IMPROVED FILTRATION AND WASHING OF AL-HYDRATE PRODUCT: COST SAVINGS BY MODERN FILTER DESIGN

Hahn J*, Bott R and Langeloh T

BOKELA GmbH; Gottesauer Str. 28, 76131 Karlsruhe, Germany

Abstract

Filtration and washing of Al-hydrate product in alumina refinery plants is usually performed on pan filters since this vacuum rotary filter type is well adapted to the filtration of coarse particles. It is the target to achieve a filter cake that is as dry and free of soda as possible. The single stage process with feeding the precipitation product directly onto a pan filter is a wide spread process design for Al-hydrate product washing. In the last decade BOKELA has introduced a new generation of rotary vacuum filters such as disc, drum and pan filters with new and innovative designs. With this new generation of pan filters, the filtration and washing out of the Al-hydrate product is performed with significantly improved filter capacity, reduced maintenance and operation cost compared to conventional designed pan filters. The most efficient process design, however, is a two stage process. First, deliquoring of the precipitation slurry on disk filters and second, washing of the re-slurried hydrate on a pan filter.

1. Introduction

For filtration and washing of Al-hydrate product different process designs i.e. combinations of different filter types are in use, such as drum filters in series for a three-step filtration, disc filter and drum filter for a two-step process, disc filter and pan filter for a two-step filtration or pan filter for a one-step filtration.

The most efficient process design is the two stage process, with deliquoring of the precipitation slurry on disc filters and a second washing of the re-slurried hydrate on a pan filter. However, a single stage process is wide–spread, with feeding of the precipitation product (as first stage hydrocyclone underflow) directly onto a pan filter. The advantages of both methods strongly depend on the technology used. In order to g*et al.*l the benefits of these processes, modern filtration equipment with advanced design for high capacity and low maintenance levels is required.

2. Product filtration on pan filters

Figure 1 shows a schematic flow sheet of filtration, two step counter-current wash and steaming of Al-hydrate product on a pan filter. The feed slurry is diluted with filtrate in order to better control the solids concentration and to get a constant solids content in the feed flow. Thus, the caustic content is also diluted which improves filtration behaviour of the slurry so that both cake formation and washing are performed under better conditions. The high caustic content of the slurry has a negative influence on the filterability. By diluting with lower concentrated filtrate the slurry will filter better and cake wash is improved. Cake washing can also be performed with three counter-current wash stages.

The standard pan filter consists of 20 filter cells with a planar base and a flat bottom with a slope towards the filter centre. During filter operation, each filter cell passes through the separate wash stages of the pan filter. The control head in the pan centre divides the filtrate flows from the filtration zones to either two or three receiver vessels where the liquid is separated from air. For optimal operation each cell should be completely empty before passing on to a following wash zone, in order to avoid dragging of caustic to clean wash areas/filtrates.

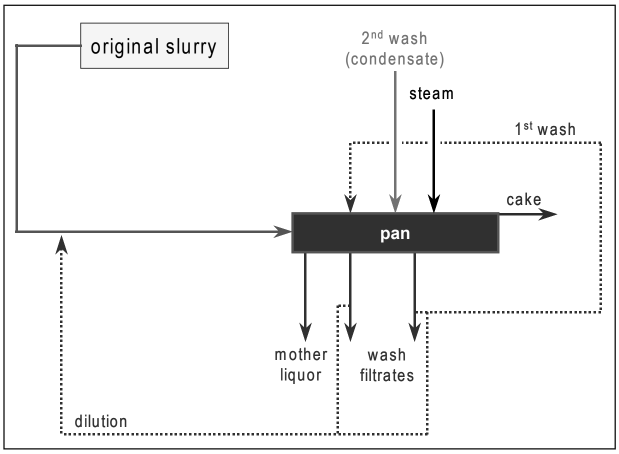

Figure 1. Flow sheet for one-step filtration on pan filter.

2.1 BOKELA Pan Filter Design

The special design of the new pan filter generation of BOKELA consists of the following features.

The Forced Feeding System ensures a homogenous cake thickness at the whole filter surface by even slurry distribution. The motorized slurry distributor supplies equal slurry streams to equal areas on the filter surface.

