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New Aerated Distribution (ADS) and Anti Segregation (ASS) Systems for Alumina

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Abstract

Two tonnes of alumina is required to produce one tonne of aluminium. The logistics of alumina therefore represent an important part of the aluminium production, including unloading of ships, internal transport and storage, fume treatment and finally distribution into the electrolysis pots. Over the last 20 years several automated distribution systems utilizing pneumatic conveying have been developed. These systems are closed, resulting in less dusting. However, due to the erosive properties of alumina and relatively high transport velocities, such systems require high maintenance frequencies. Problems also arise because secondary alumina forms scales when conveyed pneumatically.

We present here a new system utilizing low conveying velocity air-slides with adequate capacities. The Aerated Distribution System (ADS) has been installed and tested in regular production and it shows very little need for maintenance. The system also includes a separation unit to remove the scales, thus eliminating scaling problems. The difference in maintenance frequency, the lifetime cost and the "up-time" strongly favours the ADS when compared to other available systems. Another advantage of the ADS is that several pots fed by this system more easily may be treated as one unit instead of several individual pots.

When introducing automated alumina distribution systems, improved homogeneity of the ingoing alumina is usually required to ensure stable logistic flow. A system to reduce segregation when filling silos and A-frames has been developed and operated in production, demonstrating a relative homogenizing factor of 1.47 on the alumina put through the system.

Introduction

Point feeding of alumina to the alumina reduction cells is done to ensure that the feed is in the right amount and in the right place in the cells. However, a weakness of such a feeding system is that it is very dependent on the granulometry of the bulk feed (alumina).

Due to segregation, the particle size distribution varies when the bulk material is transported. These variations may cause problems in the point feeders, such as plugging of the feeders due to changes in flow properties. A too high fraction of fines may give unwanted effects in the alumina reduction cells, such as decreased rate of dissolution of alumina, sludge formation and anode deformation. Another problem with fine alumina is that it contains higher concentrations of impurities, mainly from the dry scrubbing process. This is due to their larger specific surface area compared to coarser particles.

Storage and Logistics

Segregation is a phenomenon to consider when transporting and storing alumina. In order to define the segregation in the logistic loop and storages in a plant one needs to quantify the segregation. In order to quantify the segregation effects throughout an aluminium smelter a typical arrangement of sampling points is configured as shown in Figure 1. The intention is that all transitions and handling operations are to be covered. As a general approach the sampling campaigns are carried out in such a way that the day-to-day operations are not adjusted in any way, since the main objective is to find the status of the plant during normal operation. The campaigns usually lasts for 40 days, this number being chosen based on the process cycles in the plant in order to avoid and to identify process systematic variations. Usually one takes one sample at every point, and in the pot room one sample from several pots, also in some cases several samples every day. Such a campaign typically delivers between 1200 to 2000 samples to be analysed for size distribution and sometimes also for chemical composition of the samples after fume treatment.

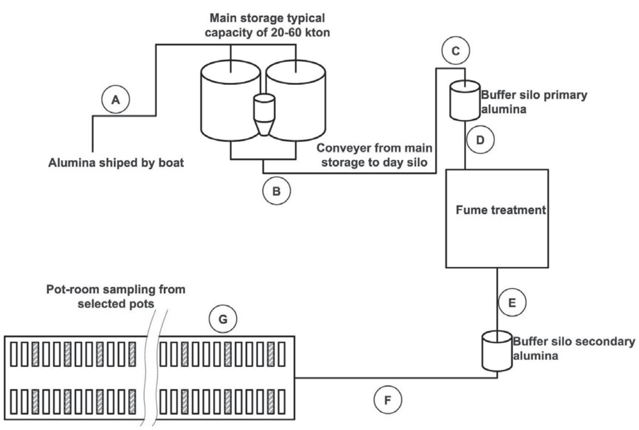


Figure 1: Typical layout of one potline in an aluminium plant.

Data generated from a campaign are compared and checked against logged data from the process. All these data are then pre-analysed using multivariate tools, and then the individual relationships can be picked out and studied closer.

Segregation

Alumina is a free-flowing powder, which means that it cannot be consolidated and kept in the form. It would collapse to a heap with a material-dependent angle of repose. Free flowing powders containing particles with diameter ratios down to 1.5 (d_{max}/d_{min}). Within its particle size distribution it can and will segregate when handled. Segregation is a general term for several mechanisms of particle separation due to varying properties, such as size, density, shape, etc. When handling alumina tests has shown that the mechanism Air Current Segregation is dominant.

