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Dry separation using a fluidized Sink-Hole

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ABSTRACT

Dry separation of heavy-mineral particles such as iron ore in the nominal size range of 1–10 mm is a significant challenge. This paper reports the findings of dry separation experiments conducted under batch conditions using a novel device referred to as the Sink-Hole fluidizer. The device utilizes a fluidized bed, with vibration applied as an additional energy source to disrupt the tendency of the excess air to pass through as bubbles. The fluidized bed is covered by a fine mesh containing holes with a nominal 1 mm square aperture. A much larger hole located at the centre acts as the "Sink-Hole". When the system is fluidized the media expands, passing up through the Sink-Hole, spilling onto the adjacent mesh, and sifting back into the lower bed. For this work nominal 200 µm sand was used as the bed media. Tracer particles of density 2.4 to 4.8 RD, covering the size range from 2.0 to 8.0 mm, were added onto the mesh. The vibration caused the particles to repeatedly pass over the Sink-Hole, resulting in some sinking through the media, and others remaining on the mesh. By adjusting the mass of sand in the system and the superficial air velocity, it was possible to vary the separation density from 2.5 to 3.2 RD, whilst holding the *Ep* values in the range 0.1 to 0.2 RD.

1. Introduction

Water has become a critical issue in the mining industry due to competition for this limited resource from multiple users, and the increasing need to mine in hot, arid regions of low rainfall. If water-based beneficiation processes are introduced into a mineral processing plant, then there is the requirement to ultimately remove the water from both the product and the waste. In some operations, there is a trend towards crushing to finer sizes to better liberate and recover the valuable components, resulting in more fine particles and hence water reporting to tailings dams. The difficulty of dewatering the final product leads to higher product moistures, transport and materials handling difficulties, higher transport costs per unit of solid, and increased energy costs downstream in utilizing the ore.

Plainly, there are significant advantages if ore can be beneficiated using dry methods. The major challenge of course is in achieving a separation performance that is acceptable, in terms of throughput, grade, and recovery (Lockhart, 1984). It must be recognized that dry beneficiation is not a universal panacea, given the trend towards mining below the water table (producing a wet feed stock), and the inevitable rainfall that will occur, and the concerns over fine particulates entering the atmosphere. Wet processing will continue to dominate, perhaps complimented strategically by dry processing, for example to achieve early gangue rejection at coarser sizes, or for that portion of the ore that is sufficiently dry. This approach should in turn, limit the grinding of gangue material, and reduce the quantity of ultrafine particles reporting to the wet beneficiation circuit.

Dry separation technologies are increasingly being used in coal preparation, especially in China, covering a limited size range down to about 6 mm (Dwari and Rao, 2007; Youzhi et al., 1998; Zhou et al., 2018; Azimi et al., 2013). Luo et al. (2008) have succeeded in separating coal over the size range 0.5–6 mm using a fluidized bed containing a dry, dense medium, subjected to vibration. However, for dense minerals, such as iron ore, reported separations are limited to particles larger than 11 mm (Oshitani et al., 2013). The dry separation of dense minerals smaller than 10 mm has always been difficult. Nayak and Pal (2013) have noted this fraction is becoming increasingly significant. For these reasons, this research is focused on attempting to perform efficient dry beneficiation of dense minerals over the size range of 1–10 mm.

The use of a dry, dense-medium, fluidized bed is an option for dry density based separation. The medium is established through gas-solid fluidization. The bed becomes a pseudo-fluid with a characteristic viscosity and density (Kunii & Levenspiel, 1991). The effective density of the gas-solid fluidized bed contributes directly to the separation density. An object with a density less than the effective density floats, while denser objects sink. The control of the effective density (Oshitani et al., 2001; Oshitani et al., 2004) is critical to the performance, dependent on the nature of the fluidization (Kunii & Levenspiel, 1991; Geldart et al., 1984).

Most dense medium fluidized beds exhibit bubbling behavior associated with the gas in excess of that needed for minimum fluidization. Many have found that reduction or elimination of these bubbles can improve fluidized bed performance (Levenspiel, 2002). The

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introduction of vibration serves to break up the bubbles to achieve more uniform particulate fluidization (Luo et al., 2008). Generally, vibration also reduces the airflow rate required to achieve minimum fluidization, resulting in a lower bed voidage and thus a higher effective density (Marring et al., 1994).

