

## Hydrocyclones Productivity Impact in the Alumina Industry

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### Abstract

Alumina ( $\text{Al}_2\text{O}_3$ ) is an important and elementary raw material for numerous industrial applications ranging from construction to filling materials, abrasives and catalysts. It is calcined from aluminium tri hydrate  $[\text{Al}(\text{OH})_3]$ , smelted to produce metallic aluminium which is casted in different forms and shapes as per the end user industry.

The challenge to any existing or new designed alumina refinery is to maximize the production recovery of alumina out of bauxite ore and minimize the energy costs per ton of alumina. Hydrocyclones AKA-VORTEX and distributors AKA-SPIDER, arranged as primary and seed distributors, constitute essential elements of the overall manufacturing process for the treatment of the aluminium tri hydrate  $[\text{Al}(\text{OH})_3]$  under challenging conditions of hot caustic soda slurry. These wet mechanical process solutions are used in the classification step of the aluminium tri hydrate crystals, to get the coarse (sandy) particles as the pre-product for the alumina ( $\text{Al}_2\text{O}_3$ ), and the finer particles as the seed to reuse for the precipitation process.

An explanation of the installation and operation of such highly specialized hydrocyclone systems designed and installed in a green field project at a major alumina refinery group, will be presented.

**Keywords:** Alumina refinery, Aluminium tri hydrate classification, Hydrocyclones, Distributors.

### 1. General Information on Alumina

The industrial production of aluminium is still based on a two-stage process that was introduced in principle more than 100 years ago:

- In the **alumina refinery**, the Bayer Process is used to produce alumina as an intermediate product from the bauxite raw material.
- In the smelter, the aluminium oxide dissolved in a cryolite melt is reduced electrochemically to metal (electrolysis according to the Hall-Héroult method).

In the operation of an **alumina refinery** there are large number of interacting processes, leading to frequent disturbances which sometimes act as a chain reaction. The challenge of any alumina refinery is to maximize the production of alumina and minimize the energy costs per ton of alumina. As a result, a steady-state operation is difficult to attain, and the refinery in general, does not run always at its optimal operating conditions [4].

All equipment used in the refinery should able to be operated satisfactorily, even with considerable fluctuation of the process parameters. But, due to the fact that all the function of the equipment is based on physics, there are some limitations which have to be considered for the design of a plant as well as for the operation. In this respect AKA-VORTEX hydrocyclones and AKA-SPIDER distributors, arranged as primary and seed distributors, constitute essential elements of the reliable overall manufacturing process for the treatment of the aluminium tri hydrate  $[\text{Al}(\text{OH})_3]$  under challenging conditions of hot caustic soda slurry.

The importance of a satisfactorily running alumina plant can also be seen in the high demand and the corresponding production of alumina over the last decade, presented in the following chart, Figure 1.

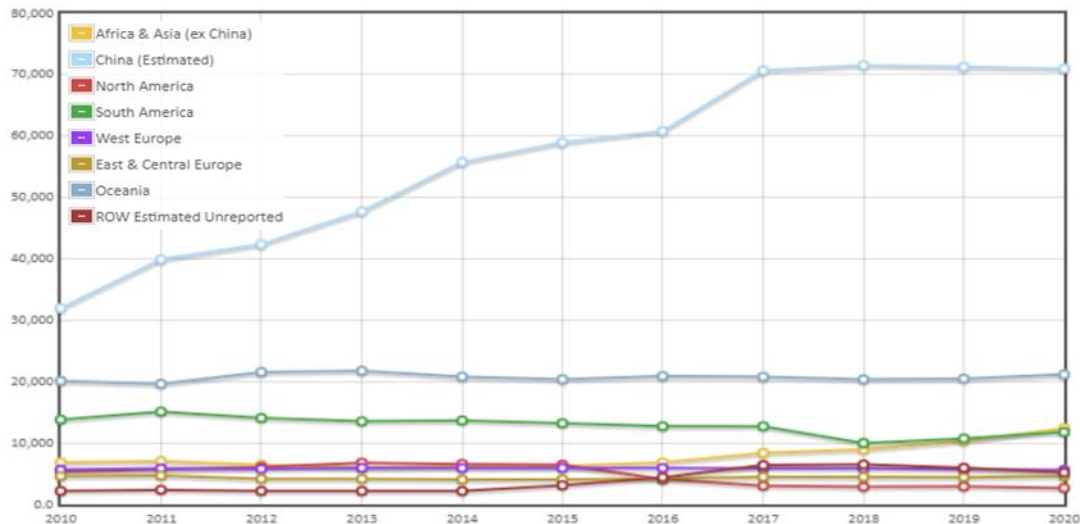


Figure 1. Alumina production 2010–2021 [1].

