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Detailed characterisation and separation of fly ash fed to the Inverted Reflux Classifier

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ABSTRACT

This paper provides a detailed analysis of the separation of valuable cenospheres from different fly ash feeds using the Inverted Reflux Classifier (IRC). Even though the IRC was found to be effective in recovering cenospheres [A. Kiani, J. Zhou, K.P. Galvin, Upgrading of positively buoyant particles using an Inverted Reflux Classifier, Advance Powder Technology. 26 (2015a) 119–125], the separation performance can vary depending on the cenospheres and fly ash properties. A typical fly ash feed sample was characterised in terms of surface morphology, elemental composition, density and size distribution, providing more detail of the fly ash feed properties and their possible effects on the separation performance. The separation of cenospheres from three different fly ash feeds (Feed 1, Feed 2 and Feed 3) with the cenosphere concentrations at about 0.51 wt.%, 0.85 wt.% and 1.14 wt.%, respectively, was then examined using the IRC. Under the same operating conditions, about 64 wt.% and 93 wt.% of the cenospheres were recovered from the fly ash Feeds 2 and 3, respectively. For the fly ash Feed 1, only 49 wt.% of cenospheres was recovered despite the fact that the feed rate was lower. The results support the proposition that by increasing the cenosphere concentrations in the fly ash feed, the positively buoyant particles are more likely to form streaming structures and can be separated much more effectively from the negatively buoyant fly ash particles [A. Kiani, J. Zhou, K.P. Galvin, Enhanced recovery and concentration of positively buoyant cenospheres from negatively buoyant fly ash particles using the Inverted Reflux Classifier, Minerals Engineering, 79 (2015b) 1–9]. Moreover, the separation of cenosphere particles in Feed 3 was further promoted by the presence of larger particles, achieving a recovery of about 93 wt.% and grade of 80 wt.% at a high solids throughput of 4.9 t/(m^2 h).

1. Introduction

Cenospheres are one of the most valuable components found in fly ash waste. Therefore, the separation of the cenospheres from the fly ash is desirable. However, the combination of recovery and concentration of valuable positively buoyant cenospheres in fly ash is challenging. Both the cenospheres (i.e. the particles of density less than water) and dense fly ash (i.e. the silicate aluminate particles) consist of silica and alumina, providing the same surface properties. Hence flotation is an ineffective method for their separation. Considering the densities of cenospheres and dense fly ash to be 800 kg/m^3 and 2000 kg/m^3 respectively, the free settling ratio [3] will vary from around 5 down to 2.2 for Newton's through to Stokes' regimes respectively, indicating that there is potential for an effective wet gravity separation.

Enhanced wet gravity separation provides a more appropriate approach to separate the fine positively buoyant cenospheres from the negatively buoyant fly ash. In our previous study [1], an Inverted Reflux Classifier (IRC) was used to separate the cenospheres from the fly ash. The IRC combines an inclined settler with an inverted fluidization column. The benefit of another phenomenon referred to as streaming formation [4] arises naturally in the IRC, enhancing the recovery of the cenospheres from the fly ash. Previous work has shown the phenomenon only occurs at elevated concentrations of the cenospheres and at higher overall feed solids concentrations [2]. According to these studies, different separation performances for various fly ash feeds in the IRC are expected. The fly ash and cenospheres were thoroughly characterised, providing more detail on the particle properties. The separation of the cenospheres from different fly ash samples in the IRC was then reported and analysed.

2. Experimental

2.1. Experimental equipment

2.1.1. Inverted Reflux Classifier

A schematic representation of the Inverted Reflux Classifier (IRC) is shown in Fig. 1. The laboratory scale IRC, essentially an inverted fluidised bed installed above a system of parallel inclined channels, was used to separate the cenospheres from the fly ash. The vertical

