MAXIMISING FLOTATION

Figure 1. Eriez StackCell Somerset Middlemount installation.

Eric Wasmund, Eriez Canada, Jose Concha, Eriez Peru, and Homie Thanasekaran, Eriez Australia, examine how innovations in cell technology can help maximise mineral recovery from froth flotation – resulting in more profitable and sustainable projects.

Froth flotation is a physico-chemical process, first introduced more than a century ago, that has revolutionised metallurgy and virtually every aspect of our economy and the modern world.

Formerly, extractive metallurgy was a costly enterprise, with only a few limited methods available for inexpensively concentrating valuable ore to a level suitable to make smelting and refining economical at a scale that would touch the masses. Before this time, metals and alloys were largely used to make goods that would be considered luxury or 'high tech' items today. The discovery and industrial adoption of froth flotation around 1900, enabled the mass-scale development of metal sulfide ore bodies – such as copper, zinc, and nickel – and a significant increase in the service of these metals to mankind. An estimate of global copper production since 1900 by the US Geological Survey illustrates the rapid increase in the production and use of copper, which coincides with the development of froth flotation for porphyry copper ores

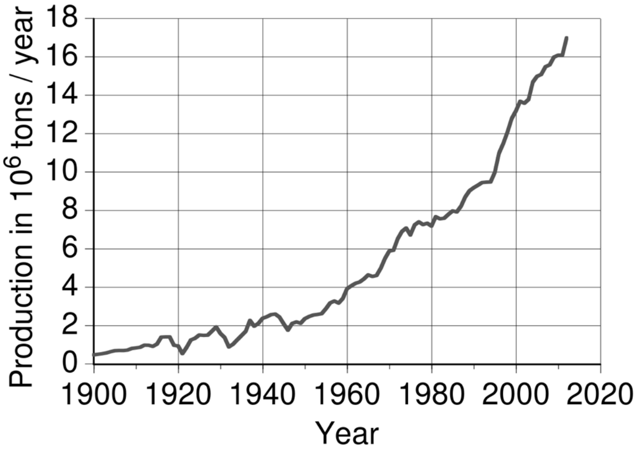

Figure 2. Annual global production of copper since 1900.

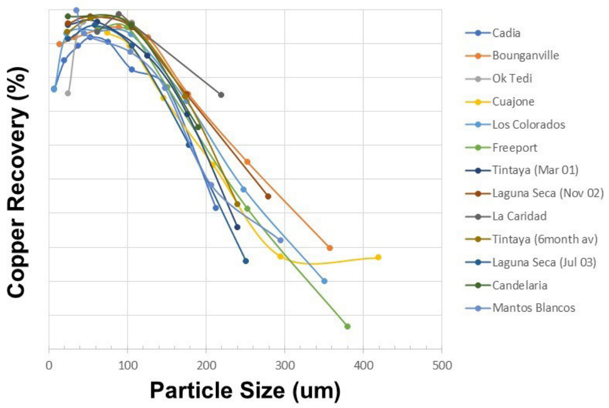

Figure 3. Copper flotation recovery by size for various sites. Source: Vollert et al, 2019.

Figure 4. Cutaway of the 2-stage Eriez StackCell®.

starting around 1900 (Figure 2). Curves for the other industrially significant base metals show comparable trajectories emanating from this starting point around 1900. With the advent of froth flotation, copper became a metal that could be used for modernising towns and cities around the world by way of electric motors and generators, transmission systems, telephones, piping and heat exchangers, among other familiar modern devices. We are all beneficiaries of this technological revolution.

The conventional flotation process generally consists of adding fine particles of ore, with at least some surface exposed mineral, into water and adding air bubbles and kinetic energy, usually in the form of mixing. Under the right conditions, the bubbles will collide and attach to a hydrophobic mineral surface and provide enough buoyancy to lift the bubble-particle out of the pulp and into a froth phase, which can be recovered through a launder system. By repeating this step in multiple stages, also known as rougher/scavengers and cleaners, the target mineral can often be enriched by an order of 50 or more times.

Industrial research and practise have identified some of the most significant factors – which include the amount of surface exposure of the target mineral, bubble size, and surface-active chemical additives – that can adjust the hydrophobicity of the target mineral, density, particle size, electrochemistry, and hydrodynamics of the cell. All of these parameters need to be optimised together to achieve the best flotation performance.

Industrially, this is a continuous process, consisting of cells or tanks in series. The tanks usually have a mechanism that provides mixing and introduces air. Mechanical agitation in a conventional cell achieves four functional objectives: keeping the solids suspended (so the cell does not sand), shearing the incoming air to produce fine bubbles, adding enough turbulent energy into the pulp for bubbles and hydrophobic particles to disperse and successfully collide to form bubble-particle aggregates, and providing a sufficiently quiescent fluid environment for the aggregates to rise successfully through the pulp. Efficient collisions of fine ore particles with bubbles require high energy to be successful, while recovery of bubble-particle aggregates into the froth generally requires low energy. In fact, excess turbulence in the pulp will cause bubble-particle aggregates to break apart and become lost. This phenomenon, known as drop-back, is one of the main reasons why there is an upper limit on particle size for conventional flotation. The mechanical energy added into the cells is therefore a trade-off for conventional mechanical cells.

