Flotation taking its coarse

As ore grades decline, mining companies are looking for ways to improve the processing efficiency of these ores and reduce treatment costs. Coarse flotation is one solution, finds Ailbhe Goodbody

Coarse flotation is becoming more important as ore grades decline; when ore grades are lower, there is less ore suitable for beneficiation. As a result, new mines need to process additional tonnage to extract the same amount of metal or minerals as they would extract from higher-grade deposits.

This means that the front-end processes- including mining, hauling, material handling, crushing, grinding and floating - are all increased proportionately to get the same amount of a commodity, increasing both capital and operating costs.

In this area, coarse particle flotation technology generally carries multiple potential advantages. A reduction in energy and media consumption can decrease the cost of mineral processing, and coarse grinding helps to make the best use of the mined ore feed.

The biggest savings will be achieved in comminution energy, as coarse flotation requires less grinding. In most mineral beneficiation plants, the largest cost is the energy used to grind the ore; comminution uses at least 3% of total global electricity production, and according to the Coalition for Energy Efficient Comminution (CEEC), it accounts, on average, for more than 50% of a mine's energy consumption and 10% of total production costs.

"Grinding, the most expensive step, becomes more costly based on how fine you have to grind," says Eric Bain Wasmund, global managing director

at Eriez Flotation Division. "This is the area where coarse particle flotation is a game changer."

In this way, coarse flotation can also make more complex orebodies more feasible to mine. Antti Rinne, VP of flotation business line at Outotec, suggests: "It should also open opportunity to process orebodies that have not been economically viable while using traditional processing methods."

Coarse flotation can also improve the recovery if suitable collectors are used. Henrik Nordberg, mining R&D manager at Nouryon, says: "When applying coarse flotation, a smaller percentage of the ore will be finely ground and lost during flotation."

Another significant benefit of coarse flotation is that it results in a much coarser final tailings product. "The industry currently produces fine tails, which are more chemically reactive and difficult to dewater," explains Wasmund. "This creates a long-term risk management issue, as demonstrated by tailings dams throughout the world."

Processing of smaller tonnages also decreases water usage, so overall coarse flotation can fit well into the sustainability agenda when trying to decrease ecological footprint of mining operations.

However, the adoption of coarse particle flotation technology may also carry some drawbacks. Debbie Laney, mining chemicals technical sales manager at Chevron Phillips Chemical Co, says: "For instance, during the flotation process, the recovery of both fine and coarse particles is lower than the recovery of middle-sized fractions. Froth flotation has typically worked best in the 10-100µm size range."

Eriez Flotation Division's HydroFloat was designed for coarse particle mineral concentration. It has the capacity of a density separator and the selectivity of a flotation device

Optimal recovery

Optimal recovery of coarser particles requires a holistic approach that combines new cell design with tailored reagents and related application knowledge. Traditional flotation cells achieve good recovery across a range of 20-250µm, but recovery will start to drop below 40µm or above 200µm. In certain special applications, normal flotation can recover particles even up to 300-400µm in size, but with lower recovery.

Rinne advises that the target of coarse flotation should be in rejecting as much non-valuable material in as coarse size fraction as possible, without losing too much valuable material in the process. He notes: "There are several technologies, techniques or devices that can recover coarse particles, and it is too early to say which will be the best overall solution in the longer run, or if more than one technical solution will be needed to cover the whole range of flotation applications and ores."

Eriez's approach for coarse particle flotation is to introduce the pulp into a liquid fluidised bed using a counter-current approach like a conventional column. Wasmund says: "This provides improved contacting, greater buoyancy and a more uniform residence time distribution. The addition of a freeboard above the bed and a zero-order froth complete the conditions for allowing optimised coarse particle recovery."

Eammon Guitard, global marketing manager at Solvay Mining Solutions, comments: "The physics of traditional flotation cells presented a constraint in recovering coarser particles. Over the past two decades, flotation cell manufacturers have cleverly overcome those physical limitations and have designed cells that can float coarse particles (>300µm) efficiently. These new flotation cells are being evaluated at the commercial scale."

Certain flotation reagents can also be used to increase the recovery at both the coarse and fine ends of the size recovery curves. Laney says: "Smaller bubble size has been seen to increase the probability of collision and reduce the likelihood of detachment, which leads to better flotation of particles at both the finer and coarser ends of the spectrum."

Nordberg recommends selecting a suitable collector formulation designed for coarse particles, as well as optimising other process parameters like water temperature, pH and salinity of the water. "To achieve high recovery in coarse particle flotation the collector formulation needs to be optimised to be able to create a suitable froth that can carry the coarse particles," he explains. "Nouryon has several case studies were our unique collector/frother formulations have made it possible for beneficiation plants to increase recovery for coarser fractions."

Equipment trends

Major trends in coarse flotation technology range from advances in flotation equipment, particularly as it relates to float cells and bubble generation, to

reagents specifically designed for coarser ore. Many of the equipment manufacturers working in this area of mineral processing are adapting their flotation tank designs to accommodate higher throughputs and ores that are lower grade and more complex.

For equipment manufacturers, the traditional way of handling coarse flotation has been to increase equipment size. "Outotec is the only company that has complete industrial references of running 600m^3 mechanical flotation TankCells," says Rinne. "One benefit of Outotec's TankCell technology has always been suitability to most of the different flotation applications, and Outotec has long experience in tailoring flotation technology for complex orebodies."

Rinne states that Outotec's current TankCell product portfolio seems to fill the need for mechanical flotation cells in size at the moment, but it could be possible to further increase the efficiency of mechanical TankCell flotation machines at least by 30%, depending on application, compared to how TankCells have traditionally been utilised in flotation circuits. He says: "Such improvements will be significant, but anyhow incremental compared to what e.g. coarse flotation might do in the future."

