

How Additional Vacuum Disc Filter Design Can Support Operations

Jurgen Hahn¹, Christelle Zschernitz² and André Egger³

1. Senior Manager, Product and Business Development

2, 3. Senior Manager, Sales Support

BOKELA, Karlsruhe, Germany

Corresponding author: jhahn@bokela.com

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Abstract

Vacuum disc filters are running successfully in seed filtration applications in all alumina refineries worldwide. The paper will discuss the latest developments of vacuum disc filters operated in alumina refineries. In addition to the latest process data in fine seed and coarse seed applications, the paper will provide designs and process data of two special applications.

First, the BoVac Disc Filters of BOKELA allow for seed re-slurry in an extension of the discharge chute. This is a very cost efficient and maintenance friendly opportunity especially if the seed filters are installed on top of the precipitation tanks. With a re-slurry in the filter discharge chute extension, the re-slurried seed can be guided not just in the precipitation tank under the filter, but through the connected pipe in any of the neighbour tanks. This increases availability and flexibility of the operation in combination with a minimum of extra equipment and extra cost.

Second, the BoVac Disc Filters of BOKELA have an optional design that allows for cake wash. In alumina refineries this design is used for fine seed wash. The current standard is still to wash the fine seed on drum filters that have two to three times the footprint compared to disc filters. This requires more space, bigger and thus higher CAPEX. Therefore, the ability of using disc filters for fine seed wash applications reduces both CAPEX and OPEX which is in line with reduction of energy consumption and associated reduction of the plant's CO₂ footprint.

Keywords: High Performance Disc Filter, Seed and Cake Wash, Seed Re-slurry, CAPEX Reduction, OPEX Reduction.

1. Introduction

Most alumina is produced using the Bayer Process to process bauxite and convert it into alumina and bauxite residue. This Bayer Process has several filtration steps as the following simplified process flow sheet shows (Figure 1).

Precipitation is a part of the refinery that can cover as much as six filtration steps which are:

- Product deliquoring (optional)
- Coarse seed filtration
- Fine seed filtration
- Fine seed rinse (optional)
- Fine seed wash (optional)
- Calcium oxalate filtration (optional)

The production requirement of a 1 Mt alumina refinery is about 200–400 t/h of fine seed, 1000–2000 t/h of coarse seed and 170–200 t/h of product. And many refineries produce 2–5 Mt alumina per year which results in the requirement of huge filtration areas for the duties mentioned above. The target values of all duties can be reached with vacuum filtration and do not need pressure filtration. This is beneficial to keep the OPEX low.

