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Thesis abstract

Application of the REFLUX™ Classifier in the hydrodynamic classification of minerals by particle size

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One of the most important operations in the mineral processing industry is the classification of particles according to their size. These separations are essential for preparing the feed for comminution, or for beneficiation over specific particle size ranges covering density separation or flotation. This study examined the application of the REFLUX™ Classifier in particle size classification, a system consisting of a set of parallel inclined channels above a vertical fluidised bed. A model feed of pure silica was selected and used throughout the study, covering a broad size range up to a nominal 710 µm. A novel feed preparation method ensured the consistent delivery of the feed, not only across a given experiment, but also across the entire study. Mass balance reconciliation became very reliable. This approach of using the same feed proved valuable in linking the different elements of the study.

This work demonstrated the benefit of split fluidisation (side-water) in preventing the entrainment of ultrafine particles to the coarse underflow, whilst not significantly impacting the separation size. The by-pass of ultrafine particles to the underflow was also minimised by ensuring a fluidised bed was present. In the absence of a fluidised bed, the underflow stream would have received a dilute and well mixed flow, resulting in misplacement of fine particles. The overall strategy enabled remarkably sharp separations, with the Imperfection, I, typically as low as 0.11 to 0.13 for solids throughputs up to 92 t/(m^2 h). The family of partition curves was observed to be very consistent, with strong closure evident at the finer and coarser ends. These results contrast significantly with the relatively poor separations reported in the literature for hydrocyclones and other hydrodynamic separators.

It was found that the lower fluidisation rate acted as the key control variable for separations finer than 200 µm. The required fluidisation velocity was consistent with values calculated using the Richardson and Zaki (1954) equation. However, at coarser separation sizes, the side-water became much more important, especially for the more concentrated feeds. In order to minimise the water consumption, the REFLUX™ Classifier was modified by halving the lower cross-sectional area of the vessel. This modification delivered a doubling of the superficial fluid velocity for a given flow rate, and helped to address the increasing challenge of producing sharp separations at these coarser sizes.

To ensure sharp separations, it was also demonstrated that the volumetric water-to-solids ratio in the overflow needed to be at least 5.5. Below this point, the high internal solids concentration within the inclined

channels likely impeded the ability of the coarser particles to segregate, misplacing them into the fine overflow. By providing sufficient water through either the feed or the side-water, coarse particles were efficiently rejected by the inclined channels and correctly reported to the coarse underflow. Whilst most of this work was completed at solids concentrations of 50 wt.% in the feed, solids concentrations as low as 2–8 wt.% were also examined. In these cases, high volumetric feed fluxes produced Imperfections as low as 0.06, less than half that of the other experiments in this study, further demonstrating the positive effect of lower solids concentrations in the inclined channels.

The maximum solids throughput was shown to be proportional to the separation size. Moreover, the separation size correlated directly with the underflow solids yield. At lower separation sizes, and therefore higher underflow yields, the higher downwards flux led to a higher solids concentration above the fluidised bed. When this solids concentration increases to the point of converging with that of the fluidised bed, the height of the bed is no longer discernible, meaning the system becomes flooded. Therefore, finer separations required lower solids throughputs, whilst coarser separations could accommodate much higher solids throughputs.

Through all the experiments in this study, it was discovered that the inferred internal concentration correlated directly with the suspension viscosity, and in turn linearly with the Imperfection. This internal concentration was based on the well-established empirical model of Laskovski et al. (2006). An empirical model was then developed to describe the separation performance of the REFLUX™ Classifier based on a given separation size, and information of the total solid and water inputs. Using an assumed underflow solids concentration, often ~65 wt.% in this work, the water and solid outputs were calculated for each stream, and the overall Imperfection determined. This empirical model therefore provides a complete description of the REFLUX™ Classifier in separating silica based on particle size across the full range of conditions in this study.

The strength of the data in this study allowed for direct comparisons to be made between two of the most common distributions used in the field of size classification — the Whiten equation, and the Rosin-Rammler function. The experimental data from this work adhered to the Whiten equation over a range of $\pm 5E_p$, much wider than that of the Rosin-Rammler function, providing significant evidence in favour of the Whiten equation. It was also discovered that the Whiten equation has a functional equivalence to the fundamental Fermi-Dirac distribution used in quantum mechanics, which is governed by a Boltzmann distribution incorporating a chemical potential difference. This equivalence offers prospects for an improved framework for describing the role of a hydrodynamic driving force in particle size classification.

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