TUESDAY, AUGUST 24, 2004, P.M.

SESSION 35: FIFTH UBC-MCGILL INTERNATIONAL SYMPOSIUM ON PARTICLE SIZE ENLARGEMENT IN MINERAL PROCESSING

FLOCCULATION
Sponsor: Mineral Science and Engineering Section, The Metallurgical Society of CIM
Room: CHEDOKE C
Chairmen: H. EL-SHALL, University of Florida, Gainesville, Florida, U.S.A., and
H. HAMZA, CANMET, Devon, Alberta, Canada

PAPER 35.1 — 14:00
ULTRA-FLOCCULATION: THEORY, EXPERIMENT, APPLICATIONS.

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Starting from fundamental principles of colloid-hydrodynamic theory of disperse systems we have shown that application of strongly non-uniform hydrodynamic fields allows to achieve not only faster rates of flocculation of suspension, but also supports significant improvements in the quality of clarified water and separation characteristics of solid phase. Specifically, it has been experimentally proven that the new treatment method based on these principles (then termed as "ultra-flocculation") allows:

-Increase the output of thickeners and pressure filters by 1,5-1,7 times;
-Decrease solids fall through into the filtrate in the process of vacuum filtration by 2-3,5 times;
-Improve the rate of purification of water phase in the upright thickener by 1,5-1,9 times;
-Decrease flocculant consumption by 1,5-3 times;
-Increase the effective operational life time of cloth filters by 3-4 times;
-Ensure sustainable operation of separation equipment, i.e. decrease the sensitivity of process to variation in suspension concentration, as well as to variations of suspension composition and dispersion characteristics;

Apply flocculant solutions of concentration 2-3 times higher, thus increasing the capacity of equipment used for solutions preparation.

PAPER 35.2 — 14:20
STIMAN OBSERVATION OF AGGREGATE STRUCTURE IN CLAY FLOCCULATION.

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Effective flocculation and dewatering of slurry streams containing clays (particularly kaolin and smectites which are often <200nm in lateral dimension) is becoming increasingly urgent. Release of water (often >75 wt%), for recycle and reduced make-up water consumption, from slurries in tailings streams and dam beds is usually slow and incomplete. Changes in settling rates and solids density of tailings containing clays can be achieved in practice by changes in pH, dissolved cations and flocculant additions. To achieve fast separation of clays from water and minimization of retained water, individual particles need to be bound in the initial stages of thickening into large, high-density aggregates, which may sediment more rapidly with lower intra-aggregate water content. Quantitative STIMAN (STructural IMage ANalysis) cryo-SEM imaging, shows that the structure of aggregates formed before flocculant addition has a determinative effect on these outcomes. Without flocculant addition, 4 stages occur in the mechanism of primary dewatering of kaolinite: initially separate particles and aggregates are dispersed (<0.3GP, where GP is the gel point); a partially-gelled chain network then forms linking particles edge-edge (EE) still well below the GP but remains largely suspended; after an induction time, this network structure rearranges from EE to face-face (FF) contacts densifying, compacting and dewatering the aggregates with settling rates well above Stoke's Law estimates for >20μm particles or aggregates; the GP is rapidly reached during settling producing a network spanning the vessel with compressive strength. This sponge-like structure with EE oriented particles limits slurry dewatering because the steric effect in the resulting partially-gelled structure is much more dominant than the electrostatic effects predicted by DLVO theory. Van der Waal's forces at very close distances, as particles slide across each other, may be responsible for the EE to FF change in structure. In this way, the previously extended network contracts, and when the solid volume fraction is low, the continuous network breaks apart forming aggregates and aggregate associations as flocs which are able to freely settle. These densified aggregates settle at increased rate, give lower bed density and retain less water after drainage. With flocculant addition, the internal structure and networking of the pre-aggregates is largely preserved but they are rapidly and effectively bound together by the bridging action of the flocculant(s). The STIMAN

analysis shows that there is a inverse correlation of intra-aggregate porosity (and void permeability) with Darcian permeability (and extent of dewatering) whereas there is a strong positive correlation of Darcian inter-aggregate permeability with settling and primary dewatering rate.

PAPER 35.3 — 14:40

THE EFFECT OF METALLIC CATIONS ON ZETA POTENTIAL OF PURE HEMATITE.