The total alumina production of 1,284,167 thousand metric tonnes is the quantity of aluminium oxide tri hydrate produced from 2010-2021 and expressed as 100 %, nominal aluminium oxide ( $\text{Al}_2\text{O}_3$ ) equivalent, irrespective of further processing. Total alumina production figures have two components, that to be used for:

- the production of aluminium (metallurgical grade alumina)
- any other purpose (chemical grade alumina)

## 2. Overall Process and Integration of AKW A+V Equipment

The production process for aluminium starts with the mining of bauxite ore. Layers of bauxite are typically found near the surface, so it is generally extracted through open cast mining. Around 90 % of the world's bauxite resources are in tropical and sub-tropical regions.

The bauxite main chemical form is  $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$  or  $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$  and it mainly consists of impurities such as sand, ferric oxide, titanium oxide. The extracted bauxite is treated further using the well-known Bayer Process.

In the following, the overall process procedure to produce aluminium is presented.

- **Crushing:** Crushing down to 10 mm
- **Grinding:** Grinding take place with hot caustic soda
- **Digestion:** Conversion of impure bauxite to sodium aluminate (supersaturated solution)
- **Clarification:** Bauxite residue settles at the bottom and is washed and filtered prior to disposal
- **Precipitation:** Conversion of sodium aluminate to aluminium hydroxide (filtered liquid is cooled down and treated with seed crystals (aluminium hydroxide))
- **Hydrocycloning:** For the removal of fine aluminium hydroxide crystals
- **Filtration:** Aluminium hydroxide crystals are filtered to separate them from the caustic liquid

- Calcination: Conversion of aluminium hydroxide to pure alumina
- Smelter: White powder alumina is smelted by large amounts of electricity to be converted into molten aluminium using the Hall-Héroult process
- Casting: The molten liquid is casted in different ways, e.g.: Open mould ingot casting: Ingots are used to produce car wheels, engine blocks and other automotive parts.

The bold marked part of the process shows the process step where AKW A+V hydrocyclones and distributors with its proven technology are integrated and guaranteeing the best performance of aluminium hydroxide classification as highlighted in Figure 2.

