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Effect of wash water on the mineral size recovery curves in a spiral concentrator used for iron ore processing

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ABSTRACT

Spiral concentrators are widely used in the iron ore industries to concentrate heavy iron oxides from light silica gangue minerals. The operation of a WW-6 spiral for the concentration of an iron oxide ore is analyzed through the size recovery or partition curves of the minerals. Several tests conducted following a factorial design using wash water addition, feed rate and slurry solid concentration as studied factors show that for the tested conditions the wash water addition has the most important effect on the spiral performance with its effect being mainly located on coarse particles.

1. Introduction

Spiral concentrators are gravity based separation devices used for the preparation of coal, iron and heavy mineral ores (Wills, 1992). A spiral can be described as a centrifugal sluice in which the centrifugal force combines with gravity to operate the separation between light and heavy particles. The separation of particles in a spiral is also impacted by the drag force and the lesser known Bagnold force which specifically acts preferentially upon particle size rather than weight (Atasoy and Spottiswood, 1995; Burt, 1984; Bouchard, 2001). For a given ore feed size distribution the main operating variables for a spiral concentrator are the feed rate, the slurry concentration, the wash water addition and the position of the cutters or splitters used to separate the tailings, middlings and concentrate streams.

Dallaire et al. (1978) investigated the effect of the feed rate and slurry solid concentration on a Humphrey spiral operation for iron ore. These authors reported that increasing the feed rate is favorable to concentrate grade but hampers valuable species recovery and that increasing the feed slurry solid concentration should increase recovery at the expense of concentrate grade. Few authors discussed quantitatively the effect of wash water addition on the operation of spirals. The discussion indicates that wash water is an important control variable used to wash away entrapped light minerals from the concentrate stream (Burt, 1984; Bouchard, 2001). Richards and Palmer (1997) indicate that significant benefits were observed after the removal of wash water from spirals treating light minerals. These studies are mainly based on global performance indices such as grade and recovery but did not investigate the effect of spiral operating variables on the recovery of particles as a function of their size and specific gravity.

This paper uses the mineral size recovery curves to investigate, using a 2^3 factorial design, the effect of the slurry solid concentration, slurry feed rate and wash water addition on a WW-6 spiral processing an iron ore. The first section describes the set-up used for the tests and the test results are analyzed in the second section.

2. Test set up and experimental conditions

The tests are conducted using a spiral operated in a close circuit at the COREM pilot plant in Quebec, QC, Canada. The set up used for the tests is described first followed by the test conditions.

2.1. Test set-up

The spiral used for the tests is a 7 turn WW-6E from Roche Mining. The set-up used for the experiments is shown in Fig. 1. The feed material is a ground ore from the Mount Wright Arcelor-Mittal mine in Quebec (Hyma and Meech, 1989). The ore is mixed with water and the slurry is loaded into pump box A (see Fig. 1). The slurry is pumped to a distributor at the top of the spiral. The distributor is connected to 12 rubber pipes that can be easily moved in and out of the spiral feed wells. This set up allows a fast and accurate adjustment of the spiral feed rate. The slurry that is not used as the spiral feed is returned to pump box

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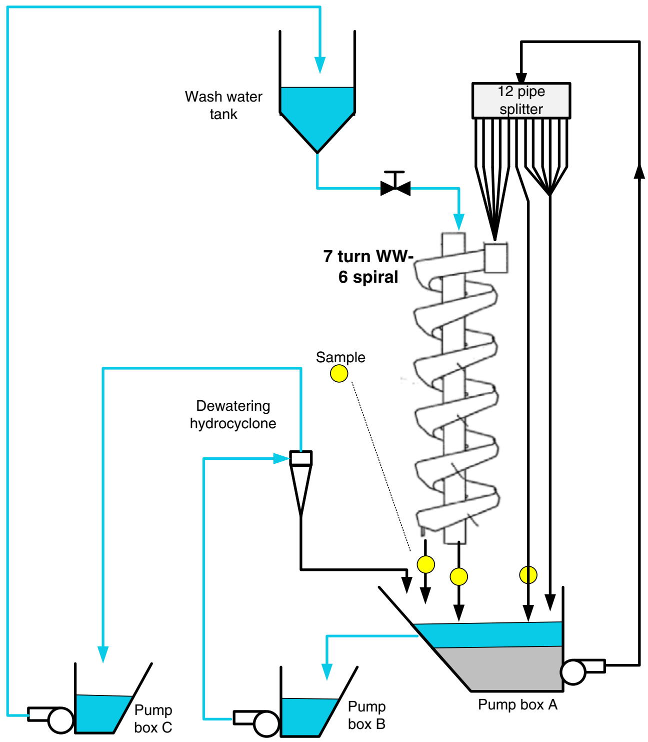

Fig. 1. Experimental set-up.