The thoroughly manufactured discharge scroll with wear-resistant flights (Hardox 400) and its fixing from the top beam (no centre bearing) allows it to achieve a minimal thickness of the remaining heel layer and thus results in less recycled washed hydrate.

The Heel Re-slurry System removes the remaining heel layer from the filter cloth using an air blow impulse for breaking up the heel and a high pressured filtrate stream for mixing it up with fresh slurry. This procedure results in longer filter cloth lifetimes, 2 – 3 times longer cycles between caustic wash and better washing of the hydrate.

BOKELA cake wash systems ensure an equal wash water distribution onto the filter cake. The free flow construction over a set of weirs prevents blocking of nozzles and distributes a homogenous water flow which ensures an equal washing of the cake. Counter-current washing on each pan filter minimizes the wash water consumption.

Sharp splitting and fast drain of the filtrates and pre-separation of liquid and air is realized in the Pre-Separation Control Head. Thorough engineering of the main part of the hydraulic system minimizes scaling and leakages and results in significantly lower pressure losses in the filtrate system.

The Quick Drainage Cell design accelerates the drainage in the pan filter cell and minimizes carryover of filtrate between the filter zones. In Figure 2, the filtrate drainage of the Quick Drainage Cell and of a conventional pan filter cell is shown. It can be seen that filtrate drainage of the Quick Drainage Cell is much faster (1.1 % residual filtrate volume in the cell after 8 s) than filtrate drainage of the conventional cell (4.3 % residual filtrate volume in the cell after 8 s) which leads to significantly less filtrate carryover. Less carryover and thus less remaining filtrate achieves better washing efficiency and reduced amount of wash water/condensate. As a result, 25 % less usage of wash condensate can be guaranteed.

An optional Steam Cabin allows optimized washing and dewatering by heating of the hydrate and condensation of steam in the filter cake. Ten kilograms of steam per tonne of hydrate typically reduces the cake moisture by 1.0 – 1.5 wt% and 20 - 25 kg of steam per tonne of hydrate typically reduces the cake moisture by 2.0 – 2.5 wt%.

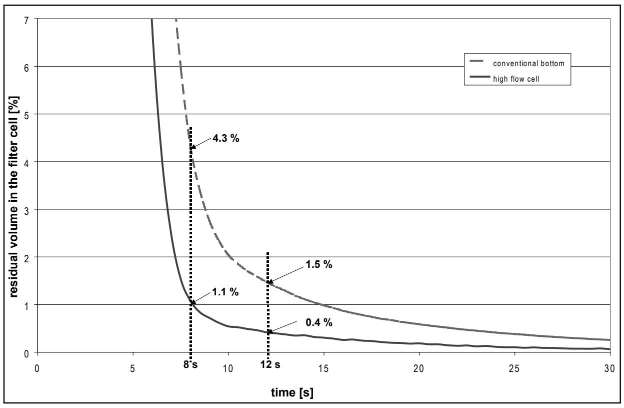

Figure 2. Filtrate drainage of BOKELA Quick Drainage Cell (high flow cell) and from conventional pan filter cell

2.2 Comparison of Pan Filter Performance

In 2007 BOKELA has performed measurements on running pan filters in two alumina refineries to compare the BOKELA pan filter with a conventional pan filter. It was the target to examine the effects of the Quick Drainage Cell design and the Pre-Separation Control Head on the wash efficiency of the pan filter. The examined filters were both new filters, installed and commissioned in the last three years, both having a counter current wash system. Differences exist with regard to design and construction of the filters and with regard to feed conditions. In order to ease comparison of both applications, the test results have been converted on the basis of the filtration theory /1/ to slurry properties as shown in Table 1 to ensure a proper comparison.

Table 1: Average values of feed slurry

x_{50}	**105 µm**
c_S	800g/l
c (Na_2O)	85g/l

2.2.1 *Cake Wash*

Figure 4 shows the soluble Na_2O-content in the product hydrate versus the wash ratio, which is the amount of wash water/condensate per ton of product hydrate. For better comparison, the figures have been converted to a soda content in the feed slurry of 85 g/L Na_2O on both filters.

