Hydrocycloning Technology Contribution to Productivity Improvement through Fines Loss Recovery and Seed Classification

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Abstract

Since 1978, AKW Equipment + Process Design high performance polyurethane based hydrocyclones, type AKA-VORTEX, have been successfully installed and used in more than 50 alumina refinery projects. With the alumina industry returning to growth after a challenging market period, key players have understood that a successful come-back requires first a careful and thorough look into their overall production process, with a focus on productivity improvement:

- By increasing the product discharge, at same input capacity,
- By increasing efficiency through higher recovery rate,
- By minimizing losses of valuable materials from usual discharge streams.

If the first 2 productivity improvement levels are already well established, recently, a particular focus was put on the recovery of fines lost throughout the various liquor streams of the alumina plant. This aspect on which limited attention had been put on in the last decades, now raises more attention, with AKW Equipment + Process Design offering unique process solutions to make it an opportunity. The recovery principle of such losses, characterized by low alumina content and specific size range of particle size distribution (PSD), will be presented on the basis of a selected example.

Keywords: Alumina refinery, alumina classification, hydrocyclones, seed classification, fine loss recovery.

1. Background of AKW Equipment + Process Design / AKW Apparate + Verfahren GmbH ("AKW A+V")

AKW A+V is a medium-sized, privately owned company focused on process engineering and equipment supply, as well as on plant engineering, construction and service for mineral processing plants. Since the year 1833, kaolin, feldspar and silica sand have been processed in the area around Hirschau/Germany. This is where AKW A+V was founded in 1963, initially as a research department of the mining company Amberger Kaolinwerke. Since the early beginnings, innovations, new product ideas and technologies have been key drivers, which have now turned the company into a global operating enterprise with headquarters in Hirschau (Bavaria, Germany), and with offices in Kiel, Moscow, Shanghai, São Paulo, Dubai and agencies in many other countries. With the aim to increase the wide-ranging service capabilities, improve the customer satisfaction and provide the best solution for each individual application, AKW A+V opened in the year 2011 a new and enlarged technical test center. This test center (and warehouse), arranged on an area of approx. 900 m² right next to the headquarters, is equipped with a full range of process equipment, ensuring effective test work and allowing the characterization and development of almost all sort of processing steps. Combined with measurement capabilities (3D digital microscope, XRF system, laser particle size analyzer), small scale up to pilot tests can be organized and fully handled out of one place.

Figure 1. (a) Test center and warehouse; (b) Test center extract from the main hall.

2. Introduction

The Bayer process is constantly evolving and the specific techniques, employed in this highly sophisticated industry, for the various steps of the process do not only vary from plant to plant, but also are often held as trade secrets. As a more detailed, but not comprehensive, description of the Bayer process, the ground bauxite ore is fed as an aqueous slurry, typically prepared with spent liquor and added caustic, to a series of digesters, where about 98 % of the total available alumina is released from the ore as caustic-soluble sodium aluminate. The digested slurry is then cooled. The aluminate liquor leaving the flashing operation contains from 10 to about 20 w.-% insoluble solids.

This clarified sodium aluminate liquor, also referred to as "green liquor", is a hot caustic liquor, generally containing the highest values of dissolved sodium aluminate. Sodium aluminate-containing liquor is kept at elevated temperatures during the beneficiation steps so as to retain its high values of dissolved sodium aluminate. It is charged to a series of precipitation tanks, and almost always seeded with recirculated fine particle aluminium trihydroxide crystals. In the precipitation tanks it is cooled under agitation to induce the precipitation of alumina from solution as aluminium trihydroxide. The fine particle aluminium trihydroxide crystal seeds act as crystal nucleation sites for this precipitation process. Aluminium trihydroxide crystal formation (the nucleation, agglomeration and growth of aluminium trihydroxide crystals), and the precipitation and collection thereof, are critical steps in the economic recovery of aluminum values by the Bayer process. Bayer process operators strive to optimize their crystal formation and precipitation methods so as to produce the greatest possible product yield from the Bayer process while producing crystals of a given particle size distribution. A relatively large particle size is beneficial to subsequent processing steps required to recover aluminum metal. Undersized aluminium trihydroxide crystals, or fines, generally are not used in the production of aluminum metal, but instead are recycled for use as fine particle aluminium trihydroxide crystal seed. The state of the art technique to separate the coarse particles as product and the fine particles as seed (coarse and fine seed) utilizes hydrocyclones.

