BUBBLING INNOVATION

Michele Tuchscherer, Homie Thanasekaran, and Eric Wasmund, Eriez, evaluate how the properties of gas bubbles can impact the separation, leaching, and flotation processes.

Liquid and gas systems have been exploited for many years across diverse fields of chemical engineering and process metallurgy. As summarised by F.D Richardson in his 1971 lecture of the American Institute of Mining Engineers (AIME), "Droplets and bubbles are of great importance to the extractive metallurgist in his attempts to speed up processes…" Gas injection and bubble-making are used to accelerate high temperature processes, such as decarburisation in steel-making, as well as smelting and converting in sulfide processing. Gas dispersion is also used in more familiar processes, including a personal favourite of many engineers, beer making.

Spargers and the flotation process

In the area of extractive metallurgy mediated in aqueous environments, gas bubbles are also fundamental to separation processes and unit operations. The most important of these are froth flotation and hydrometallurgical leaching. As knowledge of the principles governing these separation processes has increased, more attention has been placed on the properties of bubbles and their populations – such as bubble concentration, stability, and size distribution. It is now recognised that the efficiency and speed of these extractive processes can be greatly improved and optimised by using engineering principles to tailor bubble properties.

Figure 1. Eriez StackCell – a two-stage mechanical cell.

Figure 2. Eriez SlamJet insertion sparger.

Gas bubbles in extractive metallurgy

The class of equipment that creates and delivers bubbles into liquids is known as sparging systems. In the case of flotation, an ore is introduced into water and ground into a finely divided state to form a slurry. The grinding endpoint has been selected so that that an optimal amount of the ore particles are liberated, meaning that a significant fraction of the surface has an exposed hydrophobic species. In many cases, the ore surfaces are naturally hydrophobic, such as graphite. In other cases, hydrophobicity is achieved through the use of ‘collectors’, which are surface-active chemicals. These attach to exposed mineral surfaces and provide an outward facing hydrophobic tail that confers hydrophobicity. Once the particle surface has a significant hydrophobic character, it is ready to be combined with air bubbles introduced through a sparging system.

When the sparged air bubbles approach ore particles, they may collide, and if a bubble successfully collides with a hydrophobic species on a particle, the bubble may attach. This is based on surface chemistry and the thermodynamic preference of a hydrophobic surface to be in contact with air rather than water. When a bubble or bubbles have successfully attached to a particle in water, there may be enough buoyancy created by the bubbles to counteract the gravity acting on the particle and the ‘bubble-particle aggregate’ has become floatable. In the absence of other countervailing forces, such as excessive convection and froth layer drop-back, the bubble-particle aggregates will rise to the top of the flotation vessel and be recovered in a froth layer.

Optimising bubble populations

In the flotation process described, the properties of the bubble population are key to producing an optimal flotation response. The production of bubble-particle aggregates is often described by the law of mass action and as a first-order rate process, so that the speed of the process depends on the concentration of reactants. Flotation is dependent on a number of successive steps: collision, attachment, and the successful transport and collection of bubble-particle aggregates in the froth phase, such that postulated rate constants often show a dependence on the product of the theoretical probabilities associated with each step. The probability of bubble-particle collision depends on the particle size, bubble size, and hydrodynamic conditions in the cell. Bubbles that are too large and bubbles that are too small will not collide efficiently with liberated particles. In the absence of surfactants, bubbles are unstable and will coalesce upon collision, so ‘frothers’ are employed by the industry to stabilise the bubbles and minimise coalescence. In addition to the size of the bubbles, the total volume and the total surface area of bubbles, normalised by the dimensions and working volume of the flotation cell, are typically optimised for each type of flotation system.

Sparging techniques and equipment

Introducing optimised bubble populations is a key component used by the experts to design the sparging system of every different type of flotation unit on the market.

In the case of mechanical cells such as FLS' Wemco, Metso's TankCell or Eriez' StackCell (Figure 1), air is fed into a central rotor inside the tank, and this acts as a sparger by shearing the air into fine bubbles. The volume of air, surfactant dosage, slurry rheology, and shear energy of the rotor create the bubble properties. In the case of a Jameson cell, the sparging system consists of downcomers that entrain and shear air into the feed pulp as the high-pressure slurry impinges against the liquid interface. Because each of these sparging approaches produces different bubble properties, each with their own advantages for different types of ore particles, there has been some discussion over the last decade about including different types of cells in series when the feed has a broad particle size distribution or multiple mineralogical characteristics. This can create the best of all worlds in complex applications.

Another approach to sparging is external insertion lances, such as the Eriez SlamJet® (Figure 2). In flotation, the SlamJet is used mainly in columns, although it has also been used to improve the performance of mechanical cells. The SlamJet injects air through a self-sealing orifice producing a median bubble size of approximately 0.8 mm, depending on water chemistry. The SlamJet has practical advantages, such as the ability to customise the flow of gas by adjusting it or turning units on and off. They can also be isolated and removed from the tank without draining it. The SlamJet has been the industry standard for more than 30 years and has inspired numerous imitators. Despite the advantages of the SlamJet, there are applications where even finer bubbles are required, such as fine particle or slimes flotation.

