

Concentration Machinery and Equipment in Alumina Refining

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Abstract

Demand for mineral resources continuously grows but their quality deteriorates and the cost increases because the mining companies have to turn from development of rich ore deposits to development of deposits with substandard or out-of-balance ores. Changes in material composition of bauxites cannot but adversely affect established alumina production process. Sooner or later this will necessitate making decisions to improve manufacturing. The paper presents positive results achieved and considers prospects of employing processes and apparatus initially developed to concentrate ores and non-metal materials at certain ore preparation stages, grinding, thickening and decomposition in alumina production.

Keywords: Process and apparatus, ore concentration, alumina production, improvement.

1. Introduction

Splitting of industrial production into separate branches, each with its own specifics brought into existence free-standing industrial processes and apparatus, e.g. [1, 2, 3]. Today the alumina production also has its own generally accepted basic manuals to calculate and design processes and apparatus for its implementation [4, 5]. Quality characteristics of bauxites gradually deteriorating with development of ore bodies and changes in mine development systems ultimately reduced alumina content and increased content of harmful impurities in commercial bauxites. With every year the issues of conditioning the raw materials incoming into the process get more and more pressing [6]. Meanwhile the use of the traditional pool of apparatus is not always able to provide for required economic efficiency of the process and quality of final product. The use of apparatus initially developed for chemical production or concentration of ores or non-metal materials at different stages of ore preparation, grinding, classification, thickening in alumina production makes possible in many cases to achieve required technological result.

2. New Bauxite Concentration Processes

In this context the experience accumulated by expert professionals of Pavlodar Aluminum Smelter should not be left unmentioned. Depletion of Turgay bauxite reserves in the second half of the 90s posed the problem of developing a new technology to process low grade highly sideritized bauxite from Krasnogorsk deposit. At the moment “Aluminum Kazakhstan” LLC has developed and implemented alumina production process from substandard bauxite raw materials of Kazakhstan as per sequential Bayer sintering diagram. Flow charts have been implemented, apparatus designed and manufactured made possible to increase annual alumina production capacities to 1 500 thousand tons as compared to the designed 1 034 thousand tons. The principal engineering solution in processing substandard raw material was to implement unique process flow chart to remove impurity components of bauxites by removing a part of iron sands and kaolinites [7, 8]. Vertical sizing vessels and elutriating apparatus which are the base of the flow chart are hydrosizers widely used in sand beneficiation have been modified for the process specifics.

Industrial pulsation chemical reactor adapted for hydrochemical processing of sintered material was tested at the sintering stage integrating in all stand-alone equipment unit all processes stages – leaching of sintered material, thickening of solids, clarification of aluminate liquor and sand washing – reduced secondary loss and specific consumption of washing water [9, 10]. Experience of applying hydrocyclones in concentration of ores and non-metal materials formed the basis to develop at PAS the only one in the post-Soviet countries complete flow chart to classify the product hydrate in decomposition area employing battery hydrocyclones [11, 12],

Changes in material composition of bauxites create similar challenges at the alumina enterprises in Russia. Currently, high carbonate content in SUBR bauxite results in its accumulation in the manufacturing solutions. High carbonate content in solutions reduces evaporation performance, increases specific steam consumption, misbalances alkaline consumption towards more expensive caustic. Together with ETC RUSAL Alumina Directorate we made a decision to consider the possibility of concentrating the initial rock mass by air elutriation by “SEPAIR” technology. Initially developed to beneficiate coal the device demonstrated stable process characteristics and simplicity of control under varying input conditions (initial moisture content of the material including) and for other ore and non-metal materials. The process realized the principle of separating the products by density in the upward current and in the vortex chamber above the perforated belt, Figure 1.

Design of the process chamber combines conventional principles of pneumatic separation in the vertical channel and vortex technologies to separate initial material components with density pitch from 0.01 t/m³ in dry process and extract from 95% and more useful products. Actual EPM classification efficiency (average probable deviation from theoretical separation conditions) for conventional dry concentration processes, e.g. Chinese FGX ranges from 0.2 to 0.35. By the data presented by «COALTECH» (SAR) on studies of coal concentration parameters carried out in 2018 on «SEPAIR» plant the real EPM of the plant was 0.1-0.17 (depending on the size of separated material), which is practically comparable with traditional wet concentration indicators.