Rinne also notes that it is good to remember that in order to achieve final grades, there will always be need for traditional flotation cells after coarse flotation circuits. He adds: "This is one reason why Outotec is still also further developing its TankCell product family. In case of complex orebodies, there will also be an increasing need for fine and ultra-fine particle flotation devices that Outotec is also working with."

Eriez Flotation Division has also recognised the importance of increasing the size of its largest units. Wasmund says: "We recently designed a 5m-diameter HydroFloat that will allow us to double the throughput compared with our current largest sized unit."

Using the HydroFloat technology, coarse particle flotation takes place in a

dense-phase, liquid-particulate fluidised bed, rather than in the stirred tank used for conventional flotation.

"The HydroFloat enables two new trends in the business," observes Wasmund. "The first is to recover coarse metal units in the tailing streams of current and historical mining operations. You can make a business case in many situations to do this at an existing operation.

"Rio Tinto recently reported that a pilot HydroFloat at their Kennecott facility [in Utah, US] was recovering up to 70% of coarse particle copper and up to 90% of coarse particle molybdenum. This trend is facilitated by conventional mechanical cells used in concentrators worldwide which are not efficient for floating coarse particles. Newcrest's Cadia facility has already commercialised the HydroFloat for this application, and we know a number of other projects where this approach is being put into practice now."

Newcrest Mining's Cadia facility in New South Wales, Australia, has already commercialised Eriez Flotation Division's HydroFloat for coarse flotation

The second trend that Wasmund sees, which is underway with a number of mining and engineering companies, is to incorporate the HydroFloat into the mill circuit. This allows the reduction in capacity and cost for grinding as well as generating a coarser tail.

To put some numbers to the potential benefits, Wasmund cites a case study that was published in *Mining Magazine* in 2017 (‘The best coarse of action', pp. 48-49, July/August 2017).

In this case study, ore was taken from the secondary mill cyclone underflow

at a polymetallic mine in Mexico where the p80 was about 700µm. The mass below 160µm, comprising about 30% of the total, was removed as this could be sent to conventional flotation in an industrial implementation. The mass above 700µm, comprising about 20% of the total, was also removed and could be returned to the mill feed in that same hypothetical industrial configuration.

The remaining 50% of the mass was fed to a HydroFloat, which captured more than 95% of the main pay-metal in a mass of 15%. The remaining 35% of the mass could be rejected in a single pass as a coarse barren tail with a p80 of 560µm.

"For comparison, a conventional tail in this plant has a p80 of 220µm," says Wasmund. "Considering the return of the +700µm mass to the mill circuit, the HydroFloat technology could enable about 44% of the total mill feed to be rejected as a barren tail with a p80 almost 2.5 times higher than conventional schemes."

This would substantially reduce the necessary size and operating costs of the secondary grinding mill. It would also mean 44% of tailings would have a size distribution that would allow rapid dewatering, meaning they could be conveniently stored or used for building dam walls or roads. The result would be a reduction in the size of fine tailing impoundments and the associated amount of water that is tied up in them.

"We are very excited about the environmental benefits that the HydroFloat introduces," comments Wasmund. "Increased recovery of pay-metals currently lost to tails, smaller tailing areas, better water resource management and vastly reduced energy costs are all new possibilities for mining operations throughout the world, thanks in part to the HydroFloat."

Reagents trends

Companies that make mining chemicals are also adapting their flotation

reagents for higher throughputs and lower-grade ores. Laney notes that industry attention is increasingly focused on mineralogical diagnostics and the development of reagents specifically designed for the coarser and finer ore fractions.

For example, Chevron Phillips Chemical is developing reagents and creating blends that are able to extract more of the valuable minerals from the ore, while rejecting the gangue minerals for copper, copper/molybdenum, copper/gold and gold ores.

Solvay (and its predecessors Cytec and American Cyanamid) developed many of the flotation reagents in use today and is focusing on innovation to keep pace with advances in the mining chemistry discipline.

The company points out that due to the increasing complexity of orebodies, reagents are needed that can be strong yet selective against penalty elements, and robust across various ore types, thus requiring tailored formulations for every operation. Lower grades and high throughputs necessitate reagents with faster kinetics.

Guitard says: "Solvay Mining Solutions found that the traditional constraints in the design of flotation reagents are no longer applicable for some of these newer cells, thus allowing for a broader palette of reagents to be used."

To that end, Solvay has invested in developing chemical solutions that improve coarse particle recovery, available via the AERO CP Series product line, which are designed for improved coarse particle recovery in conjunction with the latest generation flotation cell technologies.

Guitard notes: "We see our customers asking for customised reagent suites by ore type in order to maximise metallurgical performance across the entire mine plan. This mine-to-mill reagent strategy will increasingly become the industry norm.

"We anticipate that the onset of more flexible flowsheets, new cells and novel chemistries will have ripple effects on the design of comminution, classification and thickening circuits, resulting in a very different concentrator."

Nouryon is continuously developing tailor-made collectors for mining companies with different flotation requirements

Meanwhile, Nouryon is continuously developing tailor-made collectors for mining companies with different flotation requirements. "The development is a combination of the beneficiation plant's process optimisation and optimisation of the collector formulation from Nouryon," says Nordberg. "The most successful cases have been when the beneficiation plant and Nouryon have had a close collaboration with extensive information exchange."

The use of formulations instead of single chemistries to be able to process more complex ores with high recovery is increasing globally. "Another important trend, in particular in Europe and in South America, is more environmentally friendly flotation chemistries (e.g. low eco-toxicity) but with maintained performance and maintained cost," points out Anders Hägg, marketing manager at Nouryon. "When it comes to more sustainable flotation chemistries, Nouryon is taking a leading position developing solutions for the future together with our key customers."