3. AKA-VORTEX – The special Polyurethane Hydrocyclones for the Alumina Industry

Hydrocyclones are important and economically viable systems for the wet-mechanical separation and classifying processes of ores and minerals. Capitalizing on more than 50 years of own development, AKW A+V hydrocyclones (AKA-VORTEX brand) demonstrate a mature construction, compact design and are also continuously improved.

Over the time, AKA-VORTEX polyurethane based hydrocyclones have shown significant advantages with regard to their key design features, as follows:

- Highly wear-resistant, leading to outstanding product life time
- Very even and smooth inner surface, improving the separation efficiency
- Light weight
- Different material qualities, allowing to cater for specific requirements:
  - Hardness possibilities ranging from 50 – 90 Shore A
  - Heat resistance up to 100 °C
  - Pressure resistance up to 3 bar without need of metal cover
- Optimum separation characteristic at varying operation parameters
- Special flange system to connect the different hydrocyclone sections
- Easy maintenance owing to the low number of single sections of the hydrocyclone and no gaskets
- Easy detection of wear and blocking, by use of a lamp torch
- Modular system through the use of simple connectors and adaptors (feed part, overflow and underflow nozzle)

The modular arrangement principle makes the AKA-VORTEX flexible and adaptable to different operation conditions. By combining more than 3.000 different types of hydrocyclone sections into various modifications, different results on flow rate, capacity, pressure loss and cut size (typically expressed as d50) can be reached.

This is shown on Figure. 2 on one exemplary hydrocyclone AKA-VORTEX.

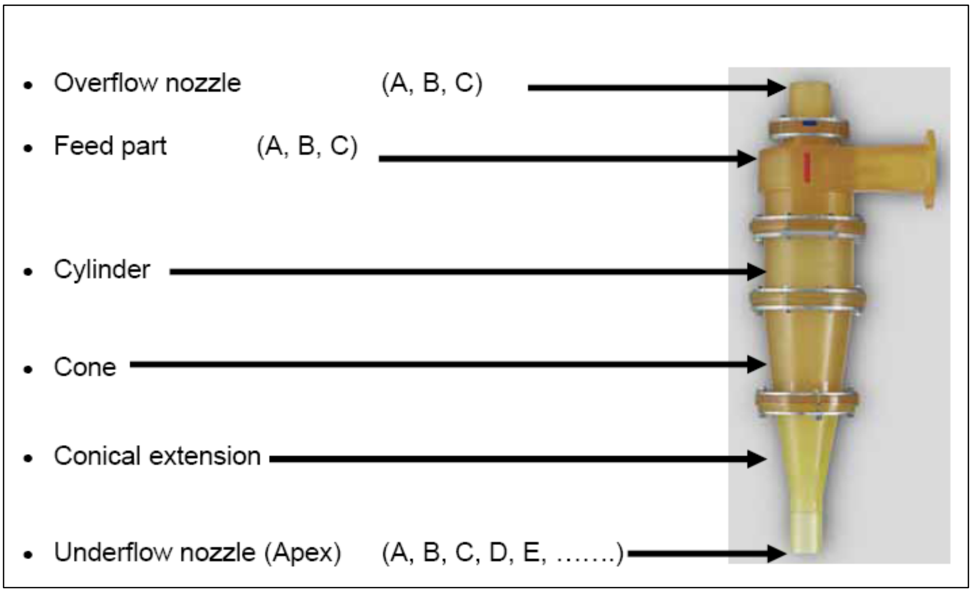


Figure 2. Different sections of AKA-VORTEX hydrocyclone.