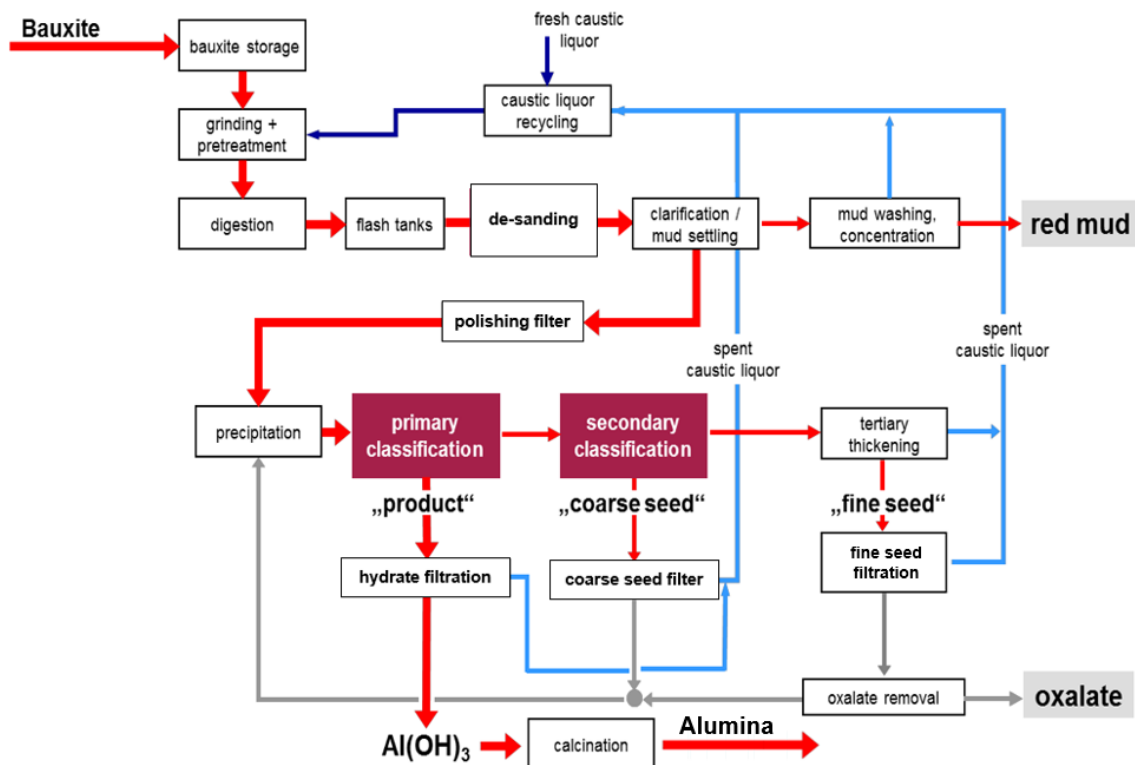


Figure 2. General process flow diagram. Primary and secondary classification steps are including hydrocycloning solutions.

### 3. Hydrocyclones AKA-VORTEX Use for Alumina Processing

The use of hydrocyclones in the alumina industry using the Bayer Process goes back to a development in the late sixties between VAW, a German alumina producer (Schwandorf, Lünen, Stade) and AKW. Shortly after this successful introduction of cyclones in the Bayer Process, NABALCO, Gove was the first Australian refinery which installed AKW hydrocyclones in 1978. Kwinana, Pinjara and Wagerup followed shortly after [3].

For the aluminium hydroxide classification, one up to three stages of hydrocyclone distributors are used to produce a defined product (typically, maximization of +45 µm particles), as well as a coarse and fine seed which are recycled into different stages of precipitation.

The primary hydrate classification step (after precipitation, but before filtration and calcination) is needed for the further process steps and results in the requirement for a coarse product (so-called sandy alumina) with reduced fines content. In general, the reduced fines content will improve the filtration ability and will minimize the dust exposure at the calciner and smelter.

Therefore, a specific demand of +45 µm aluminium hydroxide particles content is requested after the hydrocyclones separation before it enters the filtration stage. In order to achieve such a target, the solids content of the feed to the hydrocyclone needs to be within a specific range.

Exemplary feed parameters:

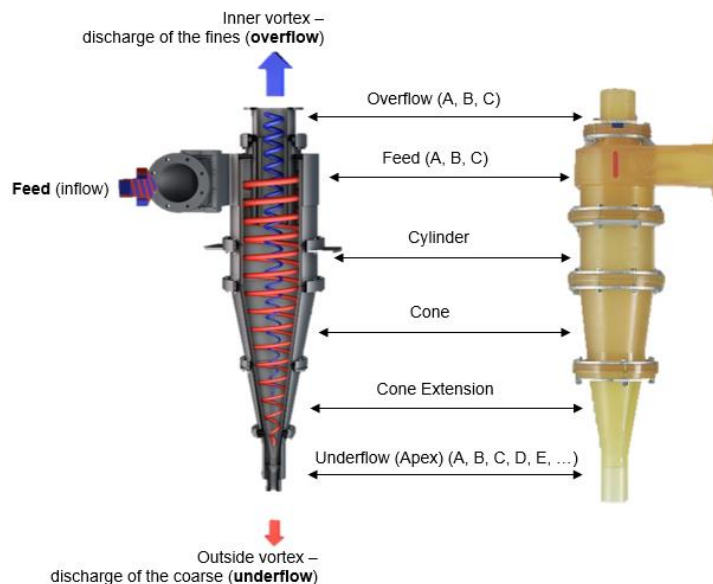
- Solids content of feed: 400–500 g/l
- Amount of particle +45 µm: 90–95 %

The amount of particles +45 µm in the product (underflow) is influenced (besides the geometry of the hydrocyclone itself) by:

- Solids content of the feed
- Amount of particles +45µm in the feed
- Number of stages
- Pressure drop
- Achievable solids content of the underflow

#### 4. Hydrocyclone AKA-VORTEX Principle and Selection

In principle, the hydrocyclone is a solid bowl centrifuge of “slim” design. It can be compared to a high-speed tubular centrifuge as well as a long-tube decanter. However, in the case of the hydrocyclone, the body is stationary. A rotation is initiated by the flow arising from the tangential feed under pump pressure. The fluid subjected to centrifugal forces, that lead to the creation of a primary vortex, which is directed downwards, and an internal secondary vortex directed upwards. This leads to a segregation effect of the particles presented in the fluid, due to a radially outward sedimentation as shown in Figure 3.



