

Power Saving in Mixing Steps for a Sustainable Environment

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Abstract

This paper draws attention that with the growth of economy, the demand for energy has grown substantially. Further, the high level of energy intensity in industrial sectors is a matter of concern. In such a scenario, efficient use of energy resources and their conservation assume tremendous significance and is essential for curtailment of wasteful consumption and sustainable development. Recognizing the fact that efficient use of energy and its conservation is the least-cost option to meet the increasing energy demand, being a dedicated supplier, it is our duty to provide institutionalize and strengthen delivery mechanism for energy efficiency services to entity of alumina industries.

This paper investigates into how the mixing technology can be improved by using efficient impeller design of Top Entry Agitators for critical application like Precipitation, Pre-desiccation, etc. in alumina process so that process improvement & reduction of power consumption can be achieved simultaneously at the same to fill the gap of challenges between process safety philosophy & the most economical design of agitator.

This paper also highlights careful use of resources and consideration of sustainability and opportunity by saving energy to save operating costs and at the same time to carry out process optimization at an example of running references.

Keywords: Suspension, Pumping capacities, Power consumption, Power savings, Density and concentration distribution.

1. Introduction/Mixing Basics

In the past, there was almost no emphasis on a reliable handling energy resources. This topic became more and more important over the last years. That's why industry, especially aluminum industry where almost 50% of the costs are energy costs, have to pay attention to sustainability and to reduce the carbon foot print. To achieve that goals energy and OPEX costs can be reduces but only without affecting the necessary process performance.

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2. Status of Precipitation Mixing




There are different approaches to mix a precipitator. Generally, we distinguish between the draft tube and open type equipment. Only the open systems are considered here.

This is to be described using the example of the 4500 m³ precipitator like shown in Table 1 below. These vessels are mixed either with very large impellers at low power or with small impellers at high power. Low power means high torque and high CAPEX cost, while high power means low torque and low CAPEX cost.

However, the solutions with small impellers have always had problems with scaling and disturbed overflow.

Table 1. Technical data of precipitators.



Application				
Volume	[m ³]	4 500	4 500	4 500
Tank diameter	[m]	14 000	14 000	14 000
Power	[kW]	55	75	55
rpm	[1/min]	3.4	9.4	6.5
Impeller dia	[m]	9 800	5 590	8 400
Impeller Tank ratio	[-]	0.7	0.4	0.6
Tip speed	[m/s]	1.74	2.75	2.86
Torque	[Nm]	154 485	76 197	80 313

The three impeller designs shown in above table cause different flow. The counter-flow-design has a large diameter ratio and slow rotational speed with a high torque. The axial-flow-3-bladed-design has a small diameter ratio and fast rotational speed but lesser torque. The axial-flow-2-bladed-design has combined both designs.

3. Power Consumption

There are four main influencing factors on the power requirement of an agitator in the precipitator.

1. Need to arrange the uniform mixing to achieve an overall flow through the vessel and mass transfer for the chemical reaction
2. Natural overflow in the cascade
3. Need to avoid scaling in the bottom and wall as much as possible
4. Start-up after a power failure

Figure 1. shows an impression of the existing flow pattern inside the precipitator. Here turbulences occur between single stages and a general homogenously distribution can be expected. These kind of velocities and flow pattern are required to achieve the 4 main factors above.



Figure 1. CFD simulation of precipitation.

Uniform Mixing

Solids loads of 500-1000 g/L are used in the precipitator. Contrary to popular belief, low solids concentrations require more impeller power than high ones. The reason lies in the mutual hindering of the particles when settling. The more particles in the vessel, the more particles hinder each other when settling. A high solids concentration of 40 % and more by volume is recommended to save energy. Figure 2 below shows settling power of different suspension loads. Settling power is calculated using swarm settling velocity of the loads, volumetric load and density differences. This value can be considered as a power of the solids while settling and is the minimum power requirement to keep particles in position and avoid further settling. The graph shown in Figure 2 displays that sometimes, higher loads are less effortful to be handled than medium loads