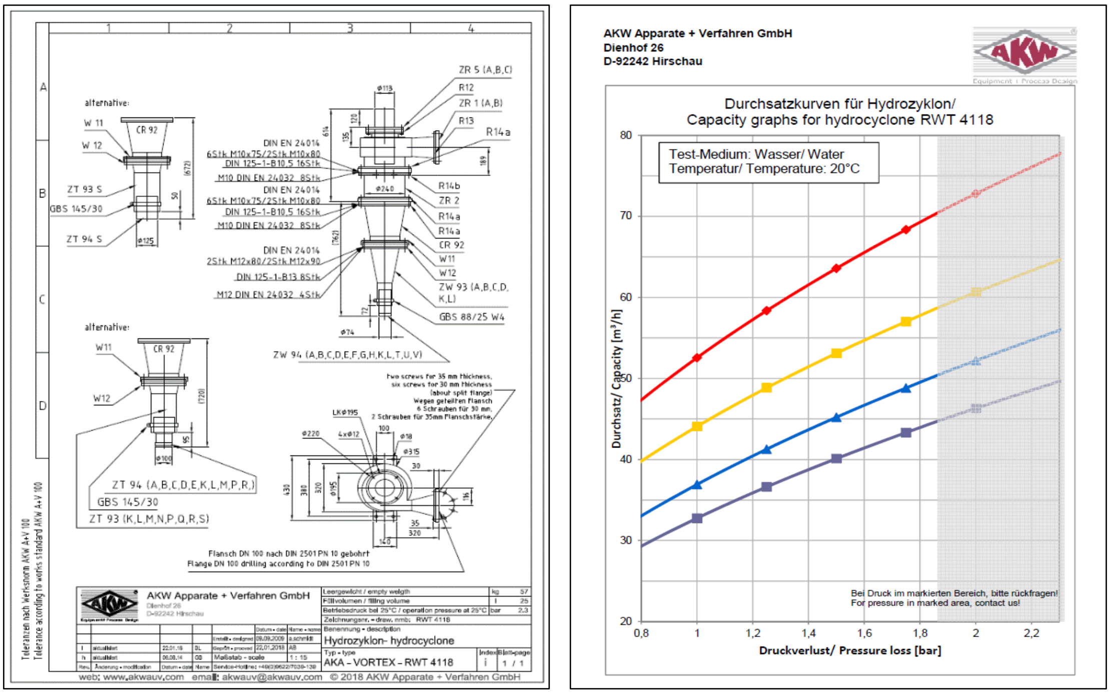


Figure 3. (a) Referring installation drawing; (b) Referring capacity curves (m³/h) vs. Δp (bar).

3.1. AKA-VORTEX Hydrocyclones Product Range

The conical hydrocyclone with its rotational flow generated by pump pressure, is a separation device which has been in use in process and preparation technologies for a long time. However, due to the wide range of specific raw materials and solids that have to be treated, AKW A+V product range developed over time and nowadays consists of different geometric types:

- **Conical hydrocyclone**
- FLAT-bottom hydrocyclone
- **TWIN-hydrocyclone**
- Hydrocyclone with gritbox
- Hydrocyclone with PU liner
- Special hydrocyclones (cast steel, ceramic lined, canister type)

3.2. Polyurethane TWIN-Hydrocyclones

The TWIN-hydrocyclone is a combination of two single hydrocyclones, connected by the mean of a proprietary designed TWIN feed part. Such TWIN feed parts are available for the 100 mm, 150 mm and 200 mm diameter TWIN-hydrocyclones. This special hydrocyclone was developed to minimize the investment costs as a result of the reduction in the number of valves requested (and more generally of all functional parts), the optimization of the quantity of steelwork required, and the overall space saving (optimized footprint). The TWIN-hydrocyclone works in the same way as a single hydrocyclone, but with a doubled feed capacity. In Figures 4 and 5, the principal of the TWIN-hydrocyclone is shown.