This paper explores the potential of a novel system, the Sink-Hole fluidizer, to achieve sharp density-based separations under dry conditions. The system consists of a vibrating, dense medium fluidized bed. A mesh screen with a 1 mm aperture is located at the surface of the expanded fluidized bed. A much larger hole, 13 mm in diameter, is located at the centre of the screen. Clearly, the permeability is greatest at the Sink-Hole compared to the mesh holes. Therefore, the fluidization and vibration promote strong transport of the fluidized sand through the Sink-Hole, resulting in the excess sand spilling over and onto the mesh, and ultimately returning to the zone below. This arrangement creates a pseudo surface for supporting the density tracer particles. Those particles that pass over the Sink-Hole then tend to either sink or float depending primarily on their density. The vibration also supports the transport of the particles across the mesh, periodically exposing the particles to the Sink-Hole.

This paper is focused entirely on batch separations of density tracer particles. Ultimately the goal is to develop a continuous steady state separator exploiting the separation mechanism investigated in this paper. Clearly, where particles of a given size exhibit a separation at a given density, the key question is whether other size particles separate at a similar density or a different density. The composite separation covering the broad size range ultimately governs the overall separation performance for particles covering a wide size range. These issues are examined in this paper.

Fig. 1b. The general arrangement used to supply vibration to the fluidized bed.

2. Experimental

2.1. The Sink-Hole fluidizer

Fig. 1(a) shows a schematic and Fig. 1(b) a photograph of the fluidized bed Sink-Hole system. A 200 mm diameter air-fluidized bed (4) was mounted on a Kason screen (30 in. diameter) (1) which vibrated at 50 Hz. A 1 mm square aperture mesh (6) was located near the surface of the fluidized bed, mounted 125 mm above a porous plate (3) used to distribute the fluidizing air. This 1 mm mesh screen had a large 13 mm diameter central hole (7) referred to as the Sink-Hole. Note that since the earlier Sink-Hole work of Kumar et al. (2017), the unit has been rebuilt to provide more rigid support and uniform bed vibration. Also,

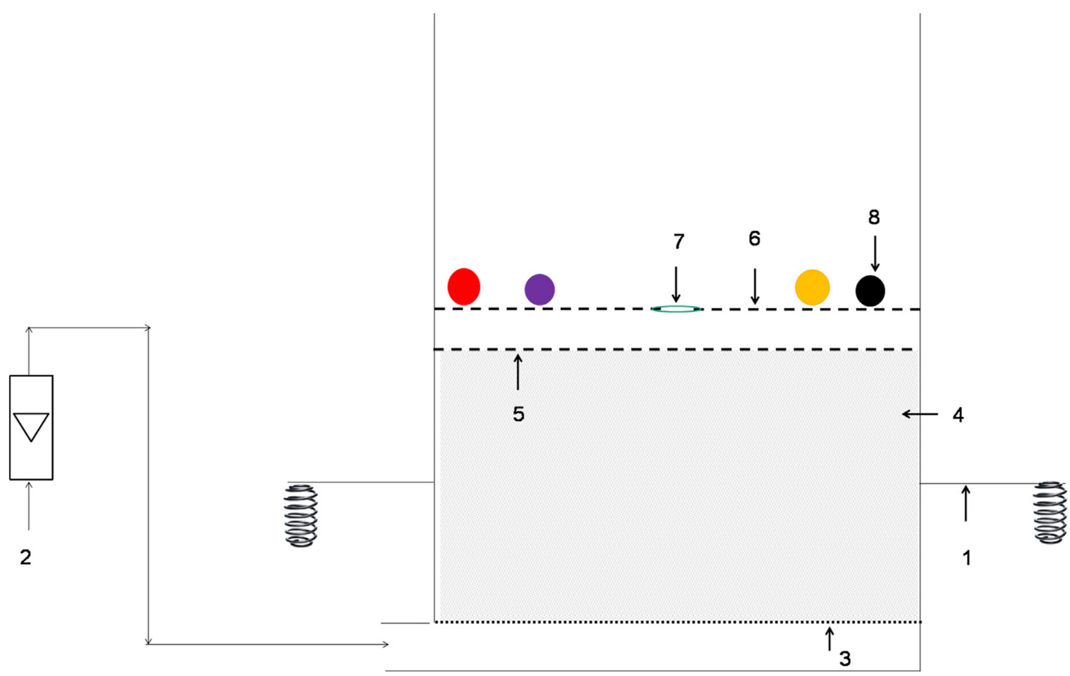

Fig. 1a. Schematic representation of the batch Sink-Hole fluidizer prior to commencing an experiment. The unit was mounted on a vibrating Kason screen via supports (1). Air entered at the base via a rotameter (2) and passed through a porous distributor plate (3) above which sat the fluidized medium (4). A 1 mm square aperture screen (5) to collect the particles that sink was mounted 110 mm above the distributor plate. Another 1 mm mesh (6) was located 125 mm above the distributor plate. A 13 mm diameter circular Sink-Hole (7) was located at the centre of the screen. Tracer particles (8) were initially placed on top of the screen.