# DOE Helps Reduce Testing Time and Boost Performance of Largest Ever Flotation Cells

FLSmidth recently installed two turnkey SuperCell™ flotation machines – the world's largest flotation cells – at Rio Tinto's Kennecott Concentrator (one of the largest copper and molybdenum mines in the world). In the past, an extensive testing campaign has been required to fine-tune and validate the performance of flotation cells. In this application, FLSmidth substantially reduced the amount of testing required by using Design of Experiments (DOE) to simultaneously test the effects of all factors including multiple factor interactions. DOE was also used to determine the optimum values of cell parameters under a wide range of operating conditions.

"The first of two SuperCells was built, tested, and commissioned in 110 days from start to finish, much less time than has been required in the past," said Dariusz Lelinski, Product Development Manager for FLSmidth. Statistical analysis of the results showed that this cell exceeds the performance guarantee: copper recovery of 85% with a copper concentration of 20% and molybdenum recovery of 85% over the full range of operation. Both of the SuperCells provide significantly more than a 1% increase in recovery of both copper and molybdenum, which provides substantial revenue increase to the mine owner.

Figure 1: FLSmidth SuperCell™ flotation cell

Froth flotation is a process for separating minerals from gangue, the worthless fraction of an ore. Froth flotation takes advantage of differences between valuable minerals and waste gangue in hydrophobicity, the degree to which a substance is repelled by water. Hydrophobicity differences are increased through the use of surfactants and wetting agents. FLSmidth SuperCells utilize a universal tank that can be fitted with any of three types of flotation mechanisms manufactured by FLSmidth. The first cell was commissioned with a WEMCO® self-aspirated mechanism with a top mounted rotor. It was also fitted with internal launders and has a volume of 300 cubic meters. The second cell will be used with two forced-air designs. These include the Dorr-Oliver® cell with a conventional bottom rotor and the newer XCELL® mechanism which has a mid-rotor design. The second cell has the same internal size but the use of external launders provides a volume of 330 cubic meters when fitted with a bevel tank bottom and 350 cubic meters without the bevel bottom. Three 1.5 cubic meter pilot cells were installed with each of the three types of mechanisms.

An extensive two-step validation process is required with this type of equipment. First, the basic assumptions used to design the cell are validated by running the cells with water only and comparing the results to the computational fluid dynamics (CFD) simulations. Next, the cells are run with actual slurry and their performance, especially recovery and grade, is compared to vendor performance guarantees. It was negotiated before the installation that the mine owner only pays for the cell after it is proven to meet the performance guarantee. This validation process has traditionally been long and expensive because each run ties up expensive equipment and requires a lengthy setup process. Many runs are needed to validate the wide range of operating conditions under which the cell must be able to perform.

“We heard that DOE might have the potential to reduce the time and cost involved in cell validation while also providing the potential to improve cell performance,” Lelinski said. “We looked at several different statistical software packages with DOE capabilities but they seemed to be targeted more at statisticians than engineers. Design-Expert® software from Stat-Ease, Inc., on the other hand, is designed for people like us – engineers that want to solve a problem but don’t want to get neck-deep in statistical methods. The software makes it very easy for users to perform quite sophisticated DOE analysis.”

Prior to installation, operational information from over 100 existing 257 cubic meter SmartCell® flotation units s were utilized to develop CFD models of the newly designed cells. The CFD models in turn were used to optimize the design of the new SmartCells. After the installation of the first cell, the cell hydrodynamics were extensively tested on water in order to validate the accuracy of the simulations. Hydrodynamic experiments typically require a ten-hour process to set up the cell for each run. The FLSmidth team used DOE to design an experiment that would provide the desired test coverage with the least possible number of runs. They explained to Stat-Ease technical support that the time required to perform the experiment could be substantially reduced by blocking the experiments to reduce the amount of changeover required between runs.