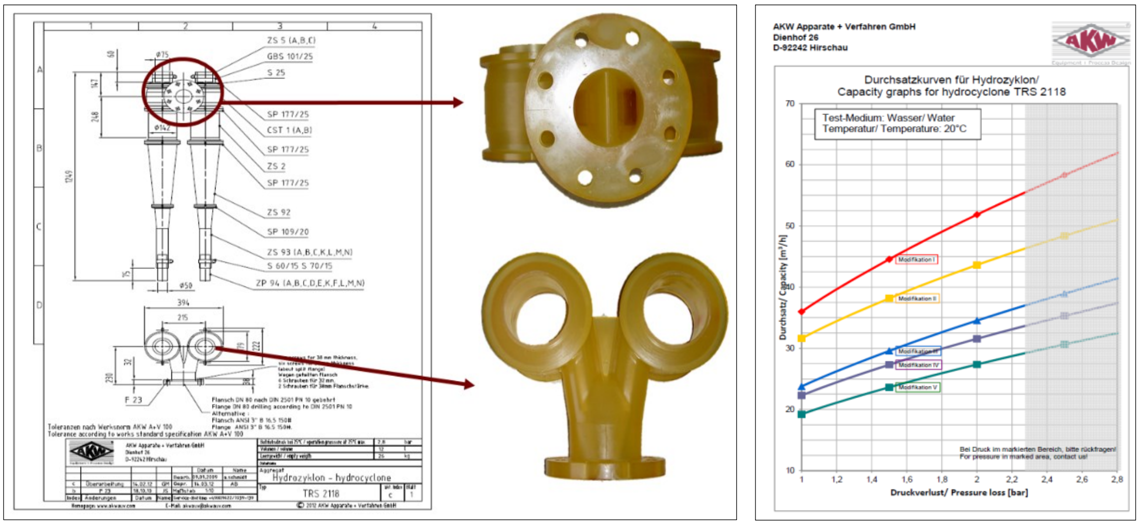


Figure 4. (a) Installation drawing TWIN-hydrocyclone; (b) Capacity curve.

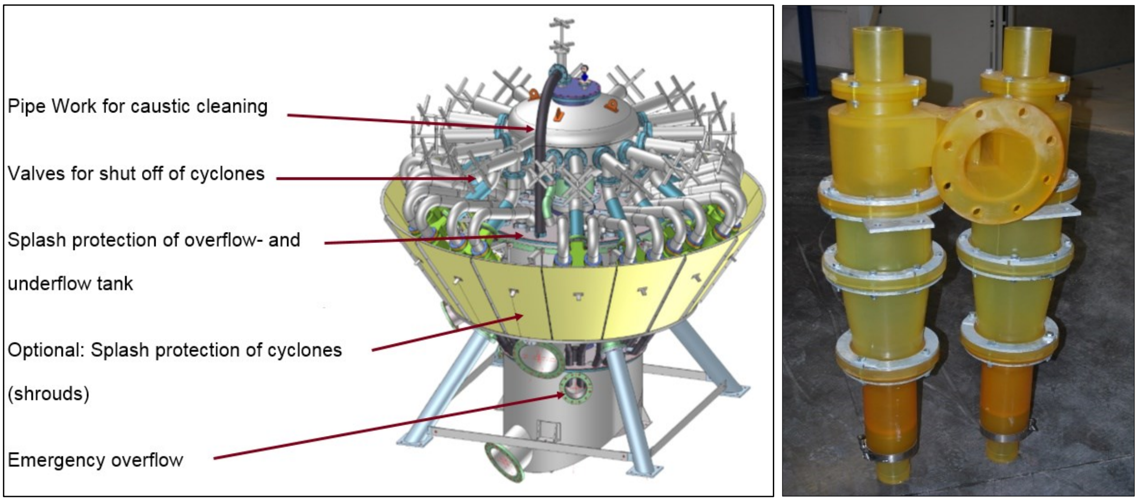


Figure 5. Exemplary cluster design equipped with the unique TWIN-hydrocyclone version.