Air Current Segregation. Air current segregation is caused by airflow, induced by the material itself as it falls in a concentrated stream at any significant height. When falling in a silo, the bulk material accelerates the surrounding air due to drag forces, inducing an air current. The induced airflow follows the particles as they fall down to the heap surface. In a silo the airflow turns upwards when it meets the silo walls. It continues up along the walls and then follows the top of the silo back to the feeding point, from where it is accelerated downwards again. At high air velocity the airflow will carry the fine particles. If the air velocity is reduced sufficiently or changes direction, the particles will separate from the air stream and fall down. The result of this is that the fine particles are collected at or near the silo walls. The coarser particles are found in the centre of the heap. This is the reverse of the normally expected segregation pattern. Concentrations of fines are found at the silo wall and especially when the level in the silo has been kept constant for a long time, giving the surface a long exposure to dust. Alumina starts to separate due to this mechanism even when only freefalling 500 mm.

Process effects of segregation. In order to close the conveying system one has chosen to use air-slides and pneumatic conveying. The use of air-slides for conveying and distribution is possible due to the fluidizing properties of alumina. Advantages obtained by the use of air-slides are the high capacity and low velocity, and thereby low wear. The low velocity preserves the particle size distribution of the alumina. Further, the properties of alumina allow one to use inclinations of less than 1° for the air-slides. It is this feature that permits them to be used as a distribution system in the pot rooms. However, when the fluidisation properties are changed due to segregation, one may experience that the capacities of the air-slides are severely reduced. In Figure 2, one can see that the capacity decreases significantly when increasing the content of the sub 42 µm fraction, even when increasing the fluidisation velocity. Also pneumatic conveying facilities will be affected by changes in the fluidisation properties.

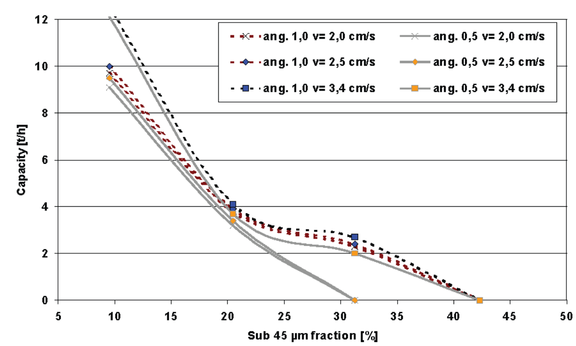


Figure 2: Transport capacity of pot air-slide 150x150 mm, when changing the content of fines (sub 42 µm)[1].

When a method of conveying is chosen, and its design and parameters are set for an alumina having certain specifications, the need to keep variations inside the defined specifications is essential in order to ensure controlled and stable logistics. In order to keep the alumina within the specification range, segregation and attrition should be held at a minimum.

During one of our sampling campaigns [2] continuous monitoring of dust was carried out using a NEO DM4 in one of the prebake pot rooms. The alumina was sampled from 22 pots with one sample from a point feeder each day over a period of 41 days. The average value of the daily 22 samples is used for comparison with dust concentration measured by the monitor. The dust and fines content values are centered and normalized in order to compare them with each other. The centering and normalizing was done using the Equation 1:

$$Y_i = \frac{X_i - \overline{X}_{i=1-n}}{S_{n-1}} \quad (1)$$

where

Y_i - normalized and centered value
X_i - measured value
$\overline{X}_{i=1-n}$ - mean value of all samples (1 to n)
S_{n-1} - standard deviation of the sample series

As can be seen from Figure 3, the dust concentration in the pot room air follows the content of fines in the alumina fed to the pots. This plot illustrates not only the variation in the working environment for the operators, but also the total dust emission from the pot room. Keeping a strict control of the alumina when handled can reduce this variation. However, the co-variation also indicates a possibility of using dust monitoring to indicate the alumina quality. Also this co-variation shows that when buying a cargo of alumina having a high content of fines, one should reroute this alumina to the sections of the factory, which have both sufficient "*hooding*" and gas collection efficiency.

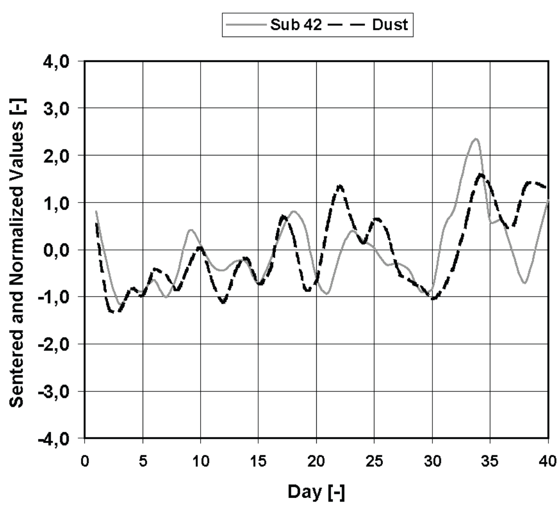


Figure 3: Centered and normalized data for sub 42 µm content and dust concentration in a pot room.

