

SIMULATION OF COLUMN FLOTATION

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ABSTRACT

The aim of this work was to use the COLFLOT program to simulate industrial flotation columns. First, the main features of the column flotation process are outlined and a comparison is made with conventional mechanical cells. The model used to represent the flotation process in a column is briefly described. COLFLOT is a computer program that was developed from the concentration profiles calculated by the model. The program is then applied to simulate two industrial columns operating at Gibraltar Mines, Canada.

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1. Introduction

Column flotation is receiving new attention since its invention in Canada in the early sixties. Various industrial scale columns are now operating in Western Canada and Chile, mostly as cleaners in copper sulphide flotation and in the processing of bulk Cu-Mo concentrates.

A review of the state-of-the-art in column flotation was published in Brazil in 1986 (1). Since then, there have been publications on its application to the beneficiation of coal fines (2) (3) and on the modelling and scale-up of flotation columns (4).

The objective of this work was to simulate a column flotation operation using the COLFLOT program (5). This is a computer program developed for the simulation, modelling and scale-up of flotation columns. The data recently published by Dobby and Finch (4) on the operation of two flotation columns at Gibraltar Mines, Canada, were used for comparative purposes.

2. Characteristics of the column flotation process

The column has now been described widely and here there will only be mention of the key features that make it a strong competitor to conventional mechanical flotation cells. Thus, from the pilot and industrial testing of various ores the following conclusions have been made (1):

- (a) The column yields equal or greater recoveries than conventional cells with greater selectivity.
- (b) The column is more selective than the cells due to the cleaning action of the concentrate by the wash water and to the turbulence-free hydrodynamic regime in the column. It has been shown that practically no feed pulp reaches the top of the column (6).
- (c) The column requires less maintenance, less energy consumption and less dosage of certain reagents than the mechanical cells. On the other hand, the column requires a greater degree of instrumental and automatic control that results in a simpler operation.
- (d) Operating and investment costs are less than for conventional equipment of the same capacity on a tonnage processed basis.
- (e) Column flotation allows the processing of pulps of higher percent solids than mechanical cells without metallurgical losses. Also,

the column operates with less air hold-up (% volumetric of air in the pulp) so that air consumption is less too.

- (f) Some authors have shown that the high recoveries obtained by the column are due to a greater efficiency in the collection of the fine particles. By the same token, other researchers have found that coarse particles are less efficiently captured in the column than in the cells. What should be in mind is the fact that at least in theory, it should be possible to adjust the bubble size distribution to a particular particle size distribution in order to maximize overall recovery. Production of a controlled range of bubbles is a feature that no mechanical cell can offer at present.

As a final comment, the present authors want to stress that the flotation column is just a piece of equipment and therefore, in principle, its application should be possible whenever the flotation process is to be used for mineral beneficiation. This equipment represents a further advance towards a higher level of sophistication of the flotation process if control of the bubble size distribution is achieved by adequate diffusers.

3. Column simulation

The model.

Different mathematical models of column flotation have been proposed during the last decade (7) (8) (9). One of these has been the version used by Girardi (9) to analyze the process and provide experimental values of the flotation parameters in a lab scale unit. The same model has been recently applied in engineering projects, simulation of column flotation circuits and design of particular units (5).

The fundamental assumption included in practically all the models is to consider the column as a plug flow reactor, where the flotation mechanisms are provided by countercurrent flow of air bubbles and particles.

A schematic diagram of the column zones and internal flows considered in the model is shown in Figure 1. A change in the linear velocity of the liquid phase (pulp) along the axis of the column is assumed. The "mass transport of particles" occurred as a result of flotation mechanisms is graphically defined as a line between the

liquid and gas phases.

In order to evaluate the deviation from the plug flow condition of any column, the model includes a mixing parameter, D_L (axial dispersion coefficient). Mass balances of the different zones of the column considering the mixing effect are calculated using similar differential volumes as is shown in Figure 2. The balance in Figure 2 is given by (see symbols at the end):

$$(1-\varepsilon)AU_L C_L(z-dz) + \left(-(1-\varepsilon)AD_L \frac{dC_L}{dz} \right) z-dz = (1-\varepsilon)AU_L C_L(z) + \left(-(1-\varepsilon)AD_L \frac{dC_L}{dz} \right) z + \varepsilon AK C_L(z) dz \quad (1)$$

The general model is obtained solving the mass balance equations at each of the flotation column zones.

