Influence of Bed Material Characteristics on Fluidized Bed Properties

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Abstract

In this work, we investigate the feasibility of using denser bed materials for fluidization and their influence on fluidized bed cell parameters. Quartz in three size ranges (- 1180 + 850 µm, - 850 + 425 µm, - 425 + 250 µm) and aluminum oxide were used as bed materials for fluidization experiments. The existence of some upper size limit for fluidization was confirmed by attempting fluidization in the HydroFloat cell using the stated bed materials at a water rate of 1.08 cm/s, airflow rate of 0.04 cm/s, and a target bed level of 14 cm. The influence of bed material mass and density on bed level was also studied by running the fluidized bed cell with - 425 + 250 µm quartz and aluminum oxide at a water rate of 1.19 cm/s, airflow rate of 0.04 cm/s, and a target bed level of 15 cm. The potential influence of bed material on bubble size was investigated by analyzing images of the cell during experiments. Our results confirm the existence of some upper size limit beyond which fluidization is unfeasible i.e., the bed becomes packed and bubble dissipation is limited. However, using a denser bed material at a finer size remains a feasible strategy for increasing the apparent density of the bed at identical bed characteristics. Frother concentration is the dominant factor influencing bubble size with bed material showing a marginal influence on bubble size.

Keywords: Coarse particle flotation, fluidized bed cell, detachment, bed material

1 Introduction

Flotation is one of the most widely used concentration processes in metallurgical processing plants. It is cost-effective and can be easily adapted to a variety of ores (Wills and Finch, 2015). A lot of processing routes commence with flotation after the comminution circuit with the aim of limiting the amount of product going downstream for subsequent processes such as leaching and smelting. With current processing challenges such as rising energy costs, declining ore grades, and consequent increase in ore complexity, there is the need to transition to coarse processing (Asamoah et al., 2021, Calvo et al., 2016, Maron et al., 2019). In processing materials at coarser sizes, it is also possible to limit the activation of some gangue minerals that may adversely influence the pulp chemistry of downstream processes (Asamoah et al., 2018a, Asamoah et al., 2018b, Asamoah et al., 2019a, Asamoah et al., 2019b, Asamoah et al., 2020). However, flotation is a size-dependent process and does not fare well in conventional cells (Dankwah et al., 2021, Jameson et al., 2007, Tao, 2005, Gaudin, 1931). The literature on the subject identifies the limiting factor as bubble-particle detachment (De F. Gontijo et al., 2007). This is when a hydrophobic particle is unable to be collected due to the instability of its bubble-particle aggregate.

The major factor causing detachment is high cell turbulence in conventional flotation cell environments (Soto and Barbery, 1991, Ralston et al., 1999, De F. Gontijo et al., 2007, Jameson et al., 2007). Advances in flotation technology such as fluidized bed cells seek to provide a quiescent environment under which coarse particles can be recovered. These have been successful with multiple authors reporting high recoveries and good gangue rejections in the literature (Jameson et al., 2007, Jameson, 2010, Kohmuench et al., 2001, Awatey et al., 2013, Kohmuench et al., 2018).

However, the technology is relatively new and there remain some unknowns that may influence its performance. Our previous work showed that the particle weight in fluid is the major detachment force and that the influence of cell turbulence is largely dependent on this force (Dankwah et al., 2022a). We have subsequently attempted to control this factor in a fluidized bed cell by using coarser bed materials with the aim of allowing higher water rates to be used whiles generating lower cell turbulence or elutriating the bed material (Dankwah et al., 2022b). Our results showed that there may be an upper particle size limit beyond which fluidization is unfeasible. This limits the extent of control over bed characteristics using particle size.

In this work, we seek to investigate the feasibility of using denser bed materials for fluidization to achieve the same aim and to investigate the resulting cell dynamics. Our key research questions include:

1. How does bed material type influence the relationship between fluidization water rate and bed level?
2. How does adjusting bed material type control apparent bed density?
3. Does bed material type control other parameters such as bubble size and bed permeability?

2 Experimental

2.1 Model Minerals and Reagents

Samples of model quartz (SiO_2) and aluminum oxide (Al_2O_3) were sized into various fractions and used as bed material for fluidization experiments. SiO_2 was sized into - 1180 + 850 µm, - 850 + 425 µm, and - 425 + 250 µm with the alumina in a size fraction of - 250 µm. PPG500 at a concentration of 1 ppm was added to the water reservoir and allowed to circulate the system before measurements were taken.

