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# The use of FrothSim to optimise the water addition to a column flotation cell

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**Abstract**

This paper examines the use of the FrothSim flotation simulator to improve the performance of an industrial column flotation cell. The performance of an industrial retreat column cell is simulated, and, from the discrepancies between the simulated and experimental results, a problem with the wash water distribution is postulated.

The scientific reason for the reduced performance with uneven wash water addition is described in detail. Further simulations indicated the potential for improvement with an even wash water distribution, resulting in both improved performance and reduced wash water usage.

The simulated uneven wash water distribution was confirmed industrially, and the headers were redesigned and installed. A sampling campaign to compare the performance before and after the modifications showed that the flotation performance was improved dramatically, with a statistically significant decrease in gangue recovery, without a commensurate reduction in valuable mineral recovery.


*Keywords:* Froth flotation; Flotation froths; Simulation

## 1. Introduction

This paper examines the use of the FrothSim simulator to optimise water addition to the zinc retreat columns at Teck Cominco's Red Dog mine in northern Alaska. The two retreat columns at the Red Dog mine account for approximately 20% of the final concentrate produced and have the lowest grade of all the streams that are combined to form the final concentrate.

Initially, the aim of this research was to compare the performance of the columns and the predictions given by FrothSim in order to verify the software's ability to accurately predict the trends seen in a real flotation cell.

It should be noted from the outset that this paper deals with cells in which wash water is added internally. The trends obtained when water is added to the top surface of the froth will not necessarily be the same as those given in this paper. The effect of water addition on the froth surface has been investigated in a previous paper (Neethling and Cilliers, 2001).

## 2. What is FrothSim?

FrothSim is a flotation simulation package that has been developed to simulate the performance of flotation cells and circuits. It combines a fundamentally based fluid dynamic model for the froth phase of a flotation vessel with a distributed rate constant model for the pulp phase.

The details of the froth modelling have been covered in detail in previous publications (Neethling et al., 2000; Neethling and Cilliers, 2002), but in summary, the model makes use of interlinked descriptions for all three phases. The motion of the gas phase is dictated by the distribution of the bubbles entering the froth and the stability of the bubbles at the top surface. The liquid motion is a result

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of the net effect of the viscous drag of the flowing bubbles, gravity and capillary suction brought about by surface tension. The solids consist of two classes, namely the particles that are attached to the interfaces and those that are unattached. The attached particles follow the gas motion, but can become detached during coalescence and bursting, while the unattached particles predominantly follow the liquid motion, but also undergo hindered settling and dispersion. The solid motion has an impact on the liquid motion through the effect of solids concentration on the fluid density and viscosity.

## 3. Base case simulation

In order to compare the trends in performance measured experimentally to those predicted by the simulations, a base case simulation was initially carried out in which the flotation parameters were adjusted to get a close approximation of the operating performance of the plant. An exact match is not possible since the model is fundamentally based and there are thus very few adjustable parameters.

### 3.1. Setting up the base case simulation

#### 3.1.1. Assumptions

The pulp and froth are linked in FrothSim and the simulations predict the composition and flow rates for both the tailings and concentrate, based on a given feed composition and rate. Since the simulation is fundamentally based, even the adjustable parameters are actually physical traits of the system, but are just those for which no or limited data is available.

To model the pulp, it is assumed that the rate kinetics are first order and that the pulp zone is well mixed. The well-mixed assumption is justified by the experimental data shown in Table 1 confirming that the tailings concentration and the concentration in the pulp just below the interface are virtually the same.

#### 3.1.2. Physical dimensions

FrothSim simulates arbitrary shaped cells using Cartesian or cylindrical coordinates in two dimensions with symmetry in the third. For the retreat columns, cylindrical coordinates with angular symmetry are used. This does not allow simulation of the radial launders that divide the froth into quadrants, which are present in these columns. It can be overcome, however, by simulating the froth zone as four circular quarters, each with an equivalent circular radius of a quarter of the total froth area.

Table 1
Comparison between pulp and tailings composition

| | Tailings (%) | Pulp below froth (%) |
|---|---|---|
| Galena | 5.8 | 5.9 |
| Sphalerite | 59.4 | 57.9 |
| Pyrite | 15.4 | 18.1 |
| Non-sulphide gangue (NSG) | 19.4 | 18.1 |

Table 2
Froth zone dimensions (base case)

| | |
|---|---|
| Froth depth (pulp to weir lip) | 110 cm |
| Froth depth (pulp to froth surface) | 120 cm |
| Froth depth (weir lip to surface) | 10 cm |
| Cell radius (quarter cell) | 90 cm |
| Wash water addition position (depth from froth surface) | 20 cm |

The heights of the wash water inlet and froth depth were set as specified. Table 2 gives the dimensions for each quarter of the froth zone, as simulated. The depth of the froth over the overflow weir was set at 10 cm, and was confirmed by plant operators as an appropriate value.

#### 3.1.3. Solids

The solids were divided into 12 classes, consisting of four mineral types; sphalerite, galena, pyrite and non-sulphide gangue (NSG), each with three particle sizes; 5, 15 and 44 μm. The pulp rate constants for the 12 classes were estimated by iteration using FrothSim and experimental data from a previous study of this cell. The data used in the iteration, however, were taken under conditions significantly different to those currently in operation, namely shallower froth, different spargers and different bubble sizes in pulp and froth. The rate constants were subsequently scaled for this study according to the $k$–$S_b$ relationship in which the rate constant is proportional to the gas rate and inversely proportional to the pulp bubble size (Gorain et al., 1997).

#### 3.1.4. Feed rate and air flow rate

The superficial gas velocity of air into the cell and the volumetric feed rate were set from the plant data.

#### 3.1.5. Bubble size and bursting rate

Amongst the most critical variables in the performance of flotation froths are the incoming and overflowing bubble sizes. The bubble size determines the recovery of water, where, with everything else being equal, the relationship between water recovery and bubble diameter is approximately an inverse squared relationship (Neethling et al., 2003). In this case, the average incoming bubble size, measured using a bubble viewer, has been used. The overflowing bubble size, however, was not available.

The surface bubble size was consequently used as the only adjustable parameter in order to yield the measured volumetric recovery to concentrate. It was found that, due to the very small bubble sizes, small changes in bubble size have a very significant effect on the performance. Such changes were unlikely to be observable by image analysis, and this approach was considered the most appropriate under the circumstances.

The air recovery, or fraction of air entering the cell that flows over the weir, was estimated as 40% from image analysis of video footage of the overflowing froth. As the air recovery approaches 50%, the impact of the estimated bursting rate on the simulated results decreases