**Figure 3. Operation principle / different sections of a hydrocyclone AKA-VORTEX.**

Standard type hydrocyclone diameters for hydrate classification have a range from 100 mm up to 200 mm (325 mm). Larger cyclones with 150–200 mm diameter are used for the primary classification (so-called product) while the smaller cyclones with 100–150 mm nominal diameter are used for the secondary classification stage (so-called coarse seed) and more and more often for the fines recovery in various streams.



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

For hydrate classification two different applications have to be differentiated:

- Product Classification
- Seed Classification

Due to the fact that in the alumina business, specific conditions are given and thus special attention must be paid to certain specifications, all the equipment, especially the hydrocyclones, have to be engineered and produced in such a way to meet the following demands:

- Hydrocyclones to be made of high wear resistant polyurethane (PU)
- Hydrocyclones to be high temperature resistant up to 100 °C
- Hydrocyclones to be chemical resistant for high pH as the feed slurry content of caustic soda (NaOH)
- Hydrocyclones to process specific cut sizes with flexibility to adjust the feed and underflow throughput
- Hydrocyclone distributors to be equipped with automatic valves in order to control the flow and pressure inside the distributors automatically by the system
- Hydrocyclone distributors to be equipped with pressure safety valves (PSV)
- All hydrocyclones to be covered with splash guard to ensure having a safe operating environment

The corresponding AKA-SPIDER hydrocyclone distributors are developed by our experts in simulation and modeling using the latest technologies and software to ensure a smooth operation in optimal flow within given pressure drops. In the filtration process step of the alumina refinery AKW A+V installed **three primary distributors** and **three seed distributors**. From both types, two distributors are in operation and one distributor is in standby mode for cleaning and/or maintenance purposes, thus ensuring no interruptions of the operation process at all times.

The primary distributors each contain 24 hydrocyclones (18 manual and 6 automatic valves) while each seed distributor has 46 hydrocyclones (34 manual and 12 automatic valves). All automatic valves are fully controlled by the main control panel according to the pressure reading to maintain the pressure constant inside the feed tank. This will guarantee that all hydrocyclones will have the same feed pressure and specific cut size. The distributors are designed in such a way to reduce the overall footprint while keeping full access to each hydrocyclone for adjustment and/or maintenance. Sampling points are also considered in the design of the AKA-SPIDER for all feed, overflow and underflow tanks.

Due to the fact that the slurry contains a high temperature caustic soda, and to ensure having a safe environment in case of splash or leakage during operation, all distributors are equipped with splash protection covers made from stainless steel to cover all overflow and underflow tanks. As for the hydrocyclones, these are also protected with stainless steel splash guards. In addition, each hydrocyclone has a separate valve to adjust the feed capacity of the distributor or to close it for emergency and/or maintenance activity.

The hydrocyclone distributors are equipped with a pressure safety valve with rupture pin which is designed for emergency cases. If the pressure reached to the maximum limit inside the feed

tank, the rupture pin will allow the emergency valve to release the slurry from the feed tank to the bypass pipe and passing the distributor to avoid the damage of the unit.

### 5.1 Process Figures of Primary Hydrocyclone Distributor

The process information, material characteristics and details of primary hydrocyclones installed at EGA refinery is given in Table 1–3 respectively. The general arrangement of primary hydrocyclones are also given in Figure 5.

