PRESSURE FLUCTUATIONS AS A DIAGNOSTIC TOOL FOR FLUIDIZED BEDS

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Pressure Fluctuations as a Diagnostic Tool for Fluidized Beds
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Abstract

The validity of using bubbling fluidized bed (BFB) similitude parameters to match a hot BFB to a cold BFB is being studied. Sand in a BFB combustor and copper powder in cold BFB model have been analyzed and found to be out of similitude. In the analysis process, it was determined that the condition of the screen covering the pressure tap affects the quality of pressure data recorded. In addition, distributor plate design and condition will affect the hydrodynamics of the bed. Additional tests are planned to evaluate the validity of similitude concepts in BFB.

Pressure Fluctuations as a Diagnostic Tool for Fluidized Beds

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Objective

The purpose of this project is to investigate the origin of pressure fluctuations in fluidized bed systems. The study will assess the potential for using pressure fluctuations as an indicator of fluidized bed hydrodynamics in both laboratory scale cold-models and industrial scale boilers.

Progress

Experimental Setup

BFB Models

The bubbling fluidized bed (BFB) similitude study was performed in two geometrically similar BFBs. The cold model was made of Plexiglas tubing with an inside diameter of 5.08 cm and a column height of 32 cm. Pressure taps are located 1.27 cm and 3.81 cm above the distributor plate. The BFB combustor consists of a 20.32 cm diameter ceramic wall surrounded by a water jacket. The BFB combustor has pressure taps located at 5.08 cm and 15.24 cm above the distributor plate.

The most recent set of BFB similitude runs in the cold model were completed using newly created distributor plates, which is geometrically similar to the distributor plate in the hot bed. The new plate has 197 holes, properly scaled to match the 197, 2.38 mm dia. holes arranged on a 1.4 cm pitch, square grid used for the distributor plate in the hot bed. The new 5.08 cm diameter BFB distributor plate for the cold bed contains 0.61 mm diameter holes spaced in a 3.5 mm square grid. The original distributor plate for the 5.08 cm diameter BFB has 37, 3.18 mm holes in a 15.88 mm square grid.

Background

CFB and BFB Similitude

As discussed in previous reports, similitude is achieved in bubbling fluidized beds by matching the following similitude parameters.

$$\mathrm{Re}_p = \frac{\rho_g U d_p}{\mu}, Fr = \frac{U^2}{g d_p}, \frac{\rho_g}{\rho_s}, \frac{H}{d_p}, \frac{D}{d_p}$$

Using these parameters, two BFBs can be properly scaled to achieve similitude. To test for similitude, characteristic Bode and power spectral density plots of the pressure fluctuations are produced using the standard FFT analysis techniques discussed in previous reports.

Past studies have shown that the following dimensionless parameter groups should be used to match similitude in CFBs:

$$\mathrm{Re}_p = \frac{\rho_g U d_p}{\mu}, Fr = \frac{U^2}{g d_p}, \frac{\rho_g}{\rho_s}, \frac{H}{d_p}, \frac{D}{d_p}, \frac{M}{\rho_s \cdot D^3}, \frac{L_v}{D}$$

The dimensionless parameter groups are the same as those used in matching BFBs, only a mass and a L-valve term are added. M is the mass of particles in the system while L_v is the height of the L-valve.

Results and Discussion

The BFB combustor and cold BFB were operated with the following dimensionless parameters.

BFB Combustor	**Cold BFB**
Re_p=3.618	Re_p=3.622
Fr=88.148	Fr=88.553
ρp/ρg = 7640	ρp/ρg = 7420
L/D = 1.01	L/D = 1.01
D/d_p = 338.7	D/d_p = 338.7

The BFB combustor was fluidized with 600 μm round sand while combusting a nearly stoichiometric mixture of air and natural gas. For the cold BFB, 150 μm diameter, spherical copper powder was fluidized with air.