4. Alumina Refinery Specials

The challenge to any alumina refinery is to maximize the production of alumina and minimize the energy costs per ton of alumina. In the operation of an alumina refinery there are a large number of interacting processes and conditions that may cause frequent disturbances which sometimes can results in a chain reaction. As a result, a steady-state operation is difficult to attain, and the refinery, quite often, does not run at its optimal operating conditions. All equipment used in the refinery should be able to operate satisfactorily, even with considerable fluctuation of the process parameters.

But due to the fact, that all the function of the equipment is based on basic principles, there are some limitations which have to be considered for the design of a plant and its equipment as well as for the operation. Some limitations for the operation of hydrocyclones are discussed in the following. In principal there are 4 applications for hydrocyclones inside an alumina refinery.

- Desanding of digested slurry : to unload the thickeners and remove undissolved particles
- Product classification : the so-called sandy alumina

- Seed classification
- Fines loss recovery

In this paper, the focus is on what is generally called the “hydrate classification” stages that comprise the last 3 points.

Hydrocyclones have been used in the past either in parallel or series with settlers. The process target was the optimization, debottlenecking and expanding of existing plants. Later on, modern Greenfield plants started to incorporate hydrocyclone clusters in hydrate classification, to eliminate the use of settlers as classifiers. And lately, hydrocyclone clusters were further implemented as a mean to recover the fines from various liquor streams, that used to be lost or unnecessarily recycled before.

Standard type hydrocyclones diameters for hydrate classification have a range from 100 mm up to 325 mm. The smaller cyclones with 100 mm – 200 mm nominal diameter are used for seed classification and fines loss recovery, while the bigger cyclones with 200 mm – 325 mm are used for the product classification (sandy alumina).

4.1. Product Classification

The main driving force for the use of hydrocyclones as product classifiers is the product requirement of the aluminium smelters (Electrolysis). The well-known term of “Sandy Alumina” describes an aluminium oxide with a minimum content of fine particles -45µm. A typical composition of a “Sandy Alumina” is given in Table 1.

Table 1. Typical composition of sandy alumina.

Physical Properties	% - Min.	% - Max.	% - Typical
+ 150 µm (+ 100 mesh)	n.a.	15.0 %	3 %
- 45 µm (-325 mesh)	n.a	10.0 %	5 %
- 20 µm (- 635 mesh)	n.a.	1.5 %	< 1.5 %
Attrition Index		20.0 %	< 20.0 %
BET	60.0	80.0	

To achieve a sandy alumina with a 6 – 8 % content of particles -45µm, it is necessary to feed the calciner (nowadays normally fluidized bed calciner) with a classified hydrate product with at least a content of particles -45µm ≤ 4 %, as some attrition and breakage of hydrate/alumina inevitably takes place in the calciner.

This target generally should be achieved with a “high” solids content of the feed and should be constantly guaranteed also with fluctuations in the amount of fine particles. The feed parameters for hydrocyclone clusters are in the range of:

- Solids content of feed: 400 – 500 g/L
- Amount of particle -45µm: 6 – 20 % w/w

The efficiency of classification and therefore the amount of particles -45µm in the product (underflow) is influenced (besides the geometry of the hydrocyclone itself) by:

- PSD of the feed
- Solids content of the feed
- Number of stages
- Pressure drop
- Achievable solids content of the underflow

4.2. Seed Classification

Generally it can be stated that an increased concentration of solids in precipitation increases the generation of fines in the circuit. A high concentration of solids with fine particle size results in better conditions for precipitation productivity. Three major crystallization mechanisms: nucleation, growth and agglomeration of crystals, are in interplay when producing gibbsite (aluminium trihydroxide) as the preferred phase. The yield of gibbsite is largely determined by nucleation and growth of particles, while agglomeration is responsible for producing a coarse crystal of commercial interest. Optimization of the Bayer plant precipitation parameters is the most important part of the entire industrial process. However optimum conditions for maximum yields does not always coincide with the optimum product size specifications, demanded by the smelters. The target of a modern plant concept is to operate under optimum conditions and remain within the product size specification range. The operation of a secondary hydrocyclone stage to get a coarse and fine seed is a technically feasible solution for this target.

