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Froth collapse in column flotation: a prevention method using froth density estimation and fuzzy expert systems

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Abstract

This paper aims at describing the use of two well-known techniques, i.e. expert systems and soft sensors in order to develop a prevention method for the froth collapse problem. This will be achieved by monitoring concentrate froth solid-to-liquids ratio. This scheme is outlined like an alternative solution to artificial vision based methods, and it was tested by simulation under several perturbations affecting the metallurgical performance.

Keywords: Column flotation; Process control; Expert systems

1. Introduction

Froth collapse is a serious trouble in column flotation. Not only virtual sensors, which are also called soft sensing, but also expert systems have widely been used so as to solve such a problem. Both technologies are combined in this work to prevent froth overloading and the subsequent froth collapse.

The expert system has been designed based on a multivariable predictive control (Chuk et al., 2001) applied to a laboratory flotation column (Figs. 1 and 2) having the froth depth H_f and gas holdup E_g as outputs, and the tails and air valves positions—x_{vc} and x_{vc}—as manipulated variables. The floated valued mineral is fluorite.

2. Experts systems applied to column flotation

In order to avoid the froth collapse, expert systems usually use image processing, measuring several physical variables of the froth like colorimetric, geometric and dynamic information. See Hyötyniemi et al. (1998) and Cipriano et al. (1998).

In simple terms, the operators' compiled experience leads to a froth classification intuitively related to density. The most interesting fuzzy froth defined categories are dry, wet, and stiff. Wet froth typically has "empty bubbles", i.e., the concentrate load being low. When the optimal froth is rather dry, bubbles are loaded with mineral, but froth still floats out from the cell. The most critical case is the extremely stiff froth. This pathological situation may result in the collapse of the froth surface; no concentrate flows out.

This practical criterion agrees with the definition of froth overloading phenomenon used by some authors, which has been traditionally characterized by the maximum possible solids content in the froth product. Practical considerations indicate that when froth

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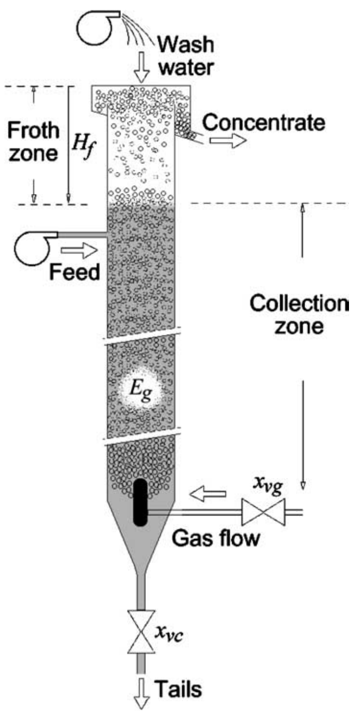

Fig. 1. Flotation column diagram.

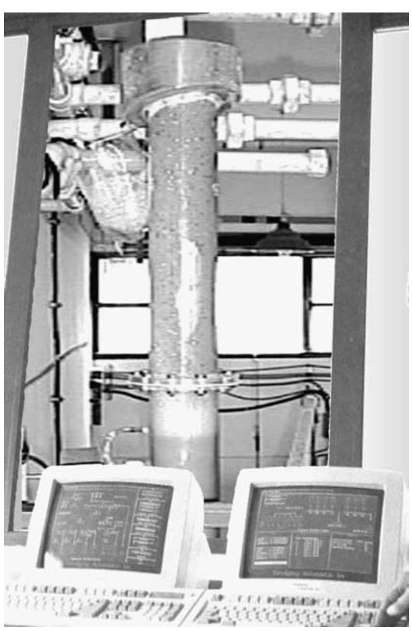

Fig. 2. Laboratory flotation column.

solid-to-liquid ratio by volume is higher than 0.4, froth gets so thick that it tends to collapse (Lutrell and Yoon, 1991).

Bearing this idea in mind, froth collapse prevention has been implemented within the expert system proposed in this paper using a solid-to-liquid ratio soft measure.

The expert system also considers concentrate grade and recovery optimization. In the last few years the following solutions have been proposed:

Kosick and Dobby (1990) have presented an advanced control based on the compilation of the operators' experience in a knowledge data base.

Bergh and Acuña (1994) have shown the use of hierarchical supervisory control, and Karr (1996) has used genetic algorithms to minimize a cost function which optimizes the concentrate grade.

Hirajima et al. (1991) and Bergh et al. (1998) have used fuzzy systems, and this way has been also followed in this work. In fact, it is the basic tool used by most commercial real-time expert systems.

Generally, optimization is carried out by modifying control loops set points implemented on the column, such as froth depth, gas holdup and bias rate. It will be shown that an efficient expert control system with easy re-calibration can be achieved just setting up the first two above mentioned parameters, applying occasional changes to the wash water rate and defining adequate supervising policies. Reagents flows are held constant.

3. Soft-sensors

Some system outputs are either difficult to measure or inaccessible. Sometimes sensors are also too expensive or sensing systems have intolerable pure delays.

Soft-sensors (Tham et al., 1991; Gonzalez, 1999), or "software based sensors" are software estimators oriented to inferring these process outputs from other secondary ones.

Froth solid-to-liquid ratio direct sensing is a very difficult task. A soft-sensor is a good choice. Deviations from real value are no relevant because this measure is applied to a prevention system rather than to a local control.

Recent implementations of soft sensors use neural networks or fuzzy computing. Gonzalez et al. (2003) have researched several dynamical local models for soft-sensors used to describe the concentrate grade in a rougher flotation bank, including Takagi and Sugeno, fuzzy combinational, wavelet and multilayer perceptron based models.

Besides, well-known algorithms can be seen as soft sensors, e.g. Kalman filters or ARMAX models. Here, an estimation based on a dynamic-minerallurgical model is used as a soft sensor.

4. Plant model

The froth solid-to-liquid ratio estimation and the minerallurgical indexes behavior analysis has been carried out using a column model developed in two sections: the dynamic and minerallurgical ones. Both are briefly described below.