Over a wide range of wash ratio, the BOKELA filter always needs 30 - 35 % less wash water. For example 0.01 % Na_2O in the cake can be reached on a BOKELA filter with 0.18 $m^3/t_{dry\ hydr.}$ while a conventional filter needs 0.29 $m^3/t_{dry\ hydr.}$. Less wash water/condensate requirement means less water in the process, less evaporation, less energy, lower operation costs and finally better competitiveness.

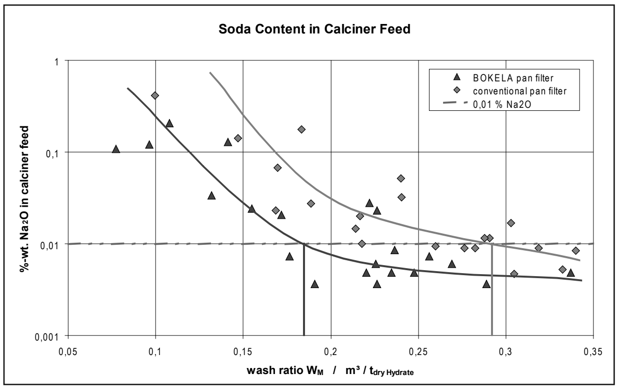

Figure 4. Soluble soda (Na_2O) content in the product at 85g/L Na_2O in the slurry

2.2.2 *Solids Throughput*

Again, for better comparison, the measured values/figures have been adapted with the filtration theory to the average values shown in Table 1 regarding the slurry throughput. Figure 5 shows the cake moisture versus solids throughput of the pan filters.