4.3. Concept

The basic concept consists of a two stage operation. The primary stage is producing the product as underflow of the cyclones. The secondary stage is fed with the overflow of the primary stage and the by-pass of the precipitator. The target of the basic concept is:

- To achieve a product of 2 % ≤ 45µm with only one primary stage, with a minimum tolerable amount of -45µm in the feed of approx. 6 %

The maximum tolerable feed concentration for the primary stage is about 350 g/L, which requires the dilution of the precipitator outlet by adding filtrate to the feed. The overflow of the primary stage plus the complete by-pass from the precipitator is fed to the secondary stage. The feed concentration for the secondary stage should not exceed 500 g/L .

The process parameters of this two stage process can be summarized as:

- Feed: 5800 m³/h liquor with 94 % +45µm
- Product: 600 t/h
- Seed: 3600 t/h (80 % coarse seed, 20 % fine seed)

The equipment of this process would be:

- Primary Stage: 3+1 ZVN/D 15-30, with 15 TRT 4118 II (TWIN Type)
  Feed pressure: 150 kPa
- Secondary Stage: 6+2 ZVN/D 15-30, with 15 TRT 4118 IV (TWIN Type)
  Feed pressure: 155 kPa

The resulting flow sheet is shown in Figure 6.

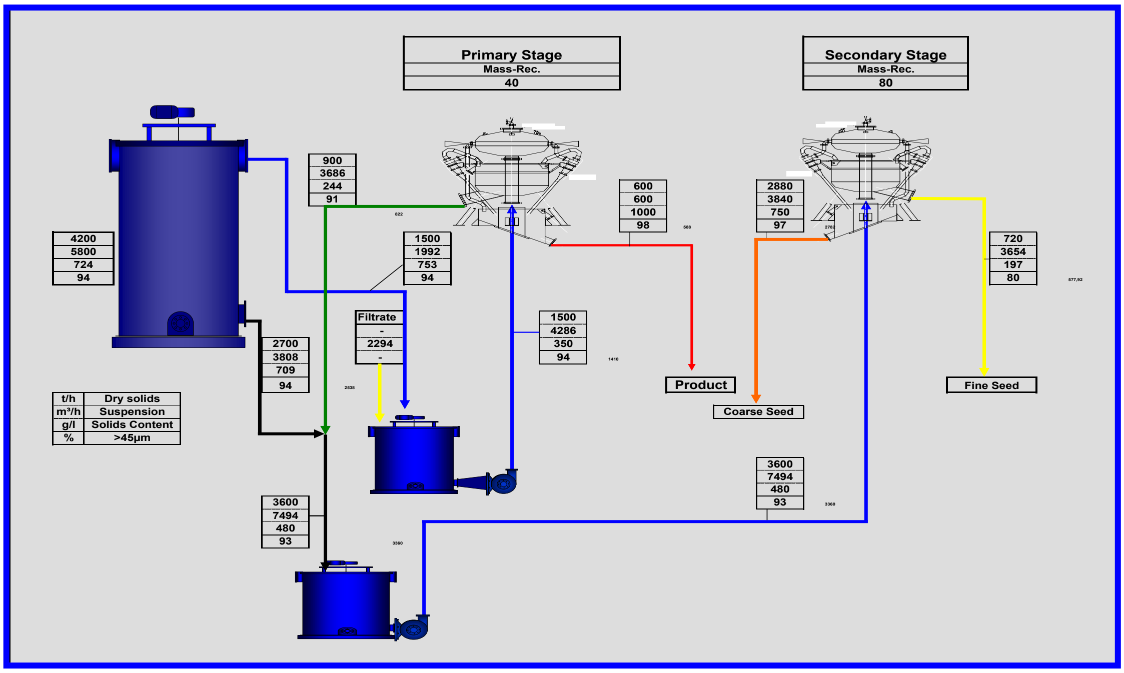


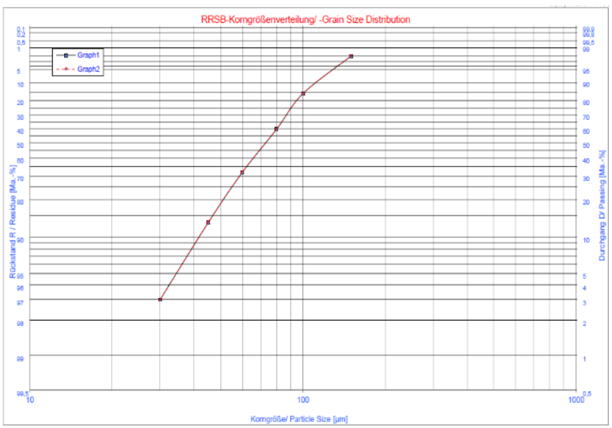
Figure 6. Flow sheet.

5. New Demand for Fines Loss Recovery

In 2017, AKW A+V was contacted by an alumina refinery to investigate how to maximize the recovery of fine hydrate left in the product filtrate in an existing installation. Indeed, primarily due to damaged filter cloths that are not detected or changed early enough, noticeable amounts of hydrate particles are lost to the filtrate. In order to improve the overall yield of the operations, a growing interest is being put on these "losses" in order to limit them and recover the valuable material that it contains.

According to the situation at the given alumina refinery, the solids content in the filtrate was indicated to be varying from 1 g/L up to 15 g/L, hence highlighting fairly low concentration ranges for hydrocycloning operations.

