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Direct measurement of internal material flow in a bench scale wet low-intensity magnetic separator

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ABSTRACT

In this work an ultrasound-based measurement method is used for monitoring suspension velocity and build-up of magnetic material inside a wet low-intensity magnetic separator, a process used e.g. in beneficiation of magnetite ores. Today the only available option is to monitor material transport between unit operations; i.e. flow rate, solids concentration, and particle size distribution of suspension flow in pipes are measured online using standard equipment.

An acoustic backscatter system is fitted to the tank of a separator, and used to monitor the internal flow. A method called ultrasonic velocity profiling is used to capture internal velocity profiles. Simultaneously, the backscatter signal intensity is used to get indications about local solids concentration of the flow, and build-up of magnetic material. The methods are evaluated in realistic conditions, where the effect of varying factors relevant to machine performance is investigated. The included factors are; the slurry feed rate, the slurry solids concentration, the magnet assembly angle, and the drum rotational speed.

The presented method gives useful information about the internal material flow inside the separator. The velocity measurements capture the, sometimes complex, internal flow patterns, for example the presence and velocity of a recirculating flow in the dewatering zone. Additionally, keeping a balanced material loading in the concentrate dewatering zone is important to separator performance. Using the signal backscatter intensity it is possible to qualitatively monitor this material loading. Generally these direct measurements can aid in improvements to machine design, process optimization, and process control.

1. Introduction

In mineral processing, material transport is commonly monitored between unit operations; flow rate, solids concentration, and particle size distribution of suspension flow in pipes are measured online using standard equipment. In many situations this information could be complemented or replaced by measurements inside the process equipment. Additionally the mining industry has a constant need to optimize the performance of their processes. In wet low-intensity magnetic separation (LIMS) four factors of major importance are; throughput, amount of gangue in the concentrate, loss of magnetic material to the tailings, and the total water usage of the process. Being able to monitor the material transport inside a separator during various operating conditions would help in optimizing these factors.

Wet LIMS is used to separate ferromagnetic particles from non-magnetic particles. The particles are fed to the separators in suspension with water, and the material is separated into a thick magnetic concentrate and a dilute tailings stream. For a more detailed description see e.g. Stener (2013). Fig. 1 shows schematic drawings of separators with three tank designs adapted from Metso (2014). The magnetic assembly has been divided into zones using the concepts of Davis and Lyman (1983), and the shaded area indicates approximate pulp level as in Forciea et al. (1958).

There are a large number of factors influencing magnetic separator performance. Dardis (1989) and Morgan and Bronkala (1993) describe a number of these, for example; the feed rate of magnetic material, the magnetic grade of the feed, the feed solids concentration, the magnet assembly angle, and the drum rotational speed. In addition there are a number of machine design parameters which affect the separator performance, e.g. the drum-to-tank clearances, the separator magnet assembly design, and the separator tank design. Dardis (1989) worked with the process of dense medium

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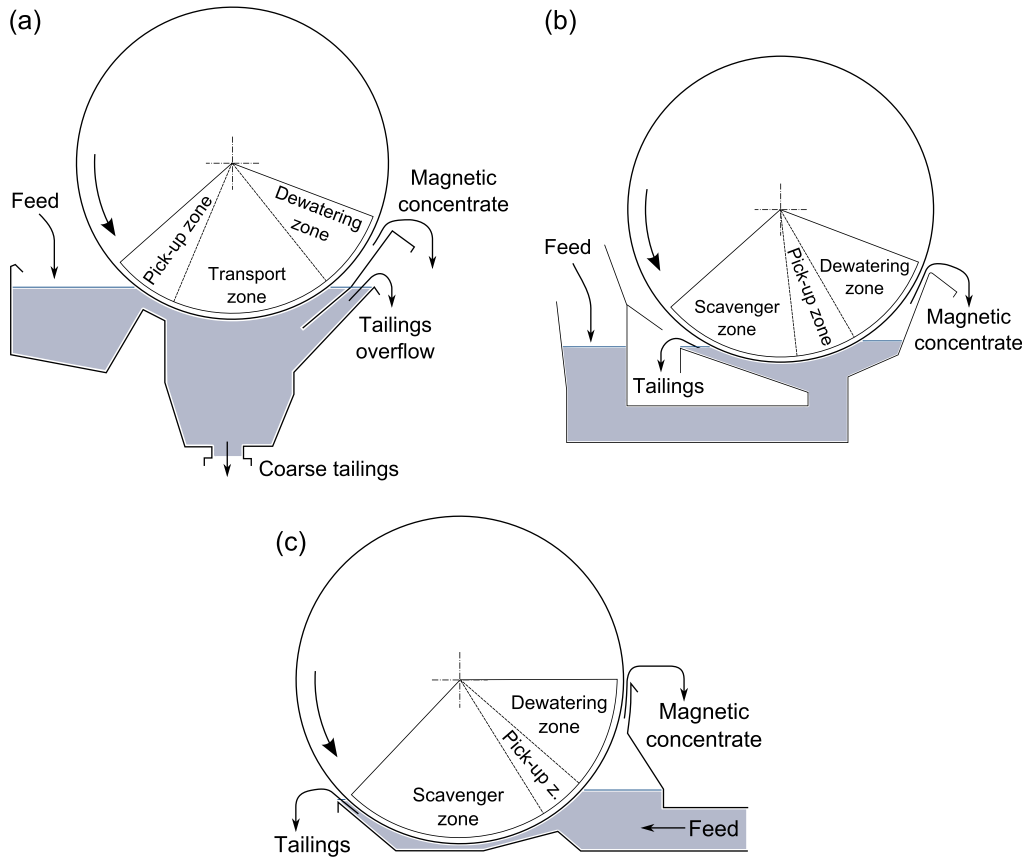

