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MODERN TECHNOLOGIES FOR DIFFICULT TO FILTER SUBSTANCES IN ALUMINA REFINERY

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Abstract

Results of using of Outotec's technological solution for liquid and solid phase separation for processing of aluminum raw material to alumina and chemical products are shown. Laboratory test work simulating Outotec SUPAFLO thickener with alumina production sludge showed that capacity can be increased at least in 1,3 times while reducing flocculant consumption in 3 times compared with existing technology. High density of thickened product and low solids content in overflow were achieved. Pressure filters, vacuum filters and capillary ceramic disk filters using in Outotec technological flowchart for red mud and amorphous aluminum hydroxides filtration and washing allow getting product with required chemical composition with 21-80% residual moisture level and 35-280 kgDS/m^2·h capacity.

Introduction

The development and application of high-performance equipment and process solutions for separation of the liquid and the solid phases is an important task in processing aluminium-containing raw materials for production of alumina and chemicals.

Thickening is a high-performance method for separating the liquid and solid phases under gravity and makes it possible to separate the liquid and solid phases with their low proportion in the slurry.

Filtration means the process of separating heterogeneous systems using porous baffles that let pass the dispersion media and inhibit the disperse solid phase. Pressure difference in the slurry to be separated and behind the filtering baffle is the driving force of filtration. It is advisable to implement filtration with a high proportion of the liquid and the solid phases in slurry. Filtration makes it possible to produce the liquid phase that contains almost no solids, and the solid phase without the filtrate impurities.

Thickening

In the alumina production, the thickening equipment performance was boosted either by increasing the radial thickeners diameter or by increasing the number of thickener layers. Thus, initially large diameter thickener taking too much area and multilayer radial thickeners were designed. Later it became clear that the process advantage from using multilayer thickeners was not that large and they were more difficult to operate compared to conventional thickeners.

Further intensification of thickening in production of alumina was implemented by using flocculants of high molecular mass for thickening and by improving the thickener design.

Existing equipment and technology for sludge thickening of alumina production is characterized by a lack of capacity and high consumption of flocculent for settling. Comparable technology thickening of sludge of alumina production had specific capacity less 1,25 t/m^2·h (upstream velocity less 6,0 m/h) at flocculant dosage 20-25 g/t.

Outotec's optimisation of thickeners design was performed in the direction of increasing the efficiency of using the horizontal section area with subsequent decrease of the capital costs. This resulted in creation of the SUPAFLO thickener and the process. SUPAFLO high rate thickeners and clarifiers are installed in different industries: non-ferrous metallurgy, mining and food industry, production of mineral salts, for treatment of industrial and household sewage. The thickener is widely used not only thanks to its high performance, but also due to a high underflow density, a very clear overflow, low flocculant consumption, possibility of automatic regulation and control of the thickening process.

In SUPAFLO high rate thickeners source slurry is fed to the Floc-Miser feedwell tangentially, promoting smooth agitation of slurry and its mixing with the flocculant. The feedwell dimensions are selected to ensure aeration of the feed slurry. Flocculant is fed to the feedwell through the flocculant spargers and mixed to slurry. Flocculated slurry is fed through the feed slot between the well and the reflecting cone to the fluidised area of the bed.

In the fluidised area the particles are already flocculated, therefore the fluidised bed operates as a filter for the incoming slurry: it holds the solid particles and let pass upwards the clear liquid only. Fine solid particles that were not flocculated in the feedwell or small floccules have more contacts with other flocculated particles in the fluidised area and they form larger floccules and settle from the fluidised area to the thickening area. The fluidised area level is continuously maintained above the feed point and the upcoming flow of liquid is filtered by the bed. Such filtration effect results in production of a very clear overflow and correspondingly to flocculant saving.

The advantage of SUPAFLO idea is that it allows reconstruction of conventional thickeners available at the plants by installing the Floc-Miser feedwell.