The aim of the work was to study the preparedness of GB-1 (ГБ-1) bauxite with extraction from it of the high quality bauxite and bauxite with CO₂ content. Tests carried out on bauxites of Bogoslovsk Aluminum Smelter at «Gormasheport» laboratory to assess preparedness by air elutriation produced the combined concentrates of the Ist, IInd and IIIrd quality with the yield of 40, 13 and 47 %, respectively. The process was found to be able to smoothly vary the quality and balance of concentrate within the framework of fractional makeup of the raw material. Studies to elaborate the process and develop an industrial flow chart for preliminary concentration of SUBR bauxites to increase the yield of calcite concentrated classes [13] are in progress.

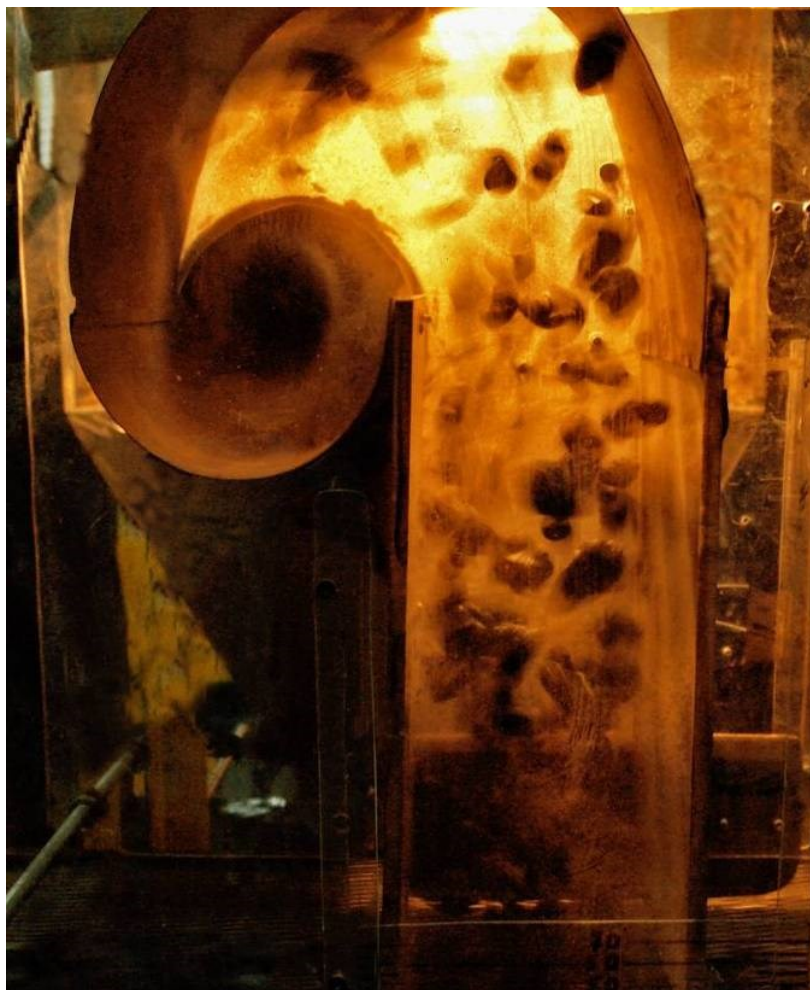


Figure 1. Separation process in laboratory plant.

Important for the prospective viability of the process is the possibility of operating «SEPAIR» under any climate conditions. The plant can actually be located at the bauxite mining site. To install the complex requires minimum of buildings and structures. To operate at temperatures from - 30 to + 50 °C requires only a shelter from precipitation and wind. Only the control panel requires a heated room. The plants are installed on compacted soil without foundations (Figure 2).

3. Efficient Crushing Equipment

Changes in bauxite characteristics adversely affect the process of crushing the initial material, too. For coarse and medium crushing the bauxite preparation traditionally employs hammer and jaw crushers. Review of international crushing practices shows that as of today in common use are toothed roll crushers of different design to crush most diverse materials. This is because the toothed roll crushers are most fit to process materials prone to sticking or containing clay intrusions. To use crushers of other types to process such materials is either impossible in general or involves frequent downtimes for long and labor consuming cleaning of the crushing camera or crushing elements.



Figure 2. «SEPAIR» plant, «Molodezhny» surface mine, Kazakhstan.

Advantages of toothed screw crushers: smaller dimensions and weight as compared to other crusher types of analogous performance, e.g. jaw and cone crushers, low overgrinding, possibility of processing frozen and viscous-plastic products, maximum yield of products of prescribed size, compactness, simple design, quick replacement of operating tools, possibility of working under rubble, Figure 3.