The effort to achieve similitude between a combustor and cold BFB model has been largely unsuccessful to date. Up to this point, natural gas has been the only fuel burned in the combustor. Seeking to determine whether using natural gas as compared to other fuels affects the performance of the system, a coal feed system was connected to the combustor. Once at the desired temperature, the fuel source was switched to coal. As more coal and less natural gas was introduced, the temperature in the bed began to decrease and the freeboard temperature began to increase. The heat transfer from the fluidized bed to the water jacket was too great. Burning coal at 720 deg C was determined to be unsuccessful.

To allow the use of coal, the fluidized bed temperature must be increased. This is not possible with 600 micron particles, the bed to wall heat transfer is too great. To decrease the rate of heat transfer, larger sand particles will be substituted. Using larger particles, the bed temperature can be raised faster and higher than with small particles. At higher bed temperatures, coal can be burned and compared to the performance of a natural gas fired fluidized bed.

In order to achieve similitude with a hot fluidized bed at temperatures higher than 725 deg C, the density of the fluidizing gas in the cold model (20 deg C) must be decreased below that of standard atmospheric conditions. To accomplish this, the 2" fluidized bed has been modified to allow fluidization at sub-atmospheric pressure by using a vacuum pump like an induced-draft fan. With the vacuum pump, appropriate superficial velocities can be achieved at pressures below atmospheric pressure at the desired air density.

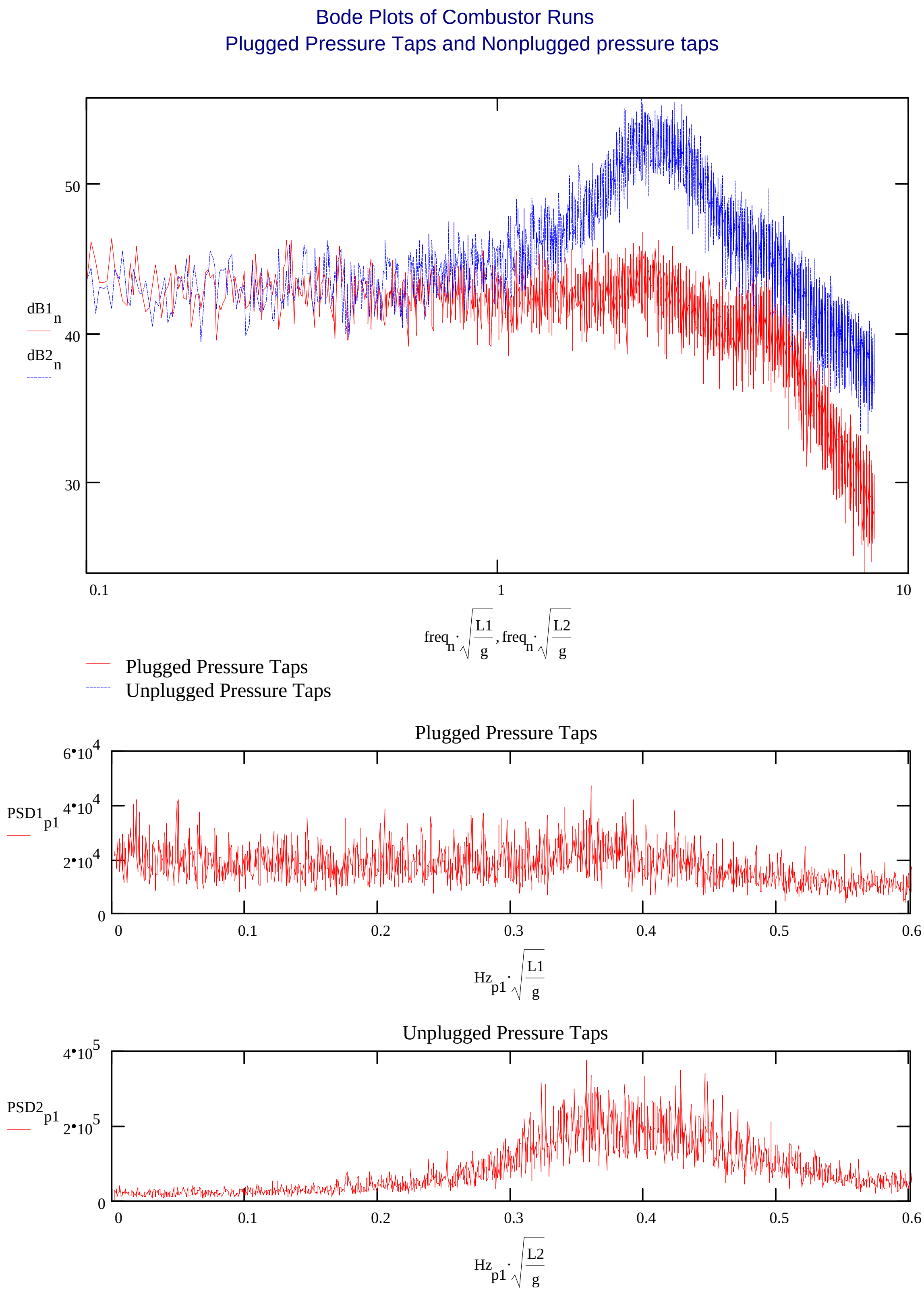
Additional problems were encountered with the pressure taps in the combustor. After much use, the screens covering the taps began to become plugged with particles. Once plugged, the screens dampen the magnitude of the pressure fluctuations. The dominant frequency is still found in the data, just at a much lower amplitude. See Figure 1 for a comparison of bode plots with plugged and unplugged pressure taps.

