Design and Operation of Pan Filters at the Physical Cake Moisture Limit

Jürgen Hahn
Sales Director, BOKELA GmbH, Karlsruhe, Germany
Corresponding author: jhahn@bokela.com

Abstract

Pan filters are operated in alumina refineries for filtration and washing of Alumina Hydrate product. This vacuum rotary filter type is particularly suitable for filtration and washing of coarse particles. The main target of this separation duty is to achieve a filter cake that is dry and as free of soda as far as possible. BOKELA pan filters are operated in various alumina refineries where other OEMs' pan filters of the latest design are also operated. In such cases both technologies are processing identical feed slurries and are configured to satisfy the operator's demand for achieving soda-free product with minimum moisture content at maximum solids throughput with maximum availability. The paper discusses and reports on the pros and cons of these filters with respect to specific solids performance, wash liquor demand (cake wash efficiency and steam demand). Also examined is how filtrate solids can be minimised, and the interval between two wash cycles maximised.

Keywords: Product filtration, product washing, deliquoring, pan filter.

1. Product Filtration on Pan Filters

One of the last process steps in alumina production is the deliquoring and washing of the product hydrate. It is the aim of this filtration step to remove the liquor and the caustic which is a contaminant for the valuable alumina hydrate product. This process step is a basic prerequisite for achieving clean hydrate and a good product quality.

Filtration and washing of alumina hydrate product is usually performed on pan filters. With its horizontally arranged filtration area, the pan filter type is well adapted to the filtration and washing of coarse particles. The main objective of this operation is to achieve a filter cake that is free of leachable soda and as dry as possible. The single stage process of feeding the precipitation product (as first stage hydrocyclone underflow) directly onto a pan filter is a wide spread process design for alumina hydrate product washing. Another widespread process design is the use of disc filters for product deliquoring followed by washing of the discharged and re-slurried solids on pan filters. Product filtration on pan filters includes a two-step counter-current wash, although three counter-current wash stages can also be realised, and optional steaming of the filter cake.

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 the following wash zone, to avoid direction of higher caustic liquors to clean wash areas/filtrates.

Pan filters have been operated for decades and in the last years have undergone various design modernization measures to improve operation and process performance. In modern Alumina refineries, pan filters are often operated at the physical limit of cake moisture removal.

2. BOKELA Pan Filter Design

In recent years BOKELA has steadily modernized the design of pan filters and introduced innovative features such as the forced feeding system, fast flow cells, a pre-separation control head with up to five process zones, an effective heel re-slurry system and BOKELA FrameTrak - a completely new filter cloth fixing system. These innovations have significantly improved capacity, operation and maintenance of pan filters [1].

The special design of the BOKELA pan filter (Figure 1) consists of the following features:

