Minerals Engineering 121 (2018) 83–89

Contents lists available at ScienceDirect

Minerals Engineering

journal homepage: www.elsevier.com/locate/mineng

Improving fine particle flotation using the StackCell™ (raising the tail of the elephant curve)

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ARTICLE INFO

Keywords:
Flotation
Copper sulfides
High-efficiency

ABSTRACT

For decades, the conventional flotation machine has been the accepted tool for processing sulfide ores. As plant capacity increases, machine size has evolved to as much as 600 cubic meters to keep pace with the required retention times. However, the excessively large size of these machines requires extreme floor space, foundations and power to operate. Recent work conducted by Eriez has shown that high-efficiency flotation machines which are based on focused energy input can achieve similar results with significantly less retention time, floor space and power. Comparable performance is achieved through intense contacting in a separate chamber which provides concentrated energy input focused specifically on bubble/particle interaction. When compared to conventional technology, data show that this novel approach can achieve the same recovery as a mechanical cell in a fraction of the residence time. This paper will discuss the theory of operation of the StackCell™ and present data from various lab- and pilot-scale test programs.

1. Introduction – present day flotation practices

Concentration of fine particles using froth flotation has been practiced for well over a century. Extensive fundamental research has been conducted on all aspects of the chemistry and hydrodynamics of the flotation process. As defined early on by Gaudin et al. (1931), the process is particularly successful when applied to a particle size range of approximately 15–150 µm. This early work, presented as the well-known "Elephant Curve" (Fig. 1), shows a clear drop-off in flotation performance outside of this range. The decline on the coarse end is typically attributed to excessive turbulence, buoyancy limitations and particle drop-back from bubble coalescence in the froth. The latter has been shown to result from competition for the available bubble surface area. Recent work show that coarse particles are indeed floatable (Gontijo et al., 2007) and that the recovery limitations realized in industry can be overcome through novel machine designs specifically tailored for coarse particle flotation (Mankosa et al., 2016c).

The reduction in flotation recovery for fine particles has been well documented over the past decades (Flint and Howarth, 1971; Fuerstenau, 1980; Luttrell, 1986, Miettinen, 2007) and is attributed to reduced collision rates and poor adhesion characteristics. A great deal of research was focused on fine particle flotation with advancements made through improved hydrodynamics. One of the most significant improvements was development of microbubble flotation for fine particle recovery (Yoon et al., 1988). This work, however, was generally focused on column cells for coal and industrial minerals. As such, there has been no significant advancements to extend the "tail" of the elephant curve for sulfide applications. In fact, size-by-size deportment data collected from the tailings streams of currently operating plants show that a significant amount of value still resides in the finest fraction that is discarded as refuse (Mankosa et al., 2016b).

Since the beginning of this millennium, flotation machine manufacturers have focused on increased cell size. This trend is clearly shown by the data presented by Noble (2012) and reproduced in Fig. 2. These results show an approximate fivefold increase in machine size every 20 years; culminating with an increase from 100 to over 660 cubic meters since the turn of the century. This dramatic increase in size has clearly been driven by operator's desires for fewer, high-capacity machines - resulting in a simplified plant layout and reduced maintenance. Unfortunately, the increase in size can be contrary to cell performance. Larger machines require increased energy input to maintain particles in suspension. The increased energy input results in greater turbulence which is a major contributor to the loss of recovery for coarse particles. Likewise, the size and reduced number of cells in series can result in an increase in by-pass or short-circuiting of material; this having a negative effect on the slower flotation species (i.e., fines). The large cells are

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https://doi.org/10.1016/j.mineng.2018.03.012
Received 22 December 2017; Received in revised form 12 March 2018; Accepted 13 March 2018
0892-6875/