Distributor plate design has an effect on the hydrodynamic behavior of fluidized beds. To address this, the 5 cm BFB distributor plate was redesigned to correctly match the 20 cm fluidized bed combustor's distributor plate. Recent tests have shown that the screen placed over the distributor plates may affect bed hydrodynamics as well as the geometry of the distributor plate. In a test with 0.6 mm glass beads, the Bode plot was changed drastically by removing the screen from the distributor plate. See Figure 2 for a comparison of the new 160 hole distributor plate with and without screen. To avoid the effect of the screen, future tests will be run without screens covering the distributor plates.

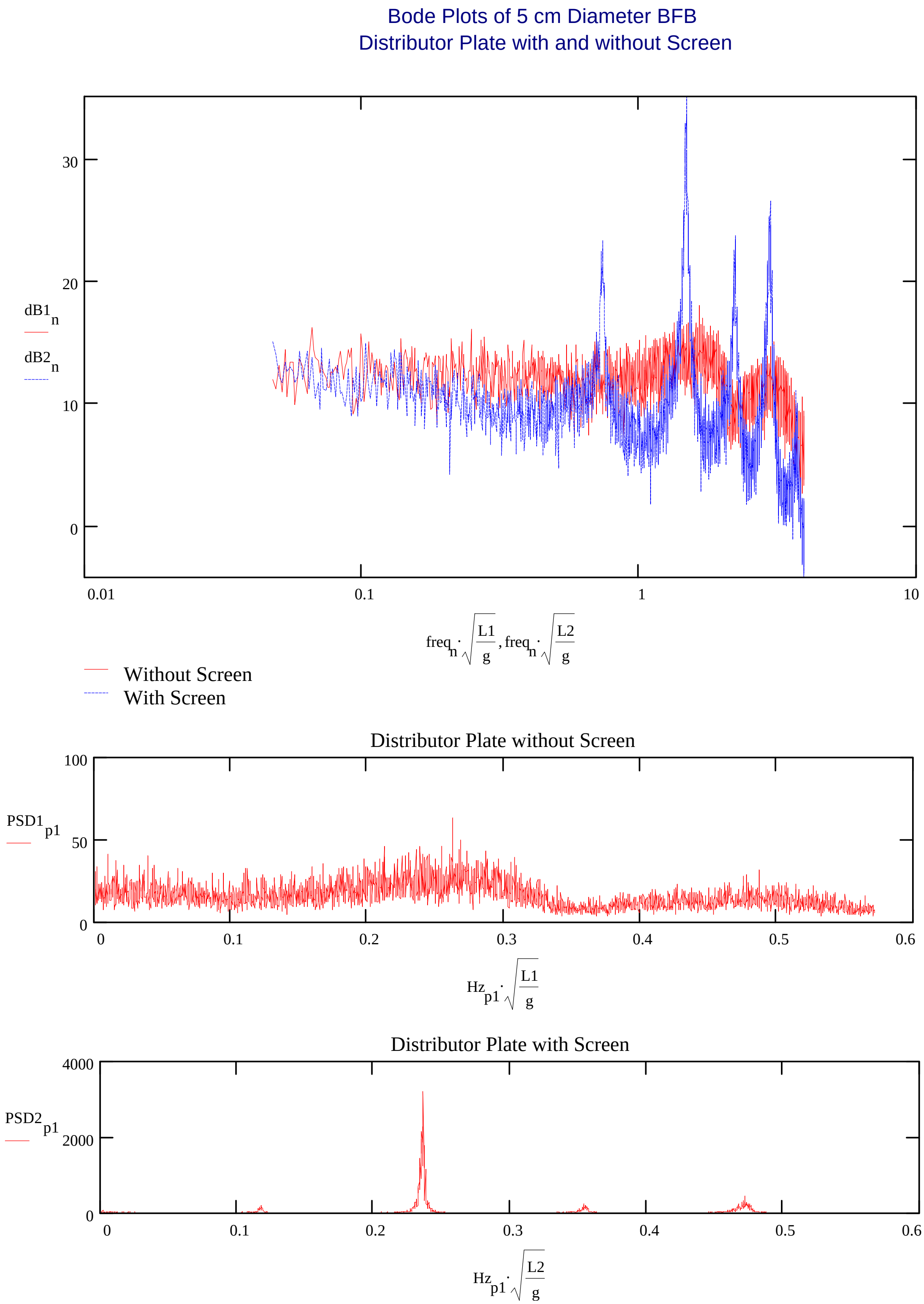
Tests were run to measure the coefficient of restitution of steel and glass particles. Previous tests in the circulating fluidized beds showed that the coefficient of restitution of a collision between the top plate and the fluidizing particles is important for determining the hydrodynamics of the fluidized bed. In the past, the top plate has been replaced by "dead" space. The dead space was an extension that allowed the particles to reach the top of the riser and not collide with the top plate. With the extension in place, two properly scaled circulating fluidized beds demonstrated good similitude results. To further test the hypothesis that the coefficient of restitution, tests will be run with top plates of differing composition. Tests have shown that glass beads and steel particles have very similar coefficients of restitution when collided with a mild steel plate. Consequently, steel top plates have been constructed for both the 2” and 4” circulating fluidized beds.

Future Work

Future work will focus on identifying the source of the characteristic peak shift in the Bode plots that were observed. As a part of identifying this source, we will begin to look for characteristic frequencies by listening to the bed with a microphone. Additional experiments will be run to characterize L-valve performance and the affect L-valve height has on overall circulating fluidized bed similitude studies. The circulating beds have been equipped with a pressure tap to measure the pressure at L-valve air inlet. This pressure’s effect on bed hydrodynamics will be investigated. The vacuum pump BFB fluidization system will be calibrated and used to fluidize copper particles in similitude with the BFB combustor operating at approximately 840 deg C. Finally, the effect of top plate coefficient of restitution will be further investigated.



Plugged and Unplugged Pressure Tap Comparison
Figure 1



Distributor Plate Screen Comparison

Figure 2