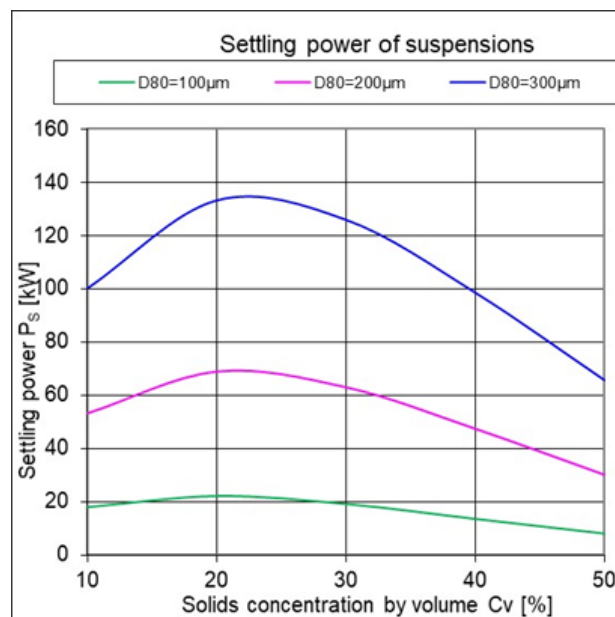


Figure 2. Settling power of suspensions.

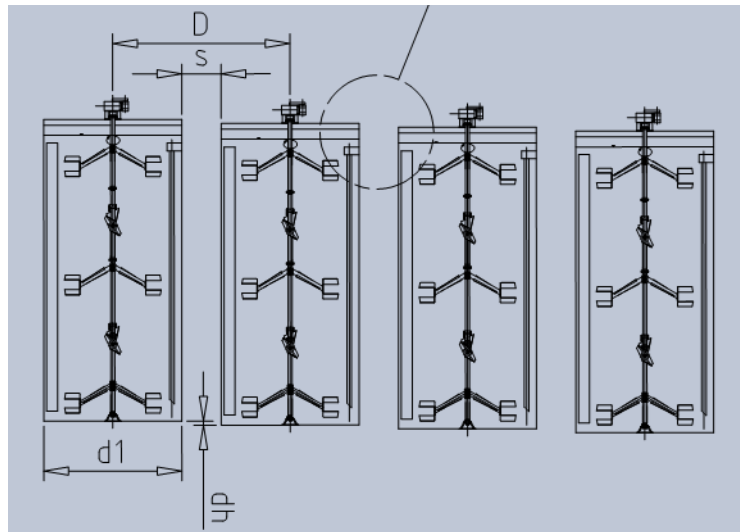


Figure 4. Overflow design.

Restart

Usually, 20-50 % by volume is run in the precipitator. Solids settle in the vessel again during the shutdown. While shut down the particles start to settle and the sedimentation height will increase. Over the time this fixed bed will increase in height and will be compacted. Depending on shutdown period there is the risk that the bottom stage of the impeller is submerged with solids and enclosed in a solid bed. The restart must then take place in a fixed bed. Figure 5 shows a sketch of different layer indicating different settling heights coming from long time shut down.

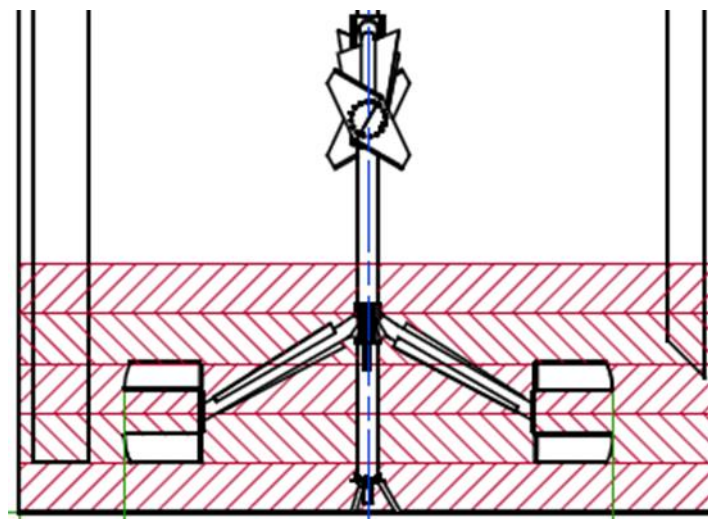


Figure 5. Restart condition due to sedimentation height.