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The presence of metallic cations in solution will affect the aggregation or dispersion of the fine hematite particles, depending on the type of cation adsorption: either specific or non specific adsorption. In this work, the zeta potential measurements were carried out on a sample of pure hematite as a function of pH and metallic cations concentration (Ca^{2+}, Mg^{2+}, Mn^{2+}, K^{+}, Na^{+} and Al^{3+}). The objective of these studies was to clarify the effect of these metallic cations on the surface chemical properties of pure hematite. The cations K^{+} and Na^{+} adsorbed as non-specific species and caused only the reduction on the values of zeta potential (in terms of absolute value) over the entire range of pH values tested. For the Al^{3+} cation, in the acidic pH range it adsorbed as a specific species and increased the zeta potential values. The cations Ca^{2+}, Mg^{2+} and Mn^{2+}, adsorbed as a non specific species at pH levels less than 6.0 and caused the reduction of zeta potential due to the compression of the electrical double layer. However, for pH values greater than 6.0, these cations adsorbed as a specific species causing the zeta potential to increase and became more positive as the pH value increased (alkaline). This effect could be due to the adsorption of some hidroxy complex species of these cations, which contributed to the positive charge. The effect of metallic cations (Ca^{2+}, Mg^{2+} and Al^{3+}) concentration, at pH 4.0, 7.0 and 10, showed the following results: a) at pH 4.0, increasing the concentrations of Ca^{2+} and Mg^{2+} resulted in on a small reduction in the value of the zeta potential. At this pH, increasing the concentration of Al^{3+} cations caused the zeta potential to increase due to specific adsorption of a negatively charged Al^{3+} hydroxy complex b) at pH 7 and 10, increasing the concentrations of Ca^{2+} and Mg^{2+} caused the zeta potential to change its charge from negative to positive.

PAPER 35.4 — 15:00

PURIFICATION OF KAOLIN BY SELECTIVE FLOCCULATION.

A.B. LUZ and A. MIDDEA, Center for Mineral Technology-CETEM, Rio de Janeiro, Brazil, and

Kaolin clay is heavily used in the paper industry as a coating and a filler, however to attend the specifications required by the industry it has to be processed. Kaolin is also used as a filler and pigment in various materials, such as paint, plastic, rubber etc. Some crude kaolins as mined in Northern Brazil, contain colored impurities such as iron oxide and rutile/anatase. These minerals normally are stained by iron and as a result vary from yellow to dark brown in color. The kaolin beneficiation process used in that region consists mainly of degritting, fractionation by centrifuge, high gradient magnetic separation, bleaching with sodium dithionite, filtering and drying. In some kaolin clays from that region, titanium oxide mineral occurs in fine fraction, lower than 2 μm, and so making the industrial process more difficult. The conventional method of classification and bleaching with sodium dithionite, markedly improves kaolin brightness, but has little effect on anatase removal. In fact, the fine fractions resulting from centrifugation, in many cases contain more TiO_2 minerals than the original whole clay or the coarse fraction. The present work is related to purification of Brasilian kaolin clay using selective flocculation for removing its colored impurities such as rutile and anatase. This study was conducted in bench scale and it consisted of: blunging, screening, conditioning and decantation. Overflow and underflow resulting from settling of the flocculated material were then dried and submitted to TiO_2 and brightness analyses. Sodium polyacrylate and sodium silicate were added to kaolin clay suspension as dispersant and ammonium hydroxide was also added to adjust pH. After degritting, the minus 44 μm fraction was conditioned with hydroxamate surfactant and then polymers of different anionic charge were added. The influence of pH and type of polymer on efficiency of TiO_2 removal, as well as kaolin mass recovery were studied. The results obtained in the present study are quite promising. It was possible to diminish TiO_2 content and increase kaolin brightness (ISO) from 82 to 88%.

COFFEE BREAK — 15:20 - 15:30

PAPER 35.5 — 15:30

IMPROVED DEWATERING OF KAOLINITE CLAY MINERAL DISPERSIONS.

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In this work, the modification of interfacial chemistry of colloidally stable kaolinite clay dispersion has been carried out to improve its flocculation performance and dewatering behaviour. Synergistic action between dispersion pH, hydrolyzable metal ion and high molecular weight polymeric flocculant structure type (anionic polyacrylamide-acrylate copolymer (PAM) and non-ionic polyethylene oxide (PEO)) was found to play a pivotal role in inter-particle bridging, the enhancement of the settling rate and extent of consolidation of the pulps. Flocculation with PEO led to higher settlings rates in acidic than alkaline pH, whilst for PAM, the maximum dewatering rate was achieved in the neutral pH range 6 - 7.5. Upon shear, the PEO flocculated pulps showed dramatic improvement in consolidation to 40 wt%, the extent of which was greater at lower than high pH values. For PAM-based pulps were however, not shear-responsive, lower sediment solid contents of 15 – 23 wt% was observed between pH 3 and 11. Hydrolysable metal ions, Mn(II) and Ca(II), used respectively at pH 7.5 and 10.5 in conjunction with PAM and PEO, significantly enhanced the settling rates and consolidation of the pulps. The findings exemplify the strong links existing between pH-mediated particle surface chemistry, polymer structure-conformation, inter-particle bridging and dewaterability of kaolinite dispersions.

