Development of Test Units for Open Channel Fluidized Particulate Heat Exchanger

ABSTRACT

This paper will describe a test apparatus to evaluate a proposal for a fluidized particle heat exchanger. The heat exchanger uses a bank of tubes containing supercritical CO2 in counterflow with a fluidized particulate flowing in a sinusoidal channel. The sinusoid consists of three bends and four straight passes. A small test rig has previously demonstrated a single bend at ¼ scale with ambient conditions, the next design will be used to test a single bend at full scale. These rigs are designed to observe the variables affecting the nature and stability of the flow and provide insight into potential problems.

The fluidized bed test units are created using a transparent polymer, PETG, to allow for observation of the particulate flow and reduce static buildup. Beneath the fluidized bed is another PETG container that serves as an air plenum. These two containers are separated with a perforated plate, a stainless steel mesh and several mesh filters which form the sparger. The air plenum in combination with the sparger allows for the uniform distribution of air necessary to fluidize the particulate. An air conveyor system is used to recirculate the particles and ensure continuous flow.

The current full scale test unit is used to observe differences in wall effects in comparison to the ¼ scale model. Once scaling effects are understood, another test unit will be used to further evaluate particulate flow along the full path length of proposed fluidized particle heat exchanger. This new test unit will include the three bends and four straight passes of the proposed heat exchanger. The longer path length is used to observe the change of bed height along the flow path and in turn the effect that has on fluidization. Current design plans do not test for heat transfer properties of the concept but is a possible consideration going forward.

BACKGROUND

Particle heat transfer technology is one of the primary fields of interest for furthering concentrator solar power technology. Current CSP technology focuses on the use of molten salt plant but particle technology will allow for better thermal storage and the ability to reach higher temperatures. As such research is conducted into a variety of particle to fluid heat exchangers. Due to the high efficiencies expected in a super critical CO_2 cycle, the heat exchangers are designed with that use in mind.

Previous work with industry has suggested three main types of heat exchangers for use: shell and plate, serpentine tube and axial flow fluidized bed heat exchanger. Of these types the fluidized bed is the hardest to build a demonstration model due to cost of the surrounding infrastructure. To further investigate potential problems in the design, lab scale models have been constructed to explore potential problems.

INTRODUCTION

The concept behind this design is to provide an axially flowing particulate rather than an isothermal fluidized particulate bath as the hot stream. For the demonstration model, the intent was to create a 3-bend sinusoidal path along which the particulate would flow. The particle inlet should naturally form a pressure gradient creating an overall axial flow pictured in Figure 1.

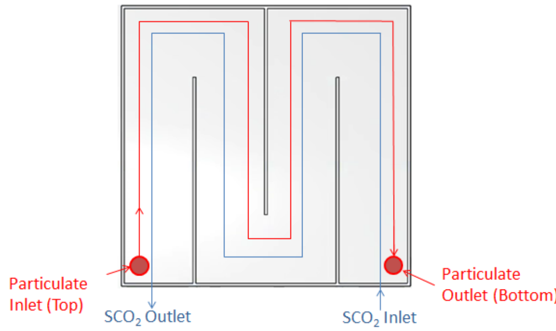

Figure 1: Axial Counter Flow Fluidized Bed

PARTICLE/PARTICLE HANDLING

Accucast ID50 will be the test particulate due to ready availability and use in previous high temperature particle heat exchanger and receiver experiments. These particles fall under Geldart's type B classification (see Figure 2), determined by the ratio of particle density to diameter, meaning that they behave similarly to sand. Unlike sand, these ceramic particles are manufactured for high uniformity and spherocity. The particulate is recirculated through the use of an air conveyor; this ensures a constant inlet and outlet condition forcing a steady state condition.

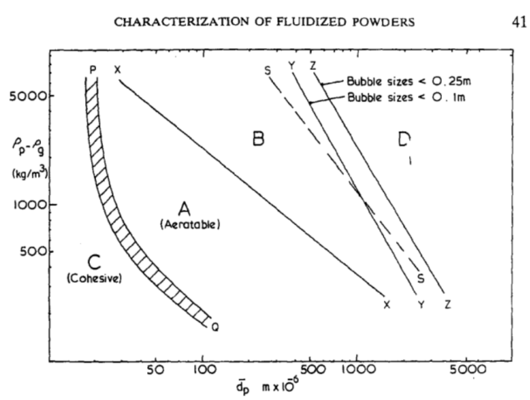

Figure 2: Powder classification groups for similar fluidization (Geldart 1986)

QUARTER SCALE SETUP

A quarter scale prototype, Figure 3a, was created for preliminary study prior to moving to a larger scale. The walls are made using a clear plastic, PETG, in an attempt to reduce static charge buildup within the system. In comparison to the above design, the outlet location has been relocated to the side wall for ease of manufacturing and to ensure a uniform air flow from the air plenum into the fluidized bed. Between the bed and plenum a perforated plate acts as a structural support for the stainless steel mesh which combined form the sparger. Air filters layers are added to the sparger to ensure that there is a large enough pressure drop to for a uniform distribution of air.