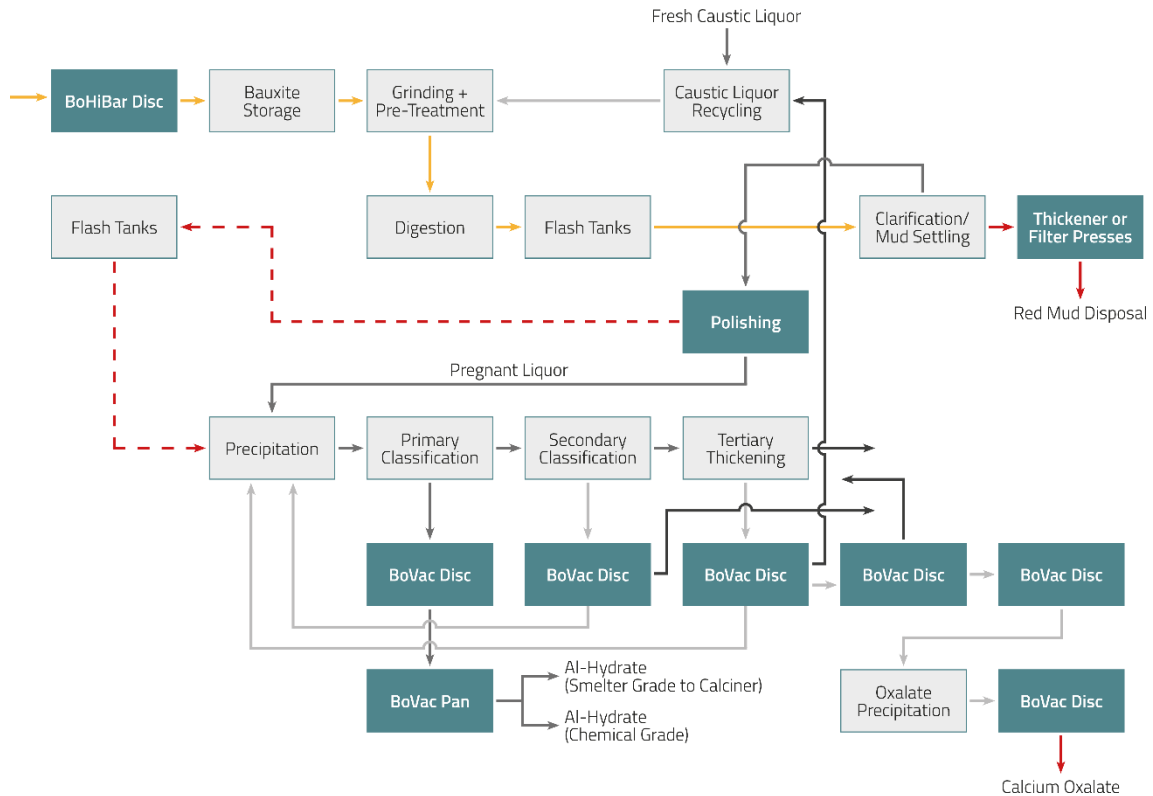


Figure 1. Simplified Bayer Process flow sheet.

From all vacuum filter types, disc filters provide the largest filtration area per unit and the highest filtration area per 1 m² footprint. This keeps the size of the filtration buildings small which results in low capital expenditure (CAPEX) if this filter type is used. Furthermore, there has been a technical development of the vacuum disc filters in the last decades. The standard design with 3.9 m disc diameter and up to 12 discs has been replaced in the 70's–90's with large diameter disc filter pushing the disc diameter to 5.3–6.0 m having a maximum of 3 discs. And finally at the beginning of the new millennium the high-performance disc filters [1] appeared on the market with disc diameters of 5.6–7.5 m and a maximum of 4 discs.

The special design features like:

- Joint single trough design (no agitator required)
- Fast exchangeable filter segments
- Pre-separation control head
- Adaptable form zone angle/vacuum
- Internal piping with low pressure losses
- Automatic operation without slurry overflow
- Online cloth wash while filter is in full production

result in:

- High speed operation (up to 6 rpm)
- Full cake discharge with low discharge pressure
- Adaptability to production requirements
- Integration in automated process control system
- Fast and simple maintenance
- Availability greater than 98 %

Because of this development, high performance vacuum disc filters such as the BoVac Disc L132 and L176 are running successfully in seed filtration applications in all alumina refineries worldwide.



Figure 2. BoVac Disc L176 on coarse seed duty

2. Coarse seed and product deliquoring duty

Typical operation data of these high-performance disc filters for coarse seed filtration and product deliquoring is listed in Table 1.

Table 1. Specific feed flow rates in coarse seed and product deliquoring duties.

Duty	Unit	BoVac Disc L132	BoVac Disc L176
Coarse seed filter feed	[m ³ /m ² ·h]	11–13	10–11.5
Coarse seed moisture	[%·m/m]	14–16	14–17
Product deliquoring	[m ³ /m ² ·h]	13–15	12–14
Product deliquoring	[%·m/m]	14–16	14–17

The figures in Table 1 clearly confirm the success of the design developments as listed above. If the solids are coarse ($d_{80} > 75 \mu\text{m}$), the high-performance disc filters separate $> 10 \text{ m}^3/\text{m}^2\cdot\text{h}$ which means that the filters with 4 discs reach $> 2000 \text{ m}^3/\text{h}$ of feed flow with a water content of the filtered seed in the range of 14–17 %·m/m.

After filtration, the coarse seed solids are mixed with pregnant liquor and returned to precipitation. In many refineries the coarse seed filters are placed in a filtration building. The filters are in the top floor and drop the solids into agitated re-slurry tanks placed at the bottom level of the building. In these tanks the solids content can be set depending on the requirement of precipitation and the re-slurried coarse seed will be pumped back to precipitation. This requires a significant amount of energy as we talk about 1500–3000 m³/h of slurry flow per 1 Mt/a alumina production. And due to the scaling nature of the slurry this line needs a standby line to allow for regular caustic cleaning. This is high OPEX and high CAPEX.