2.2 Fluidized Bed Operating Parameters

Fluidized beds were built using the model minerals (quartz and aluminum oxide) at varying size fractions and bed masses. Bed-level measurements were carried out assuming the sparger of the cell was at point 0. The sparger in the HydroFloat sits above the tailings cone and can be considered as an initial fluidization point.

The bed material was introduced incrementally, and the resulting bed levels were recorded for each kilogram of material added. This was done until the target bed level was attained. The HydroFloat was run for at least 5 mins to elutriate extreme fines and to stabilize the bed. Further top-up of bed material was added where necessary to maintain the bed level. The gas rate was kept at a constant of 0.04 cm/s, and the superficial water rate used was 1.08 cm/s and 1.19 cm/s respectively. Bed – levels targeted were 14 and 15 cm respectively.

2.3 Bubble size measurements and analysis

During fluidization experiments, images of the fluidization water were taken and analyzed using ImageJ, an image processing program. Figure 1 shows one of the images taken during experiments. A ruler in the image was used as calibration to determine the length (in microns) per pixel. This was then used to estimate the bubble diameters.

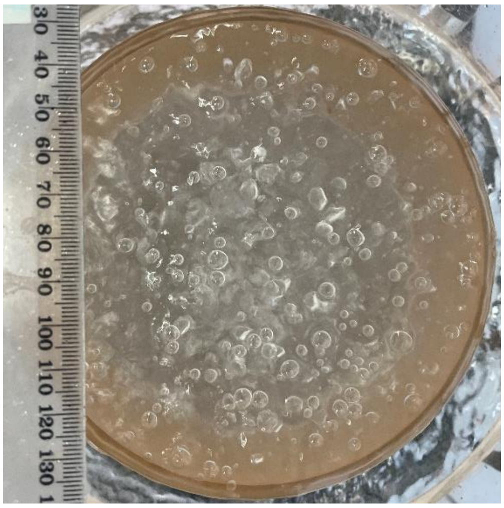

Figure 1 Sample snapshot from fluidization experiments used to estimate bubble size

3 Results and Discussions

3.1 Limits of Particle Size on Fluidization

In our previous work (Dankwah et al., 2022b), we suggested that there may be an upper particle size beyond which fluidization may be unfeasible. Beyond this size range, the bed tends to be packed with permeability being limited. This hinders bubble dissipation and feed movement through the bed, adversely affecting flotation recovery. Figure

2 shows the amount of bed material required to reach a bed level of 15 cm at a water rate of 1.08 cm/s. The first three materials represent the various size fractions of quartz, while the last represents the aluminum oxide used. Aluminum oxide, being much denser than quartz, required a higher bed mass to attain an equivalent bed level as quartz. However, fluidization was not adversely affected. Bed permeability was identical to that of the – 425 + 250 µm quartz material used. The coarse quartz beds (- 1180 + 850 µm and – 850 + 425 µm) showed poor fluidization even though they were of a lower density and lower bed mass compared to the aluminum oxide used. This confirms the case of particle size being the limiting factor in fluidization.

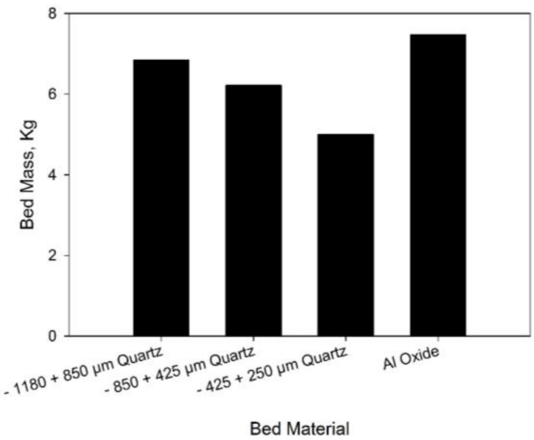

Figure 2 Bed mass required to attain a bed-level of 15 cm at a water rate of 1.08 cm/s.