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

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

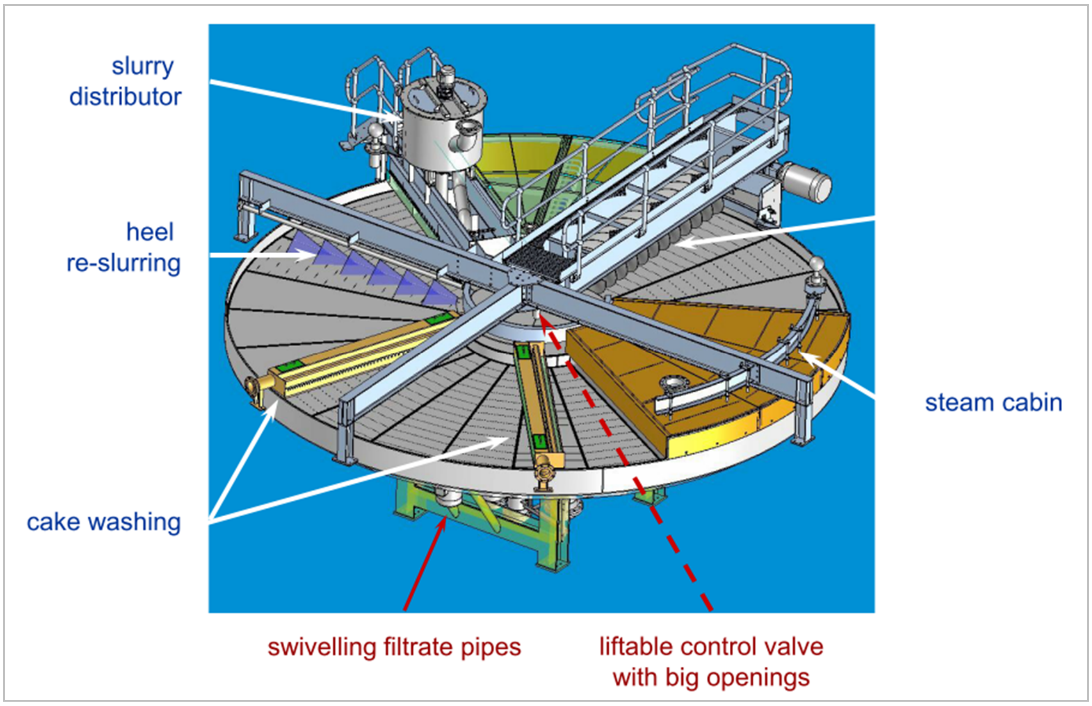

Figure 1. General arrangement of a BOKELA pan filter.

- A Pre-Separation Control Head provides for sharp splitting and fast drain of the filtrates and pre-separation of liquid and air. 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. Filtrate drainage of the Quick Drainage Cell is much faster (1.1 % residual filtrate volume in the cell after 8 seconds) than filtrate drainage of a conventional cell (4.3 % residual filtrate volume in the cell after 8 seconds), which leads to significantly less filtrate carryover. Less carryover and therefore less remaining filtrate achieves better washing efficiency and reduced wash water/condensate demand. A wash condensate reduction of 25 % 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. 10 kg 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%.
- The well manufactured discharge scroll with wear resistant flights is fixed at the top beam (no centre bearing) which achieves a minimal thickness of the remaining heel layer and consequently less recycled washed hydrate.
- The Heel Reslurry System removes the remaining heel layer from the filter cloth using an air blow impulse for breaking up the heel and a high pressure filtrate stream for mixing it up with fresh slurry. This procedure results in longer filter cloth lifetimes, 2 – 3 times longer cycles between caustic washes, and better washing of the hydrate.

These innovations have significantly improved performance and capacity of pan filters with respect to solids throughput, residual soda in cake, removal of cake moisture, as well as operation and maintenance.

3. Preconditions for low soda content and dry filter cakes

To achieve alumina hydrate that is as free of soda and as dry as possible, it is necessary that the filter cake is washed intensively and dewatered on the filter. The main preconditions for an efficient cake wash and for intensive dewatering of the filter cake can be summarized as follows:

- homogenous filter cakes with even thickness over the pan radius
- homogeneous wash water distribution
- sharp separation of filtrates without filtrate carryover into the next zone
- minimal pressure loss to ensure highest active pressure difference by:
    - optimized hydraulic system
    - minimal cloth resistance by choosing a filter cloth that is as open as possible (limited by the amount of solids passing through the cloth into the filtrate)
    - clean and open cloth (no entry resistance)
    - removal of heel (which can lead to higher amount of solids in the filtrate)

As outlined above the BOKELA pan filter has been designed to satisfy these requirements.

The forced feeding system ensures the formation of homogenous filter cakes with even thickness, the precondition for an effective cake wash with low wash liquor consumption. If the filter cake is of inhomogeneous thickness over the pan radius the wash liquor preferably flows through areas of lesser cake thickness. This leads to inefficient use of wash liquor since areas of larger cake thickness i.e. areas with a high amount of solids, remain poorly washed.

The optimized hydraulic design of the control head and the filter cells guarantee quick filtrate drainage and complete emptying of the cells. These are essential preconditions for sharp filtrate separation and an effective counter-current cake wash.

Since the control head design enables up to five process zones, the turbid initial filtrate from the cake formation period can be recirculated to the filter pan. In this way, clear filtrates are achieved and product loss through filtrate solids is minimized. This increases the options to choose the best suited filter cloth with minimal cloth resistance, and allows intensive heel reslurry and cloth cleaning.

On BOKELA pan filters the effective heel reslurry enables filter operation with very long periods between regular caustic washes. While caustic washes on pan filters operated for alumina hydrate filtration is typically required 1 to 3 times per week for 1 – 2 hours, BOKELA pan filters need a caustic wash only every 15 to 90 days. Accordingly, the operational availability is increased by 1 % to 2 %.

Figure 2. BOKELA pan filter in operation.

4. Operational results from various refineries

BOKELA pan filters are operated in various alumina refineries for filtration and washing of alumina hydrate product. Often pan filters from other OEMs also with the latest design are also operated in these refineries. In such cases both technologies are processing identical feed slurries and are configured to satisfy the operator’s demand for soda-free product with minimum moisture content at maximum solids throughput and maximum availability.

Table 1. Operational results (solids throughput, moisture content) for same feed slurry.