Below there is an example shown some vessel data and particle properties (Figure 5, [1]). Considering restarting, there is initially no flow and no movement and therefore almost no turbulence which support movement of particles. The Reynolds number will be extremely low. Each impeller has a specific power number (Newton number) which is depending on flow pattern and linked to the Reynolds number. With extremely low Reynolds number, the power number for an impeller is extremely high. In the example, dealing with Aluminum hydroxide and considering the following data:

- Tank diameter 12 m
- Filling height 28.7 m
- Impeller 6.8 m
- 6 rpm
- 500 g/L
- 21 Vol%
- Settled height 10.1 m
- Vertical pressure 78 KN/m²
- Re* = 0.01
- Ne* = 1500

Reynolds and power numbers will lead to approx. 38,800 kW, which is absolutely not feasible.

Table 2. Conditions for the example to calculate restart power.

	quartz sand fine	quartz sand coarse	hematite	aluminum hydroxide
$d_{p,50}$ [μm]	160	375	75	110
sediment density ρ_s [kg/m ³]	2600	2600	4520	2430
density of the settled suspension ρ_{sed} [kg/m ³]	1886	1956	2947	1783
solid volume fraction of the settled suspension $c_{v,sed}$ [%]	55.4	60	55.4	54.8

There are various approaches to turning the fixed bed back into a fluidized bed. Air or liquid is blown in to liquefy it again. But in any case, it is crucial to reduce scaling at the bottom and in the corners as much as possible during normal operation, as this allows more solids to settle volumetrically at the bottom until they reach the geometric height of the lowest impeller.

4. Example – Running Reference

In an existing plant, STC made adaptation of a precipitator (Figure 7). in which the natural overflow did not work because too many solids had settled on the bottom (Figure 6.). As a result, the restart also did not work after the required 20 minutes.



Figure 6. Example - existing precipitator residuals.



Figure 7. Example - existing precipitator.

Also based on principle design requirements, given in references [2] to [9], an adapted design was elaborated to maximize the flow velocities especially in the corners to avoid settlement. Based on the main factors from above and the process requirements there was an impeller arrangement with hydrofoils of a very low power number chosen. So, the general power requirement due the shape of the impeller was reduced. A fifth stage had been added to improve the vertical flow and overall solids distribution using a better interaction between the single stages. This flow and interacting is sketched also in Figure 8. Central pumping direction of the impellers will support also the next stage and makes the creation of the required flow pattern easier. Supporting each other all impeller are capable to create an overall flow within the vessel. Diameter ratio (dimensional ratio between impeller diameter and vessel diameter) was chosen to achieve the required power input for e.g., solid distribution, but also will not led to high torque arrangements (large impellers and low rotational speed). Technical data are mentioned in Table 3.



Figure 8. Flow behavior of mixing device of adapted design.

Table 3. - Data of adapted design.

Volume [m ³]	Tank Diameter [mm]	Installed Power [kW]	Rpm [1/min]	Impeller diameter [mm]	Impeller Tank ratio [-]	Tip speed [m/s]	Torque [Nm]
4500	14000	55	7.55	6600	0.47	2.61	69570

Even after implemented the above arrangement, the flow rate directly at the entry of the dip pipe was still not enough, which was arranged very low. That's why a special bottom impeller was installed with very low bottom clearance, which keeps the corners and the dip pipe free. This low bottom clearance transfers the axial flow almost completely to a radial flow towards the dip pipe. Velocities and improvements are indicated in Figure 9. Velocity magnitude around the dip pipe could be increased from approx. 0.1 m/s to 0.4 m/s.

