Heat transfer from single, vertical, longitudinally finned tubes in an air fluidized bed
by Steven Daniel Hickel

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Chemical Engineering
Montana State University

Abstract:
Heat transfer coefficients were measured from vertical, bare and longitudinally finned tubes to a circular air fluidized bed. The fluidized particles were glass beads and limestone particles. Experimental parameters were fin height, bed particle diameter, bed particle type, and air fluidizing velocity.

Results for the finned tubes indicate that for increased air mass velocity the heat transfer coefficient rises. In several cases a maximum was obtained for the value of the heat transfer coefficient. The smaller fin height tubes generally gave higher values for the heat transfer coefficient. For a given tube, the glass beads gave a higher maximum heat transfer coefficient, but at a much lower air mass velocity than where the peak occurred for the limestone particles. The best performance was obtained with the 1/2 inch fin height tube using glass beads, and with the 3/8 inch fin height tube using limestone particles.

The Nusselt numbers for the finned tubes were correlated with two equations. The first equation was for the limestone data and the second was for the glass bead data.

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Date October 8, 1981

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by

STEVEN DANIEL HICKEL

A thesis submitted in partial fulfillment of the requirements for the degree

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Approved:

Robert L. Nickelson
Chairperson, Graduate Committe

F P McCandless
Head, Major Department

Graduate Dean

MONTANA STATE UNIVERSITY
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ABSTRACT

Heat transfer coefficients were measured from vertical, bare and longitudinally finned tubes to a circular air fluidized bed. The fluidized particles were glass beads and limestone particles. Experimental parameters were fin height, bed particle diameter, bed particle type, and air fluidizing velocity.

Results for the finned tubes indicate that for increased air mass velocity the heat transfer coefficient rises. In several cases a maximum was obtained for the value of the heat transfer coefficient. The smaller fin height tubes generally gave higher values for the heat transfer coefficient. For a given tube, the glass beads gave a higher maximum heat transfer coefficient, but at a much lower air mass velocity than where the peak occurred for the limestone particles. The best performance was obtained with the 1/2 inch fin height tube using glass beads, and with the 3/8 inch fin height tube using limestone particles.

The Nusselt numbers for the finned tubes were correlated with two equations. The first equation was for the limestone data and the second was for the glass bead data.

INTRODUCTION

A fluidized bed is a column containing solid particles and having a porous bottom through which a fluid can be forced to flow. The motion of the fluid moving through the particles causes them to be lifted and mixed. The degree and dynamics of the fluidization are dependent upon the physical characteristics of the system and the rate at which the fluid flows through the system.

In a gas fluidized system, such as is used in this experimental program, several regimes exist during fluidization. Before the upward force of the air is equal to the weight of the bed material there is no fluidization and the bed remains fixed. The properties of the bed during this stage are essentially the same as those of a fixed bed. When the air velocity is increased above the point where the force of the air can support the weight of the bed, the bed begins to fluidize. This point is called the minimum fluidization velocity, or the incipient fluidization velocity. Near minimum fluidization there is only mild mixing of the particles with the air flowing between the particles and no bubbles.

being formed. Further increase in the fluid velocity causes larger and larger bubbles to form, increasing particle mixing. The bed expands during this stage of the fluidization. This regime of fluidization is called aggregative, because expansions and contractions in the bed volume result in a time dependent bed density. Bubble size increases with fluid velocity increase until these bubbles occupy the entire cross section of the column. We now lose the so called dense phase fluidization, where there is a clearly defined upper surface of the bed. At these high fluidization velocities the terminal velocity of some particles is reached and they are thrown high in the column. Intense mixing is occurring in the bed. The upper boundary of the bed becomes hard to distinguish and particles are carried out of the column. This regime is called the dilute-, or lean-phase fluidization region. These regimes are shown in Figure 1. For greater detail and terminology the reader is referred to numerous texts (1),(2),(3),(4).