The liquid profile concentration can be described by

$$\frac{C_{Li}(x)}{C_{Lo}} = A_{1i} \exp(N_{1i} x) + A_{2i} \exp(N_{2i} x) \quad (2)$$

Where the index i is dependent upon column zone. The gas phase profile concentration may be expressed as:

$$C_{gi}(x) = B_{1i} \exp(N_{1i} x) + B_{2i} \exp(N_{2i} x) + B_{3i} \exp(-Pe_{gi} X) + B_{4i} \quad (3)$$

COLFLOT

The concentration profiles of both column zones have been used to develop a computer program called COLFLOT. This software is able to provide valuable information about metallurgical results and scaling-up of a column if it is fed with the operational parameters of the flotation process. To calculate the plug flow deviation, COLFLOT includes a subroutine based on an empirical relationship for bubble columns proposed by Mashelkar (10).

COLFLOT must be fed with the following information:

- rate constants
- grades (valuables and gangue)
- column dimensions
- feed rate (mass)
- wash water flow

- concentrate/feed ratio
- feed % of solids
- operational gas holdup
- specific gravities of feed and concentrate

The result of the simulation process is printed in a few seconds and includes:

- Grades and recoveries by element (species)
- Air flow requirement
- Solid and liquid mass balance information

To simulate industrial column flotation operations, the data published by Dobby and Finch (4) on the Gibraltar Mines columns were used. These are two columns which operate as cleaner and scavenger-cleaner fed by a copper rougher concentrate. The data used are shown in Table I.

Table I. Operating parameters of Gibraltar Mines columns used for COLFLOT simulation

	Cleaner	Scavenger
Column diameter (m)	0.895	0.895
Recovery zone length (m)	9.3	9.3
Feed rate (tpd)	118.0	61.5
Feed wt. % solids	14.0	6.5
Fractional gas holdup	0.14	0.12
* Washing zone length (m)	2.7	2.7
* Wash water flow (m ³ /d)	230.0	270.0
Feed grade (% Cu)	15.0	3.1*
* Feed s.g.	3.0	2.8
* Concentrate s.g.	3.3	3.0

* Values assumed by the present authors

Figure 3 shows the grade-recovery curves obtained by simulation using the COLFLOT program and the prediction given by the Dobby and Finch model. Also shown in the figure is the operating point of the plant.

It is observed that both models gave different grade-recovery curves. The main difference between both simulations is the values assumed for the rate constant of chalcopyrite and gangue in both

columns. Dobby and Finch used rate constants extrapolated from laboratory tests whereas in the COLFLOT program no such measurements were made. When COLFLOT was run with the rate constants given by these authors no good correlation with the operating point of the plant was obtained Table II shows the rate constants used in both cases.

Table II Rate constants used for column simulation (s^{-1})

		Dobby & Finch*	This work
Chalcopyrite	cleaner	0.011	0.0075
	scavenger	0.012	0.0048
Gangue	cleaner	$2-4 \times 10^{-4}$	7×10^{-4}
	scavenger	$2-5 \times 10^{-4}$	2.2×10^{-4}

*Mean values recalculated by the present authors

A criticism that may be raised to the rate constants determined by Dobby & Finch is their similitude in the cleaner and scavenger stages. From a mineralogical point of view, is difficult to imagine the presence of fast floating particles in the scavenger stage that may result in a similar rate constant to that determined in the cleaner cells.

Conclusions

Column flotation models can be very useful to predict industrial scale metallurgical results. However, there is a lack of empirical information about the industrial column flotation process parameters. This situation prevents a more precise simulation by any model. In particular "in situ" measurements of rate constants of floatable components should be determined.

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SYMBOLS

A	Cross sectional area
A_{ji}	Model constant, liquid phase
B_{ji}	Model constant, gas phase
C_G	Concentration in the gas phase
C_L	Concentration in the liquid phase
D_L	Axial dispersion coefficient
K	Rate constant
N_{ji}	Peclet number function
Pe_G	Peclet number (gas phase)
U_L	Linear velocity
x,z	Distance, from top (recovery and washing zones)
ϵ	Gas holdup, fractional

