BRINGING COARSE PARTICLE FLOTATION TO THE MASSES

Jose Concha, Marin Hanu, and Eric Wasmund, Eriez, Canada and Peru, discuss the growing importance of flotation in global resource extraction.

Flotation is one of the most industrially significant unit operations in global resource extraction. Before flotation (BF), the vast majority of useful materials, such as metal-bearing minerals, existed in the earth's crust at such low concentrations that they were un-economical for extraction in significant quantities with available technology. The discovery and rapid adoption of flotation around the turn of the last century led to the global availability of materials at sufficient purity, and in such quantities, that they could be enjoyed by the masses. It has been remarked that the average person today has a higher standard of living than any previous generation in history, and much of this is because of the abundant supply and inexpensive price of metals and materials, such as fertilizer minerals, throughout the world in the after flotation (AF) era. Everywhere, the development of societies and their increasing standard of living is linked to the per capita consumption of these materials, happily forestalling Thomas Malthus' grim projection that the global population would outstrip earth's resources some time in the 19th century.

Figure 1. Eriez's CPF pilot plant at a customer site.

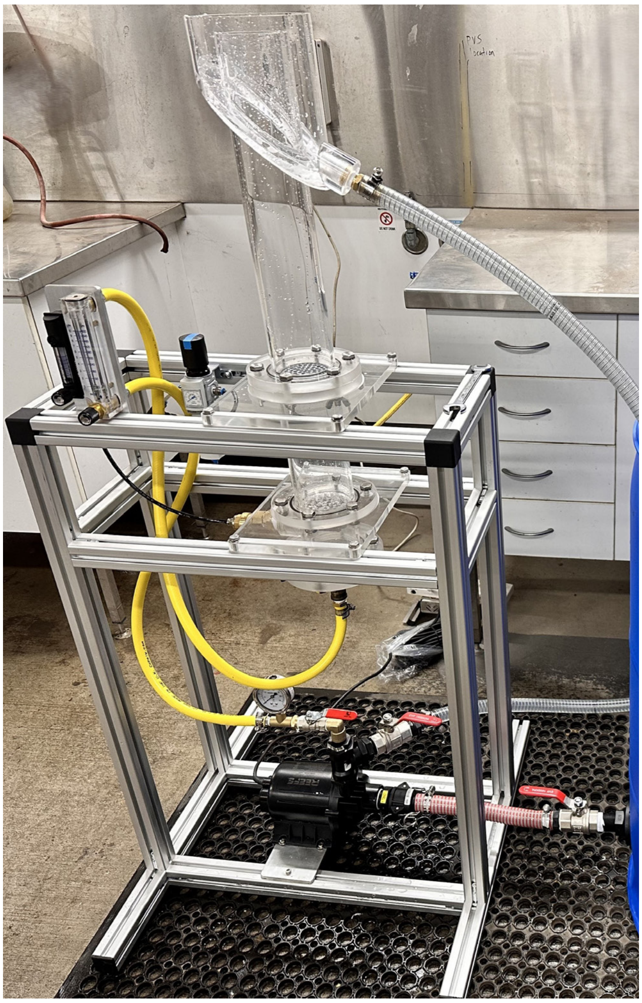

Figure 2. The JKHFMini lab unit.

What is flotation?

As an introduction, it is a physico-chemical process whereby air bubbles are contacted with fine particles dispersed as a pulp in water. Under the right conditions, the bubbles will adhere to hydrophobic regions of particles and the buoyancy of the bubbles will lift the hydrophobic particles out of the pulp where they can be recovered separately from the residue. The process is typically repeated in multiple tanks, and for an ore like copper, the metal can be concentrated up to 70 times with recoveries up to 90%, which can then be treated economically by processes such as smelting and refining.

Despite the pre-eminence of flotation, there has been relatively little innovation in the basic technology. This is evident by benchmarking flotation with other technologies that were discovered around the same time, such as the automobile or the aeroplane. The most significant achievement over the last 50 years has been to make flotation tanks bigger, which is important for handling lower ore grades, but is hardly a technological breakthrough.

This is even more disheartening because one of the main shortcomings of conventional flotation has been known for almost 100 years: the size range for effective flotation of a particle is relatively narrow. If the particle is too small, it is difficult for a bubble to attach, and if a particle is too large, it is easy for the bubble to detach from the particle and drop back into the pulp. In Klassen's classic text from 1970, 'An introduction to the theory of flotation', he states, "an increase in the upper size limit of floatable particles is of economic significance... If it were possible to float larger particles with high efficiency, then the cost of grinding, filtration, thickening, and drying would be much lower." Klassen knew that coarse particle flotation (CPF) was the key to radically improving flotation, but nothing was done for another 30 years.

The emergence of HydroFloat®

About 20 years ago, Eriez developed and commercialised the first generation of HydroFloat, an industrial CPF machine. After gaining acceptance in phosphate, potash, and lithium, the HydroFloat was tested in the copper industry. The HydroFloat works by countercurrent contacting of bubbles and feed pulp in a fluidised bed. An upward flow of water creates drag (or lift) that augments the buoyancy of bubble-particle aggregates. Combined with the elimination of the conventional froth layer, or a zero-order froth, this minimises drop-back. These features allow a significant increase in the largest particle size of ore that could be floated. In dozens of applications, Eriez has shown that the top size that could be floated was higher by 2.5 times, compared with conventional flotation. Copper is an important metal for CPF technology, and in 2023, McKinsey identified CPF as a key technology for addressing the expected copper supply shortfall in the green energy transition. It has been shown that CPF allows users to increase plant throughput by 10 – 30%, increase global recovery by 3 – 6%, reduce energy costs by 10 – 20%, and reduce fresh water consumption by 20%. It can be combined with Anglo's hydraulic dry stacking (HDS) technology to create safer tailings storage.