PAPER 35.6 — 15:50

ENLARGEMENT OF FINE PARTICLES IN THE OIL SAND INDUSTRY - FLOCCULATION AND THICKENING.

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Efficient and effective management of extraction process tailings is an essential ingredient for the continued success and development of Alberta's vast oil sands resources. Open-pit oil sands operations north of Fort McMurray recover bitumen from flotation circuits. Process tailings are managed in carefully engineered and monitored external tailings management facilities and in below-grade mine pits. In order to support reduction of production costs and improve upon established tailings management practices, CANMET has been working with the oil sands industry in a collaborative framework to assess the potential to integrate thickened tailings into oil sands extraction process flowsheets. Albian Sands has commercialized the process while others, including Syncrude Canada Ltd., continue to evaluate the suitability of the process for their operations. This paper provides an update on R&D work undertaken in recent years to assess and develop the potential of thickened tailings technology for the open-pit oil sands operators of northern Alberta. The aim of this work was to explore opportunities to optimize process efficiency and environmental sustainability by improving water and energy conservation and develop more alternatives for tailings management and reclamation.

PAPER 35.7 — 16:10

TESTING OF FLOCCULANT-ASISTED HYDROCYCLONE ON QUÉBEC CARTIER MINING COMPANY'S IRON ORE TAILINGS.

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The flocculant-assisted hydrocyclone involves the addition of a flocculant to the cyclone feed for the purpose of obtaining a clear cyclone overflow, and thereby eliminating or reducing thickener requirements in tailings disposal operations. This paper describes the testing of this concept on the iron ore tailings of Québec Cartier Mining Company's Mount Wright Concentrator. The current practice at Mount Wright makes use of conventional hydrocyclones and thickeners for the disposal of their tailings, which are generated in a spiral gravity separation circuit. The test work was conducted primarily on their cyclone overflow product which becomes the feed to the thickeners. A detailed study was carried out to determine the sedimentation properties of these tailings in terms of their response to a variety of flocculating reagents, and to varying conditions of pH, pulp density and flocculant dosage. The tailings were then processed in a laboratory hydrocyclone with the aid of flocculants. The use of a shear resistant flocculant, in particular, was found to yield cyclone overflows with low solids contents. Based on the test results obtained, a conceptual flow sheet has been proposed for the treatment of the iron ore tailings at the Mount Wright Concentrator.

PAPER 35.8 — 16:30

EFFECT OF FIBROUS MATERIAL ON FLOCCULATION AND DEWATERING OF FINE WASTES.

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Bench and pilot scale testing results suggest that significant improvement in dewatering characteristics of fine particles could be obtained by the addition of fibrous materials. Case studies involving flocculation and dewatering of wastes from phosphate, bauxite, and kaolin processing plants are presented in this paper. Several dewatering techniques were investigated, including sedimentation thickening, filtration, centrifugation, dewatering on screens, and seepage-

induced dewatering and consolidation. Advantages and limitations of commercial application of some of the developed techniques are discussed.

PAPER 35.9 — 16:50

IMPROVING DENSIFICATION OF FINE COAL REFUSE SLURRIES TO ELIMINATE SLURRY PONDS.

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F. SCGOENBRUNN and F. BACZEK, Dorr-Oliver Eimco, Salt Lake City, Utah, U.S.A.

Fine refuse slurry impoundment is a requirement for the coal industry to dispose the fines. Impoundment maintenance is an on going problem for the coal industry and its breakage creates environmental as well as financial problems. Deep Cone thickener technology which has been successfully applied in the alumina industry to dewater red mud was evaluated for fine refuse slurry. Preliminary obtained in a pilot-plant test showed that properly flocculated conventional thickener underflow slurry could be thickened to about 52.5 wt % solids and could replace belt filter press. The Deep Cone thickener was also found to dewater clean coal slurry to about 70 wt % solids. Further testing of the unit at other coal preparation plant is in progress.