Courtesy of Kingston Process Metallurgy

Project leader Trevor Lebel and technologist Ashley Lamey adjust the gas flow and monitor the pressure sensors on the drop tower during a test.

An eye on the inside

Kingston Process Metallurgy tests optical probe to help maximize copper recovery from concentrate in flash furnace

By Kylie Williams

An optical probe for non-ferrous process metallurgy is being developed by a team of Canadian, German, and Chilean scientists and engineers to monitor the flame during flash smelting of copper concentrate. The probe is designed to withstand the hot, dusty conditions in a flash furnace to provide instantaneous feedback and alert operators when intervention is required to maintain steady combustion. This enables the efficient use of energy and material inputs, environmental compliance and desired composition of end products.

Flash smelting is a relatively straightforward step at the beginning of the copper refining process. Copper concentrate, the product of flotation – composed mostly of sulfide copper minerals such as chalcopyrite, bornite and pyrite – is fed into the furnace. The concentrate, roughly one−third each copper, iron and sulfur, is mixed with oxygen-rich air and burnt at well over 1,000 C to oxidize the concentrate. The melt produced settles and separates into copper matte, which carries on through the metallurgical process, and slag, which is further treated to remove entrained and dissolved copper.

Any variation in the mineralogy of the concentrate blend being fed into the furnace can change the heat balance within. Some minerals ignite quickly, whereas others are slow to catch. The mineralogy of the copper concentrate impacts the flash combustion behaviour, which in turn impacts the grade of the matte, the amount of copper in the slag, as well as dust generation and temperatures of the molten phases.

Over two-thirds of the 200 copper smelters worldwide employ flash smelting technology to turn copper concentrate, which is typically about 30 per cent copper, into a matte containing 50 to 70 per cent copper. The International Copper Study Group (ICSG) predicts that around 70 per cent of smelters will continue to use flash smelting until at least 2021.

Currently, furnace operators rely on experience to monitor performance. They can calculate the ratio of copper plus iron over sulfur for the feed, but there is currently little consideration given to the mineralogy of the concentrate going in or how this will impact combustion within the furnace.

"Furnace [performance] is currently based on feedback […] from matte and slag assays, so any change in the feed material will impact the process control considerably," said Victor Montenegro, manager of process and flowsheet research, development and innovation at Aurubis, a global copper processing company with headquarters in Hamburg, Germany.

An optical solution

Aurubis is taking part in an operational study to test a new optical probe that "reads" the flame inside the flash furnace. Over the past two years, Aurubis has sent concentrate samples to metallurgist Boyd Davis, principal of project development at Ontario-based Kingston Process Metallurgy (KPM), where they are working to commercialize a concept initiated and patented by Professor Roberto Parra at the University of Concepción in Chile.

"The system is based on an optical probe that collects and analyzes light from the flame," said Davis. "The spectrum and brightness of the flame emission contains information about the combustion process."

Optical sensors are used widely to monitor industrial processes and are not new to metallurgy. Pyrometers are often used to measure the temperature of a flame, but this optical sensor measures a wider range of frequencies on the electromagnetic spectrum to indicate mineral composition and physical changes in the flame rather than just temperature.

"We are looking at the entire visible and near infrared spectrum," said Davis.

The drop test

KPM developed a drop tower to simulate furnace conditions to test the probe in 2017. The drop tower, a vertical tube about six feet tall and 20 centimetres in diameter, is different from previous testing methods because it feeds a small amount of concentrate at a rate of a few grams per minute and controls the amount of oxygen within. The feeder is designed to release just the right amount of concentrate or pure material into the drop tower: not so small that the sample gets over-oxidized, and not so large that it is hard to control.

"We are getting results that are closer to an actual smelter operation," said Davis.

Davis and Hans-Peter Loock, head of the Department of Chemistry at Queen's University, co-supervised Arthur Stokreef, a master's student at Queen's, who evaluated the viability of optical emission spectroscopy as a means for monitoring flash combustion reactions at the burner.

"We required something simple and rugged that gives us information about the temperature and stability of the flame in a copper flash-furnace," said Loock. "Operators don't like to disrupt their processes, so we required an instrument that was fully compatible with existing operations and can be inserted without any downtime."

The fibre optic cable itself, similar to the cable that brings television to homes, is enclosed in a solid, custom-made, air-cooled sleeve to protect the fibre from the extreme temperatures it operates in and dust (dust is a problem as it can build up, forming accretions that block the incoming light). From within the protective housing, the fibre optic cable points at the flame and sends information to an external spectrometer.

Stokreef demonstrated that it is possible to obtain the temperature, brightness and stability of the flame in a copper flash furnace using the blackbody emission spectrum. He developed flame brightness profiles for two concentrate samples supplied by Aurubis and two pure mineral samples, chalcopyrite and pyrite. Stokreef found that monitoring the flame brightness provided an early warning signal that can improve furnace availability and help stabilize matte grade and that the ratio of flame temperature to brightness was useful for monitoring feed distribution in the laboratory.

"The sensor only provides part of the picture," said Loock. "When combined with other sensors, such as composition of the flue gases or the feed, one can expect to see both an increase in the efficiency and a more consistent matte composition. It is important that the sensor provides instantaneous feedback and rapid intervention is possible."

Gathering more data

The optical probe has so far been tested at two Aurubis smelters, one near Hamburg the other in Bulgaria, and at the Chagres copper smelter north of Santiago, Chile, but more data are needed.

"The preliminary results show that the probe could be an effective monitoring or controlling tool for operation," said Montenegro. Once a reliable database of combustion characteristics for different feeds with different mineralogy, combustion temperature and de-sulfurization behaviour is established, the combustion behaviour of different blends can be predicted.

"This prediction could be useful to adjust the operating parameters accordingly to maintain a consistent matte grade and minimize copper losses to slag, ultimately resulting in higher efficiency," said Montenegro.

The next challenge is to generate enough data over a longer period. "Then you're able to see operational upsets that happen and go to the data and see if you can predict those process upsets," said Davis. "This takes time.

Forging ahead

The drop tower designed by KPM has proven to be a useful tool for studying flash combustion processes. Experiments performed using the drop tower show that the mineralogy of the copper concentrate feed going into a flash furnace has a significant impact on the conditions required for the production of matte with consistent copper grade.

The ICSG expects that world refined copper production will increase by around 2.8 per cent in 2019 and 1.2 per cent in 2020. The majority of copper smelters worldwide will continue to employ flash furnace technology to recover copper from copper concentrate and also from recycled materials. Monitoring and maximizing the efficiency of furnaces, such as using this inexpensive new optical probe, is necessary and especially significant for custom smelters, which may see several different blends in a day.

"I believe that we are just at the beginning in our effort to create sensor webs for non-ferrous metallurgical processes," said Loock. "Optical sensors will certainly be part of this picture, but they will have to be integrated with other tools to optimize these complex processes." CIM

CIM MAGAZINE Published in *CIM Magazine*, June/July 2019 issue, Vol. 14, No. 4, pages 38-39.