3.2 Influence of Bed Material on Bed Height

Given that the coarser fractions of the quartz bed hinder the fluidization process, they were not considered for subsequent tests. Figure 3 shows the relationship between bed mass and bed height for quartz (- 425 + 250 µm) and aluminum oxide at a water rate of 1.19 cm/s. The general relationship of an increasing bed height with increasing bed mass is not new and is intuitive. The interest here lies in the steepness of the plots. The bed level of quartz is more sensitive to changes in bed mass compared to aluminum oxide. This is a consequence of their difference in density as aluminum oxide packs higher masses for equivalent volumes compared to quartz. At the targeted bed level of 15 cm, quartz used a bed mass of 4.5 kg while aluminum oxide used 7.45 kg. This indicates a consequent higher apparent bed density for the aluminum oxide bed. At identical bed behaviour and characteristics, we expect the aluminum oxide bed to outperform that of the quartz bed in coarse particle flotation due to its potential to limit the particle weight in fluid. Another advantage of using a denser bed is the feasibility of using higher water rates without significantly increasing cell turbulence or leading to elutriation of the bed material.

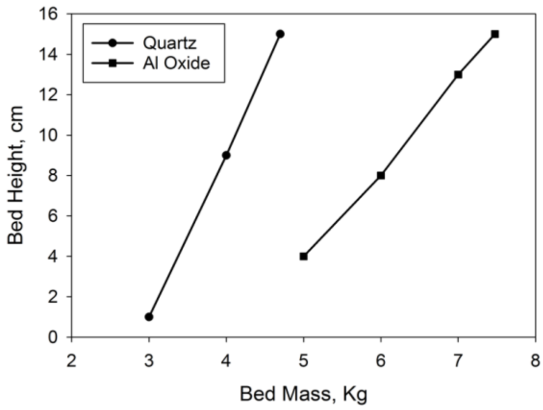

Figure 3 Relationship between bed mass and bed height for quartz (- 425 + 250 µm) and aluminum oxide at a water rate of 1.19 cm/s

3.3 Influence of Bed Material on Bubble Size

Previous works in the literature have speculated on the potential influence of bed material and its particle size on resultant bubble sizes (Fosu et al., 2015). The key idea is that as bubbles travel through the bed, they are broken down into varying size ranges by the pressure of the material. In this work, we were interested in how the bed material may affect subsequent bubble size as this potentially influences flotation performance. Figure 4 shows the bubble sizes during fluidization under the conditions (a) water only (b) water and frother concentration of 1 ppm (c) water, frother (1 ppm) and quartz bed. The largest influence on bubble size is frother concentration. Adding frother to the water stream results in more closely sized bubbles of smaller sizes. This may not necessarily be beneficial for extremely coarse sizes as buoyancy is limited. The addition of the bed expands the bubble size range due to two potential reasons. Firstly, the potential for bubble coalescence is higher as bubbles may travel through similar channels within the bed. This results in coarser bubbles being formed as the bubble travels through the bed. In other instances, the bubbles may be broken down upon contact with bed materials resulting in potentially smaller bubble sizes. This is unlikely in a highly permeable bed as the one considered; however, the possibility remains as shown by the outlier bubble sizes in Figure 4.

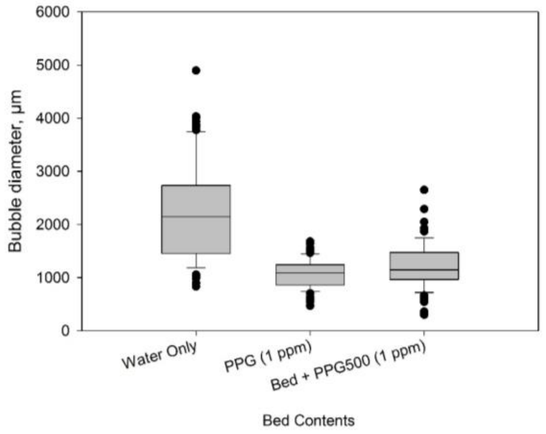

Figure 4 Bubble size during fluidization with water only, water and frother (1 ppm) and water, frother (1 ppm), and quartz bed

4 Conclusions

1. There is an upper particle size limit beyond which fluidization is unfeasible.
2. Using denser bed materials provides an avenue for controlling apparent bed density. However, bed permeability must be controlled by limiting the upper size of such materials.
3. Bed material has limited influence on the bubble size of fluidized bed flotation compared to frother concentration and may not influence performance beyond physical factors.
4. Controlling bed density using denser but finer bed materials may be a feasible way to enhance coarse particle flotation performance.

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(including surface effects); Surface Chemical Control in Grinding/Milling; Mineral formation-Processing Relationships; Bulk Property-Surface Reaction Relationships in Processing Contexts (oxidation, activation, dissolution and molecular adsorption); Agglomeration Chemistry; Impact of Water Chemistry on Processing, Mineral Sands; Synthetic Rutile and Pigment Processing, etc.