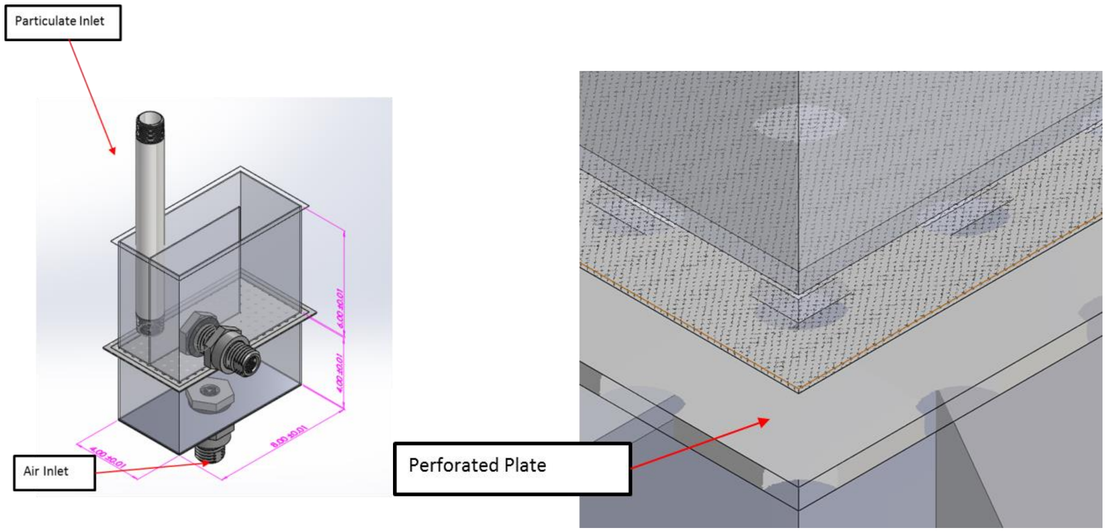

Figure 3: Quarter Scale Setup

Tests, pictured in Figure 4, show that a gradient forms as the particulate flows through the system. The slope of the gradient is dependent on the level of fluidization within the system as shown above. The greater degree of fluidization on the right leads to a much reduced gradient. Also important to note is that the amount of bubbling along the bed path changes with the bed height: bubbling increases as the bed depth decreases. At this scale, wall effects are greatly exaggerated due to the difference in the volume to wall surface area. Additionally, the side outlet has a disproportionately large effect on the flow near the exit; therefore a setup has been created to simulate the fluidized bed at full scale.

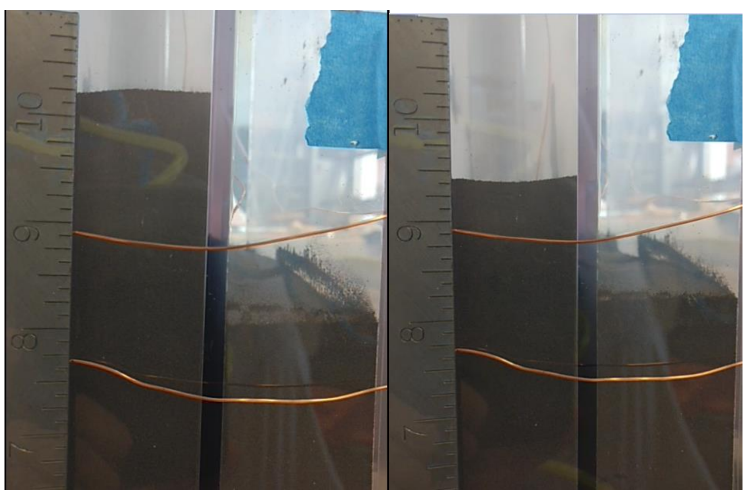

Figure 4: Steady State Flow Gradient (Side View) a) Low Fluidization b) High Fluidization

FULL SCALE SETUP

The full scale setup has a cross section of 1.2 m x 1.2 m, unfortunately a bed of that size would be prohibitively large to test at a lab scale. As an alternative a single representative bend has been created at 0.3m x 0.3m, Figure 5. The singular bend will allow for tests with similar wall effects to the large scale model and to better observe potential stagnant regions. Additionally, the static effects at the walls will e redcued. Preliminary tests have shown that the setup is well fluidized.

Figure 5: 1) Cad Design for Single Bend 2) Fluidization of Single Bend

TESTING PLANS

Despite the use of the transparent PETG walls, observing the fluidization of the particles is still difficult. In order to check for problem areas due to the bed height the heat transfer coefficient at varying locations within the stream will be measured. A cartridge heater with an internal temperature sensor will be placed at varying locations in the bath. By measuring the temperature of the heater, the ambient conditions near the heater and the power input the heat transfer coefficient can be calculated and compared to expected heat transfer coefficients for a fluidized bath.

CONCLUSIONS

These investigations have thus far shown that the axially flowing fluidized bed is a feasible option for a particle-sCO_2 heat exchanger. From the experiments that have been run, we have confirmed three features of the Babcock and Wilcox design: (1) localized jets should not form provided the bed is deep enough and there is enough pressure drop across the sparger to ensure uniform pressure in the supply plenum, (2) no obvious flow stagnation or phase separation has been observed especially at the turns, (3) the bed height gradient need not be excessive if the fluidization is adequate. Further experiments will continue to characterize the fluidized bed's axial flow.

REFERENCES

Geldart, D. *Gas Fluidization Technology.* Wiley: London, 1986.