Fig. 1. Schematic drawings of three wet LIMS tank designs. (a) Con-current type separator. (b) Counter-current. (c) Counter-rotation.

recovery, which has many similarities to the process of magnetic separation of fine magnetite in preparation for pelletizing.

Also Lantto (1977) studied the factors affecting separation performance and found magnetic flocculation inside the separator to be the major mechanism for recovery of fine magnetite particles. Rayner and Napier-Munn (2000) saw similar effects, and concluded that to achieve efficient magnetic flocculation inside the separator the concentration of magnetic material in the feed has to be sufficiently high. According to Lantto (1977) the factor which limits capacity when working with coarser material is the solids flow rate. When working with finer material the feed needs to be diluted more, because of the greater specific surface area, and slurry flow rate becomes the capacity limiting factor.

Regarding concentrate quality, however, the misplacement of gangue particles into the concentrate tends to increase with a decrease in particle size, mainly due to entrainment of gangue in chains of ferromagnetic particles. Also, if the feed is fine enough the gangue particles tend to act as part of the fluid medium; the recovery of gangue to the concentrate becomes proportional to the recovery of water to the concentrate (Hopstock, 1985). In the current work the focus lays on counter-current type magnetic separators used for cleaning of a magnetite material prepared for pelletizing, which means that the feed material is fine. Rayner and Napier-Munn (2003) also investigated the process of dense medium recovery, and propose that the mechanism controlling magnetic separator concentrate density is one of drainage.

Another factor which seems to have a strong influence on concentrate solids concentration, and as mentioned above, the concentrate quality, is the material build-up inside the separator. This material build-up is strongly affected by e.g.:

- The magnet assembly angle, which controls how high the magnetic material is lifted by the magnets and the drum in the concentrate dewatering zone; a high lift gives increased throughput and less material build-up in the dewatering zone.
- The drum rotational speed; a faster rotational speed gives more capacity for material throughput, but also less time for water to drain.
- The distance between the overflow weir and the separator drum; a wider gap gives an increased capacity for material throughput, but also a risk of a more dilute concentrate.

To get a better understanding of the internal material transport processes in wet LIMS internal measurements are needed. Until now no means exist for internal measurements in process equipment like the wet LIMS. In this work the possibilities to do measurements inside a wet LIMS using two ultrasound-based methods combined to an acoustic backscatter system (ABS) is investigated.

The first method uses cross-correlation between ultrasound echoes to estimate particle velocity in flow of suspensions. Already in 1976 Dotti et al. used cross-correlation of ultrasound echoes to measure blood flow velocity. In a review by Hein and O'Brien (1993) the development of cross-correlation based ultrasound velocity measurements are summarized. The use of ultrasonic sensors in the process industry is later reviewed by Hauptmann et al. (2002).

Using the second method, information about the local solids concentration is extracted from the backscatter signal amplitude. This has been described in detail by e.g. Hunter et al. (2011); they used a pulse-echo ultrasound based system to monitor particle set-