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Short communication

Dense medium separation in an inverted fluidised bed system

K.P. Galvin, J. Zhou, K. van Netten*

Centre for Advanced Particle Processing and Transport, Newcastle Institute for Energy and Resources, University of Newcastle, Callaghan, NSW 2308, Australia

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ABSTRACT

The purpose of this work was to examine the novel concept of performing a wet dense medium separation, utilising magnetite, on a fine (−1.0 mm) coal feed in an inverted fluidised bed system. The feed was a natural mixture of coal and mineral particles and the fluidised bed system was an Inverted Reflux Classifier. The Inverted Reflux Classifier, which consists of a system of inclined channels below a fluidisation zone, was selected for use as it has been previously used for the separation of positively buoyant cenospheres from negatively buoyant fly ash particles in water. In the current work, the dense magnetite medium established an elevated bed density such that lower density coal particles tended to rise relative to the medium and high density mineral matter tended to settle. The magnetite medium was present in both the feed to the unit and the downwards fluidisation. At a low feed throughput of 6.8 t/m^2 h and an effective bed density of 1537.4 kg/m^3, a combustible recovery of 81.9% at a product ash of 12.2% was obtained. Detailed analysis showed the separation performance was significantly poorer than the results reported for a standard water based Reflux Classifier. It was concluded that the presence of the dense medium slowed the speed of separation, leading to unsatisfactory performance as the particle size decreased, especially below 0.3 mm. It was therefore concluded that the standard water based Reflux Classifier was vastly more effective in achieving efficient gravity separation of the fine coal compared to the novel variation examined here.

1. Introduction

In coal preparation, dense medium separators are one of the primary methods used for separating the low density coal product from the high density minerals such as clay and sand. In Australia, for example, 60–85% of all coal plant feed is treated by dense medium cyclone (DMC) circuits (Atkinson et al., 2007). Due to the excellent performance of dense medium separators, there has been on-going interest in finding methods to extend the operating range to finer particles (de Korte and Engelbrecht, 2007; Wills, 2006).

In this work, we propose the use of dense media within an inverted fluidised bed system, more specifically, an Inverted Reflux Classifier for the treatment of fine coal (−1 mm) particles. The Inverted Reflux Classifier was selected as it has been previously used for the water based separation of positively buoyant cenosphere particles from negatively buoyant fly ash particles (Kiani et al., 2015). By introducing the dense medium into the separator, the bed density is elevated meaning the lower density coal particles will tend to rise relative to the medium and the high density mineral matter will tend to settle.

The Inverted Reflux Classifier is, as the name suggests, a variation on the standard Reflux Classifier, and consists of a lamella inclined section below a fluidisation zone. Fig. 1 presents a schematic representation of the dense medium Inverted Reflux Classifier used in this study. In the standard Reflux Classifier, the inclined channels have been shown to produce a powerful segregation effect, providing throughput advantages while maintaining strong gravity performance (Galvin et al., 2010).

In the dense medium Inverted Reflux Classifier, the feed slurry, containing magnetite, enters the unit in the upper, fluidised bed section. The downwards fluidisation provided by the magnetite slurry entering from the top of the unit then, in principle, washes out the entrained fine gangue material trapped within the product and conveys the material towards the underflow. The downwards movement of the suspension may also cause fine coal particles to be entrained via the underflow. However, these misplaced particles are returned to the fluidised bed section by the system of inclined channels that exist just prior to the tailings discharge.

In this note, the effectiveness of the Inverted Reflux Classifier combined with the dense medium effect in separating positively buoyant coal particles and negatively buoyant mineral particles is evaluated and compared to that achieved by a standard Reflux Classifier.

* Corresponding author.
E-mail address: kim.vannetten@newcastle.edu.au (K. van Netten).

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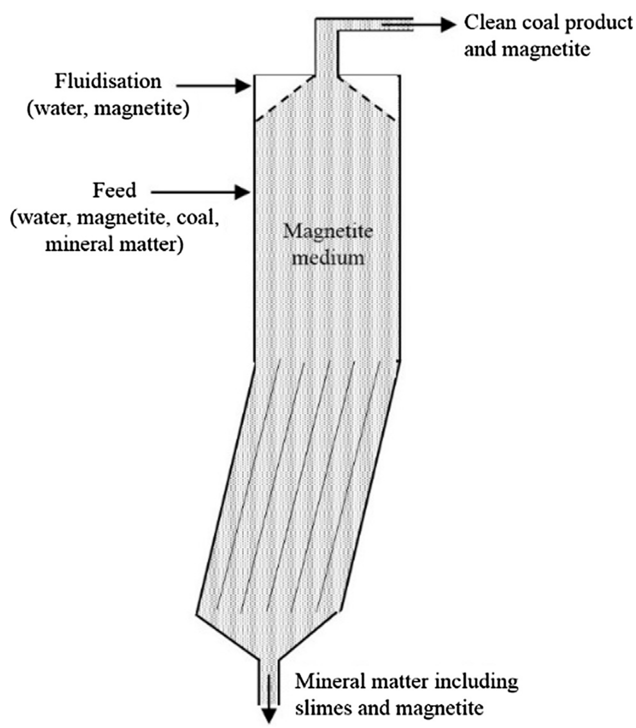

Fig. 1. Schematic representation of the dense medium Inverted Reflux Classifier.