**Table 1. Process information.**

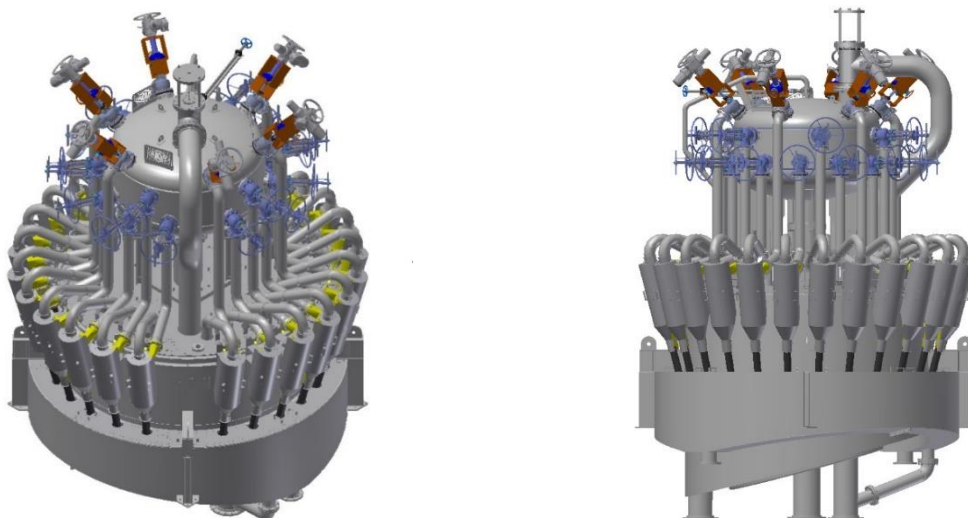
	Primary hydrocyclone and distributor	
Feed flow rate / distributor – normal	1 236	m <sup>3</sup> /h
Feed flow rate / distributor – design	1 446	m <sup>3</sup> /h
Feed density	1.489	S.G.
Solids concentration	454	g/l
Solids recovery to underflow	40	%
Cleaning caustic concentration (as Na <sub>2</sub> CO <sub>3</sub> )	470 @ 85 °C	g/l

**Table 2. Material characteristics.**

Material handled	Alumina Trihydrate [Al(OH) <sub>3</sub> ] with Spent Liquor					
	< 10	< 22	< 44	< 88	< 150	
<b>Feed</b> particle size distribution						µm less than
– Normal (medium)	0.3	2.0	8.4	33.8	87.1	% Passing by mass
<b>Underflow</b> particle size			< 44			µm less than
– Normal (medium)	0.1	0.8	3.9	20.2	75.6	% Passing by mass

**Table 3. Hydrocyclone detail.**

Hydrocyclone type	AKA-VORTEX type RWT 5118	24 each distributor
Distributor type	AKA-SPIDER type ZVC 24	2 in operation, 1 stand by
Separation cut d <sub>50</sub>	120	µm
Overflow design slurry flow	1 168	m <sup>3</sup> /h
Overflow design solids flow	392	t/h
Underflow design slurry flow	278	m <sup>3</sup> /h
Underflow design solids flow	264	t/h



**Figure 5. (a) General arrangement primary distributor, (b) isometric side view.**

## 5.2 Process Figures of Seed Hydrocyclone Distributor

The process information, material characteristics and details of seed hydrocyclones installed at EGA refinery is given in Table 4–6 respectively. The general arrangement of seed hydrocyclones are also given in Figure 6.

**Table 4. Process information.**

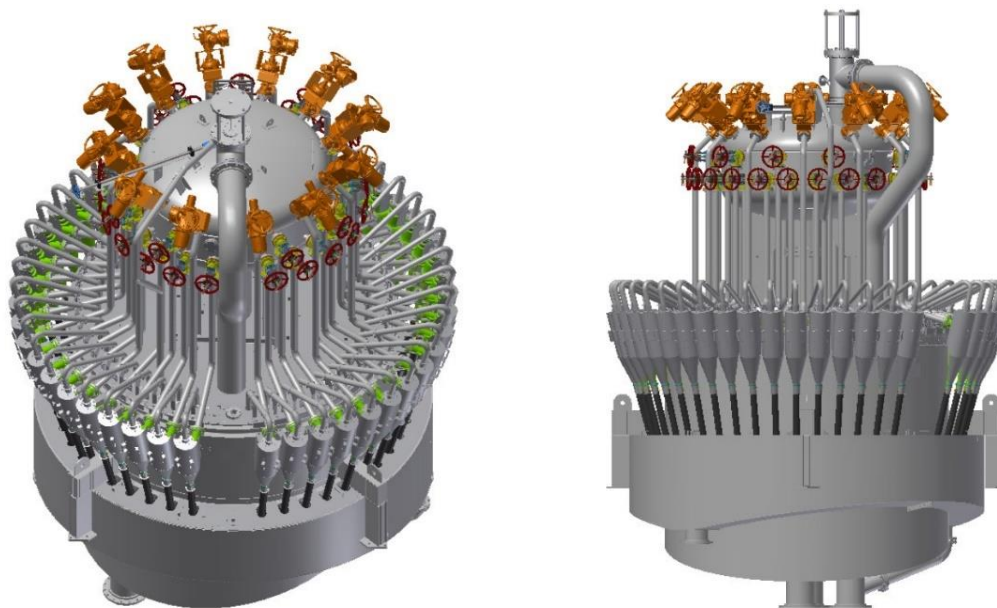
	Seed hydrocyclone and distributor	
Feed flow rate / distributor – normal	1 216	m <sup>3</sup> /h
Feed flow rate / distributor – design	1 399	m <sup>3</sup> /h
Feed density	1,456	S.G.
Solids concentration	389	g/l
Solids recovery to underflow	65	%
Cleaning caustic concentration (as Na <sub>2</sub> CO <sub>3</sub> )	470 @ 85 °C	g/l

