DEVELOPMENT OF AN ACOUSTIC METHOD FOR THE MEASUREMENT OF MIXING AND DRYING IN A VIBRATED FLUIDIZED BED

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1. INTRODUCTION

Gas-solid fluidized beds can be used for physical processes such as mixing, drying and granulation. Fine powders, however, are difficult to fluidize well with gas flow. Vibration can be used to improve the fluidization.

The objective of this research was to develop a non-invasive acoustic method to detect fluidization regimes and measure mixing and drying in a vibrated fluidized bed.

1.1 Fluidization

At low gas velocities, the bed of powder is fixed. As the gas velocity is increased above the minimum fluidization velocity (U_{mf}), the bed becomes fluidized. Increasing the gas velocity further, past the minimum bubbling velocity (U_{mb}) the bed becomes well mixed due to the action of the bubbles. Applied vibration reduces the required gas velocity for fluidization and bubbling. Pressure profiles and bed height methods for determining U_{mf} and U_{mb} are not practical for industrial applications.

The fluidizing gas dries the wet particles as it flows through the bed. For drying, the bed must be operated above U_{mb} to provide the agitation, mixing and good heat transfer required for effective drying. Monitoring is required to ensure that the solids reach the appropriate moisture.

1.2 Acoustics

Acoustic sensors are inexpensive, can withstand a wide range of process conditions, and can provide reliable, fast, on-line and non-intrusive monitoring. Passive acoustics detect the sound generated by the process itself. In vibrated fluidized beds, acoustic emissions are caused by particles colliding with each other, the bed walls, the motion and eruption of bubbles and the vibration source [1].

1.3 Signal Analysis

The standard deviation measures the dispersion of the values within a given signal. The information entropy of a signal is a measure of the randomness. The power spectrum decomposes a signal into frequency bands that allow dominant frequencies to be identified.

2. METHOD

A Plexiglas fluidized bed (I.D. of 0.113 m and height of 0.274 m) was mounted on a vibration source and vibrated at 60 Hz with variable amplitudes. The powder was ceramic microspheres of 33 μm. This powder was non-porous and analogous to glass beads. A microphone was attached in the baghouse at the top of the column directed down towards the bed. Each acoustic measurement was recorded at a frequency of 40000 Hz.

To determine the minimum bubbling velocity and the minimum fluidization velocity, the bed was initially very well fluidized. Acoustic emissions were recorded, the gas velocity was incrementally lowered, the bed was allowed to reach steady state, and measurements repeated. Measurements were recorded at vibration amplitudes of 0, 0.01, 0.026 and 0.05 mm.

To evaluate drying, solids were removed from the bed, water was mixed in with the solids and then the particles were replaced and the bed was re-fluidized. Measurements were recorded at gas velocities of 0.008 and 0.010 m/s and vibration amplitudes of 0 and 0.05 mm.

3. RESULTS & DISCUSSION

As shown in Figure 1, the standard deviation of the acoustic emissions for the vibrated bed identified both the minimum fluidization and the minimum bubbling velocities. The standard deviation indicates the amplitude of the acoustic emissions. Below U_{mf}, the bed was fixed: the acoustic emissions were low as there was no particle movement and the bed did not easily transmit emissions from the vibration source. The standard deviation of the acoustic emissions increased significantly above U_{mf} due to particle movement and the fluid properties of the bed allowing better transmission of emissions from the vibration source. Above U_{mb}, the standard deviation again increased due to the emissions from bubble motion and eruption at the bed surface and the decreased bed density for emission transmission. The power at the 60 Hz frequency of the vibration source showed similar profiles and the standard deviation was much lower in the non-vibrated bed indicating that observed variations in acoustic emissions are primarily due to the changes in transmission properties of the bed as it changes fluidization regime.

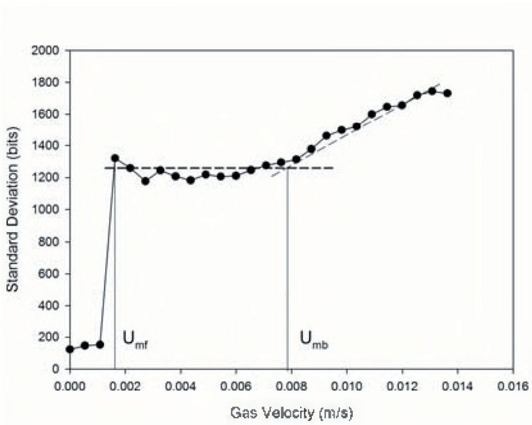

Fig. 1. Standard deviation of acoustic emissions at a vibration amplitude of 0.026 mm.

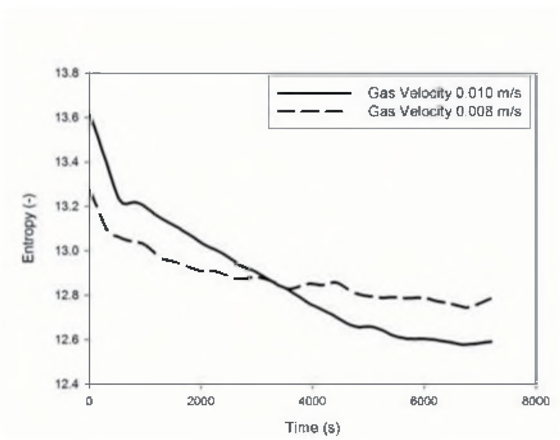

Fig. 2. Evolution of the information entropy of the acoustic emissions as the bed dries.

Figure 2 shows that the drying process can be monitored with the acoustic signals. It shows how the information entropy of the microphone signal decreased gradually as drying progressed. At a superficial gas velocity of 0.010 m/s, the information entropy reached an asymptotic value at a time of about 6000 s (100 minutes). Drying at a superficial gas velocity of 0.08 m/s was not as effective, since the information entropy had not yet reached its asymptotic value after 7000 s of drying.

Figure 3 shows that similar results can be obtained from the standard deviation of the acoustic signals. The information entropy, however, seems more sensitive to low moistures.

Since the initial moisture was 100 ppm, the non-invasive acoustic signals therefore allow for the detection of moistures of a few tens of ppms. Very few on-line methods can achieve such sensitivity.

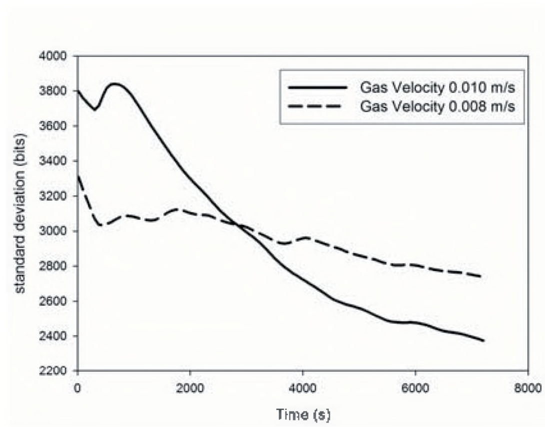

Fig. 3. Evolution of the standard deviation of the acoustic emissions as the bed dries.

4. CONCLUSIONS

A non-invasive acoustic method was developed to identify fluidization regimes and to monitor drying within a vibrated fluidized bed.

The minimum fluidization and bubbling velocities can be reliably determined from the standard deviation of a microphone signal.

The drying of fluidized solids can be monitored by using either the information entropy or the standard deviation of a microphone signal. This acoustic method can detect moistures of a few tens of ppms.

REFERENCES

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