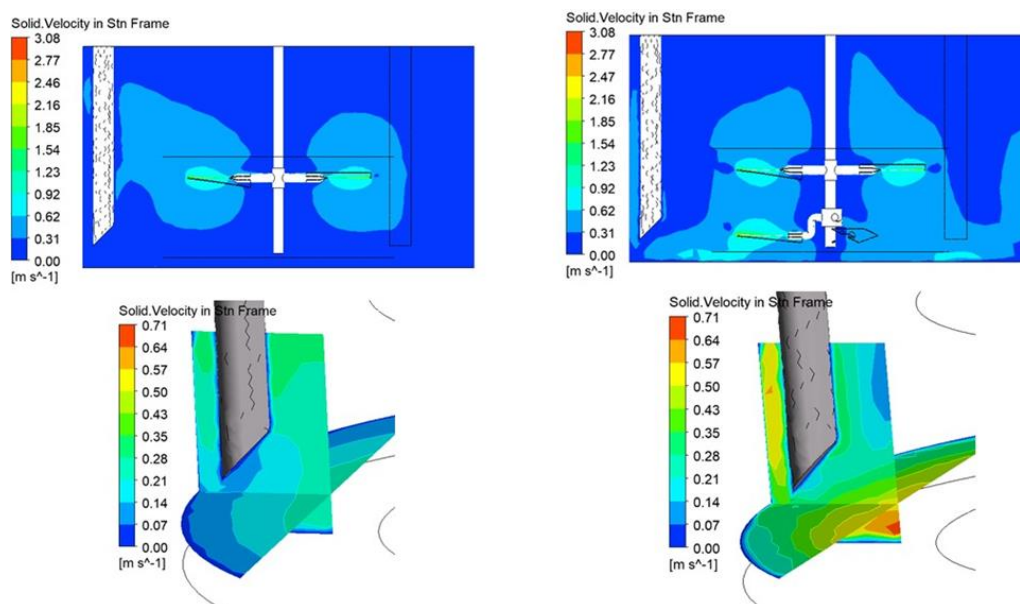


Figure 9. CFD – velocities of dip pipe area.

The result of this adaption was:

- Natural overflow without additional air supply
- Possibility to do restart after 20 min
- Density variation inside the tank < 2.5 %
- Running one year.

In addition to the process improvement, this arrangement can also save 25 % in energy, which is a really significant result (see Table 4).

Table 4. Power savings.

Value	Case 1	Case 2
Load	765 g/l	957 g/l
Vol% of solids	31.6 %	39.54 %
Sp. Gravity slurry	1633 kg/m ³	1725 kg/m ³
Wt% of solids	45.93 %	55.51 %
Current existing design	89.07 A (~ 53.0 kW)	86.19 A (~ 51.4 kW)
 REMI/STC design	67.71 A (~ 40.3 kW)	65.16 A (~ 38.8 kW)

5. Conclusions

With a smart design of the agitator, we could not only keep the major performance like solid distribution and avoiding settlements on track, we also were able to improve the performance and eliminate some existing issues. The following points could be fulfilled:

- Core requirements still perfectly display, solid distribution and concentration differences within the allowable ranges
- Natural overflow without any air support due to reduced settlements in the bottom
- Due to better distribution and a working overflow frequency of cleaning cycles reduce (numbers to be elaborated)
- Density and concentration distributions <2.5 % are achieved
- 1 year running reference
- Confirmed successful restart after 20 minutes
- Reduction of power consumption of 25 %

For existing or new plants, the improvement of the performance and sustainability should be the aim. The requirement on energy savings and reducing the carbon footprint can also be considered as a chance. By application-designed impellers and a detailed look to process requirements modifications and improvements can also be achieved.

We should take this knowledge as an opportunity for all future designs and it's also worth thinking about refurbishing existing plants. The described example has proven that there is a lot of potential and it will become more and more important to change our focus.

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