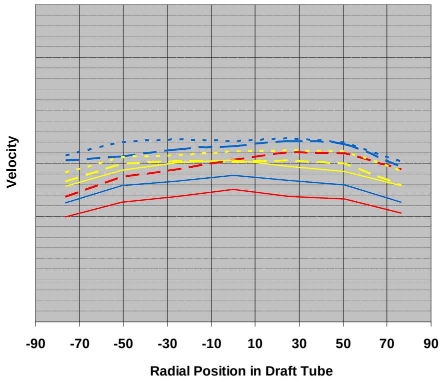


Figure 2: Velocity profiles measured during hydrodynamic testing

The Stat-Ease technical support helped him design an experiment that reduced the validation time from 3 months on similar previous projects to only 3 days on this project. Three cell factors – submergence, engagement and rotor speed – were evaluated over a very wide range to ensure a statistically significant influence on the responses of cell power, aeration rate and pulp circulation. Pulp recirculation was calculated by measuring linear velocity in the draft tube as shown in Figure 2.

The measured results matched the CFD predictions within +/- 15%, providing confidence in achieving the anticipated metallurgical performance. Besides validating the CFD results, DOE also revealed interactions between variables that had been hidden in previous validation campaigns. “We were made aware of an interaction between the rpm and the flow rate of the cell that enabled us to improve the performance of the cell,” Lelinski said.

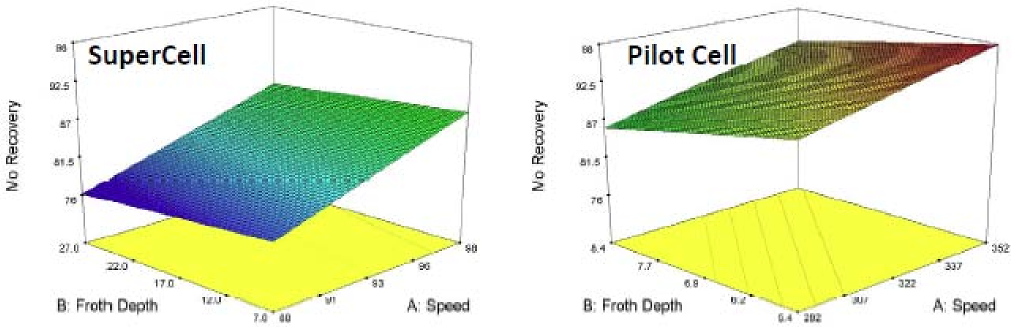
After the hydrodynamic evaluation was completed, the cell was commissioned on slurry and went into production. FLSmidth team designed a two-factor central composite experiment with seven responses to evaluate the performance of the cell as measured by the copper and molybdenum recovery and grade over a wide range of operating parameters. He was also looking for guidance in setting the two controllable cell parameters to maximize cell performance. Testing was performed on weekends over a compressed 24-hour per day schedule to reduce the likelihood of noise from ore blend or process changes upstream from the cell. Statistical analysis with Design-Expert showed that all campaign results were statistically significant.

The factors were:

A. Froth height
B. Rotor speed

The measured responses included:

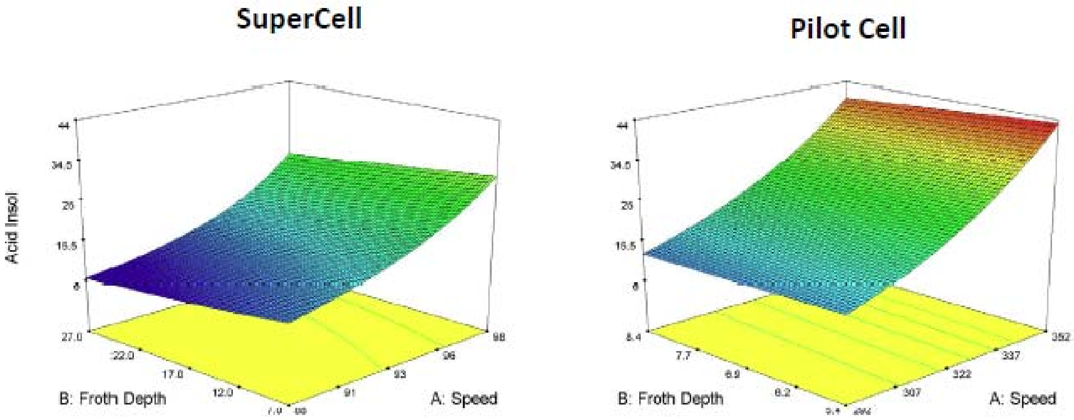
1. Feed assay
2. Concentrate assay
3. Tailings assay
4. Aeration rate
5. Absorbed power
6. Feed rate
7. Solids content



| | | |
|---|---|---|
| **Feed Flow** | 3231 gpm (22.1 min RT) | 49.7 gpm (7.2 min RT) |
| **Ore Type** | Type 2 | Type 2 |
| **Cu Feed Grade** | 10 % | 10 % |