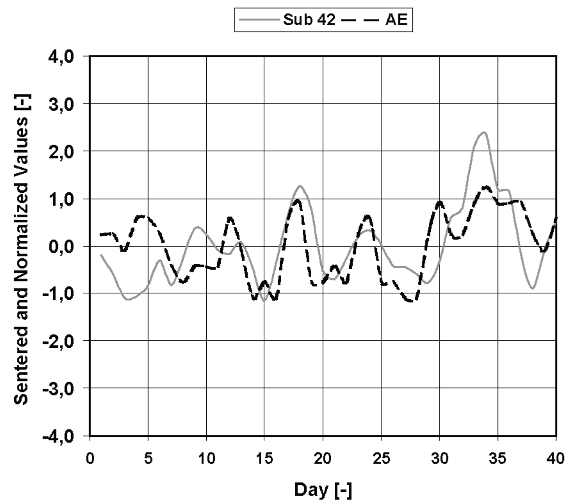


Figure 4: Centered and normalized sub 42 µm content and number of anode effects (AE) per day of the pots where alumina is sampled [2].

Today one uses mostly volumetric point feeders to add the alumina. Volumetric measuring of a bulk solid has a weakness in the fact that the particle size distributions influence the bulk density. Also the same distribution influences the flowability of the bulk solid. In the electrolysis cells one may encounter a phenomenon called an anode effect (AE). When the anode effect occurs the cell voltage increases and as a consequence the process yield drops due to the solubility properties of the alumina in the molten bath. Other process side-effects are that instead of producing aluminium, one uses energy to pollute the environment through emissions of CF_4 and C_2F_6 having an approximate CO_2 equivalent of 8000. These gases are only produced by AE in the primary aluminium production process. Anode effects are countered by the use of different feeding programs for the alumina to the pot. The variations in the fine fraction, below 42 µm, found from the sampling campaign are compared with the number of anode effects. In order to do this, one has to compare an integer value (number, of AE's) with a real number (% below 42 µm), so the values were normalized using the same normalization procedure as given before, see Equation 1.

As can be seen from the curves in Figure 4, the co-variation is not random and, especially when the content of fines rises rapidly, the regulating system cannot respond quickly enough and this results in AE's [2]. Later comparisons also show the same level of co-variation.

Systems to improve raw material stability

Anti Segregation System (AS-System)

System Description. The AS-System consists of a distribution system on top of the silo distributing alumina to the inlet seals of the anti segregation tubes mounted at the silo wall. When the alumina is filled into the central distribution unit, it is distributed through air-slides to the inlet seal. When the alumina falls down inside the tube, having valves sealed with flaps of spring steel, a negative pressure is generated due to drag forces. This negative pressure closes the valves, however, the pressure difference inside the tube and in the silo room is equal at the top of the heap, giving the valve the opportunity to open. When all the valves have been active, bypasses are activated on the conveying line from centre to the wall, starting in sequence from the silo wall towards the center. The system can be seen in Figure 5.

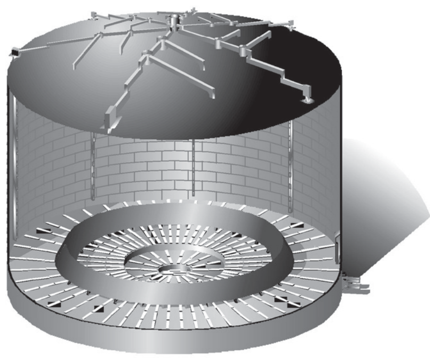


Figure 5: AS-System mounted in a silo.

Results of AS-System installation. In an attempt to reduce the variations described in the previous section, systems to counter segregation and reducing the effects of the segregation in the aluminium industry have been developed. To directly counter air current segregation one would need to put the effort into the filling procedure or configuration. A system for filling a silo via several tubes has been installed in two 6000 t silos. To measure the effect, the standard deviation of the content of fines in the in-going material is divided by the standard deviation of the content of fines in the material discharged. If this value, called the homogenisation factor, is equal to 1, there is no segregation or homogenisation. If the value is below 1, one has segregation, and if larger than 1 one has a homogenisation effect. The new system has a H_{fact} of 1.7 compared to the old storage system which had a factor of 0.7 (as shown in Figure 6) This indicate that the old storage system increases the variations because of segregation, while the new system not only prevents segregation but also reduces the variations (homogenising).