After piloting at Rio Tinto's Kennecott facility around 2013 – 14, CPF was commercially scaled to treat tailings at Newcrest's (now Newmont) concentrator at the Cadia Valley starting in 2018, and then in a pre-concentration application at Anglo American's facility at El Soldado around 2020, followed by a whole tailings treatment application at Quellaveco starting around 2023. In all of these applications, Eriez worked closely and collaboratively with the owners, consultants, and the engineering companies to learn about the challenges and perfect the technology.

Flowsheet importance

Although the HydroFloat is a key unit operation, the successful implementation of CPF depends on the development of new flowsheets, and leading companies like DRA and Ausenco are working with us on those. Earlier implementations used teeter-bed separators to pre-treat the HydroFloat feed. Working with Newcrest and Anglo, Eriez showed that, in base metals applications, teeter-bed separators could be replaced with hydrocyclones, a move that could save at least 20% of the capital cost of the application. To facilitate this improvement, Eriez developed a new feed system that allows the HydroFloat to work with higher concentrations of fine particles. Hydrocyclones were commercially implemented at El Soldado CPF and the second phase of the Cadia CPF tailings treatment facility.

A valuable partnership

Eriez has selected Weir Minerals as a best-in-class cyclone supplier and has formed a partnership that allows customers to use Weir Cavex cyclones and Eriez HydroFloats together in a modular pilot plant that can be shipped to sites to perform pilot work (Figure 1). In this way, the combination of equipment can be tested together, reducing the technical risk in engineering and designing commercial plants. Another opportunity to reduce capital and operating costs comes in making larger HydroFloats, which can treat the same amount of feed with lesser units. This reduces the footprint, cost of piping and instruments, and simplifies installation, while also increasing nameplate capacity. Eriez has already commercialised the CPF-300, a five metre diameter unit with almost four times the capacity of earlier units. Eriez is working with leading engineering companies to understand the reduction in cost and process simplification that can be achieved by making even larger sized units.

Sample testing

Another area of focus is the amount of sample that is required to prove and validate the metallurgical performance of the HydroFloat. Currently, a commercial application can be demonstrated and reliably scaled up from test-work that requires at least 50 kg of sample. But for greenfield applications, or applications where metallurgical variability needs to be investigated, the amount of sample can become prohibitive. To address this limitation, Eriez has engaged the University of Queensland's Julius Kruttschnitt Mineral Research Centre (JKMRC) to develop the world's first lab-scale fluidised bed flotation unit that uses only 1 kg of sample per test – the JKHFmini (Figure 2). This work was made possible by the formation of the Collaborative Consortium for Coarse Particle Processing Research (CPR Program), with the support of several other industry partners. Eriez are currently working with the University of Queensland and their Consortium partners to validate the scale-up pathway from the JKHFMini to production scale units. When completed, this will allow CPF applications and ore variability to be assessed from small samples, such as drill cores.

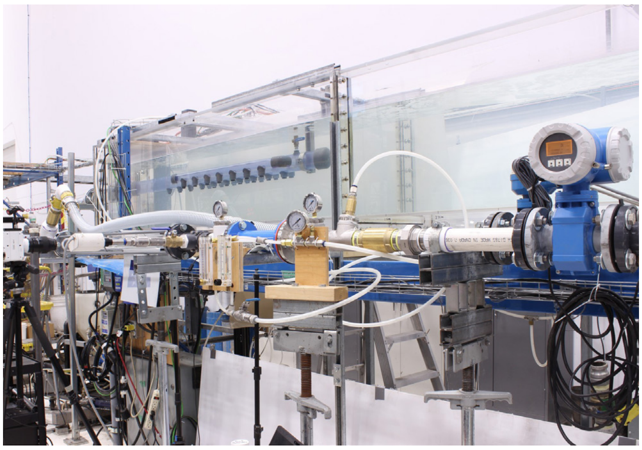

Figure 3. Experimental measurement of bubble mixing and dispersion.

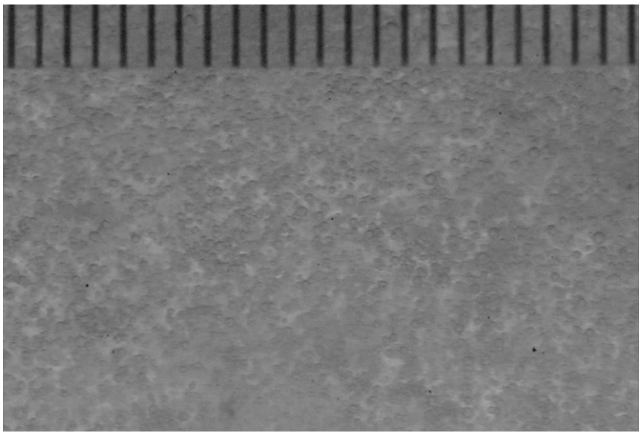

Figure 4. Bubbly flow in model HydroFloat.

Finally, as units are scaled up in size, it is important to show that the main features of the unit that depend on phenomena such as mixing, mass transfer, and flow distribution also scale to preserve similarity. To support the scale-up to larger units, Eriez is working with a leading fluid dynamics lab to perform physical and computational modelling (Figure 3).

The high-speed photograph (Figure 4) depicts how the design of the HydroFloat is tested to verify dispersion and uniform distribution of flow and bubbles. These results will allow Eriez to improve designs and scale to larger units.

An increasing number of people are agreeing that CPF will be a key enabler for making mining more efficient, less energy and water intensive, and safer for long term handling and storage of tailings. To achieve this vision, Eriez is working closely with customers, universities, engineering companies, other OEM vendors, and research facilities as they perfect CPF for applications in mining. GMR