Chapter 6

Conclusions

Among the objectives put forward at the beginning of this project, it was proposed the formulation of a dynamic model of the column flotation operation. In order to be applicable to a control scheme, the model had to be able to provide reasonable predictions about the dynamic responses after changes in operating conditions. Particular attention was devoted to the froth, since the representation of the froth phase is one of the most deficient aspects of previously reported dynamic models. Therefore, the model was to include a description of bubble coalescence, as well as a mechanistic representation of particle detachment in the froth region. Examination of the tasks described throughout the preceding chapters would show that all of these goals have been accomplished. Next, let's enumerate some conclusions derived from the results obtained, while highlighting the significance of this work.

♦ The attained model is very inclusive since it incorporates a number of subprocesses that had been examined individually before, but had never been put together in an overall dynamic representation. First of all, the effects of bubble loading, slurry density and viscosity are taken into consideration. In addition, the equations for the collection and froth regions are combined in such a way that the transition in flow regime and air content at the interface is adequately described, as well as the transport of solid species. A novel mechanistic description of the bubble coalescence process in the froth was also introduced. A most relevant feature, in comparison to other dynamic representations, is that the equations are solvable for a wide range of conditions. Such property includes the capability of predicting situations such as loss of positive bias, loss of interface or bubbly flow operation, and froth collapse.

♦ Another aspect that differentiates this model from previous dynamic representations is the capability for describing the dynamic behavior of both gas and solid phases throughout the full column length. A dynamic solution of the air phase equations for the froth had not been introduced thus far. One likely reason was the utilization of the tank-in-series representation for the froth as well as the collection region. With such approach, it is not possible to achieve the air fraction values typical of the froth region. Consequently, the froth was sometimes viewed as a black box characterized by a recovery value, which incorporates implicitly the role played by the froth stability on column performance and is normally unknown. However, by solving the dynamic equations for the air and solid species simultaneously, a more revealing description of the interactions between froth bubbles and particles is attained. At last, the volume balance of the flows entering and leaving the column can be met by an iteration procedure on either the bias flow or the position of the interface.
The description of coalescence on the basis of coalescence efficiency rate parameters is a new approach in flotation froth modeling. Two different mathematical functions were used to relate the coalescence rate parameters to the bubble sizes due to the distinct characteristics of the stabilized and draining froths. The constants in each of these functions would then vary with the other factors that influence bubble coalescence in the froth regions. Among those factors, it should be counted the frother concentration in the system as well as the viscosity of the slurry films surrounding the bubbles (which is a function of solids concentration in the slurry phase). This approach provides a new mathematical framework for representing froth stability in a column flotation model. The coalescence rate parameters can be constantly redefined as new knowledge is acquired about the determinants of froth stability. The particles shape and hydrophobicity are also expected to play a role in disrupting or preserving the stability of the liquid films.

Solution of the model equations does not require the estimation of an excessive number of parameters. The equations are based on readily known operating conditions such as gas and feed rates, bubble size distribution, solid distribution, and column geometry. Other required information about particle hydrophobicity is obtainable from the literature. The coalescence-efficiency-rate parameters are the only ones that have to be estimated, while further knowledge is acquired about the quantitative relationships between froth stability and the various elements that affect it. In contrast, other dynamic models rely on the estimation of a large number of first-order rate constants.

Determination of the air fraction profiles in a column stabilized froth using a conductivity probe suggested that there is no significant difference between the shapes of the profiles in a two-phase froth and a solid-laden froth. However, the profiles estimated with and without solids in the draining froth were quite different. Although solids overloading may cause the froth to collapse, it was observed that the rate of liquid drainage appears to slow down when the bubbles are loaded with particles. In the three-phase profile, the increase in air fraction is significantly lower than in the air-water froth. This behavior had been predicted by Ross (1991), who indicated that the particles increase the film viscosity and control the film thickness. Consequently, the rate of drainage in the top portion of the froth is limited by the presence of solids.

Several simulations were performed in order to examine the model capabilities and the agreement of the predictions with previously observed column behavior. The following points can be highlighted about the simulator performance:

1. The predicted responses of the air phase and attached solids phase were faster than those of the solids in the slurry phase. Such behavior was corroborated by measurements of the solid rates in the concentrate and tailings stream of a laboratory column before steady state was reached. One reason appears to be that the drainage and settling of particles, especially the nonfloating material, slow
down the process dynamics. The speed of the responses predicted by the model were also in close agreement with the experimental results.

2. The model predictions were compared to the results from a previous study of the dynamic behavior of a laboratory column. Step changes in a set of manipulated variables were performed, and the transient responses in the concentrate were then recorded in terms of ash content and recovery. The tailings rate was kept approximately constant during the tests, while the pulp height was allowed to vary. A reasonably good agreement was obtained between the experimental and calculated responses. For example, a small increase in aeration rate, while keeping the tailings rate constant, was observed to cause an increase in the product ash content and ash recovery. The model predicted a similar behavior under constant bias rate. An increase in frother addition rate was also followed by an increase in ash content and recovery in the concentrate stream, which was reasonably matched by the model solution.

3. At constant froth depth (position of the pulp-froth interface), the model seems to provide a reasonable approximation of the column behavior when a parameter such as gas velocity is increased. The calculated recoveries suggest that more nonfloatable material reports to the concentrate after an increase in gas rate, and that the positive bias is reduced. These trends are normally observed during column operation. The simulations also indicate that the degree of entrainment predicted under conditions of positive bias rate is significantly lower than that corresponding to cocurrent liquid and gas flows.

4. The detachment model based on the assumption of selective particle rearrangement on the large bubbles originated through coalescence provides acceptable concentration profiles. The profiles show a large reduction in free solids concentration at the top of the froth and a smaller decrease in attached solid concentration because of the reduction in available surface area. The overall solid concentration decreases with froth height, which is in agreement with other studies on column froth behavior such as the works by Yianatos, Finch and Laplante (1987), Ross and van Deventer (1988) and Falutsu and Dobby (1992). According to the simulation results, the concentration of solids along the collection region increases with height, which was also reported in the forementioned investigations.