Filtration

The major problems in separating phases in production of alumina and accompanying chemicals arise in filtration of red mud [1,2] and aluminium hydrate of an X-ray amorphous structure similar to the pseudoboehmite structure [3-5].

Red mud (RM) is a solid residue after leaching of bauxites, the majority of particles being below 0,063 mm in size. In terms of the phase composition, this is a mixture consisting of hematite, goethite, silica and sodalite [6,7]. These phase components do not promote reaching high filtration parameters.

The task of RM separation from the aluminate solution is to produce the solid phase without the aluminate solution and its main components - aluminate ions and sodium cations.

In alumina plants with semi-dry storage of RM, it is filtered to remove alkali and moisture from it.

Pseudoboehmite (PB) or X-ray amorphous aluminum hydrate is an aluminum monohydroxyde, and its chemical formula is similar to boehmite AlOOH. But, in contrast to boehmite, PB does not have a clear crystal structure and does not have a water molecule in its composition, and because of this, the sediment moisture after filtration of PB cannot be below 75 % w/w. [3-5].

Aluminium hydroxide as a volumetric gel or as PB conditions can be obtained from aluminium-containing liquors by certain processing. PB is used for binding the catalytic mass which is subjected to granulation or extrusion. PB is a desirable form of hydrated alumina for use in the matrix for the zeolite Y containing hydrocarbon conversion catalyst to produce a catalyst of suitable attrition resistance and catalytic activity for use in fluid cracking systems.

Activated alumina (AOA) is based on PB precursors [3]. AOA is applied as desiccants, sorbents, catalysts etc. The opportunities of use of AOA in these areas are determined by its properties, namely specific surface, type of porous structure, contents of impurity, ability of initial raw material to extrusion granulation, form and size granules, mechanical durability of the granules, cost of the raw material and the cost of waste recovery.

In catalysts AOA from PB are used as active catalyst and support (Claus-process, isomerization, cracking, reforming, dehydration etc.). One of the largest modern-day uses of AOA is that of a catalyst support for catalytic muffler on automobiles.

The neutralisation of aluminium-containing solutions is carried out in conditions favourable to precipitation of PB. With reference to the solutions of alumina production it could be done, for example, by passing of carbon dioxide gas through an aluminate solution at a low temperature. The most widespread acid for neutralisation of aluminate solutions is nitric acid because the anion NO_3^- is the most effective stabiliser of the PB structure.

X-ray amorphous aluminum hydroxide is also widely used in pharmaceutics [8].

Various types of filters and filtration flow diagrams are used to separate the cakes from the liquid during the extraction PB or X-ray amorphous aluminum hydroxide. All of them are characterized by low productivity and there is no single point of view for the choosing of equipment.

Experimental

After leaching of cake and aluminate solution, slime was separated using a laboratory unit simulating SUPAFLO thickener (Fig.1). Slime particle size distribution, mm %: +0,63 – 0,5-1,5; +0,2 – 15-20; +0,005 – 30-40; -0,005 – 40-50. Content in aluminate solution, g/l: Na_2O_{total} – 85-95; Al_2O_3 – 80-90. KLEARAL 990 was used as a flocculant as a solution with 0,01% concentration in the amount of 0-11,8 g/t. The solid phase content in the feed slurry was 10,5-18,4% w/w. The temperature was 70-75 °C.

Figure 1. Picture of bench-scale test unit of SUPAFLO thickener

While thickening the task was to get solids content in overflow less 1 g/l, density of underflow 1,68-1,70 t/m^3, specific capacity more 1,5 t/m^2·h.

For filtration and washing PB were used laboratory equipments simulating Outotec Larox Filters [9]:

1. Filter-press – FP (Fig.2);
2. Rubber belt filter – RB (Fig.3);
3. Ceramec Disk filter – CC (Fig.4).

Figure 2. Picture of bench-scale test unit of Filter-press

The advantage of pressure filters compared to the filtration equipment of other types include low sediment moisture thanks to high filtration pressure, low power consumption during operation, possibility of sediment washing in the pressure filter, filtrate purity, low consumption of auxiliary reagents (coagulants, flocculants).