3. Re-slurry in the Filter Discharge Chute

To minimize CAPEX and OPEX, more refineries put the (coarse) seed filters on top of the precipitation tanks and drop the solids directly into the precipitation tank as shown in Figure 3. In comparison to the solution with an extra filter building, where fine and coarse seed is filtered, re-slurried with pregnant liquor and pumped back to precipitation, the on top installation is only about 60–70 % of the CAPEX.

However, the on top installation requires a solution for the situation when the precipitation tank on which the filter is positioned, needs to be taken out of service. Conveyor belts which are temporarily moved under the filter discharge are still a widespread solution. However, the reliability of the conveyor operation and the physical movement is not in line with current operation and safety standards and often are the reason for downtime and production losses.



Figure 3. Disc filter placed on precipitation tanks.

The latest mechanical design development of the high-performance vacuum disc filter allows for the re-slurry of the solids in an extension of the discharge chute. While the filter is in operation and discharges coarse seed solids into the discharge chute, pregnant liquor is added to the chute extension in an amount and volume as required to achieve a suitable solids content for the growth precipitators. The discharge chute extension ends in a pipe with a diameter suitable for the performance range of the disc filter. The pipe ends in a divider that allows to guide the flow into two different precipitation tanks. This solves the issue with the unreliable conveyor belts.



Figure 4. Disc filter with chute extension to allow for solids re-slurry.

4. Fine Seed Filtration

While coarse seed is remarkably similar in most alumina refineries, there are significant differences when it comes to fine seed. On the one hand there is the particle size that results from the split in the hydro cyclones which can range from a d_{50} of 45–55 μm to a d_{50} of 65–75 μm . And on the other hand, there is the Na-oxalate content in the solids. If the Na-oxalate content is low and does not require removal from the fine seed or is removed elsewhere, then again high-performance vacuum disc filters are used because of their huge filtration area on the small footprint [2]. The specific flow rates are in the range of 3–6 $\text{m}^3/\text{m}^2\cdot\text{h}$ feed flow with water contents in the solids in the range of 10–14 wt.%.

Na-oxalate precipitates in the form of needles with a d_{50} typically smaller than the d_{50} of the fine seed particles. This is why they accumulate in the fine seed when the seed is split in cyclones. Several producers use this fact to remove the oxalate from the hydrate. The traditional way is to filter the cyclone overflow which contains both Na-oxalate and fine hydrate in the form of solids. Ideally, the maximum amount of filtrate (spent liquor) is removed which is why the filter cake is washed in this case. Cold water is used for this wash to prevent sodium oxalate from dissolving. The right balance of wash water/condensate consumption is important as on the one hand the solids should be theoretically free of caustic to improve the efficiency in the further processing of the oxalate-containing solids. And on the other hand, wash water should not get into the filtrate (spent liquor) to prevent dilution which would increase the evaporation requirements.



Figure 5. Drum filter on fine seed duty with cake wash.

Drum filters and horizontal belt filters are the type of vacuum filters used in this fine seed filtration and wash duty. For a comparison of the different filter types, the following example and data is used:

- Plant size: 2 Mt/y alumina
- Fine seed throughput: 600 t/h
- d_{50} : 75 microns

The three filter types have the following typical design features which result in the filter sizing as described in the table below. As the disc filter has the biggest filtration area per unit and the largest area for cake formation, the number of filters in operation is only 1 unit. Horizontal belt filters require two units in operation and drum filters 3 units.

Table 2. Typical filter performance data, design figures and resulting area requirement.

	Unit	Horizontal belt filter	Drum filter	Disc filter
Area used for cake formation	%	45	28	43
Area used for cake wash	%	25	28	25
Area used for cake drying	%	25	25	20
Specific solids throughput	t/m ² ·h	3.5	2.5	3.75
Required filtration area	m ²	172	240	160
Typical filter sizes in operation	m ²	100	80	176
Number of filters in operation	-	2	3	1
Number of filters installed	-	3	4	2

The footprints of the above filter sizes are now put into a filter building including about 2 m around the filter to enable servicing and maintenance activities.

