Flotation circuit optimisation using modelling and simulation software

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How is your flotation plant running? Is it achieving target throughput, recovery and grade? If not, why not? Could it be due to feed ore variability, grinding and liberation issues or reagent type and dosage? Or could it be insufficient residence time since you are now operating at 50% more throughput than originally designed?

When was the mineralogy of the feed last measured? Or a metallurgical survey to determine accurate flows around the circuit conducted? How about the gas dispersion in each flotation cell – are bubbles of the correct distribution for given particle sizes being created?

It is nearly impossible to optimise your flotation circuit performance without knowing the answers to these questions.

Over the past decade there has been a significant advance in flotation circuit optimisation through performance benchmarking using metallurgical modelling and steady-state computer simulation. This benchmarking includes traditional measures, such as grade and recovery, as well as new flotation measures, such as ore floatability, bubble surface area flux and froth recovery.

Such circuit optimisation is a powerful tool in achieving the best possible flotation performance. Outotec’s HSC Chemistry software, which incorporates a new simulation module, can assist with this optimisation.

Firstly, how do you benchmark your flotation circuit?

There are several ways to do this, including:

- **Mineralogical assessment of flotation streams**: determine the ore mineralogy, degree of liberation, mineral associations and locking at different particle sizes.
- **Metallurgical assessment of performance**: perform plant surveys to determine grades and recoveries of streams around the circuit (requires mass balancing of experimental data). Froth carry rates, concentrate lip loadings and flotation cell residence times can also be determined.
- **Comparison of plant to laboratory performance**: determine the maximum attainable recovery from the ore and compare this to current plant recovery.
- **Gas dispersion in each flotation cell**: determine the bubble size distribution, air hold-up, superficial gas velocity and bubble surface area flux.
- **Froth phase performance**: determine the recovery across the froth phase, froth stability and froth transport distances.
Modelling and simulating flotation performance

The results from these studies can then be used to calibrate a floatability component model of the circuit. The flotation model developed by the AMIRA P9 Project, of which Outotec is a sponsor, is regarded by industry as the most suitable flotation model to use for circuit optimisation. This model incorporates ore floatability with flotation cell pulp and froth parameters, residence time, entrainment and water recovery to the concentrate.

Once the model is calibrated, it can be set-up in a flotation circuit simulator, such as Outotec’s HSC Sim 7.0. The simulator is then able to predict the performance of the flotation circuit under various hypothetical changes to the operation of the circuit. This can include changes to feed properties (such as throughput, mineral content and grind size), flotation cell operating properties (such as air rate and froth depth) and circuit configuration (for example recirculating the cleaner scavenger tails to the scavengers, or the addition of more flotation cells to increase residence time).

This provides an extremely powerful tool to assist with optimising flotation performance. The latest version of HSC Chemistry software, 7.0, includes further optimisations of existing tools such as a steady state process simulator and flowsheet capabilities, along with further additions.

So, what can HSC Sim do?

Stage 1 – flowsheet design

The first stage of any flotation optimisation process is drawing the flowsheet, which is done graphically by the user. HSC also includes “check for error” tools to ensure various streams are properly connected to the units and the process has input and output streams. If your process is large, the flowsheet can be split into several pages, i.e. comminution on one page, flotation on the next etc, followed by a summary page.

Stage 2 & 3 – mass balancing and calibration

The next stage is mass balancing the experimental data for the development of the model. HSC Sim has a new experimental mode, which can collate, organise and visualise survey or laboratory data. A “Mass Balancing and Data Reconciliation” module is included and has the following features (Figure 1):

- Individual sampling error for each stream and general or individual error model for each measurement
- 1D [unsized], 1.5D [sized but no assays] and 2D [size-by-size assays] mass balancing
- Various regression options such as least-squares regression
- Versatile visualisation tools such as parity charts and stream tables and mass balance reports

Once the experimental data has been mass balanced, the model parameters can be determined. Calibration comes next and includes elements such as global mineralogy and feed streams (grades and flowrates). The simulator element of optimisation is then ready to run.

Stage 4 - simulation

Most of the more advanced software nowadays includes a mineralogical database. HSC Chemistry 7.0, has over 4,500 different species and more than 13,000 different minerals. In simulation you can select the best matching mineral or add your own minerals into the database. It is possible to set-up HSC so that each person at a site uses and shares the very same database on the local network. HSC even has a versatile tool for automatically converting elemental assays to mineral grades.
As mineral processes do not treat minerals, but particles of different sizes and different compositions, it is important the software is designed on that basis. With HSC, you select 5 different minerals in 5 size fractions, with 3 different behaviour types for each mineral, and HSC will create 75 particles (mineral x size x types). Particles have global properties like size, specific gravity and composition and each unit uses these particle properties to determine what to do with each particle.

A structure based on particles allows you to load your liberation data from an MLA (Mineral Liberation Analyser) into the simulator and simulate the process with true (measured) particles. In the highest level, i.e. with true particles, you can have very detailed information on your process losses and impurities. At particle level you can simulate scenarios like:

- How will the change in grind influence the metallurgical performance of the plant?
- How will change in liberation influence the metallurgical performance of the plant?
- How will the concentrate quality change if we target to reject/accept some of the minerals?

Case study

HSC Sim was used to design the flowsheet of the Esperanza copper-gold deposit in Chile. One particular task of the software was to understand what benefits, if any, would result from the inclusion of a SkimAir flash flotation cell in the process cyclone underflows. Using client laboratory testwork, the resulting elemental data was converted to minerals, and their pilot testwork data was mass balanced, with models built using both laboratory flotation tests. The simulation was established on a “mineral-by-size by floatability type” level. Several different scenarios were simulated, including: circuit with and without SkimAir; number and type of rougher cells; flash cleaning; varying head grades and ore types and differing feed rates.

Figure 2 shows the simulation results with and without the inclusion of the SkimAir. The simulations showed that the SkimAir circuit produces 7.6% higher overall recovery for gold and 2.2% for copper. SkimAir technology was selected following these results and Esperanza will be commissioned in 2010.
Summary

The use of software tools for the simulation of the flotation circuit are a major advance in flotation modelling and optimisation. Steady-state simulators can be used for tasks including circuit diagnosis, process bottleneck identification, ascertaining the effect of various parameters on metallurgical performance and sizing process units properly.

Some of the more advanced simulation tools, such as Outotec’s HSC Sim, enables you to simulate mineral processes in different levels, from comminution circuits with sizes and no composition, through to flotation processes with minerals by size by floatability components, to full processes with true particles with measured liberation (MLA) data. Additionally, experimental data can be collected, elemental assays converted to mineral grades, circuits mass balanced and data reconciled in mineral by-size level. Powerfully, different scenarios can be run with the process simulation, saving hundreds of man hours (and potential human inaccuracies) in the process.

Figures 2. Gold recovery (distribution) in the Esperanza flotation circuit without SkimAir (above) and where cyclone underflow is directed to the SkimAir flotation machine (below).

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