Chapter 6
Automatic Control of Flotation Columns

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Abstract Since their first commercial application for mineral separation in the early 1980s, flotation columns have become a standard piece of equipment in mineral concentrators particularly for cleaning operations. This chapter presents and discusses the most recent advances in instrumentation and automatic control of flotation columns. It also examines how current industrial practice could benefit from recent academic developments in these areas. A particular emphasis is placed on the development of specific sensors for the continuous monitoring of process operations and their regulation.

6.1 Introduction

Flotation is a commonly used method for separating valuable minerals (metal containing) from useless mineral (gangue). It consists in injecting air bubbles in a vessel where a finely ground mixture of minerals (ore) is also introduced as a slurry. Particles are maintained in suspension by means of an agitator in the so-called mechanical cells, and by a rising flow of bubbles in column-cells. If valuable mineral particles are adequately conditioned (hydrophobicized), they should attach to the rising bubbles forming bubble–solid aggregates and move up as result of the difference in specific gravity between pulp and mineralized bubbles. These aggregates finally
reach the top of the vessel as a stable froth, where they are removed, usually constituting the valuable product (concentrate). The non-floatable particles (hydrophilic), which do not attach to the bubbles, settle and leave the vessel through the bottom port as non-valuable product called tailings. This separation scheme is called direct flotation. In some rare cases, the tailings stream may constitute the valuable product, whereas the concentrate is the discarded product (inverse flotation). In some flotation devices (i.e., columns) the froth is sprayed with clean water, which, if adequate conditions prevail, moves downwards (bias flow) cleaning the froth from undesired entrained particles.

Despite the highly sophisticated devices (instrumentation and data acquisition) often found in mineral processing plants, the huge amount of data usually accumulated in their historians is only partially used. Their utilization for automatic control purposes is rather limited, especially when compared with other types of process plants such as chemical or petrochemical industries.

For instance, typical regulatory control strategies implemented in industrial columns are basically limited to: (a) controlling the froth depth by manipulating the tailing flow rate (to indirectly influence the concentrate recovery); (b) manipulating the gas rate to attain the desired recovery. Since the bias rate is not currently measured, the cleaning action of the froth zone is, at most, manually controlled by manipulating the wash water rate. Besides gas rate, none of the gas dispersion properties, nor the bias rate are used for automatic control purposes.

However, some control strategies based on gas dispersion properties as secondary variables, such as gas hold-up and gas rate, have been proposed by academic researchers. Recent studies have shown that another gas dispersion property, called “bubble surface area flux \(S_b\)”, a combination of gas rate and some average bubble size, is strongly related to flotation performance. Thus, an extended control approach considering \(S_b\) is worth considering. This means controlling bubble size and gas rate to get a desired \(S_b\) value. All these matters will be discussed in Sections 6.4 and 6.5.

The metallurgical performance of a flotation column is determined by the valuable-mineral concentrate grade and recovery, often called primary variables, as they determine the revenue the plant is able to get from the sale of its concentrate. Whereas the grade can be measured on-line using an X-ray on-stream analyzer (OSA), the recovery must be estimated from steady-state mass balance, which usually introduces some sort of estimation error, therefore strongly limiting its use for control purposes. The long sampling times and cost of these OSA devices, usually multiplexed, also favour the use of a hierarchical control. In such a scheme, secondary variables, ideally strongly correlated with the primary ones and measured or at least precisely estimated, are controlled. In the specific case of the flotation column, the interface position (froth depth), bias rate and gas hold-up or bubble surface area flux are convenient secondary variables. Ideally, the controller must adequately deal with the interactions between the variables and take into account various operational constraints. The set points of the secondary variable controllers are optimally calculated by a supervisory control strategy which optimizes an economic criterion. This cost function is based on the relationships between the secondary and primary variables,