The target in this project was to install hydrocyclones in order to recover the hydrate particles from the filtrate that are > 30 µm, on the basis of a filtrate flow rate varying up to 1500 m³/h.



Exemplary PSD	
µm	**passing**
30	3,0%
45	13,2%
60	32,0%
80	59,7%
100	84,3%
150	98,0%

Figure 7. (a) Exemplary PSD table; (b) Exemplary PSD as RRSB graph.

The indicated PSD, presented in Figure 7, showed approximately 3 % of -30µm and ranged up to 98 % of -150µm.

It may be expected that at the low solids content in the filtrate, the recovery of hydrate particles would be low, and consequently would generate an impact on the overall yield of the alumina refinery operations!

In order to determine the best hydrocyclone dimensioning and specification, test work on site with fresh filtrate was necessary (Figure 8). As such, a series of test runs with varying filtrate conditions and different hydrocyclones specifications were executed and evaluated.

The test runs were primarily executed with the following hydrocyclone sizes:

- 200 mm diameter AKA-VORTEX hydrocyclone
- 150 mm diameter AKA-VORTEX hydrocyclone
- 100 mm diameter AKA-VORTEX hydrocyclone

Due to the low concentration, and hence no hindering of the fines together with the coarse towards the outer wall of the hydrocyclone, some separation effect could be reached already with the 200 mm hydrocyclone. However, the resulting range of solid recovery rate varied widely, from 30 to 70 %, for a volume split set at > 90 %. With the 100 mm hydrocyclones, the best and expected results could be achieved, with a solid recovery rate of significantly > 90 %, and a volume split adjusted to > 90 %.

Figure 8. (a) Test hydrocyclone on site; (b) Sampling whilst the test run.

The filtrate flow rate of up to 1500 m³/h which needed to be treated by the selected hydrocyclone, gave the basis for the specific distributor design. For this task, different solutions were elaborated and discussed with the customer, so as to be able to fit into the existing plant lay out.