This trade-off for conventional mechanical cells is illustrated by Vollert et al, who showed typical copper flotation performance by particle size for major operations that are using mainly conventional mechanical cells. Figure 3 illustrates this trade-off; there is a narrow 'Goldilocks' interval between 50 and 150 microns where conventional flotation gives a good performance. As the size is decreased below 50 microns, the recovery suffers because of low energy. On the other hand, the recovery suffers above 150 microns because of excessive energy and a high liberation requirement of conventional cells. Audits of major copper producers have typically shown 80 – 90% of the mineral units carried in the flotation waste (or 'tail') stream are either in the fine or coarse fraction. This can account for 5 – 15% of the total valuable mineral units in the run of mine feed.

This trade-off exists because of the inherent conflict between achieving successful bubble-particle contacting and bubble-particle flotation in the same cell. To avoid the trade-off, Eriez developed a two-stage mechanical cell called the StackCell® approximately 15 years ago (Figure 4). The StackCell uses two compartments: a tank within a tank. The tanks are connected in series, and isolated from one another, except where the exit from the first tank [3] feeds the second [4], and they are operated in such a way that fluid cannot move back into the first tank after it has entered the second one. As illustrated, feed is delivered through a duct [1] into the first tank, also referred to as a 'cannister'[3], consisting of a rotor-stator configuration, which mixes the feed slurry and air with extreme energy. The specific energy inside the cannister is more than 100-times higher than the average specific energy in a conventional cell, so bubble-particle contacting is optimised. The feed travels from the bottom to the top, with a residence time distribution that is designed to approximate a plug-flow in a highly turbulent mixing environment with short residence time, on the order of several seconds. This high energy input does not cause drop-back of coarser particles because bubble-particle flotation only happens in the second tank.

Figure 5. Eriez engineers performing hydrodynamic tests on a StackCell SC200.

Aerated pulp, ready to be floated, is pushed into the second tank based on a small positive pressure between the tanks. The second tank [4] is operated without mechanical agitation and separates the bubble-particle aggregates into a froth phase, which is recovered in a launder [6]. Water wash [7] can be used to increase the grade.

The StackCell has now been successfully introduced into coal, lithium, nickel and copper applications, as well as applications where the flotation rate is limited by kinetics. A StackCell can typically achieve the same metallurgical performance as a conventional mechanical cell that is 3 – 5 times larger. This allows StackCells to use less energy and operate in a smaller footprint.

Concerning the limitation in floating coarse particles, Klassen and Mokrousov added the following prescient commentary in their classic Flotation textbook more than 60 years ago: "In most cases, complete liberation of minerals can be obtained with particle sizes much larger than those that can be floated. The ore is therefore ground finer that is necessary for liberation, simply to enable flotation bubbles to lift these particles into the froth. If it were possible to float larger particles with high efficiency, then the cost of grinding, filtration, thickening, and drying would be much lower."

More than 20 years ago, Eriez developed the HydroFloat® Coarse Particle Flotation (CPF) machine to overcome this weakness of conventional cells. The HydroFloat is a flotation cell that uses a fluidised bed to create lift and increase buoyancy with reduced turbulence. This unit has been used for mined fertilizer flotation for approximately 20 years, and in the last 10 years it has been tested and adopted in the base metal and lithium markets.

The first industrial application in copper was at Newcrest's Cadia Valley copper-gold mine in 2018. The Newcrest team extensively tested and piloted this application, and the result has been that the company is able to re-process its waste stream, recovering valuable coarse ore, and also increase the grind size from its mills to increase throughput. Since then, HydroFloat CPF cells have been installed at a number of sites, including an expansion at Cadia Valley and installations at Anglo American's El Soldado, Quellaveco, and Mogalakwena concentrators. True to Klassen's prediction, modern practitioners of the HydroFloat have found that floating at a coarser size, typically two times coarser than required for conventional flotation, allows for the reduction of grinding energy from 30 – 50%, and reduced costs for de-watering as well as increased water recovery.

Froth flotation has indeed had a revolutionary impact on the world, and even after 100 years of practise, there are still innovative improvements that are allowing mankind to extract the massive quantities of green metals required for the net-zero carbon era. On the machine side, Eriez and its operations partners – such as Anglo and Newcrest – have commercialised two new cells, the StackCell and the HydroFloat, that are allowing miners to expand the range of flotation, increase recovery, reduce energy footprints and improve water use, resulting in more profitable and sustainable projects. GMR