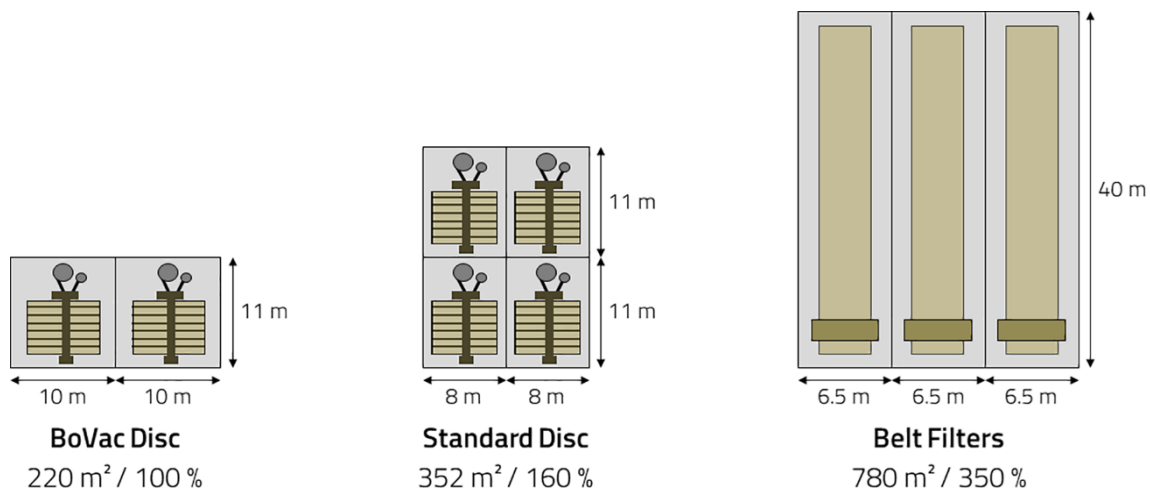


Figure 6. Footprints of the three filter options

The footprint of the drum filters is about 60 % more than the footprint of the disc filter and the footprint of the horizontal belt filters is 3.5 times the size of the disc filters. And the number of units installed is 3 horizontal belt filters and 4 drum filters versus 2-disc filters. This means less piping and cabling cost for the disc filters in comparison with the two other filter types. And finally, the specific cost per m² filtration area is lowest for the disc filters. Altogether, this results in the lowest CAPEX for the filtration building for the disc filters. The drum filter option is 40–80 % higher in cost and the horizontal belt filter solution is almost double as Table 3 shows.

Table 3. CAPEX of filter building for the three different filter options.

	Unit	Horizontal belt filter	Drum filter	Disc filter
Footprint of filters	%	350	160	100
Number of filters installed	-	3	4	2
Cost for piping and cabling	%	140	180	100
Specific cost per m ² filtration area	%	140	150	100
Filtration area installed	m ²	300	320	352
Cost for installed filters	%	119	136	100
Total CAPEX	-	160–220	140–180	100

A detailed look into the operational cost shows a similar situation. Due to the higher number of filter units in operation, the total energy requirement, the cost for filter fabrics and the spare part cost are highest for the drum filters and lowest for the disc filters as Table 4 shows.

Table 4: CAPEX of filter building for the three different filter options

	Unit	Horizontal belt filter	Drum filter	Disc filter
Number of filters in operation	-	2	3	1
Energy cost	%	125	150	100
Specific cost of filter cloth	%	140	150	100
Specific cost for spare parts	m ²	119	136	100
Total OPEX	-	125–140	140–150	100

Part of the OPEX calculation should be the amount of water that is used for cake wash and for cloth wash. And the disc filters should profit because of the lowest water consumption for cloth wash compared to the other two filter types. However, the existing data was not enough to include the water consumption into the above OPEX comparison.

In addition to the pure OPEX calculation, there is more operational demand to the fine seed filtration and wash stage. During the treatment on the filter, the Na-oxalate solids shall not dissolve, which is why cold water is used for cake wash. And the wash water shall remain in the cake and shall not go into the filtrate which limits the amount of wash water/condensate to a maximum of 0.2–0.25 m³ per tonne of hydrate. Latest developments of disc filters allow for cake wash as Figure 7 shows.