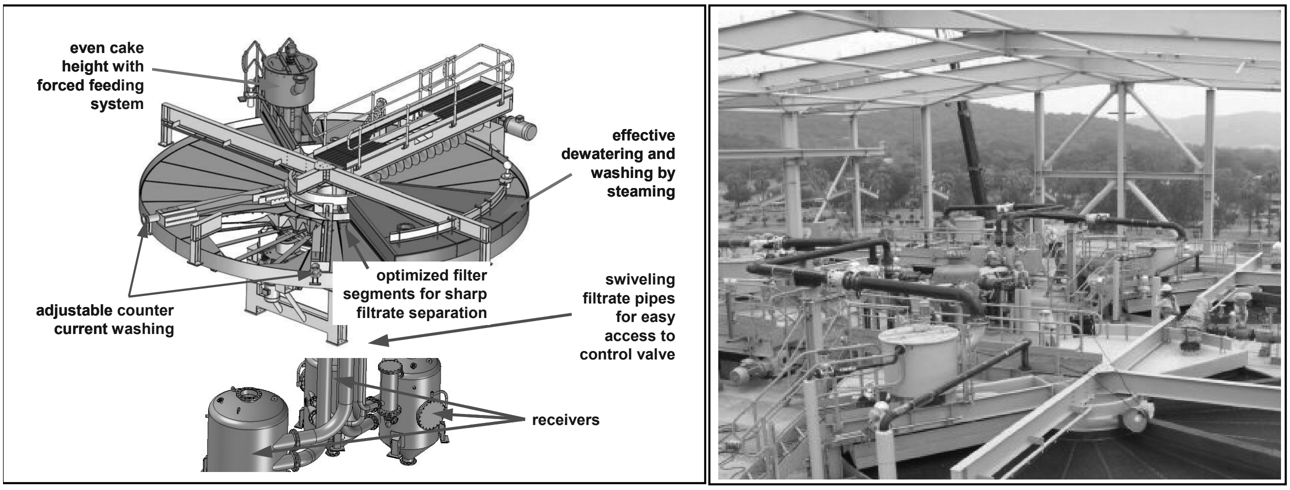

Figure 3. View of a BOKELA product pan filter

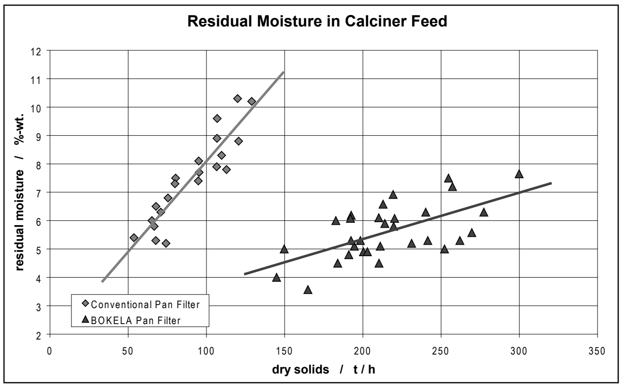

Figure 5. Residual moisture in the product on a 54m² pan filter

Standard pan filters reach 60 – 130 t/hr which corresponds with 1.2 – 2.6 t/m²/hr of specific hydrate throughput. BOKELA pan filters reach 150 – 300 t/hr which corresponds with 3.0 – 6.0 t/m²/hr. Furthermore, lower moistures after filtration have been observed on the new pan filter, which is the result of the pre-separation control head. This system reduces internal pressure losses in the filtrate system, resulting in better vacuum at the filter cloth, which is the reason for lower moisture. This lower moisture in the hydrate has the potential to increase throughput of the calciner.

2.2.3 Filter Operation and Reliability

During the comparison tests, the new generation pan filter was operating without addition of drainage aid into the wash water and without use of the installed steam cabin. The compared conventional filter could not be operated without addition of drainage aid, in order to maintain reasonable moisture in the product.

During the test work the high filter performance and operational reliability of the BOKELA pan filter has been confirmed. The filter operates at slurry throughputs of up to 350 m³/hr on a 54m² filter, maintaining the guaranteed product quality (6 % cake moisture and < 0.01 %-wt Soda), even at the lowest solids concentration in the feed slurry. Despite higher filter speed than the conventional pan filter, the BOKELA filter maintains a very stable operation with constant process data and significantly lower wash water volumes. There are no problems with scaling inside the filter pan and the minimum amount of leakage at the control head (modified control plate with labyrinth seal ring will be installed in future projects) as well as the no-leakage operation of the pan contribute to the plant safety.

2.2.4 Cost Comparison

The results of the filter operation measurements show that BOKELA pan filters achieve

- 1 – 2 wt % lower residual moistures
- lower soda content of < 0.015 wt% or less
- at least 25 % less wash water/condensate consumption
- more then double specific solids throughput

than conventional pan filters.

The following calculation demonstrates the benefits of the new pan filter generation based on a refinery output of 2 million t/a alumina, which is 3.06 million t/a hydrate. The wash water requirement to reach a soluble soda content of < 0.01 wt % is 0.18 m³/t with the BOKELA design and 0.29 m³/t with the conventional design. This results in almost 350,000 m³/a less wash water consumption. All wash water/condensate that is used has to be evaporated out of the liquor. Even if a high degree of energy recirculation (preheating and condensation) is established, there still remains a cost of about 4.2 Euro per tonne of water to be evaporated. Therefore, the saving of 350,000 m³/a wash water/condensate using the BOKELA pan filter results in a saving of almost 1.5 million Euro of operation cost per year (Table 2).

Table 2. Evaporation cost saving

	BOKELA Pan Filter	**Conventional Pan Filter**
Hydrate throughput	360 t/hr	360 t/hr
Product moisture	approx. 6 %	approx. 8 %
Na_2O in product	< 0,01 %wt	
Wash ratio	0.18 m³/t	0.29 m³/t
Wash condensate flow	64.8 m³/hr	104.4 m³/hr
Wash condensate total	567,648 m³/a	914,544 m³/a
Specific evaporation costs per t of water	4.2 €/m³ of evaporated water	
Evaporation cost (wash water)	**2,384,100 €/a**	**3,841,000 €/a**

The excellent performance of the new generation of pan filters enables significant refinery cost saving. A refinery with an output of 2 million t/a alumina can save about 1.5 million Euro per year by lower evaporation costs if the new pan filter generation is used instead of conventional pan filters.

3. Product filtration with disc and pan filters

In Figure 6, a schematic flow sheet of product filtration with disc and pan filters in series is the most advanced process design of product filtration. The first filtration step is the so-called dehydration which is performed on a disc filter. Since there is no cake washing on the deliquoring disc filter the spent liquor is obtained without any dilution.

