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Pneumatic conveying of alumina - comparison of technologies

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Abstract

During pneumatic conveying and storage of alumina, the material should be treated very cautiously. Degradation of the material must be avoided. Conveying with high air pressure may result in some cases in scaling in the pipelines. In this paper the general mechanisms of attrition during conveying are highlighted. The technical background of attrition and pneumatic conveying is described. Some general conveying options are compared. Key point is always a thorough analysis of the material to be transported. If the conveying plant is optimized to its specific task, savings in energy and investment can be made.

Keywords: Pneumatic conveying; attrition of alumina; alumina storage; alumina conveying.

1. Introduction

The requirements on a system for the handling and transport of alumina are:

- No grain abrasion and no grain fracture; the particle size portion of < 45 μm, critical for the further processing procedure, must not be increased,
- No segregation according to grain size, meaning the critical portion < 45 μm must not accumulate during transport or storage, etc., neither spatially nor over time,
- Systems must be designed wear-resistant and must have low wear during operation.

The two points stated first essentially influence the quality of the product “sandy alumina” and therefore also the operation of the subsequent aluminium electrolysis cells. The third point influences the economic efficiency of the complete production line. For alumina storage silos and feeding systems for the electrolysis cells highly efficient and proven solutions already exist with Anti Segregation System (AS-System) and Aerated Distribution System (ADS) [1].

The transport of alumina between different plant areas can be realized with either mechanical or pneumatic conveying systems. The simple plant design and the closed, i.e., environmentally-sensitive, conveying line are advantages of a pneumatic conveying system. Disadvantages compared to the mechanical conveying are the system-inherent higher power consumption and increased wear sensitivity. In Figure 1, a schematic of the general dependencies of pneumatic conveying is given. With low conveying velocities the risk for a plug of the conveying is given and the pressures are high. With high velocities the pressure difference per distance is lower, but the overall energy consumption is high. The general tendencies are shown in Figure 2.

In FLUIDCON conveying system, presented in this paper, the conveying velocities can be further substantially reduced.

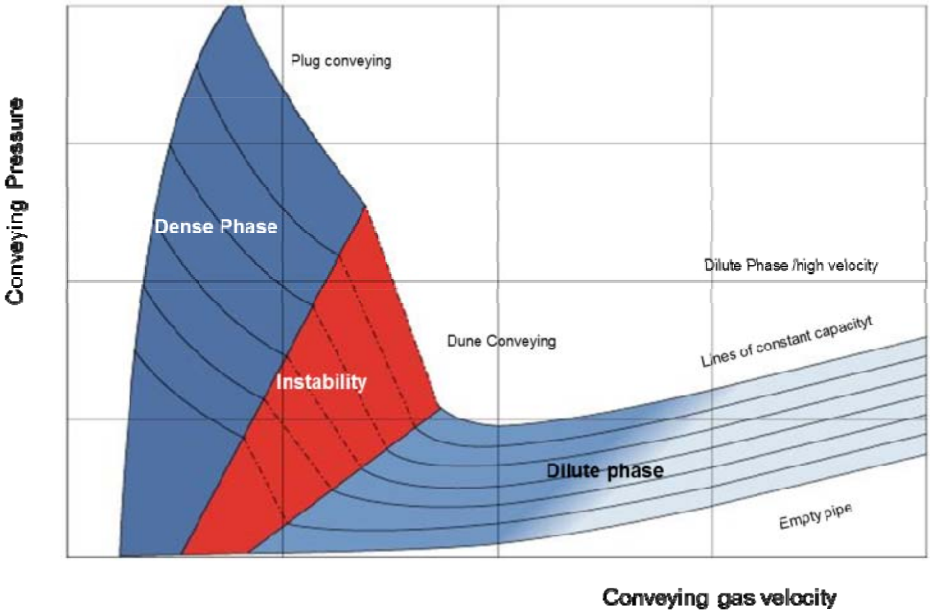

Figure 1. Schematic pneumatic conveying diagram.

