Turkish delight

Aya Sofia, built during the Byzantine rule, was the largest cathedral in the world for almost a thousand years – until the completion of the Seville Cathedral in 1520.

IM reports on MEI's Processing of Industrial Minerals '10 conference, held in Istanbul, which covered new lithium processing concepts, borates from waste and new uses for established technology

Istanbul, Turkey's largest city and uniquely half European, half Asian, played host to this year's Processing of Industrial Minerals '10 conference, organised by Falmouth, UK-based Minerals Engineering International (MEI).

From 4-5 February 2010, around 70 colleagues from the minerals processing industry gathered for two days of informative papers; covering the latest developments in minerals processing and new concepts for established technology.

Prof. Güven Önal, head of the mining engineering and mineral processing engineering departments at Istanbul Technical University, welcomed delegates to the conference with a quick tour of the industrial mineral resources that Turkey holds. Önal revealed that the value of the country's minerals industry – which includes bentonite, borates, chromite, feldspar and magnesite – totalled $1.25bn. in 2008.

One of Turkey's more important mineral exports is borates, which formed the basis of the first presentation by **Erk Inger** of the National Boron Research Institute, Turkey, who discussed boron use in space technologies – including as a fuel type.

Phosphate flotation

Closer to the ground was **Dr Salah Al-Thyabat**'s presentation regarding flotation of Jordanian phosphates for fertiliser purposes. Al-Thyabat, based at Al-Hussein Bin Talal University, Jordan, discussed the industry's need to upgrade phosphate rock by separating the mineral from its associated gangue minerals.

This can be achieved using flotation methods, with Al-Thyabat's work focusing on comparing different flotation mediums and their performance on flotation of siliceous phosphate in a column cell.

Using de-slimed siliceous phosphate samples, anionic flotation using a sodium oleate collector was compared to cationic flotation using an amine acetate collector. Results indicated that cationic flotation was more selective than anionic, effectively removing silica.

Mechanical activation

Also looking at the processing of phosphate was **Prof. Suzan Ibrahim** from Egypt's Central Metallurgical R&D Institute, who weighed up the pros and cons of mechanical activation vs. mineral beneficiation of phosphate rock for direct fertiliser applications.

As Ibrahim described, the direct application of phosphate rock is economically favoured, yet the limitation of its solubility is a significant challenge for consumers. Around 23% of total phosphate rock production is used as direct fertiliser feed, while higher cost phosphoric acid accounts for 70% of phosphate-based products.

Ibrahim outlined research looking at the economical benefits of mechanical activation of phosphate before and after beneficiation.

Using XRD, FTIR, thermal analysis, and solubility tests, Ibrahim demonstrated that mechanical activation increased the reactivity of treated phosphate samples and was economically preferable when using phosphate for direct fertiliser. The chemical reactivity of activated raw samples in 2% citric acid and neutral ammonium citrate showed better leaching attitude through all the milling stages.

Separating chromite sands

Prof. Giovanni Grieco of Italy's Università degli Studi di Milano captured delegates' attention with a review of the parameters (such as mineralogical, chemical and textural) affecting gravity separation of chromite sands sourced from different ore types.

One example is the Vavdos chromite deposit in Greece, which shows a redistribution of Cr_2O_3 from chromite to silicates owing to metamorphism. This lowers the efficiency of gravity plants, as the Cr_2O_3 contained in silicate phases is preferentially discharged into tailings.

This is an important consideration for chromite producers as the redistribution of Cr_2O_3 from chromite into newly formed silicates lowers the capability to enrich the Cr_2O_3 content of the concentrate sand. Thus estimations for altered chromite deposits that do not consider Cr_2O_3 "hidden" within silicates results in an overestimation of Cr_2O_3 recovery and Cr_2O_3 grades in the final concentrate.

At the Bulqiza chromite plant in Albania, Grieco demonstrated how grain counting on thin sections of epoxy resin-glued chromite sands was used to assess the degree of liberation.