The discharged filter cake is re-slurried with filtrate from the pan filters and then fed to the wash pan filters for final cake wash. On the pan filters a two stage counter-current cake wash is carried out. The filtrate of the second wash is used for the first cake wash and the filtrate of this first cake wash zone is used for re-pulping the cake coming from the disc filter. Thus, condensate is only used for the second cake wash. Additionally a cake treatment with steam can be performed behind the second wash zone.

The advantage of using disc filters for deliquoring is that disc filters have the highest filter area per footprint and the highest specific throughput performance which means that deliquoring can be performed with only one disc filter unit and with very small footprint even for high plant capacities of some 3 million tonnes of alumina per year (see paragraph 3.1.3). Deliquoring on a disc filter leads to an undiluted spent liquor recovery while the filter cake is re-slurried with filtrate from the pan filter. This way the pan filter feed slurry has a very low caustic content leading to improved filterability. This means that filtration and washing of the cake which is loaded with less caustic anyway is performed under better conditions. As shown in paragraph 3.1.3 consumption of wash condensate for achieving the required quality reduces to some 50% compared to the above described one-step filtration process design with pan filters. This leads to drastically reduced operation costs and makes this variant to the most feasible process design for filtration and washing of Al-hydrate product.

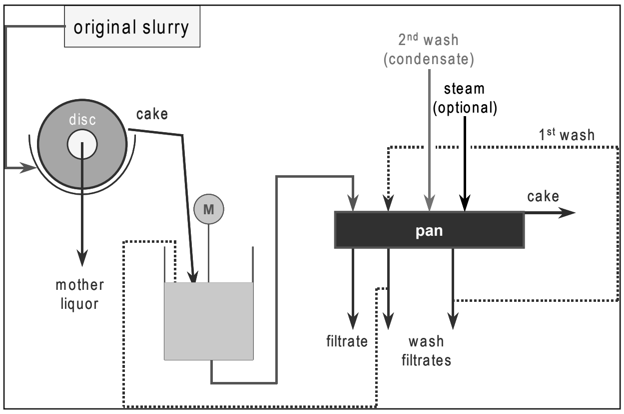

Figure 6. Flow sheet for disc-pan filter combination.

3.1 Comparison of Disc/Pan Filter with Single Stage Pan Filters

The following cost calculation for two scenarios shows the profitability of the advanced filtration and washing of Al-hydrate product with a deliquoring disc filter and wash pan filters compared to one step filtration on pan filters. The comparison is calculated for 3 million tones of alumina production per year. In Tables 3 to 5 the filter performance, operation and investment cost of both scenarios are shown. A detailed calculation is presented in /2/

3.1.1 Scenario A

Scenario A means filtration and washing of product on the one stage pan filters. The underflow of hydrocyclones is fed to the pan filters with typical feed data as follows:

- Solids content: 700 – 1,000g/L
- Caustic content as Na_2O: 150 – 170g/L
- Temperature: 55 – 65 °C

3.1.2 Scenario B

Scenario B means a two stage product filtration with deliquoring of product on disc filters and washing on pan filters. The underflow of hydrocyclones is fed to disc filters for deliquoring and the discharged filter cake is reslurried with filtrate from the pan filters. The reslurried solids are then fed to the wash pan filters for final wash. Typical feed data for the disc filters are as follows:

- Solids content: 600 – 900g/L
- Caustic content as Na_2O: 150 – 170g/L
- Temperature: 55 – 65 °C

Typical feed data for the wash pan filters are:

- Solids content: 800 – 1,000g/L
- Caustic content as Na_2O: 30 – 60g/L
- Temperature: 55 – 65 °C

3.1.3 Cost comparison of the two scenarios

In Table 3, filter sizes and performance data for pan filters of scenario A and for the disc and pan filters of scenario B are shown referring to an alumina production of 3 million tonnes per year. The required solids throughput capacity of the filters is 516 t/hr if yearly operation is 8,750 hr (Table 3).

In Tables 4 and 5, operation and investment costs of both scenarios are calculated and compared on a 3 million t/a alumina production basis. In Table 4 total annual operation and investment costs are shown for both scenarios. Table 4 reveals a significant advantage for scenario B since operation cost for scenario B range to only some 60% of total operation cost of scenario A. This cost difference of nearly 3.9 million Euros per year is effected by the much lower consumption of wash condensate which for scenario B amounts to only 50% of the wash condensate required with the pan filters in scenario A.