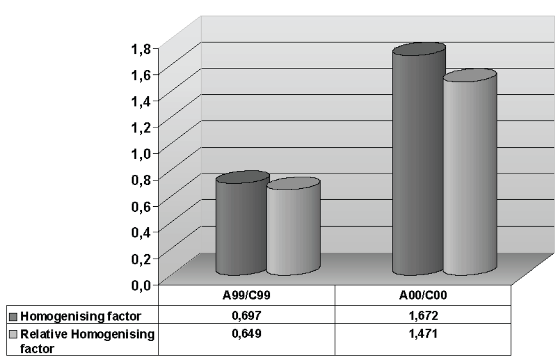


Figure 6: Homogenising factors from the old A-frame storage compared with homogenising factors for the new silos using AS-System (X99 = A-frame and X00 = silos).

As shown the reduction in variation is possible by using the AS-System©, however, one needs to do this completely throughout the whole of the process line in order to preserve the homogeneity gained.

Aerated Distribution System (ADS)

Over the last 20 years several automated distribution systems utilizing pneumatic conveying have been developed. These systems are closed, resulting in less dusting. However, due to the erosive properties of alumina and relatively high transport velocities, such systems require high maintenance frequencies. Problems also arise because secondary alumina forms scales when conveyed pneumatically.

System Description ADS. The ADS may be divided into 3 levels as shown in Figure 7:

- Level 0, from the buffer silo to the pot room
- Level 1, at the wall inside the pot room distributing from cell to cell
- Level 2, from the pot room wall to the electrolysis cell

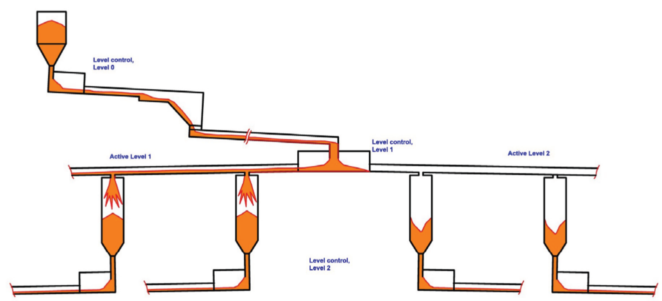


Figure 7: Principle of ADS levels.

These levels are disconnected by the level controls, giving the opportunity to operate the different levels independent. When the ADS is operated at Level 1 on one side one may operate the ADS on Level 2 on the other side of the pot room. Actually each cell is equipped with a level control mounted at the starting end of the air-slide defining each cell as an independent unit optimising the necessary time used for refilling of alumina.

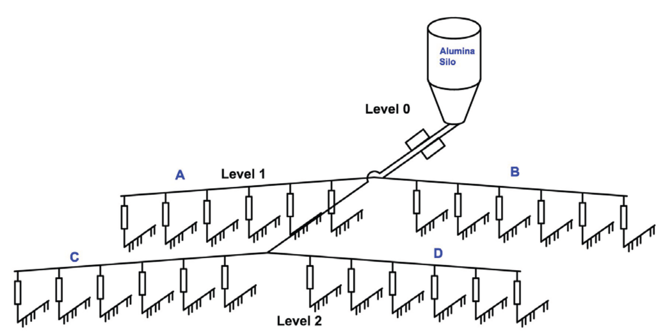


Figure 8: ADS layout.

In order to optimise the air consumption, the ADS have a layout formed as the letter H (Figure 8). Levels 0 and 1 are operated at the same time. When string (branch) A of Level 1 is operated, string D of Level 2 is operated simultaneously. Each branch is activated in sections of 3 to 5 cells at the same time. Maximum air consumption occurs when the end section of one branch at Level 1 is activated. Time and level switches control the system. The level switches will deactivate the system if the filling finishes before maximum time set. By operating the ADS in this way, the deviation in alumina consumption on each cell is taken care of. Also, the way ADS is operated keeps the air consumption well within the range of other similar systems.