		BOKELA pan filter	Other OEM's pan filter
Filtration area	[m²]	68	approx. 70
Pan diameter	[m]	9.6	approx. 10
Results for identical solids throughput			
Solids throughput	[t/h]	**120**	**120**
Moisture content	[wt-%]	**5.5**	**6.5**
Wash ratio	[$m^3_{wash\ liquor}/t_{solids}$]	0.25 – 0.3	0.25 – 0.3
Leachable soda	[wt-%]	≥ 0.01	≥ 0.01
Solids in mother filtrate	[g/l]	< 2.5	1 - 5
Results for same moisture content			
Solids throughput	[t/h]	**200**	**120**
Moisture content	[wt-%]	**6.5**	**6.5**
Wash ratio	[$m^3_{wash\ liquor}/t_{solids}$]	0.25 – 0.3	0.25 – 0.3
Leachable soda	[wt-%]	≥ 0.01	≥ 0.01
Solids in mother filtrate	[g/l]	< 2.5	1 - 5

Table 1 shows operational results in terms of moisture content and solids throughput for two pan filters (one of them a BOKELA pan filter), which are operated in parallel with identical feed slurry in an alumina refinery. The conditions and requirements of this application are close to the physical limit of cake moisture removal with mechanical aids on vacuum filters.

The results presented in table 1 show that the design of the BOKELA pan filter not only achieves the required results for moisture content and solids throughput, but allows high operational flexibility over a large range of solids throughput. For the same wash ratio and the same wash results, the BOKELA pan filter achieves a 1 percent point better moisture content (5.5 wt-% against 6.5 wt-%) with identical solids throughput. In case of identical moisture content of 6.5 wt-% the BOKELA pan filter achieves about a 66 % higher solids throughput of 200 t/h. This high performance capacity leads to a higher operational flexibility in alumina hydrate product filtration.

5. Improved Filter Performance at Product Filtration by Filter Revamping

Improving the performance of product filters does not always require investment in new filter equipment with the latest design. Increasing the solids throughput, reducing the cake moisture and improving the filter cake wash can also be realized by modernisation of existing filters.

In times of short funds, the optimization of existing filters is a very economical alternative to investment in new equipment. With the BOKELA filter revamping programme, insufficient filter performance, excessive maintenance and high operating costs of existing filters can be corrected quickly and at a reasonable price.

The possibilities and benefits of a filter revamping can be summarized as follows:

- increased filtration capacity by approximately 30% up to 135% (as per assessment)
- improved cake moistures
- improved filter operation
- reduced maintenance requirements
- typical cost range between 20 % to 40 % of the investment cost for a new filter.

The BOKELA filter revamping program comprises of the following three steps: a diagnostic step, an engineering step and a realization step. The program starts with laboratory and/or plant trials performed by BOKELA to reveal the potential for increasing the filter capacity and to make proposals for targeted modifications to the filter design. If the test results and the proposed design modifications are suitably attractive, the revamping project typically starts with the upgrading of a first filter in a step by step collaborative process involving BOKELA and the equipment owner.

Table 2. Data of pan filter and slurry and operational results before and after revamping.

		before revamping	after revamping
filtration area	[m²]	41.2	41.2
pan diameter	[m]	7.3	7.3
density of slurry	[t/m³]	1.6	1.6
concentration of feed slurry	[wt-%]	51	51
solids throughput	[t/h]	116	187
increase of throughput	[%]		61
filter speed	[rpm]	0.9	1.0
heel thickness	[mm]	22	15
Cake height	[mm]	67	75
wash ratio	[$m^3_{wash\ liquor}/t_{solids}$]	0.3 – 0.4	≤ 0.3
moisture content	[wt-%]	5.6	5.0
leachable soda in cake	[wt-%]	0.03 – 0.04	≤ 0.015

Table 2 presents the results of a revamping project dealing with the modernisation of a pan filter of 1980s design operated for hydrate product filtration in an alumina refinery. According to the revamping program outlined above, filtration tests were carried out which revealed the potential for optimization, and afterwards modifications have been realized to modernize the filter design:

- implementation of forced feeding system
- new cake wash system with wash weirs
- new discharge scroll
- new heel reslurry device
- new control head.

The target of the modifications was:

- filter capacity increase of 30 %
- reduction in soluble soda below 0.02 % (no soda peaks)

The results after filter modification as presented in table 2 show that the optimized filter now runs with 60% higher throughput and lower soda content. The targets of the client were more than achieved for both solids throughput and for soda content. The cost for these optimization measures were only about 25% of the total cost of a new filter investment.

1. Acknowledgements

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2. References

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