Figure 7. Drum filter on fine seed duty with cake wash

The addition of a cake wash system on a BoVac high performance disc filter is possible, because of its modular design. On the one hand discs can be added to increase the filtration area and thus the capacity. On the other hand, parts can be exchanged depending on the duty or the operation's preference:

- Polymer segments with 9.8 kg weight
- Guide rollers
- Alternative drives for adapted operation windows

and special parts can be added like:

- Cake wash system
- Solids re-slurry extension chute
- SS304 or SS316 trough to deal with high corrosive slurries

The complete cake wash system is placed on the upper frame of the filter which connects and reinforces the side walls. For cloth change the complete system can be lifted with the overhead crane. The on/off valve in the cake wash line needs to be closed and the flange to be opened and then the system can be lifted in one piece and placed into the inspection frame at the dedicated maintenance area of the filter building.

On fine seed duty the filter can wash the solids with a maximum amount 0.1–0.2 m³ wash water/condensate per ton of solids. The exact amount depends on the particle size distribution, the amount of Na-oxalate and the portion < 25 µm. One ton of hydrate has a volume of 0.41 m³. The porosity of a fine seed cake is in the range of 0.45–0.5. This means that a filter cake with 1 t hydrate has a void volume of 0.37–0.41 m³. With a maximum of 0.2 m³ wash water used for the cake wash, only half of this void volume gets filled with wash water. Therefore, the risk for water breaking through into the filtrate is minimal which nicely fulfils the wash duty.

The filter cake with oxalate and hydrate solids is re-slurried in a low caustic liquid to dissolve the sodium oxalate as oxalate dissolves fast in hot water. Then this slurry with the oxalate in the liquid phase is filtered again on disc or drum filters reaching specific feed flow rates of 5–10 m³/m²·h. After discharge, the fine seed filter cake is re-slurried with pregnant liquor and returned to the precipitation agglomeration section or the filters are on top of the agglomeration tanks as already described in the Chapter coarse seed filtration. The separated liquid goes for further treatment to the oxalate separation.

The challenge of the fine seed filtration is the high filtration resistance of the fine solids especially with high oxalate content. Filters with high quality cake discharge [3] are required. Furthermore, the filter cloth blinding due to oxalate is an issue. Therefore, the fine seed filters require efficient cloth wash with low penetration of condensate into the process liquid. The BoVac high performance design has cloth wash sprays located under the cake deflectors as shown in Figure 8 below. This allows for cloth wash while the filter is in full production. And the duration and frequency of cloth wash can be set in the automatic filter control system.



Figure 8. Cloth wash on BoVac Disc filters.

Finally, the filter should allow for maximum filtrate removal with minimum cake wash. All this supports the use of disc filters which are taking over as state of the art from drum filters in this duty.

5. Conclusion

Vacuum disc filters are running successfully in seed filtration applications in all alumina refineries worldwide. Especially, the development of the high-performance design at the beginning of this millennium with disc diameters of 5.6–7.5 m and a maximum of 4 discs solidified the leading position of this filter type. The special design features like joint single trough design (no agitator required), fast exchangeable filter segments, pre-separation control head (minimum pressure losses), adaptable form zone angle/vacuum, internal piping with low pressure losses, automatic operation without slurry overflow and online cloth wash while filter is in full production have resulted in high speed operation (up to 6 rpm), full cake discharge with low discharge pressure (25–45 kPa), adaptability to production requirements, integration in automated process control system, fast and simple maintenance and an availability of > 98 %.

Further developments in the last years are the additional chute extensions that allow for the solids re-slurry in these chute extensions. This supports the 30–40 % less CAPEX solution which puts the filters on top of the precipitation tanks. The pipe outlet of the re-slurry chute allows for connection with different precipitation tanks and solves the issue how to manage operation and cleaning of precipitation tanks.

Finally, the option of adding a cake wash system to the high-performance disc filters enable the use of these filters in fine seed wash duties. This is a further opportunity to reduce CAPEX by 30–50 %, if disc filters can be used instead of drum filters or horizontal belt filters which both require bigger filter buildings. Additionally, also OPEX is 20–30 % less with the use of disc filters. If all seed filtration duties are performed with only one filter type, this simplifies maintenance activities and spare part stocks.

6. References

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