The liberation degree of chromite was determined on reprocessed chromite sand tailings. Using grain counting, the mixed grain content of the feeding sand provides useful information on the capacity of the plant to separate chromite from silicates and is correlated to the Cr_2O_3 enrichment factor of the plant.

Kaolin

Dr Valerly Golyk from AKW Apparate + Verfahren GmbH presented two papers on kaolin processing, much to delegates' delight. The company specialises in plant engineering

and construction in the areas of wet-mechanical processing, with some of its recent work focusing on the use of hydrocyclones in kaolin processing.

Hydrocyclones

For more than 50 years hydrocyclones have been used to classify kaolin products, owing to the strict quality requirements demanded for kaolin grades – particularly from paper producers.

Golyk presented AKW's recent work to design a hydrocyclone capable of carrying out the finest particle classification of the last kaolin classification step. The basic problem associated with using hydrocyclones to realise the lowest possible cut sizes is that the physics require small-diameter hydrocyclones in order to achieve the required acceleration levels.

Yet small-diameter nozzles in small cyclones are disproportionally sensitive to the effects of fabrication tolerances and irregularities caused by abrasion.

AKW used a computer simulation to gain basic design information for construction of a prototype, which was tested at the company's pilot laboratories. The 50mm diameter RWS 105 hydrocyclone was taken as an initial guide at the start of the project, followed by a 35mm cyclone designed with optimised geometry.

A total of 18 modifications were evaluated, two of which were attractive for practical applications in kaolin processing: one for the compromise achieved between throughput and cut size, and another for the finer separation results achieved.

The final design was the AKA-VORTEX RWS 75 hydrocyclone; which Golyk claimed provided very good results in terms of sieve retention, fraction <2µ and cut size. It successfully produced finer particle sized kaolin grades, as stipulated by paper manufacturers.

Water injection

Golyk's second presentation examined methods of achieving higher kaolin recovery rates by using a new development in sand washing, whereby water is injected into the conical section of the classifying cyclone.

As Golyk explained, in kaolin classification the final product is isolated from the overflow of a 50mm hydrocyclone with an underflow containing sand and residual kaolin. But for a higher kaolin recovery, the underflow is further treated using a washing cyclone.

AKW found that the addition of water injection to small hydrocyclones with a diameter of 50mm improved kaolin recovery, achieving a 45-50 % reduction in the kaolin fraction (<25µ) passed into the underflow. This is a separation percentage comparable to downstream washing.

Online particle size analysis

Christian Behrens of Sympatec GmbH discussed high resolution online particle size analysis of highly concentrated ore slurries. This is of interest to many mineral processors as the particle size distribution of ground minerals is of decisive importance for downstream processes, such as flotation, separation, drying and others.

Early control of the grinding or classification stage is essential. One method outlined by Behrens was an ultrasound-based particle size analyser, OPUS (**O**nline **P**article size analyses using **U**ltrasonic **S**pectroscopy), which can perform online particle size distribution (PSD) and solid content measurement of mineral slurries.

OPUS provides a PSD of 31 size classes and can be applied for particles from nanometre range up to several millimetres. In addition, Behrens claimed that typical residue values showed an excellent agreement to off-line particle size analysis methods, such as sieve analysis or laser diffraction.

Left to right: Salah Al-Thyabat (Al-Hussein Bin Talal University), Barry Wills (MEI), Mehmet Çelik (Istanbul Technical University), delegate, Irena Grigorova (University of Mining & Geology, Bulgaria), Ivan Nishkov (University of Mining & Geology, Bulgaria).

GCC fillers

Dr Mehmet Çelik of Istanbul Technical University moved on to mineral fillers, discussing the effect of ground calcium carbonate (GCC) filler's quantity and PSD on the quality of water-borne paints.