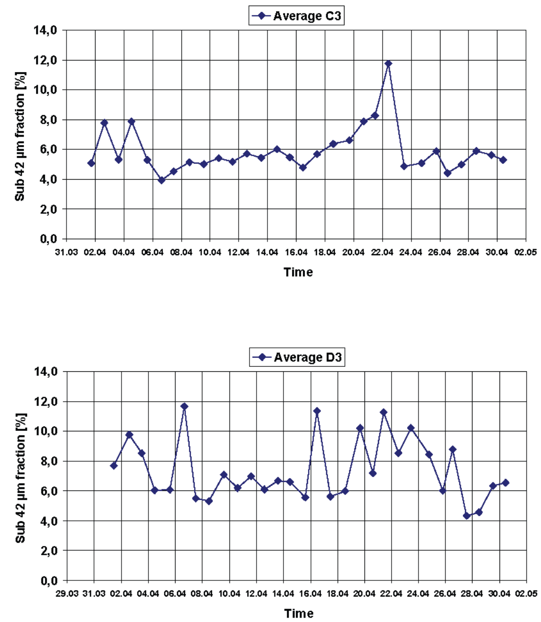
Figure 9: Installed ADS at Hydro Aluminium Karmøy.

How ADS differs from other systems. The ADS differs from other systems in its low need for maintenance. The quality factor of the air-slide distribution of alumina is due to the low velocity, and the fact that neither the start nor the stop of the system does influence the system in the same way it would with a conventional pneumatic distribution system. Since alumina is a hard material, it will act as a sand blaster if dispersed in air and convoyed at high speed. The system shown in Figure 9, consisting of 28 cells, was installed in 1996, and beside some small deviations due to it being the first full-scale installation there has been no maintenance, just periodic checks of the system. The pilot installation serving a smaller section of cells has been in operation since 1991, and it has not been necessary with any mechanical maintenance.

This low demand for maintenance and need for spare parts gives the ADS an advantage when calculating the Life Cycle Cost, and Profit (LCC and LCP). Although it is claimed that the investment are higher for the ADS (the total price including the maintenance costs and spare part costs) the ADS ends up with a competitive price.

This low maintenance frequency also results in another important strength of the ADS, namely availability. A system in need of maintenance must be shut down when repaired; reducing the availability (Up-Time), given the history of the ADS the Up-Time has proven very high. The ADS has become a system that has been installed and "forgotten" looking from an operational point of view.

Results of ADS installation. For further distribution of the alumina to the pots, there are available several distribution systems using different methods of conveying. If operating such systems in the right way, one will both preserve the homogeneity achieved earlier in the upstream handling processes, and ensure that the different pots gets the same alumina quality. This gives the opportunity to run several pots as one unit instead of several individual ones. A system developed by Hydro Aluminium uses high capacity air-slides for distribution of alumina in small amounts fed rapidly to the different pots. The result of this method can be seen in Figure 10. The section filled by the distribution system (ADS, see Figure 10 a), marked C3), gives less variation than the section filled using overhead cranes (Figure 10 b), marked D3). Samples presented in Figure 10 from [3].



a)

b)

Figure 10: Comparing variations in fines with pot section using a) ADS (C3) and b) section filled using overhead cranes (D3).

From Figure 10 one see that there is a distinct peak in the curve for ADS samples; this peak can be traced back to an upstream peak in the alumina storage shown in Figure 11.

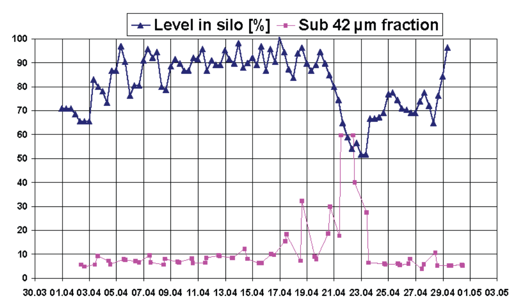


Figure 11: The level in silo and the sub 42 µm fraction in alumina from the day silo for C3 and D3.

Conclusions

Variation in the alumina feed to the electrolysis process are bound to happen, the question is how much one can let the alumina segregate. The influence and consequence of this variation influence both the process itself and the environment around the process (working environment and global environment). The margins in the electrolysis process are pressed (more and more limited), and responses found from raw material variations indicate a potential in focusing on the alumina handling and storage, and include this into the process itself. The AS-System and the ADS help to reduce the variations, giving the process a more constant input and thereby an opportunity to press the margins even further.

The AS-System itself has shown reduction in variation in the fine content of the alumina. The alumina gets an improved homogeneity when processed through a silo equipped with an AS-System.

Further downstream the ADS shows that the variation between the cells can be reduced so much that a whole section may be treated as one section. Also the ADS has shown its quality by having almost zero need for maintenance, because of the utilisation of air-slide conveying with low velocities, thereby giving the system high availability and low life cycle cost (LCC).

References

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