The advantages of conventional vacuum filters are their relatively low cost and ease of operation. Belt vacuum filters also make it possible to efficiently wash and dry the cakes.

Figure 3. Picture of bench-scale test unit of Rubber belt filter

Figure 4. Picture of bench-scale test unit of Ceramec Disk filter

The vacuum disc filters with ceramic filtering elements are similar to disc filters, but here microporous ceramic plates of a capillary type made of ceramics are installed as the filtering surface with the openings of 1,5-2 um, through which the liquid flows but air does not pass through. Moisture is removed from the sediment on these plates as long as there is liquid in the capillaries. These filters feature the following advantages compared to conventional disc and drum filters: absence of the filter cloth, low power consumption, low moisture of produced sediment, high quality of filtrate containing at most 0.2 g/l of solids, eliminating precious product losses with filtrate, efficient sediment washing thanks to its fine and even layer and absence of air flow through it, long service life of plates of over 1 year if they are fully regenerated. Vacuum disc ceramic filters are also distinguished by low operation costs and high availability factor of over 0.9.

The following materials were filtered: red mud was filtered after processing of different gibbsite-boehmite bauxites of a tropical belt, selected from the "tailings" stage of washing (L:S ratio = 2.5÷3.0) and PB produced after neutralisation of the aluminium sulphate solution by the soda ash solution.

Results and discussion

Results of experiments shown in Tables 1 and 2.

<u>Thickening of slime after cake leaching</u>

The results demonstrate (Table 1), that with the upstream velocity of 7.8 m/h the best thickening results are achieved with the flocculation consumption of 8.1 g/t, i.e. this dosage can be considered as optimal. If the flocculant consumption is increased, the solids content in overflow is decreased. Though increase of the upstream velocity improves the production rate, however it results in deterioration of other parameters of thickening.

Using of SUPAFLO thickener comparing with existing technology increases the production rate of thickening in at least 1,3 times and reduce flocculant consumption by more than 3 times.

<u>Red mud filtration</u>

In RM filtration test work on press-filter (Table 2) maximum capacity was 80 kgDS/m^2·h with 30% residue moisture level. However moisture level in some experiments was reduced to 21% due to the decreasing of filtration performance.

In the performed vacuum filtration tests, the best performance of 130 kgDS/m^2·h was reached with the RM sediment layer thickness of 5 mm and the residual moisture of 36 %. Increase of the original L:S proportion in slime resulted in reduction of filtration parameters that were also dependent on the mineral composition of slime.

In filtration of red mud using the ceramic filter, the obtained results for this type of filter are in the intermediate position between the vacuum filters and pressure filters. Theoretically, this type of filter can produce sediment with very low moisture content, but this can result in substantial decrease of performance. Therefore, for a large tonnage production of alumina in the systems of red mud preparation for storage or usage, it is preferable to use chamber-type pressure filters, which, thanks to high sediment pressure, ensure the lowest sediment moisture content. Moreover, this type of filter is suitable for separation of slurry with a wide range of L:S ratio.

There was a higher performance rate with higher residual moisture level for all used filters.

<u>Filtration of X-ray amorphous aluminum hydroxide or PB</u>

For all used filters minimum possible residue moisture level was 75-80% (Table 2). In the experiments relatively high filtration parameters were reached with the sediment layer height less than 10 mm.