Mineral additives in paint constitute anywhere from 20-50% of the total paint formulation and GCC is the most commonly used mineral additive. In paints and coatings GCC is used as an extender, but also to impart whiteness and brightness (*IM June '09, p.63: Putting the ground in calcium carbonate*).

Çelik compared the quality of paints with properties based on wet and dry paint, such as viscosity, density, opacity, gloss, Bucholz hardness, scrub and impact resistance, and fineness of fillers and pigments.

The substitution of TiO_2 with GCC was examined in two steps. Firstly, the effect of GCC's size distribution on paint properties was determined. Çelik found that the narrowest size distribution provided the best result, particularly on opacity and gloss.

The second step involved partial replacement of TiO_2 with GCC using this optimum size distribution. The paint analyses indicated that the optimum paint formulation gave almost the same properties with the standard paint, and thus at least 4wt.% of TiO_2 could be replaced by GCC without any appreciable change in service properties of the paint.

Silica: Fe removal

Hamed Haghi kicked off the second day of PIM '10 with a presentation examining scrubbing and magnetic separation of glass grade silica to reduce its Fe content. The case study was the Shenin Mine in Qazvin province, Iran, where the silica deposits comprise 93.75% SiO_2, 0.44% Fe_2O_3, 2.78% Al_2O_3, and 0.08% TiO_2. The company operating the mine requested a method to reduce the Fe_2O_3 content to <0.08%.

Three main factors (solid percent, scrubbing time and scrubber rotor speed) in the conventional scrubbing process were optimised, and the de-slimed output from the rod mill and scrubber were reported to magnetic separator.

Haghi found that the combined process of scrubbing and dry high-intensity magnetic separation produced a product with lower iron content and higher weight recovery than the same process with the rod mill product.

Haghi also examined the feasibility of cold acidic scrubbing on rod mill de-slimed silica,

Ilgin Kursun (University of Istanbul) explains her poster to a delegate.

followed by DHIMS, and also hot acidic scrubbing (HAS) before or after DHIMS. Results were favourable, but during the questions **Prof. Suzan Ibrahim** enquired about the necessity of using expensive processing techniques to produce low-Fe silica for the glass industry, pointing out that glass grade silica is itself fairly inexpensive.

Optical grading – limestone

Jarkko Haarla Jr. from Finland's Haarla Engineering Oy led delegates on to optical grading techniques, demonstrating that sometimes simple methods are the most effective. Haarla was asked to find a new technique to sort large-sized limestone output at **Nordkalk Corp.**

Nordkalk previously performed manual limestone grading either by removing the unwanted dark stones from the line simply by hand or semi-manually by operating pneumatic driven discharge plates. These methods were physically straining and could not provide 24/7 operation of the plant.

Haarla developed an automated optical grading system for the company, and is at present installing its third system at Nordkalk. The method is based on colour matrix cameras and full system automation; removing all manual stages from the grading process.

Waterjets & flotation

Prof. Raimondo Ciccu from Italy's University of Cagliari presented methods for potentially improving flotation by using waterjets. Ciccu explained that many processing methods rely on comminution or other techniques where mechanical components can suffer frequent failure owing to wear or breakdown.

Waterjets can contribute to overcoming such disadvantages since they transfer energy without contact occurring between solid materials, thus there is no wear. Waterjets are also suitable for generating high velocity streams in air or in water at relatively low pressures.

Using barytes flotation as an example, Ciccu found that the quality of the floated products was always better when a waterjet was used for agitation and bubble generation. This is owing to the more favourable size distribution of the bubbles (mean value and dispersion parameters). A higher recovery was also observed, which Ciccu rationalised occurred owing to enhanced probability of bubble-particle collision.

Lithium: hard rock sources

One hot topic was **Dr. Felix Brandt**'s discussion on processing lithium minerals sourced from pegmatite – a hard rock source, rather than the more talked about brines.

Brandt presented research undertaken at Germany's Dorfner Anzaplan which looked at combining selective fragmentation with optical sorting techniques to produce a higher purity, higher yield of lithium minerals – with a saleable feldspar by-product.