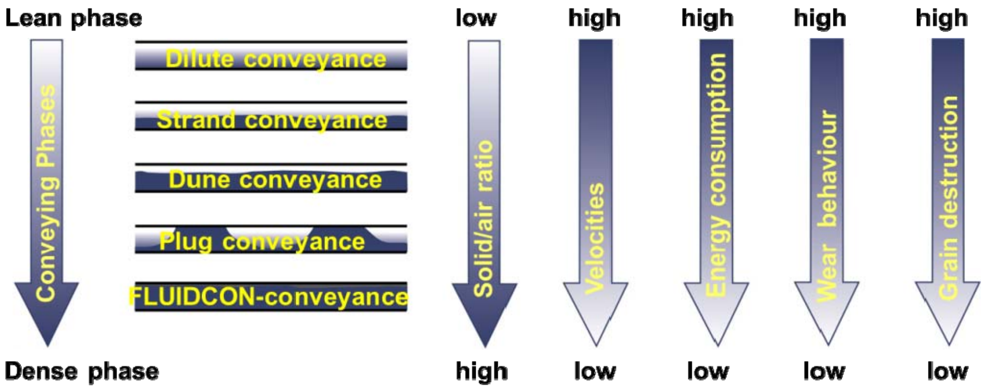

Figure 2: General relation of pneumatic conveying systems

2. Conveying principle and application of FLUIDCON

FLUIDCON can be described as a combination of aeroslide conveying and pneumatic pipe conveying. It consistently uses the advantages of both processes and eliminates essential disadvantages by combining them. Aeroslide conveying is characterized by extremely low energy consumption but needs an inclination of the aeroslide in flow direction. It therefore has a limited flexibility in the pipe routing, i.e., no vertical conveying is possible. The advantage of the pneumatic pipe conveying is the almost unlimited flexibility in the pipe routing; its disadvantage is the much higher power consumption.

Figure 3 shows the structure of a FLUIDCON conveying plant. The total gas flow supplied by a pressure generator is divided into a fluidizing gas flow and a driving gas flow. The fluidizing gas flow quantity is adjusted by a controller and is fed to the conveying pipe, distributed along the transport route, for fluidization of the bulk material. The driving gas flow is fed at the beginning of the conveying pipe and triggers the axial solids transport. Here the pressure drop of the driving gas flow replaces the inclination of the aeroslide. Due to the fluidization the bulk solid is transferred into a fluid-like state with nearly no internal friction and is lifted off the pipe bottom and introduced into the driving gas flow. It therefore does not support itself on the (horizontal) pipe wall. These are optimum conveying conditions to realize the same conveying velocities as on an aeroslide. The fluidizing gas is fed to the conveying pipe via fluidization elements, which are adjusted in their geometry to the circular conveying pipe cross section and which can be exchanged and dismantled individually without modifications of the conveying pipe. The maximum length of these elements, independently fed with gas, is currently $\Delta L = 2$ m. For the gas distribution normal aeroslide fabric is used, if necessary covered with perforated plate as wear protection. In special cases metal fabric can be used as distributor. Bends in the conveying line and vertical pipe segments are not fluidized.