E.g. replacement of hammer crusher from toothed screw crusher DShZ-500 (ДШЗ-500) at «Tamme Auto» (Estonia) increased specific yield of 25-50 mm class in crushing shale coal 2.2. times. Reduced overgrinding reduced electric power consumed by the crusher by 20 %. Elimination of product adhesion to the operating surfaces increased the crusher utilization factor from 0.3 to 0.86. For more than five years of operation the crusher is shutdown only for preventive maintenance, to replace oil in reduction gears and working parts of roller teeth [14].

Last year a toothed screw crusher DShZ-500 (ДШЗ-500) was installed in RUSAL Kamensk-Uralsky (UAS) to replace the jar crusher on the free site without construction of additional buildings and structures. Statistical data on economic performance are still being processed. However, even now it is noted that commissioning of the crusher made possible to eliminate idle time of the equipment associated with cleaning the operating zone of the crusher when processing viscous bauxite from SUBR. Nominal crushing performance increased to 250 as compared to former 170 t/h with the crushing size minus 50 mm as compared to the former 125 mm. Closed operating zone of the crusher decreased dust content in the site and eliminated injury risk. In «RUSAL» this is the second crusher of this type. DShZ 625 (ДШЗ 625) crusher was supplied in 2011 to crush and disintegrate fluorite ore from Yaroslavl Mining and Processing Plant with high clay content (up to 60%) and fluorite inclusions sizing up to 700 mm.



Figure 3. DShZ-500.20-75 (ДШЗ -500.20-75) double roll crusher with mining tooth.

4. Ore Mechanoactivation and Grinding Equipment

Another class of concentrating apparatus showing prospects for alumina production are attrition machines or «attrition scrubbers», Figure 4.

Machines of this type are high-speed mixers with high specific mixing energy. They are used to concentrate glass sands to remove oxide films from the surface of quartz grains. The chamber of the attrition machine where the suspension is fed houses two axial impellers installed on one shaft, Figure 5. When the shaft rotates the impellers with alternate blades create opposed flows of suspension. This provides for high intensity of particles' interaction with each other. Friction of particles removes surface iron oxide films and destroys grains of small strength. The centrifugal impeller installed at the top of the shaft creates additional flow of the suspension directed from the shaft towards the machine walls. Impacting the impingement plate on the walls the particles undergo additional attrition. Besides, the impeller helps the suspension move along the machine line to the discharge pocket.



Figure 4. SOV-2 (COB-2) Attrition scrubber.

Because of high mixing intensity and high abrasiveness of the process the design of the machine employs special high quality lining materials. The apparatus can be used as suspension homogenizers, mechanical activators, conditioning tanks.

By the order of «RUSAL Global Management» LLC our laboratory carried out work to assess feasibility of using attrition scrubbers at the grinding area of Windalco Ewarton. At this enterprise the bauxite is prepared by wet grinding on spent liquor in ball mills and discharged through the grating. The mills operate in open cycle. The suspension from the mill is discharged by lifters through slot discharge grating which stops incompletely ground material and balls sizing more than 30 mm. The incompletely ground material is discharged onto the scraper conveyor to remove non-standard size. The sand removal buckets act as classifiers directing fine slurry flow to the fine slurry tank, while the large lumps are rejected. The buckets are manually cleaned at certain intervals. The ready suspension is directed to the intermediate accumulation tank from where it is pumped into predesiliconization tanks through IBSH heat exchangers or directly. The quality of grinding is evaluated by fraction +4 mesh not more than 3 %. Such fineness of grinding should ensure fault-free operation of IBSH heat exchangers and all downstream equipment. However, high plasticity index of the clay component of bauxite forms agglomerates in the mill. Dispergation of suspension is evaluated by fraction +10 mesh and can exceed the top limit allowed by the procedure more than two times. This brings forth considerable problems at downstream stages of predesiliconization, thickening and washing area which, in their turn

determines stable operation of the entire plant. Removal from the process of forming clay agglomerates extracted by sizing trammel at the mills is a source of unaccounted loss of bauxite and alkali.



Figure 5. Impellers of mechanical activator.

Elaboration of the process in the laboratory revealed a possibility of achieving statutory parameters of the suspension and the process on the whole by incorporating into the existing flow chart attrition machines as repulpers immediately downstream the mills by gravity without additional pumps and tanks. The oversize product +40 mesh after repulping in the attrition machines was 3.3 % which is acceptable for the process used at the plant.