Table 1. Results of RM after leaching thickening test work

	Flocculant dosage, g/t						
	0	6,3	8,1	8,9	9,4	11,6	11,8
Upstream velocity, m/h	7,8	7,8	7,8	10,4	7,8	10,4	7,8
Density of underflow, t/m^3	1.69	1,75	1,71	1,52	1,68	1,53	1,61
Specific capacity, t/m^2·h	0,88	1,66	1,66	2,21	1,66	1,18	0,88
Solids content in underflow, g/l	1019	1070	1001	713	968	702	832
Solids content in overflow, g/l	2,4	0,75	0,59	0,65	0,65	1,24	1,07

Table 2. Results of experiments of using different types of filters for RM and X-ray amorphous aluminum hydroxide or PB separating and washing

Model of filter	Capacity, kgDS/m^2·h		Residue moisture, % weight	
	RM	PB	RM	PB
FP	35-80	170-280	21-30	75-80
RB	70-130	100-280	35-40	75-80
CC	65-100	100-160	32-33	75-80

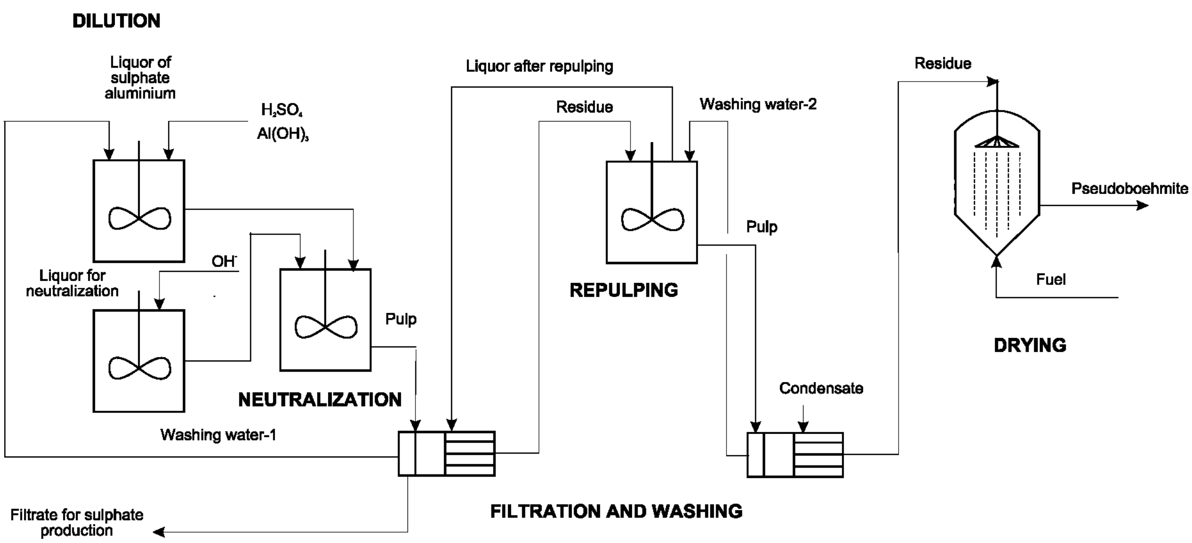

Figure 5. PFD of pseudoboehmite production

The maximum indicators in performance were obtained for pressure filter and rubber belt filter. However application of pressure filters in the process flowsheet is more advisable compared to disc vacuum filters, since there are no costs for gas consumed for drying in the drying drums. Usage of pressure filters is more cost efficient too.

Fig. 5 shows the general diagram for PB production. In this diagram it is supposed to use Outotec equipment for the main filtration, sediment washing and also for drying in the hot air stream if possible.

Conclusion

Laboratory test work simulating Outotec SUPAFLO thickener with alumina production sludge showed that capacity can be increased at least in 1,3 times while reducing flocculant consumption in 3 times compared with existing technology. High density of thickened product and low solids content in overflow were achieved. Pressure filters, vacuum filters and capillary ceramic disk filters using in Outotec technological flowchart for red mud and amorphous aluminum hydroxides filtration and washing allow getting product with required chemical composition with 21-80% residual moisture level and 35-280 kgDS/m^2·h capacity.

As a result of laboratory tests with industrial simulating Outotec's pilot equipment, were developed hardware-technological solutions for liquid and solid phase separation in aluminum raw material processing to alumina and chemical products.

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