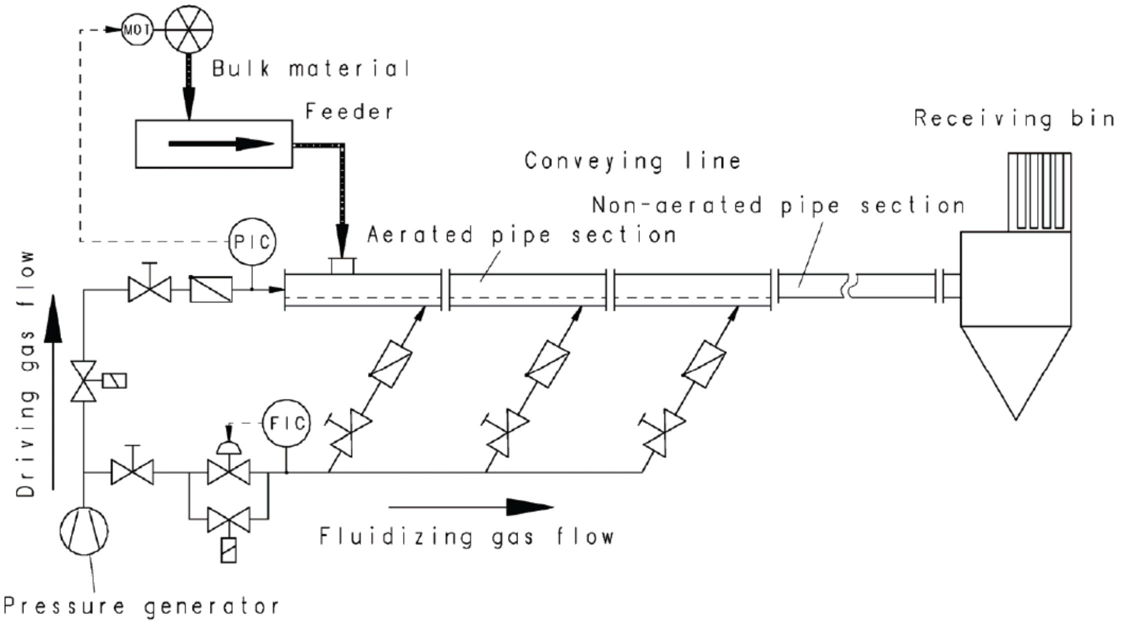

Figure 3. Layout of a FLUIDCON conveying system.

The general dependencies for pneumatic conveying including the FLUIDCON system are shown in Figure 2. The FLUIDCON-system extends the utilizable range to lower conveying velocities.

Suitable and proven solid feeders for FLUIDCON are: pressure vessel, screw feeder, rotary-valve feeder and various flap-type feeders. The implementation of multi-point feeds, i.e. the more or less simultaneous feed of bulk material into one transport line through several feeders in parallel, is also possible and used for example for the fly ash removal from power plant filters. The gas supply of FLUIDCON plants can in many cases be realized by blowers. Conveying pressures of up to approximately 300 kPa(g) are possible.

The bulk materials that are particularly suitable for FLUIDCON are all those that can be fluidized with low gas velocities and then expand substantially homogeneously. High gas retention is also of advantage. Bulk materials with appropriate characteristics are to be found in the entire hatched part of the modified Geldart-diagram (compare [8]) shown in Figure 4. The vertical axis on this chart is the difference between the particle density of solids (ρ_s) and the density (ρ_f) of the surrounding fluid. The horizontal axis is the mean particle diameter of the solid (d_{s50}). The fine materials in Group C show a cohesive behaviour and are not easy to fluidize. Group A-material is coarser and is easy to fluidize with a long retention time. Products with a Group-B- characteristic are only fluidizable with very high aeration velocities and are having a very short air retention time.

Sandy alumina is on the transition between Group A and Group B-material (assuming a typical particle diameter of (d_{s50} =80 μm) and typical solids density of ρ_s =4 500 kg/m³); this is in the zone marked with grey ellipse on the diagram. But it is still inside the hatched area of suitability for FLUIDCON-conveying. The suitability of products outside the hatched area has to be analysed for each individual case by fluidization and various other tests. All bulk materials plotted in Figure 4 have already been transported successfully with FLUIDCON.