Table 4 also lists investment costs for both scenarios i.e. cost for filter units, engineering, building and auxiliary units. These figures show that the investment cost of scenario B are some 1.1 million Euros higher than of scenario A which is mainly caused by the higher number of spare units. While scenario A requires one pan filter spare unit, scenario B requires one pan filter spare unit and one disc filter spare unit which causes some 12% higher total investment cost.

In Table 5 the annual savings in operational costs of scenario B compared to scenario A, the additional investment costs of scenario B and the time of amortization are shown. It can be seen that according to the cost calculations of Tables 3 to 5, amortization time of the additional investment cost for scenario B is less than 4 months due to the significantly lower operation cost. For internal cost calculations, the specific cost for steam and wash condensate may differ from that in Table 4 which may effect different times of amortization. Nevertheless, the tendency of this cost calculation will be the same and not depend on some variations in steam and wash condensate cost.

Table 3. Filter sizes & filter performances

		Scenario B		Scenario A
3 Mio Tonnes Alumina per Year		DISC FILTER	PAN FILTER	PAN FILTER
filtration area / unit	[m²]	88	54	54
units in operation	[-]	1	2	3
solids throughput	[t/h]	516	516	516
cake moisture	[wt-%]	15 - 18	8	8
cake moisture with steam	[wt-%]	-	6	6
final soluble soda	[wt-%]		< 0,01	< 0,01
total power consumption (filter, blower, vacuum pump, etc.)	[kWh]	215	800	1200
operation hours	[h/a]	8.760		

Table 4. Operation & investment cost

		Scenario B		Scenario A
3 Mio Tonnes Alumina per Year		DISC FILTER	PAN FILTER	PAN FILTER
		OPERATION COST		
wash condensate (4.2 Euro/t)	[Euro/y]		3.796.934	7.593.869
steam (12 Euro/t)	[Euro/y]		1.084.838	1.084.838
operators, energy, cloth, maintenance and spares	[Euro/y]	950.000		1.040.000
total operation cost per year	[Euro/y]	**5.832.000**		**9.719.000**
		INVEST COST		
units (including stand by units)		**2**	**3**	**4**
cost for filter units	[Euro]	625.000	1.218.750	1.625.000
engineering, building, auxiliary units with pumps, blowers, piping and electrical installation	[Euro]	7.375.000		6.500.000
total investment cost	**[Euro]**	**9.219.000**		**8.125.000**

Table 5. Annual cost savings, additional investment cost and amortization of scenario B

Difference in Operation and Invest Cost of Scenario B		
Additional invest cost for scenario B	[Euro]	**1.094.000**
Annual savings in operation cost with scenario B	[Euro/y]	**3.887.000**
Time of amortization of additional invest cost for scenario B	[month]	**< 4**

4. Summary

In the last decade BOKELA introduced a new generation of rotary vacuum filters such as disc, drum and pan filters with new and innovative design. For filtration and washing of Al-hydrate product, the new pan filters achieve more then double specific solids throughput, 1 – 2 wt % lower residual moistures, at least 25 % less wash water/condensate consumption compared to conventional pan filters and lower soda content of < 0.015 wt% or less. The reduced consumption of wash condensate leads to significant cost reduction. Filtration and washing of Al-hydrate on disc and pan filters are a very promising option which is enabled by new filter technology of advanced design. Deliquoring of the product on disc filters which are much more capable of handling large filtrate streams relieves the pan filter and improves cake wash conditions. Such a process leads to improved solids purity and significant savings in operation costs which lead to very short amortization time of the slightly higher investment cost.

References

1. Anlauf H., Nirschl H. S., Werner, “Theorie und Praxis der Fest-Flüssig-Trennung ”, Institute of Mechanical Process Engineering and Mechanics, University of Karlsruhe, Germany.
2. Bott R., Langeloh T., Hahn J., ”Cost Savings by Improved Filtration and Washing of Al-hydrate Product“, TMS 137th Annual Meeting & Exhibition, New Orleans, 9 – 13 March 2008.