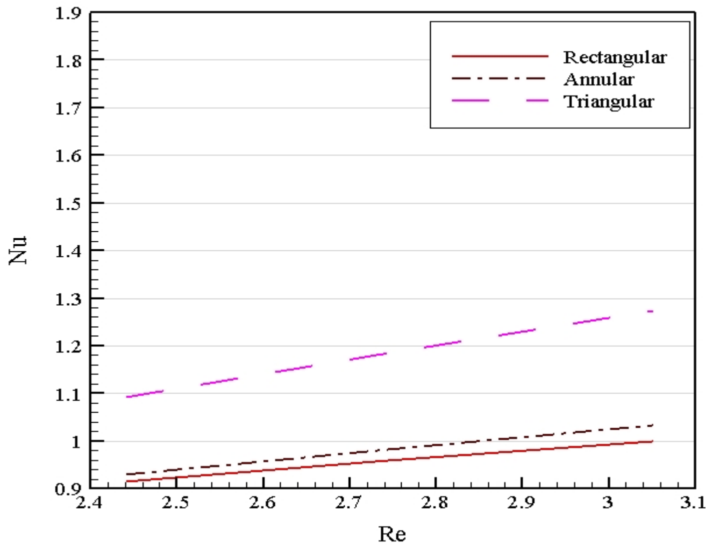

Fig. 3. Variation of Nusselt Number versus Reynolds Number for 215 microns particles diameter for three types of fin shape

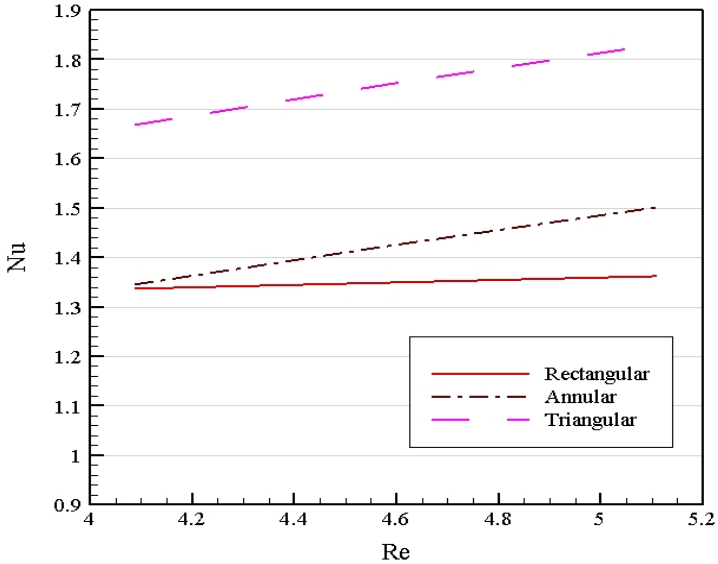

Fig. 4. Variation of Nusselt Number versus Reynolds Number for 360 microns particles diameter for three types of fin shape

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From experimental data, it is derived correlation between Nusselt and Reynolds Numbers, which is introduced in equations (7) to (12).

For rectangular finned tube and 215 microns particles diameter:

$$Nu = 0.645\,\mathrm{Re}^{0.3916} \tag{7}$$

For rectangular finned tube and 360 microns particles diameter:

$$Nu = 1.182\,\mathrm{Re}^{0.0870} \tag{8}$$

For triangular finned tube and 215 microns particles diameter:

$$Nu = 0.5913\,\mathrm{Re}^{0.688} \tag{9}$$

For triangular finned tube and 360 microns particles diameter:

$$Nu = 0.933\,\mathrm{Re}^{0.4128} \tag{10}$$

For circular finned tube and 215 microns particles diameter:

$$Nu = 0.6089\,\mathrm{Re}^{0.474} \tag{11}$$

For circular finned tube and 360 microns particles diameter:

$$Nu = 0.6746\,\mathrm{Re}^{0.4902} \tag{12}$$

V. CONCLUTION

The following conclusions were reached within the operational conditions of this work:

- With increasing air flow rate in bubbling fluidized bed, heat transfer coefficient is increased due to increase the velocity of particles contact to the fin.
- By decreasing particle diameter, the heat transfer coefficient is increased due to contact more particles to the fin with more density.
- Heat transfer coefficient in equal Reynolds particle Number is more in triangular, rectangular and circular fin shape respectively.
- Bed-to-tube heat transfer with fin is empirically correlated as a function of particle Reynolds number and Prandtl number using a power-type relation. It was found that the model predictions were in good agreement with experiments at higher heat transfer coefficients and overestimates at lower heat transfer coefficients.
- Triangular fin shape, due to having sharp top surface compared to other fins, has a higher heat transfer coefficient.

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