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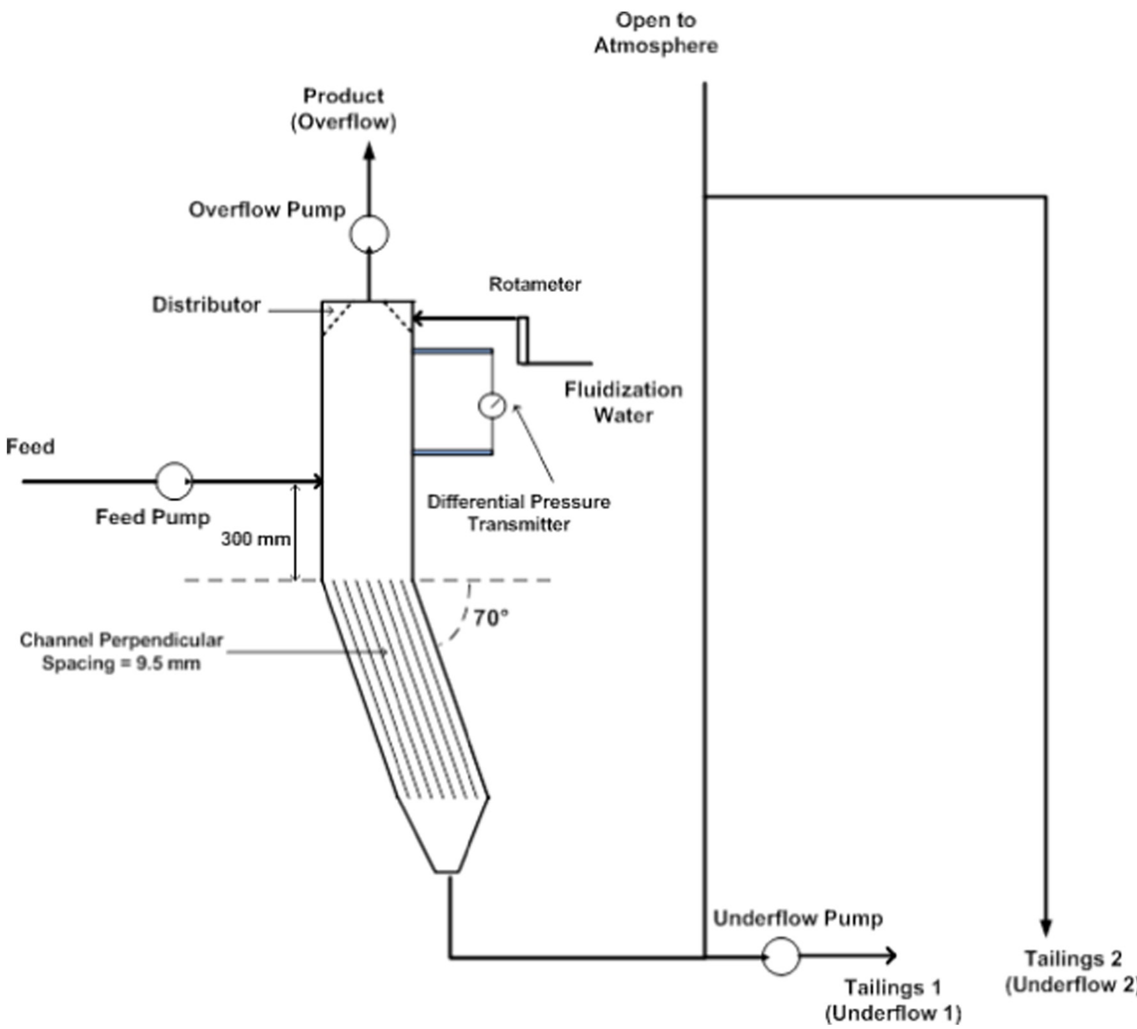

Fig. 1. A schematic representation of the Inverted Reflux Classifier.

fluidised bed was 1 m high with a cross sectional area of 86 mm × 100 mm. The inclined section consisted of eight parallel inclined channels with a perpendicular spacing of 9.5 mm. A fluidization chamber located at the top of the system had the same cross sectional area as the vertical fluidised bed, height of 110 mm, and discharge port 20 mm in diameter. The pyramid-shaped fluidization water chamber included 14 holes in each face (56 holes total), each 1.0 mm in diameter, providing a uniform fluidization flow. The feed, a portion of the tailings (Tailings 1), and the product were independently controlled using peristaltic pumps, while the fluidization water was adjusted using a rotameter. The tailings 2 stream was extended to an elevation of 1 m above the device, vented to the atmosphere in order to maintain a fixed system pressure and to ensure the system was full at all times.

2.1.2. Reflux Classifier

As part of the feed analysis, a novel approach was adopted to quantify the density distribution of the feed. A Reflux Classifier (RC) with parallel inclined channels located above a liquid fluidised bed was used to fractionate the fly ash feed into different flow fractions with a narrow range of density. Note that this mode is very different to the IRC arrangement adopted in this study for recovering and concentrating the cenospheres on a continuous basis. The inclined section consisted of 23 stainless steel plates forming 24 channels with perpendicular spacing of 1.77 mm. Channels with closely spacing are known to separate particles on the basis of their density, suppressing the effects of particle size [5,6]. The vertical section located below the inclined section is 1 m long with a cross sectional area of 100 mm × 60 mm. The fluidization water was introduced from the base of the vertical section. The fractionation process is run under semi-batch conditions. Fig. 2 shows a simple representation of the Semi-Batch Reflux Classifier process [7].

2.2. Experimental procedure

Fly ash samples with different cenosphere concentrations ranging from 0.51 to 1.14 wt.% were sourced from a power station in Australia. For each fly ash sample, the feed slurry was prepared and stirred for several hours and then fed into the IRC through a feed inlet located about 300 mm above the junction of the vertical and inclined sections. Some fine cenosphere particles were entrained into the inclined channels. However the enhanced segregation rate along the inclined channels prevented these fine cenospheres from reporting to the tailings. Some fine fly ash particles were also misplaced into the overflow product discharge. However the fluidization water entering via the top of the IRC washed the bulk of these fly ash particles from the cenospheres product.

As shown in Fig. 1, two pressure transducers were installed above the feed inlet, providing a measure of the suspension density in the upper section and hence the transition towards steady state. In fact,