Fluidized beds have many applications in modern

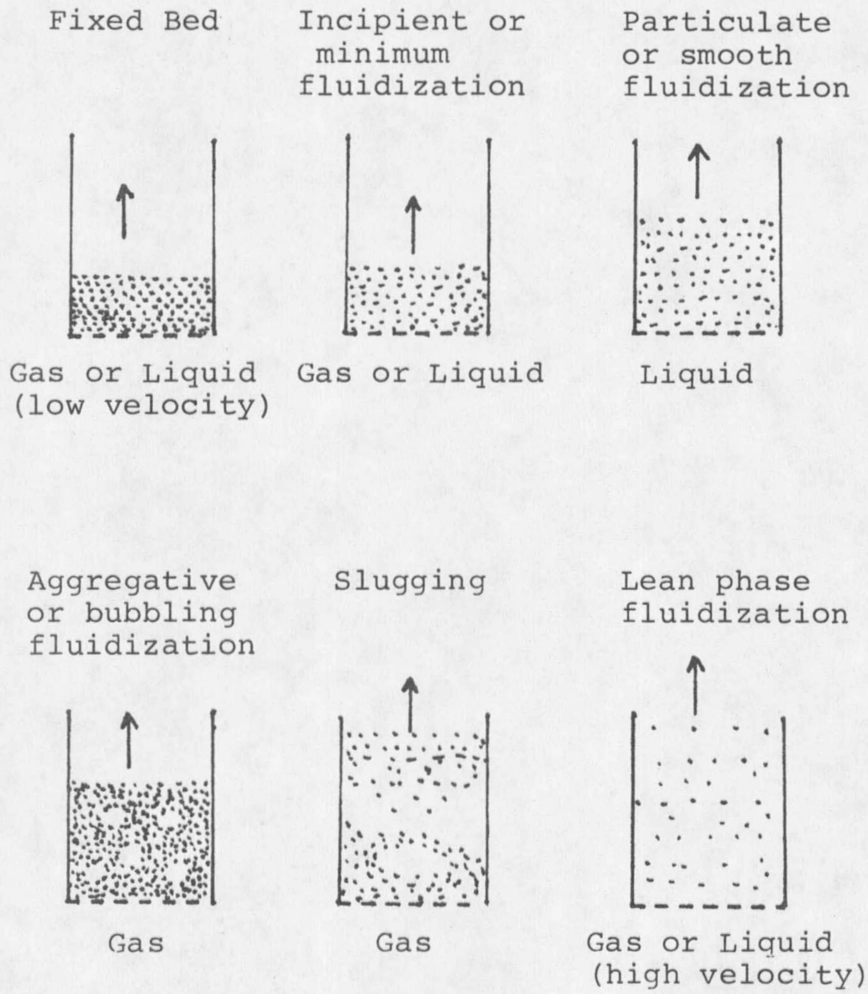

FIGURE 1. REGIMES OF FLUIDIZATION

industry. A recent development is the use of fluidized bed combustors to destroy toxic substances such as PCBs (5). New coal fired generators are also being designed using fluidized bed technology. Large particle limestone or dolomite fluidized bed combustors show great potential for reducing SO_2 emissions from a combustion chamber (6). There are currently a great number of commercial applications of fluidized bed technology (3).

The reason that fluidized beds have found such utility is that the operating characteristics are very well suited for certain processing needs. A number of the advantages are:

1. Extremely large areas of contact between solid and fluid which provide high overall rates of mass and heat transfer.
2. Easily handled fluidized solids.
3. High heat transfer rates to immersed surfaces.
4. High thermal inertia of solids.
5. Properties of a thermodynamic fluid with a low vapor pressure, even at high temperature.

This process system is not without certain disadvantages.

Drawbacks are:

1. Power is required for fluidization.
2. Particle attrition and agglomeration can be troublesome.
3. The operating rates are limited by the minimum fluidization velocity and the terminal velocity of the particles.
4. There is a certain range of particles that can be fluidized (.001-.25 Inch).
5. True counter current operation can not be obtained because of the high degree of mixing.
6. In certain applications thermal gradients may be necessary.
7. The scale up of fluidized beds is a difficult task without very accurate information and even then it is not without risk.

In spite of the various drawbacks there is considerable promise for new fluidized bed applications. This research is directed toward finding heat transfer coefficients that would be useful for someone designing a coal or other fossil fuel fired generator. I have investigated large, limestone particles and smaller glass beads to determine heat transfer coefficients from vertically orientated, longitudinally finned heat transfer surfaces. The experimental variables were fin height, particle diameter, particle type, and fluidizing gas velocity. Experiments were also performed to determine local, along the fin, heat transfer coefficients from the largest fin height tube.

THEORY AND PREVIOUS RELATED RESEARCH

The theory and previous related research is divided into two parts. The first part deals with proposed heat transfer mechanisms. The second part deals with related research that has been done on heat transfer from immersed surfaces.

Mechanisms of fluidized bed heat transfer

Heat can be transferred from an immersed surface to a fluidized bed by a number of different mechanisms. Various forms of heat transport are radiation, gas convection and conduction, and particle convection. Depending upon the particulars of fluidization, one or more of these mechanisms can dominate, acting in a series or parallel manner. A fluidized bed is essentially isothermal in the bulk, because of good particle mixing, therefore the resistance to heat transfer is in a film surrounding the immersed surface. All modeling work is done in this boundary, which extends approximately one particle diameter out from the immersed heat transfer surface. The following discussion describes some of the types of models that have been proposed. Radiation is not considered in these models, because most of the experimental work was done at low temperatures (less than 600° C) where its effect can be assumed to be negligible (10), and because in high temperature situations its effect can be estimated (1).

A number of phenomena can occur at the heat transfer surface. Bubbles contacting at or near the surface can change the heat transfer coefficient. Particles coming into contact with the surface can absorb heat and then by dispersing into the bulk, transport the heat into the bulk. The rate of heat transfer in this case will be dependent upon the residence time of the particles and other thermal-physical properties such as particle heat capacity and fluidizing medium thermal conductivity. Heat can also be transported by gas conduction from the surface. One of the first trends in modeling of the heat transfer coefficient from an immersed surface used a boundary layer approach. An illustration of this type of process is shown in Figure 2. In this model heat is conducted through a gas film. The heat transfer coefficient is defined as,