A. One pipe is used to sample the spiral feed (see Fig. 1). The spiral concentrate and reject streams discharge into pump box A via soft rubber pipes that can be easily manipulated to collect samples and measure flow rates. Pump box A overflows to pump box B that feeds a dewatering hydrocyclone. The hydrocyclone underflow is returned into pump box A while the overflow is pumped back, via pump C, to a water tank that provides the wash water addition to the spiral. A manual valve (Fig. 1) is used to adjust the flow of wash water sent to the spiral that is fairly constant providing that the level in the water tank is kept constant during the test work.

2.2. Experimental design

The tests conducted follow a 2^3 factorial design with the feed rate, feed slurry concentration and flow rate of wash water. The openings of the concentrate cutters (splitters) are set at the beginning of the test work and kept constant for all the tests. The 2^3 factorial design used for the tests is shown in Table 1 with the considered variation for the factors. Tests 1 and 10 are carried out at the reference conditions.

Table 1
The 2^3 factorial design used for the tests on the spiral.

Test	Feed rate	% Solids	Wash water
	F (l/min)	S (% w/w)	W (l/min)
1	60 (0)	37 (0)	16.7 (0)
2	48 (−1)	32 (−1)	8.3 (−1)
3	72 (+1)	32 (−1)	8.3 (−1)
4	48 (−1)	42 (+1)	8.3 (−1)
5	72 (+1)	42 (+1)	8.3 (−1)
6	48 (−1)	32 (−1)	25.0 (+1)
7	72 (+1)	32 (−1)	25.0 (+1)
8	48 (−1)	42 (+1)	25.0 (+1)
9	72 (+1)	42 (+1)	25.0 (+1)
10	60 (0)	37 (0)	16.7 (0)

The amplitudes of the changes in the feed solid concentration and volumetric feed rate are chosen so that the test conditions fall within the manufacturer's recommended values reproduced in Fig. 2. The spiral manufacturer (Roche Mining, 2011) recommends a wash water addition within 0.5 and 1.5 m^3/h which corresponds to the levels tested for that factor.

For each test the feed rate, slurry solid concentration and wash water are adjusted to the planned values. The spiral is then allowed to stabilize for 10 min with regular measurements of the feed rate and slurry solid concentration to ensure a stable operation. A timed sample of the feed stream is taken first to avoid disturbing the spiral operation. Then timed samples of the spiral concentrate and reject streams are taken simultaneously. The samples are used to obtain:

- the mass flow rate;
- the head assays (Fe, SiO_2, Al_2O_3, CaO, MgO, Na_2O, K_2O, MnO);
- the size distribution (from 1.6 to 0.038 mm) of the particles: a size of 0.025 mm is used as the mean size of the particles passing through a 0.038 mm sieve;
- the chemical composition (Fe, SiO_2, Al_2O_3, CaO, MgO, Na_2O, K_2O, MnO) of all the size fractions;
- the solid concentration of the slurry;
- the specific gravity of the ore.

2.3. Data processing and estimation of the size recovery curves

All measurements are reconciled using the BILMAT algorithm (Hodouin and Everell, 1980). The estimation of the mineral content of the streams from the chemical assays is not yet incorporated into the data reconciliation. However since iron oxides, mainly hematite, and quartz account for more than 95% of the considered ore (Hyma and Meech, 1989) the tracking of the behaviors of iron and silica (SiO_2) is deemed acceptable in a first approximation. A detailed analysis of the spiral operation would however require the estimation of the mineral contents of each stream and size fraction as the spiral classifies the particles as a function of their size and specific gravity the latter being dependent of the mineral composition.

The recovery in the concentrate stream of a species m within size interval i is noted as $R_{i;m}$ and is calculated using:

$$R_{i;m} = \frac{W_C g_{C;i} x_{C;i;m}}{W_F g_{F;i} x_{F;i;m}}. \quad (1)$$

The variable W stands for a solid flow rate, while g is used for the weight retained within the ith size interval and x is the species m concentration of the ore within size interval i. The subscript m is used to indicate a species such as iron or silica. The indices F and C indicate respectively the feed and concentrate streams. The use of mass balanced data in Eq. (1) filters out the measurement errors and provides more reliable performance indices than the direct use of measurements into

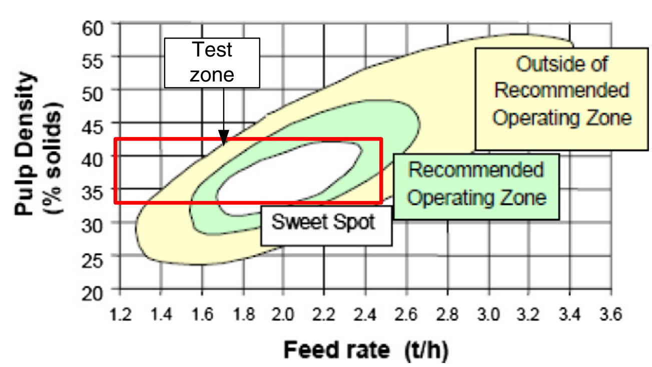

Fig. 2. Recommended operating range for the WW6E spiral (Roche Mining, 2011).