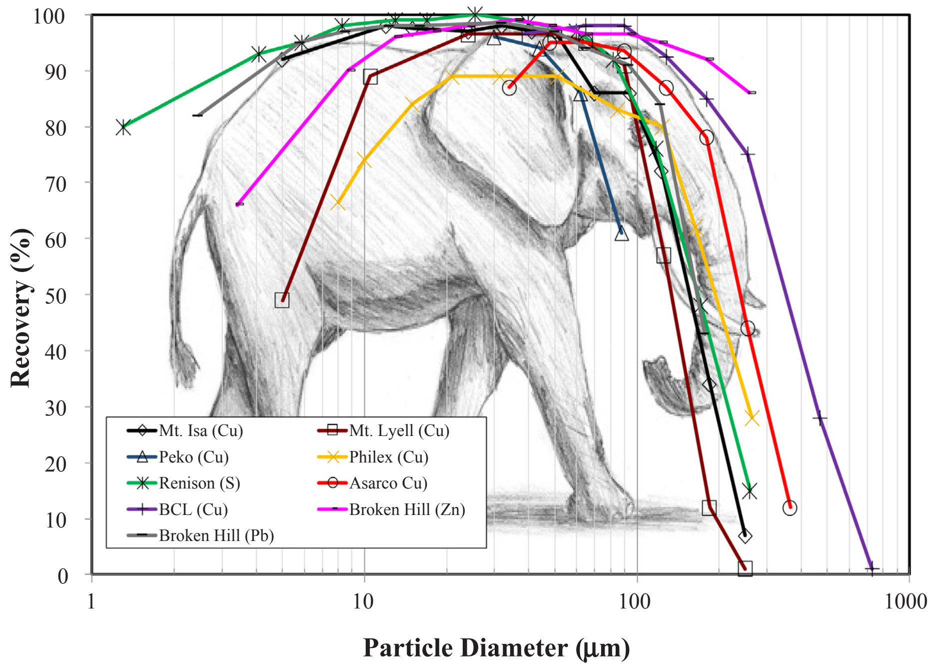

Fig. 1. Conventional flotation data for industrial sulfide flotation circuits (after Lynch et al., 1981).

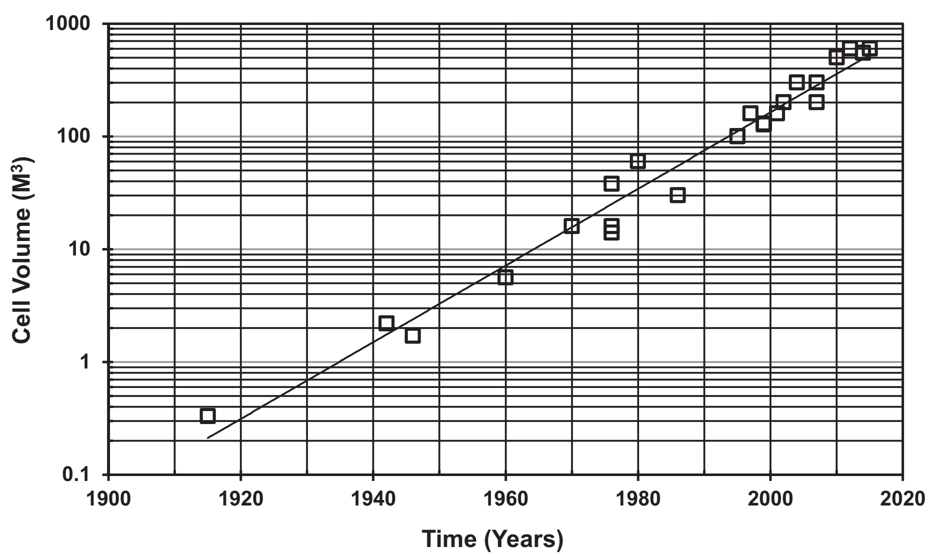

Fig. 2. Growth in conventional flotation cell volume over the past century (Noble, 2012).

also more energy efficient in that the total energy per unit volume is reduced. However, this is contrary to previous work which has shown that high specific energy input is required to improve the flotation kinetics of fine and/or slow floating particles (Mankosa et al., 2016a).

With input from major engineering houses and end-users, Eriez Flotation Division (EFD) developed the StackCell™ technology with the goal of providing a more efficient flotation option. This device builds on the concept of focused energy input to enhance fine particle recovery as well as improving flotation kinetics in the "sweet spot" of the elephant curve. This novel, patented approach de-couples the particle contacting zone within the cell from the phase separation process. As a result, overall unit size can be reduced by an order of magnitude while maintaining the same capacity and metallurgical performance. The implications of this step-change in technology are numerous and include a significant reduction in energy consumption (> 40%) as well as reductions in plant height, footprint and foundation loads of greater than fifty percent.

A schematic of the StackCell™ is provided in Fig. 3. During operation, feed slurry is introduced to an aeration canister through a side (or bottom) feed port. At this point, low pressure air is added to the feed slurry. The air and feed slurry then travel up into the aeration chamber where significant shear is imparted to the system. The shear forces imparted to the aerated slurry are used to create small bubbles and for bubble-particle contacting. In fact, all of the bubble-particle collisions occur in the aeration chamber prior to discharge into the outer tank. Once the slurry enters the outer tank, a phase separation occurs between the froth and pulp. The pulp level is maintained through the use of a level sensor and underflow control valve. The froth depth is maintained sufficiently deep to facilitate froth washing which minimizes the entrainment of fine hydrophilic gangue. The froth overflows into a froth collection launder.