For further development it would be of interest to assess feasibility of employing attrition scrubber as mechanical activators for the solid phase in leaching, thickening, washing and decomposition stages. Mechanoactivation makes possible to use such physical phenomena as changes in the solid structure, acceleration of diffusion processes by increase specific surface of the solid phase, formation of active centers on newly formed surfaces, etc. Adsorption - solvate layer forming on the surface of the particles reduces mass exchange rate at the liquid / solid phase

interface in hydrochemistry processes. In thickening processes due to accumulation of the surface charge this layer prevents coagulation and primary aggregation of particles, fixing of flocculant molecules on the surface of the solid phase and formation large floccules. Mechanical removal of this layer allows to intensify practically all stages of alumina production. Concentration experience shows that mechanoactivation of the concentrate pulp between the flotation stages at the concentrating plants allows to increase extraction efficiency of the valuable product by 5-18 %.

Earlier works carried out at PAS on intensification of leaching stages of the Bayer branch showed that mechanical activation of the suspension increases liquid phase desilicization rate 1.3 times. Mechanical activation of the raw pulp prior to the leaching stages was found to more completely disintegrate the raw material and to increase extraction of valuable components with reduction of process time [15].

The works on three-stage classification of the hydrate in hydrocyclones to produce fine active seed for decomposition noted increasing linear growth rate of crystals at the agglomeration stage 1.4 times as compared to the crystals extracted by classification on the sieve without mechanical attrition taking place in the hydrocyclones [11, 12].

Preliminary mixing of the suspension with the flocculant in the hydromixer at considerable speed and at high specific mixing energy during modification of the red mud thickening area allowed to increase aggregation of the particles and increase the clarification rate of the liquid phase to four times [16].

The goal of all enumerated works was not to directly investigate the effect of mechanical activation on the process kinetics; the produced effect was noted as accompanying. The time of mechanical activation of the suspension in all examples was from 30 to 60 seconds. Further purposeful work on this subject in alumina production was not carried out because of several reasons. Further targeted work on this subject in alumina production was not carried out because of several reasons. One of them is lack of reliable apparatus to carry out the process in industrial scale.

The experience of developing and operating the attrition machines acquired as of today allows to state the possibility of developing laboratory and industrial mechanical activators, and methods of investigating and practical application of effects observed in mechanical activation to be followed by design and large-scale production of apparatus to intensify or optimize these or those technological processes.

5. Development of Optimum Process Flow Diagrams

The trend of implementing and using concentrating equipment in alumina production should not be understood in a unique manner. The experience of operating concentration machines and apparatus under new conditions serves to develop theory and practice of the «processes and apparatus» subject on the whole. Experience of modifying the red mud thickening area at PAS has been taken into account in developing theoretical foundations of methods of calculating circular thickeners [17]. The practice of operating hydrate hydrocycloning flow chart formed the basis configuration of the methods of calculating multi-stage classification diagrams [18] used to design concentration plants. Engineering solutions for these flow charts are: configuration of wells and desludging mechanism in circular thickeners, layout of battery hydrocyclones and their operation by hydrostatic head of the suspension without additional sumps and pumps is successfully used in the concentration pumps both in Russia and abroad.



Figure 6. Mud removal system of rake type. AO «Olovokombinat». Novosibirsk.

The data of experimental studies and experience of industrial operation of hydrocyclones in AO «Aluminum of Kazakhstan», arrangement of multicyclones and experience of their operation with hydrostatic pressure of the pulp without additional sumps and pumps helped develop a new generation of these apparatus. In addition to classification diagrams of solid phase of different pulps by size or density today the hydrocyclones are successfully used to condition the pulps by solid phase content or to preliminarily thicken them in water turnover circuits. The property of fine classes of the solid phase of the hydrocyclone feeding pulp to distribute between sands and drain in proportion to the liquid phase content in them makes possible to use the hydrocyclone plants to desludge the clay-containing pulps.

Example of hydrocyclones used to desludge the pulp of lead-zinc ore prior to flotation at «AO Metal» (Bulgaria) increased the yield of lead and zinc concentrates by 8 and 10 %, respectively, and reduced consumption of flotation reagents and volume of process flows in the circuit. Multicyclones installed at the feeding line of nickel concentrate thickening pulp in Norilsk concentration plant made possible without passing through the thickener to extract into the sand fraction a part of initial product and increase the solid load for thickening by 35% without modifying the thickeners and changes in the reagent scheme. The multicyclones are equipped with automatic pressure maintenance system both at the input and systems monitoring the density of unloaded sands. Figure 7.



**Figure 7. Multicyclone-thickener with automatic control system. PJC Western Branch
MMC «Nornickel».**

Industry as a whole (this is true for the alumina industry, too) is extremely conservative. It always prefers proved processes and takes great pains in resisting innovations which has not been tested many times. Meanwhile the experience of adapting and operating concentration apparatus at chemical enterprises and in hydrometallurgy [19] allows considering the feasibility of employing in technological processes washing, classifying, crushing and other equipment well proven in the course of operation for many years under various conditions.

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