**Table 5. Material characteristics.**

Material handled	Alumina Trihydrate [Al(OH) <sub>3</sub> ] with Spent Liquor					
	< 10	< 22	< 44	< 88	< 150	
<b>Feed</b> particle size distribution	< 10	< 22	< 44	< 88	< 150	µm less than
– Normal (medium)	0.4	2.6	10.6	40.3	92.6	% Passing by mass
<b>Underflow</b> particle size			< 44			µm less than
– Normal (medium)	0.1	0.9	4.3	24.5	88.7	% Passing by mass

**Table 6. Hydrocyclone detail.**

Hydrocyclone type	AKA-VORTEX type KRT 3128	46 each distributor
Distributor type	AKA-SPIDER type ZVI 46	2 in operation, 1 stand by
Separation cut d <sub>50</sub>	60	µm
Overflow design slurry flow	1 006	m <sup>3</sup> /h
Overflow design solids flow	190	t/h
Underflow design slurry flow	393	m <sup>3</sup> /h
Underflow design solids flow	354	t/h



**Figure 6. (a) General arrangement seed distributor, (b) isometric side view.**

After the commissioning period, it was confirmed that the process design data for both stages (primary and seed hydrocyclone clusters) are in line with the operation figures and reflecting the operating conditions under which the refinery now is operated. Refinery impressions shown in Figures 7–8.



**Figure 7. Arrangement of the hydrocyclone distributors in the plant complex.**



**Figure 8. Hydrocyclone distributors. (a) primary stage, (b) seed stage. One of three clusters each.**

## 6. Conclusions

The AKA-VORTEX hydrocyclones, made of high wear and temperature resistant polyurethane (PU), are an important addition to the alumina industry. The design offers a specific cut size for the separation while having the flexibility on adjusting the needed fines separation to maximize the production yield of alumina and minimize the energy cost. These now proven solutions reveal also to less CAPEX and OPEX intensive than the technologies previously utilized such as settlers.

The AKA-SPIDER hydrocyclone distributors provide the client a unique design having the minimum footprint needed, ensuring constant pressure for all hydrocyclones, keeping full control

on the units while maintaining the safety measures, in addition of having a non-interrupted maintenance and troubleshooting with full access to all parts at all times.

Due to the high quality of the proprietary polyurethane material used in the manufacturing of the hydrocyclones, the wear occurrence is relevantly less which increases the lifetime of parts and accordingly reduces the operational cost.

AKW A+V R&D are working continuously to develop and enhance the design to increase the productivity and reduce the cost. Recently, AKW A+V has launched a new concept, called AKA-SMART, that includes solutions for wear detection inside the hydrocyclones without the need of dismantling parts or interrupting the operation. Particularly, the AKA-ALERT, which is a part of the AKA-SMART solution package and consists of inserted chips in the polyurethane material at specific sections of the hydrocyclone, has gained huge attraction. Through a simple detecting device, the operators can easily check the status of the chips, and hence identify the specific parts that require a replacement whilst operation. These steps towards a greater automation will give a real time knowledge about the wearing condition inside the hydrocyclone and eliminate extra inspection activities, consequently reduce the man-work intensity and limit the production breakdown.

## 7. References

1. International Aluminium Institute, <https://international-aluminium.org/statistics/alumina-production/> (accessed on 31 August 2021).
2. EGA (Emirates Global Aluminium) Company website, <https://www.ega.ae/en> (accessed on 31 August 2021)
3. Stephan Buntenbach, Influence of process parameters and hydrocyclones on the product quality of precipitation, *10<sup>th</sup> International Congress of ICSOBA*, Bhubaneswar, India, 28-30 November, 2008.
4. Thomas Baumann, Hydrocycloning technology contribution to productivity improvement through fines loss recovery and seed classification, *Proceedings of the 36<sup>th</sup> International ICSOBA Conference*, Belem, Brazil, 29 October - 1 November, 2018, *Travaux* 47, 335-345.