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Numerical and experimental study of the effect of a froth baffle on flotation cell performance

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ABSTRACT

In this work, the effect of a froth baffle on flotation performance is investigated both experimentally and numerically. Flotation experiments with an artificial ore comprised of 80% silica as gangue and 20% limestone as floatable component were carried out to compare the flotation performance of a baffled froth system against an un-baffled froth system. The effect of the baffle's inclination angle to the horizontal was also studied. Results indicated that a froth baffle has a profound effect on both recovery and grade. The presence of a froth baffle resulted in an increase in grade at the expense of recovery. The decrease in limestone recovery with the introduction of a froth baffle was found to be a function of the baffle's inclination angle i.e. recovery decreased as the inclination angle becomes more acute. Water recovery as well as entrainment recovery herein represented by silica recovery decreased with decrease in baffle's inclination angle. Numerical techniques were employed to model the experimental results. The 2D stream function equation/Laplace equation which is known to be adequate in describing froth transport was solved subject to boundary conditions that represent the presence of baffles. A solution was developed using finite difference methods on a rectangular map obtained using Schwarz–Christoffel (SC) mapping. Results from the simulations indicated a change in particle residence time distribution in a manner that reduces spread. The changes in residence time distribution helped in developing an explanation of the experimental data.

1. Introduction

Froth recovery is typically used as a froth phase performance measure; its definition entails quantification of the fraction of particles attached to bubbles that enter the froth phase that are recovered as concentrate. It is a function of a number of variables including froth residence time, froth mobility, stability and bubble coalescence. The dependence of froth recovery on froth residence time is well documented e.g. Yianatos et al. (1998) and Vera (2002). In most froth recovery models, the froth residence time is expressed in terms of froth depth and gas rate. Thus by manipulating these variables, froth residence time is changed. Other froth properties such as froth stability and cell design also influence froth residence time but are not readily amenable to manipulation by flotation plant operators; changing them may involve changing pulp chemical conditioning which may prove costly in terms of reagent consumption in the long run. As a result, operating plants have typically manipulated froth residence time by changing froth height and superficial gas velocity; with deeper froths generally producing high grade concentrate at lower recovery and vice versa while high superficial gas velocities result in increased recovery at the expense of concentrate grade.

Although gas rate and froth depth can successfully be used to optimize froth phase performance, is it not desirable to have an additional manipulated variable that specifically targets sub-processes in the froth phase? An additional manipulated variable that targets froth mobility which can be changed for a given flotation cell without destabilizing the whole flotation circuit? After proposing a froth transport model and comprehensive studies on froth residence times, Moys (1979) developed a novel technique to manipulate froth residence time in addition to gas rate and froth height. This technique involves the use of froth baffles. The purpose of the froth baffle is to elongate the path taken by a bubble that enters the froth phase close to the concentrate weir as it travels from the pulp-froth interface until it is recovered to the concentrate. Exciting results were obtained from Moys' technique; an increase in chalcopyrite grade that ranged between 10.4% and

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22.1% was recorded for a given recovery. Despite the potential of this work to be used as a tool for manipulating froth residence time and hence froth performance, no further work has been done on froth baffles. Froth baffles can provide the flotation operator with an additional variable to manipulate when optimizing flotation performance. It is thus the objective of the work reported herein to further investigate the use of froth baffles as a way of optimizing flotation performance. The work focuses on the effects of a froth baffle and its inclination angle to the horizontal on recovery and grade. Comparison of experimental flotation performance of a baffled froth system to the same flotation system without a baffle is done. Numerical investigations are carried out to understand and explain the experimental results.

2. Experimental description

Flotation tests were done using an artificial ore made up of 80% silica as gangue and 20% limestone as floatable component in a closed loop flotation circuit shown in Fig. 1. These experiments were done to compare the effect of a froth baffle on flotation performance i.e. limestone recovery and grade. Three conditions viz. (1) No baffle in the froth phase (2) baffle inclined at 67° and (3) baffle inclined at 45° depicted in Fig. 2 were investigated at a fixed froth depth of 10.1 cm and average superficial gas velocity of 0.90 cm/s. The baffle was inserted at a distance X_b of 5 cm from the flotation cell concentrate weir wall and it extended 2–5 mm below the pulp-froth interface. The average pulp residence time in the flotation cell was maintained at 3.0 min by fixing feed flowrate into the 8 l pulp volume flotation cell. Oleic acid and Dowfroth 250 were used as collector and frother with dosage rate of 20 mg/l of water and 30 mg/100 g limestone respectively. Dowfroth was supplied by Betachem (Pty) Ltd and Oleic acid (88%) by Merck chemicals in South Africa. Pulp percentage solids was maintained at 15%w/w while agitation rate was kept constant at 1200 rpm. At steady state, simultaneous cuts of tailings and concentrate streams were taken, sampling was repeated three times at 5 min intervals. These samples were weighed and dried for further analysis. Wet and dry samples were obtained for both tailings and concentrate.