Selective fragmentation uses electrical discharge to fragment rocks, predominantly fracturing around natural crystal boundaries. Optical sorting was applied to ores subjected to selective fragmentation, to separate particles of both different colours and transparencies – such as spodumene, feldspar, and high and low grade quartz.

By applying selective liberation processes during lithium minerals concentrate production, higher purity and higher yields can be achieved. In addition, because by-products are not ground to very small grain sizes they can be separated as monomineral concentrates – and in some cases sold commercially themselves.

Dunite: environmental uses

Also looking at green minerals was **Maria Thornhill** from the Norwegian University of Science and Technology, whose paper examined the potential for quality enhancement of olivine products through relatively cheap mineral separation methods.

Owing to its high magnesium content dunite is primarily used as a slag conditioner; an application for which it requires very little processing. Yet new uses for olivine (sourced from dunite) have emerged over the past

Suzan Ibrahim and Amanda Wills discuss some of the presentations.

decade – such as water treatment and soil remediation – that require stricter particle sizes and chemical compositions.

Using olivine sourced from North Cape Minerals' Åheim mine in western Norway, Thornhill produced three fractions of olivine – one using air classification, one via magnetic separation using a Perm Roll, and the last via analytical sieving and magnetic separation in a Frantz separator.

The three products were also subjected to a standardised leaching test (EN12457-2) in order to assess the relative mobility of nickel, chromium and aluminium. Although air classification was found to be inefficient, removal of liberated chromite using the Perm Roll separator produced a significant reduction in the chromium content of the material.

Huntite beneficiation

Ozan Kökkiliç, from Istanbul Technical University, returned delegates' attention to Turkey with his presentation examining beneficiation of huntite ores. As Kökkiliç explained, Turkey holds huge huntite deposits, many of which could produce a huntite grade with the minimum 90% purity via simple attrition and classification methods.

Using huntite samples obtained from the Denizli-Çameli huntite deposit, multi-stage attrition processes (such as tumbling, stirring scrubbing) and hydrocyclone classification were performed. From this, Kökkiliç was able to produce a marketable huntite concentration comprising 33.96% MgO, and 13.24% CaO and 1.62% SiO_2, for use in flame retardants.

Borax sludge recovery

Also looking into Turkey's mineral resources was **Dr İlker Kipçak** from Eskisehir Osmangazi University, who discussed boron recovery from borax sludge. One of Turkey's most important industrial minerals is borates, which is consumed by numerous industries including ceramics, detergents, flame retardants and fibreglass.

Turkey is one of the world's largest producers of borates, with production in 2009 estimated to total 2.1m. tonnes of boric oxide. Colemanite accounts for around 70% of Turkey's boron mineral deposits.

Kipçak proposed a two-step process for boron recovery, whereby the sludge was leached with sulphuric acid solution, and then calcium and magnesium were precipitated by adjusting the pH of leachate.

He investigated the effects of pH, temperature, concentration and time on the precipitation process. It was reported that alkaline species were successfully separated from the boron, while borax pentahydrate was produced from the evaporation of the final solution obtained after precipitation process.

Calcium bentonite

The final presentation from the conference was given by **Gulay Bulut** from Istanbul Technical University, who described new methods for producing dessicant clay from Ca-bentonite.

Bulut evaluated some hygroscopic properties of a Ca-bentonite collected from the Balıkesir region of Turkey, with a view to determining and improving the desiccant capacity of the bentonite via beneficiation techniques.

The results indicated that moisture adsorption capacities were not size dependent, while a 10% $CaCl_2$ addition was found to be sufficient for all sizes to reach 20% moisture adsorption capacity (British Standard).

In addition, a 14% maximum moisture adsorption capacity was obtained at 200°C heat activation without $CaCl_2$ addition. Moisture adsorption capacity also increased with the removal of gangue minerals in the overflow or concentrate, usually in the range of 13-15%.

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