Fine particle flotation

For fine particle flotation, another approach to sparging is the contraction/expansion nozzle of the Eriez CavTube®. The CavTube is used for applications with ultrafine liberated ore, where conventional technology, such as stirred tanks or even SlamJets, is not optimal. Pulp from a flotation cell is extracted from the cell and mixed with air before being pumped through a parallel circuit of CavTubes and being recycled back into the cell (Figure 3). The high velocity and specific nozzle geometry of the CavTube result in a sudden pressure drop which shears the air into flotation-sized bubbles, on the order of 100 microns. At the same time, nucleation of vapour and gas by hydraulic cavitation and exolution respectively, produces fine bubbles on the order of microns. The fine bubbles often attach directly on hydrophobic surfaces, because adsorption is energetically favoured for nucleation of vapours and gases from supersaturated liquids. The combination of these two populations of bubbles creates an ideal environment for floating fine particles. It has been hypothesised that the adsorbed ultrafine bubbles act as tethers for the larger bubbles that attach and supply buoyancy, producing a better result than systems where bubbles are introduced separately.

Figure 3. Eriez CavTube sparged column for fine particle flotation.

Conclusion

In other areas of extractive metallurgy besides flotation, spargers are used in a variety of gas-liquid-solid reactions where bubbles are used to transport dissolved gases into the liquid phase, and occasionally out of the liquid phase. An example of the latter would be gas stripping, where an undesired volatile compound can be removed from a liquid by sparging the liquid with a gas. More typically, sparging can be used to supply a continuous stream of reactant into a liquid phase. Two popular examples are found in aqueous leaching processes: oxidation leaching and gold cyanidation. In both cases, sparging is used to introduce oxygen into water with bubbles. Leaching tanks are typically large, stirred tanks with two levels of agitators, with SlamJet spargers located around the periphery of the tank. Oxygen diffuses through the bubble to the liquid film interface, crosses the interface, and then diffuses into the aqueous phase. Although each of these three sequential mass transfer steps benefits from smaller bubbles, the rate-limiting step is usually the transport across the bubble liquid film, which increases greatly for smaller bubble sizes. This was shown experimentally by Motarjemi and Jameson in their classic 1978 paper: 'Mass transfer from very small bubbles – the optimum bubble size for aeration.' In a quiescent column of liquid, a rising bubble will efficiently transfer most of its available oxygen over the first few metres of height, if the bubble is less than approximately 1 mm. This mass transfer rate is enhanced by forced convection and turbulence in the industrial case where agitation is included, such as a typical gold cyanidation leaching operation. Introducing air as a continuous swarm of fine bubbles, rather than depending on agitator shear, has also been shown to reduce agitator maintenance and increase operability.

The use of spargers to control the size distribution and concentration of bubbles is a key factor in many industrial processes. In flotation and leaching, there is a variety of ingenious approaches to sparging. The suitability of each option is driven by the system characteristics that are being optimised, which include metallurgical performance, maintainability, and availability. However, the key is all about making the best bubbles for the job. GMR

Eriez has dedicated flotation experts around the world to support your business. We drive the adoption of sustainable technology through innovation and strong customer partnerships.

Find us at: www.eriezflotation.com

Contact us at:

Eriez Canada
7168 Venture Street
Delta, BC, V4G 1H6
Phone: 1-604-952-2300
Email: efdca@eriez.com

Eriez USA
1901 Wager Road
Erie, Pa. 16509
Phone: 814-835-6000
Email: eriez@eriez.com

Eriez Australia -East
21 Shirley Way
Epping, Victoria 3076
Phone: 61-3-8401-7400
Email: sales.au@eriez.com

Eriez Australia -Perth
4 Casino St
Welshpool WA 6106
Phone: 61-8-9351-1200

Eriez Chile
Badajoz 130 Of. 1505
Las Condes, Santiago
Phone: +56 2 29523400
Email: efdcl@eriez.com

Eriez Perú
Av Circunvalación del Golf los Incas 134,
T-1, Oficina 806
Surco, Lima
Phone: +51 1 719 4150
Email: efdpe@eriez.com

Eriez Brazil
Av. Getúlio Vargas, n0 456 - 12 Andar
Funcionários - Belo Horizonte - MG
Brazil
Phone: +55 31 3281 9108
Email: efdbr@eriez.com

Eriez China
C2, No.10, 1st North XEDA Road
Xiqing Economic Development Area
Tianjin, 300380, P.R. China
Phone: 00-86-22-8390-4608

Eriez South Africa
30 Innes Road (CNR Graniet Rd.), Jet Park Ext. 66
Boksburg, Gauteng
Phone: 27-11-444-9160
Email: eriezmag@eriez.com