The final choice involved a TWIN-hydrocyclone type (TRT/S 2120), with 100 mm diameter and a "long version" (Figure 9). The choice of the "long version" compared to the standard version, which consists of the addition of a cylindrical section, was motivated by the concern to ensure a longer retention time of the slurry in the hydrocyclone, so as to optimize the solid recovery rate at such low concentration levels.

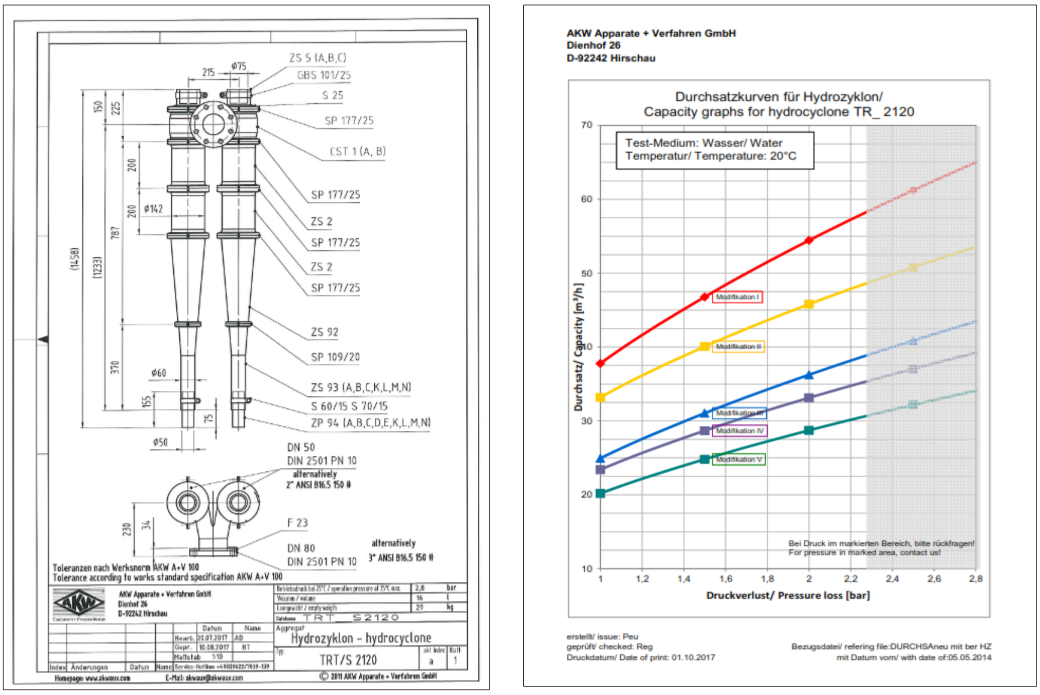


Figure 9. (a) AKA-VORTEX TWIN type TRT/S 2120; (b) Capacity curves TRT/S 2120.

On the basis of this hydrocyclone selection, a special design for the cluster was developed in cooperation with the operation specialists of the mentioned alumina refinery. The cluster design based on the required capacity results in a hydrocyclone distributor, named ZVI/F 8 combined with 8 TWIN Type TRT 2120 as shown in Figure 10.

Figure 10. Cluster design AKA-SPIDER, equipped with AKA-VORTEX TWIN type TRT/S 2120.

6. Conclusion

Although the alumina refinery constitutes a mature industry, opportunities for improvement are still existing, especially for process equipment that can offer flexibility and versatility. As such, the hydrocyclones constitute a solution of choice. As alumina refinery engineers identify weak points into their process that can lead to significant loss of valuable materials, they should consider addressing these issues with hydrocyclone suppliers that are able to highly customize their solutions in order to address at best those specific issues. To this, the high modularity of the high-performance polyurethane based hydrocyclone from AKW A+V has shown to be of great advantage. The recently gained project references in the specific field of fines loss recovery are opening a new chapter for AKW A+V hydrocyclone activity in the alumina refineries.

7. References

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