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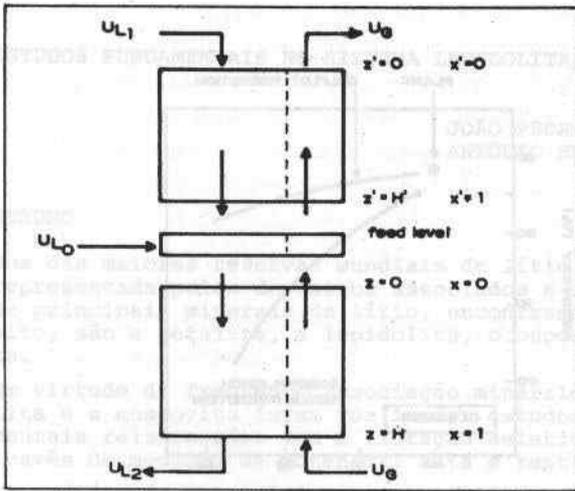


Fig. 1. Column flotation scheme including in ternal flows.

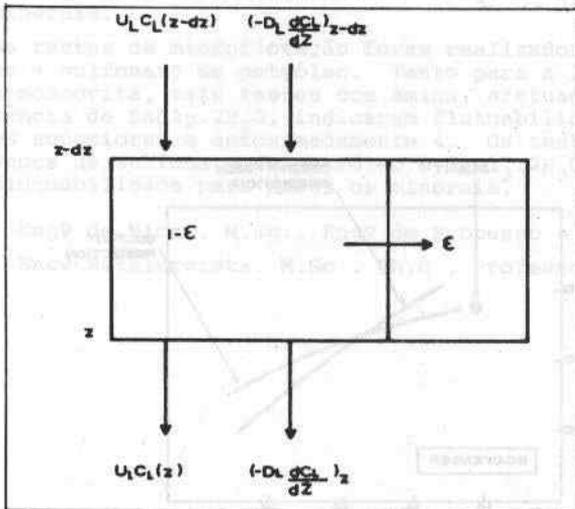


Fig. 2. Differential volume element in the column.

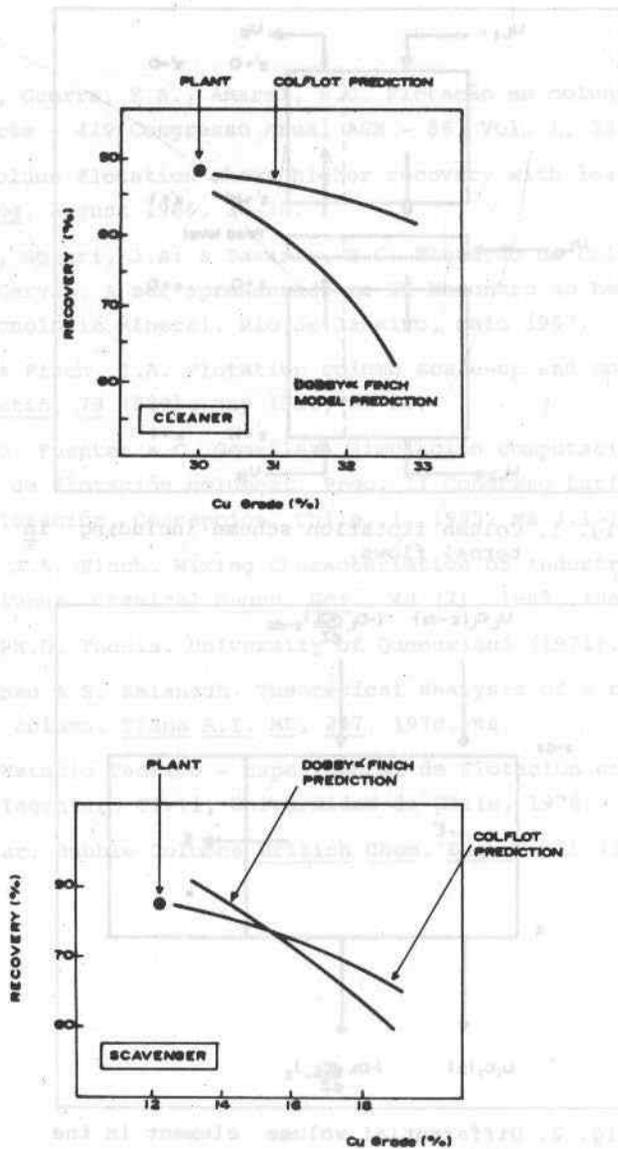


Fig. 3. Separation parameters modelled by COLFLOT and Dobby & Finch for a scavenger - cleaner copper circuit