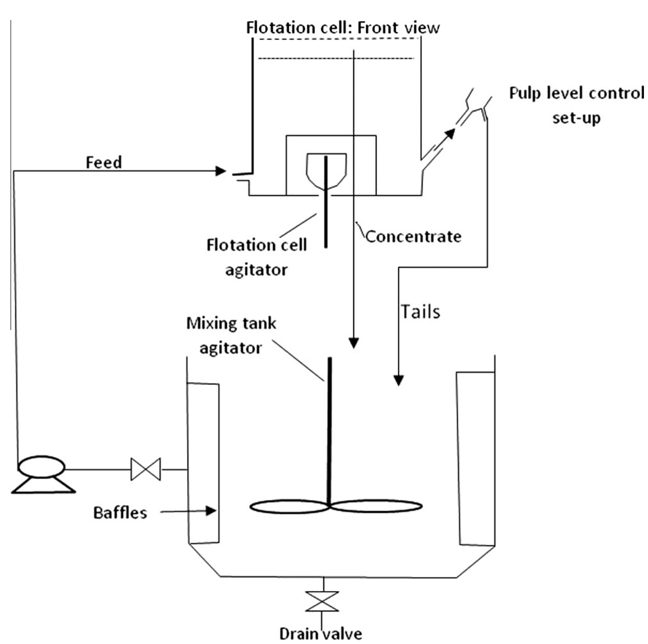

Fig. 1. Schematic of the pseudo-steady state experimental rig.

3. Results

As observed by Moys (1979), the introduction of a froth baffle has a notable effect on the overall performance of a flotation system. Froth baffles were inserted in the froth with their bottom section just below the pulp-froth interface (2–5 mm). Its positioning would impose little changes to the pulp phase sub-processes, thus it can be assumed that any change to the overall flotation performance (grade and recovery) is associated with the baffle geometry and changes in the froth mobility. Results are summarized in Fig. 3.

3.1. Limestone recovery

The recovery of limestone decreased from 72% to 67% when froth baffles were introduced into the froth (Fig. 3). The lowest recovery was recorded when the baffle angle was 45° while the highest recovery was observed when there was no baffle in the froth. These changes in limestone recovery were expected since introducing a froth baffle elongates the path followed by bubbles generated close to the concentrate weir resulting in an increase in average froth residence time. An increase in froth residence time will generally result in decrease in the recovery across the froth phase, hence a decrease in overall recovery. Furthermore, the presence of the baffle may promote bubble coalescence and particle detachment resulting in a further decrease in recovery due to particle losses.

The range of limestone recoveries observed in these experiments is 5% which is small when compared to the range of recoveries reported by Moys (1979). Thus to be sure that the observed changes in recovery are indeed a result of the instituted process changes and not due to random variations, the data was subjected to statistical analysis. One-way ANOVA was performed on recovery. The following hypothesis was tested at $\alpha = 0.05$ using the analysis package in Microsoft Excel.

Null hypothesis H_O

The means of limestone recoveries are equal for the three factors i.e. baffle positions.

Alternative hypothesis H_a

At least two of the recoveries are different.

The analysis at $\alpha = 0.05$ and F_{crit} value of 5.14 resulted in the rejection of the null hypothesis because the calculated F statistic value of 72.74 is higher than the F_{crit} value; results are summarized in Table 1a. Rejection of the null hypothesis proves that there is some significant difference in at least two of the limestone recoveries that is due to the instituted process changes and not due to random errors. To enable identification of the limestone recoveries that are different, a Post-Hoc Test based on Tukey's HSD (Honestly significant difference) test was carried out. The test (Table 1b) concluded that the differences between the recoveries of limestone in all tests are statistically significant. The conclusion was reached because the differences in the average limestone recoveries for all conditions were higher than the Tukey's HSD value of 1.38.

Now that it has been proven that the limestone recoveries obtained are statistically different and are not a consequence of random errors, it is important that we explain our results in relation to Moys *op cit.* results. Moys results show that the introduction of a froth baffle resulted in an increase in recovery while results reported herein indicate a loss in recovery as the froth baffle was introduced. This loss in recovery increases as the baffle angle becomes more acute. Before advancing an explanation for the trends observed, it is important to highlight that the flotation