Figure 3: Response surfaces for full-size (SuperCell) vs. pilot flotation cell enable scale-up to be determined

The FLSmidth team performed the experiments on both the pilot cells and the full-size cells as shown in Figure 3 so that the scale-up factors can easily be determined for any set of operating conditions. In the future, this will make it possible for the mine owners to optimize performance under any operating conditions by using inexpensive and quick experiments in the pilot cells.

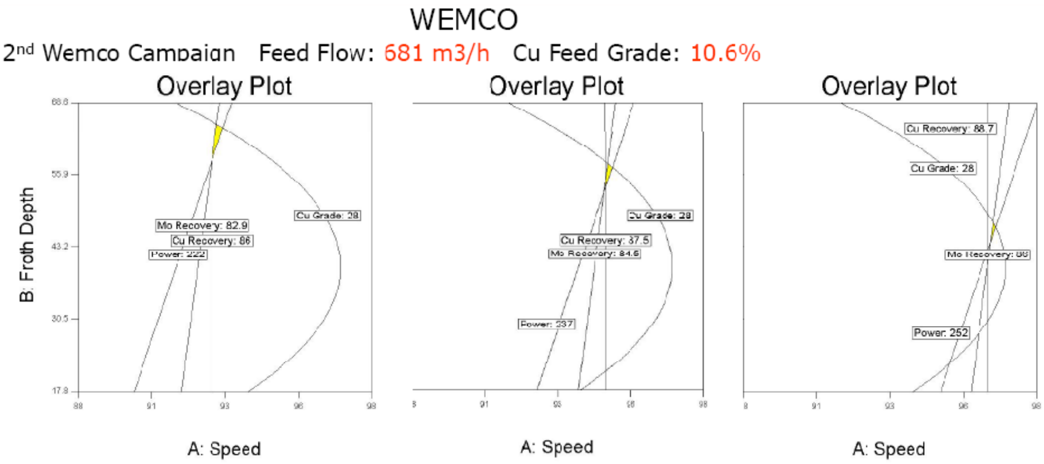


**SuperCell**

**Pilot Cell**

Figure 4: Operations able to optimize operating conditions based on experiments in pilot cell

An important benefit of DOE is calibrating the effect of operation conditions in the pilot cell vs. the SuperCell as shown in Figure 4. When it is necessary to produce a certain grade, the mine owner can now easily determine the operating conditions that will produce that grade with a high degree of accuracy in order to maximize the recovery, which in turn generates the highest revenues.



| | | | |
|---|---|---|---|
| Specific Power kW/m3: | **0.74** | **0.79** | **0.84** |
| Pumping, m3/min: | 185 | 187 | 195 |
| Airflow, cfm: | 1240 | 1250 | 1200 |
| Cu Grade, %: | 28.0 | 28.0 | 28.0 |
| Cu Recovery, %: | **86.0** | **87.5** | **88.7** |
| Mo Recovery, % | **82.9** | **84.5** | **86.0** |

Figure 5: Analysis of the influence of power consumption on the metallurgical performance of the WEMCO® SuperCell

As shown in Figure 5, evaluation of the results indicates that copper and molybdenum recovery is influenced by absorbed power. Recovery of copper increased from 86.0% to 88.7% and recovery of molybdenum increased from 82.9% to 86% with the power input increase from 0.74 to 0.84 kW/m3. “DOE played a major role in the success of this project,” Lelinski concluded. “It reduced the time required to prove the cells meet the performance guarantee. This substantially reduced validation costs. DOE also contributed to the improved performance of these cells which generate tens of millions of dollars in incremental revenues every year.”

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