Power Saving in Mixing Steps for a Sustainable Environment

Janin Klatt-Eberle[1], Detlef Klatt[2] and René Rödenbeck[3]
1. Managing Director
2. Senior Consultant
3. Project Engineer
STC-Engineering GmbH, Waldenburg, Germany
Corresponding author: j.klatt-eberle@stc-engineering.de

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-desilication, 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.

The success in mixing technology should be shown and presented here with ongoing references at the example precipitator.

The success in mixing technology should be shown and presented here with ongoing references at the example precipitator.

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	[m³]	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.

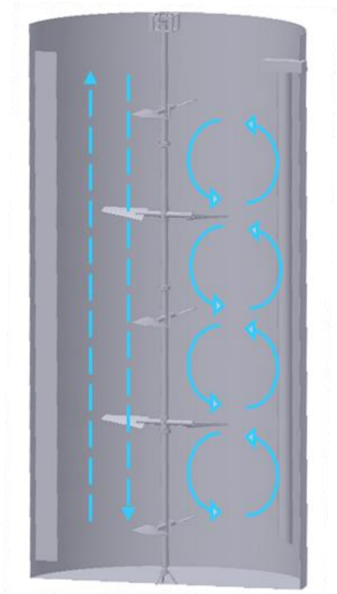

Figure 8. Flow behavior of mixing device of adapted design.

Table 3. - Data of adapted design.

Volume [m³]	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.

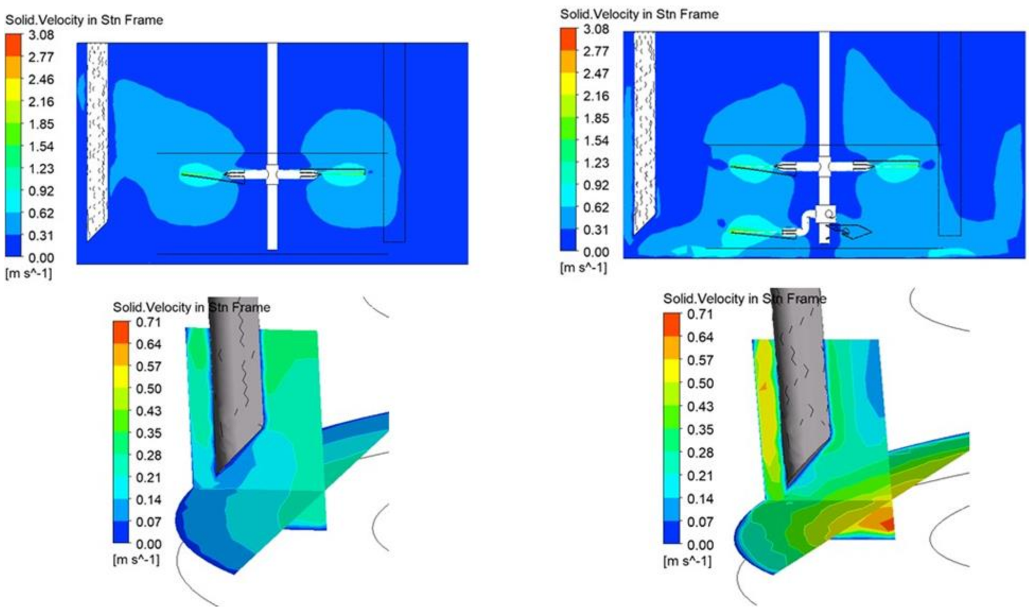

Figure 9. CFD – velocities of dip pipe area.

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/m³	1725 kg/m³
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.

6. References

1. K. D. Kipke, Anfahren in abgesetzten Suspensionen, *Chemie Ingenieur Technik*, 1983, 2, 144-145
2. Hong-Liang Zhao et al, Computational Fluid Dynamics (CFD) Simulations on multiphase flow in mechanically agitated seed precipitation tank, *JOM* 66, 2014, 1218–1226.

3. C. Devarajulu, M. Loganathan, Effect of Impeller Clearance and Liquid Level on Critical Impeller Speed in an Agitated Vessel using Different Axial and Radial Impellers, *Journal of Applied Fluid Mechanics*, November 2016, DOI:10.29252/JAFM.09.06.24824.
4. Yuan fa Ding et al, Experimental Study of Solid Dispersion in a Seeded Precipitation Tank with Slight Agitation for Gibbsite Crystallization, *Applied Mechanics and Materials* Vol 456, 2014, 537-540.
5. M. T. Hicks, K. J. Myers & A. Bakker, Cloud height in solids suspension agitation. *Chemical Engineering Comm.* 1997, Vol 160, 137-155.
6. J. Y. Oldshue, *Fluid mixing technology*. Chemical Engineering McGraw-Hill Pub. Co., 1983.
7. E. L. Paul, V. A. Atiemo-Obeng & S. M. Kresta, *Solid-Liquid Mixing*. John Wiley & Sons, Inc. 2003.
8. Jamie Fletcher, Adrian Hill, *Making the connection – particle size, size distribution and rheology*, Malvern Instruments Ltd.
9. Arthur Etchells, Henry Zhang, David Dickey, Suzanne Kresta, Instructional videos, *Advances in industrial mixing*, 2015.