2. Experimental

2.1. Materials

Coal feed was sourced from a Lower Hunter Valley coal washery and wet screened to generate a feed in the size range −1.0 + 0.125 mm. The head ash of the screened feed sample was 25.4%. Ultrafine magnetite was sourced from Sibelco and wet screened to produce a sample in the size range −0.056 + 0 mm. The D_{10}, D_{50}, and D_{90} of the screened material were 0.005 mm, 0.020 mm, and 0.048 mm, respectively, as measured by laser diffraction in a Mastersizer 3000. The dense medium was prepared using tap water and the screened solids at a concentration of 57 wt%. The density of the dense medium was therefore approximately 1850 kg/m^3.

2.2. Methodology

In the lab-scale unit, both the vertical zone and the inclined section were 1 m long. The vertical section had a cross sectional area of 0.100 m × 0.086 m. The inclined section had an angle of 70° with respect to the horizontal and a channel spacing of 8.8 mm. The feed entered 300 mm above the base of the vertical zone and was controlled by a peristaltic pump. The flowrates of the overflow, underflow, and fluidisation dense medium were also controlled by peristaltic pumps. The magnetite slurry was introduced into the Inverted Reflux Classifier at two points: through the top of the unit via the fluidisation distributor and in conjunction with the feed through the side of the vertical section. The fluidisation distributor consisted of a rectangular pyramid with four 1 in. inlets for the magnetite slurry, one on each face plate. Distributors with a greater number of finer holes were examined, but were found to block during operation. Two electronic pressure transducers were positioned near the top of the unit to assess when steady state was attained. The readings were also used to monitor for bed density fluctuations.

The flowrates used in the experiment described in this note are presented in Table 1. The effective medium density is less than the density of the prepared dense magnetite medium because the effective medium density accounts for the presence of the coal feed, which had a much lower density. Moreover, the feed rate represents a mixture of the coal feed suspension and the magnetite suspension.

Table 1
Experimental conditions.

Effective medium density kg/m^3	Feed (coal/magnetite) l/min	Fluidisation l/min	Overflow l/min	Throughput t/m^2 h
1537	4.6 (2.1/2.6)	0.5	2.1	6.8

Prior to analysis, each sample was wet screened at 0.063 mm to remove the magnetite, dried in an oven for 24 h or until a constant mass was reached, and then sieved into narrow size fractions using a vibrating sieve shaker. Analysis of the feed, product, and reject samples generated from the run was then carried out by an external commercial laboratory. A mass balance algorithm was applied to the resulting data to produce consistency. The ash% values were considered the most accurate of the measured values and thus were given the largest weighting factor in the calculations.

3. Results and discussion

Fig. 2 presents (A) the fractional ash% values and (B) the combustible recovery as a function of particle size for the separation in the dense medium Inverted Reflux Classifier operated at a throughput of 6.8 t/m^2 h.

Fig. 2 shows that the dense medium Inverted Reflux Classifier achieved a satisfactory separation for the +0.355 mm particles, with product ash% values of less than 15% and reject ash% values in the range of 50–60%. The combustible recoveries of greater than 70% for the +0.355 mm particles, as shown in Fig. 2(B), also illustrate the good separation performance for particles in this size range. The separation performance then appears to decline for particles below 0.355 mm in size. This decline is the precise opposite of that observed for the standard Reflux Classifier, which experiences higher combustible recoveries for finer low density particles as these particles are more easily conveyed towards the overflow by the net upwards fluidisation.

Fig. 3(A) presents the overall partition curve for the separation achieved in the dense medium Inverted Reflux Classifier. The curve shown, based on a two parameter symmetrical function, highlights the existence of a tail in the data at elevated densities. The partition curve presents the proportion of feed particles of a given density that reported to the product. Fig. 4(A) then presents the individual partition curves for the separation achieved in the dense medium Inverted Reflux Classifier for a series of narrow size fractions. The overall and individual partition curves for a separation achieved in a standard Reflux Classifier from a study by Galvin et al. (2010) are also presented in Figs. 3(B) and 4(B), respectively, to provide a qualitative comparison of the separation achieved in each unit. The throughput used in the previous work on the Reflux Classifier was 12 t/m^2 h.

The overall partition curve in Fig. 3(A) indicates that the quality of the separation in the dense medium Inverted Reflux Classifier was relatively poor, with the offset tail indicating a significant misplacement of high density particles. Separation performance is usually given by the *Ecarte Probable*, $Ep = (D_{25} - D_{75})/2$. For the curve shown in Fig. 3(A), $Ep = 0.11$, suggesting a strong separation performance. However, the Ep value fails to account for the effects of the tail. This is a major weakness of relying on the Ep measure. A modified *Ecarte Probable*, $Ep^* = (D_{10} - D_{90})/4$, results in $Ep^* = 0.23$ for the Inverted Reflux Classifier, correctly reflecting the poor separation performance. The curve in Fig. 3(B) shows the standard Reflux Classifier had both a lower Ep value of 0.075, and strong closure and symmetry in the partition