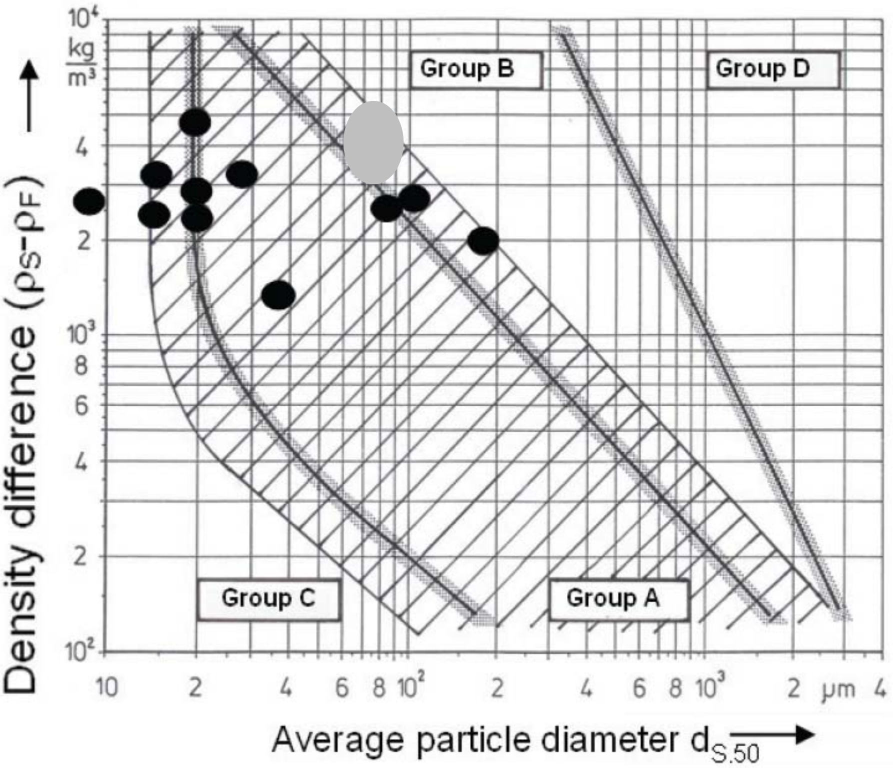

Figure 4. GELDART-Diagram with indicated FLUIDCON-suitability (hatched area).
(Black dots show materials already tested for FLUIDCON-conveying.)

Gas velocities at the inlet of the conveying pipe of vF,A ≅ (1.0 - 4.0) m/s with specific fluidizing gas flows of (0.3 - 1.0) $m^3/(m^2\cdot min)$ are realized. For all bulk materials tested a stable and pulsation-free conveying through pipes inclined upward up to $\alpha_R \cong 30°$ against the horizontal was possible without backflow. This behaviour has also been confirmed in operating plants. Restarting after conveying that has been interrupted by, for example, a power failure, i.e. starting up with a full line, is no problem with FLUIDCON. The conveying gas is fed to the conveying system at different times: when the fluidizing gas has been applied, the driving gas flow is switched on after a time delay. This picks up the bulk material that has already been transformed to a fluidized state and takes it away evenly and without significant pressure fluctuations.

3. Case study

Data from a real installation of the FLIDCON-conveying have been monitored. The basic data of this conveying plant are shown in Table 1.

The case study proves, that with the FLUIDCON conveying, very low energy consumption can be achieved. Even though the calculation still includes some safety margin, specific energy consumption below 0.6 kWh/(t·100m) can be achieved. This is a very low value for “sandy alumina“. Compared with conventional pneumatic conveying the energy demand of a

FLUIDCON-system is extremely low. In Figure 5, the energy demand of different conveying systems is compared relative to belt conveying (ratio P_{Pneu}/P_{Belt}).

Table 1. Case study data.

Parameter	Variable	Unit	Value
Bulk solid			Sandy alumina
Conveying gas			Air
Type of conveying system			FLUIDCON
Type of solid feeder			Screw feeder
Solids mass flow	$\dot{M}_S$	t/h	135
Total conveying distance	L_R	m	410
Including: total height	H_R	m	35
Pipe diameter	D_R	mm	388.8 (∅406.4 x 8.8)
Total gas volume flow	$\dot{V}_F$	m³/h at 20 °C, 100 kPa	7485
Average spec. fluidization gas flow	$\dot{q}_{WS}$	$m^3/(m^2 \cdot min)$	0.65
Gas velocity at pipe inlet	$v_{F,A}$	m/s	3.0
Gas velocity at pipe outlet	$v_{F,E}$	m/s	16.2
Pipe pressure difference	Δp_R	kPa	95
Total pressure difference	Δp_{vor}	kPa	125
Installed power of compressor	P_C	kW	254
Type of screw feeder		-	CP X-pump
Installed power of feeder	P_P	kW	65
Total specific energy consumption	W_{spec}	$kWh/(t \cdot 100\ m)$	0.576

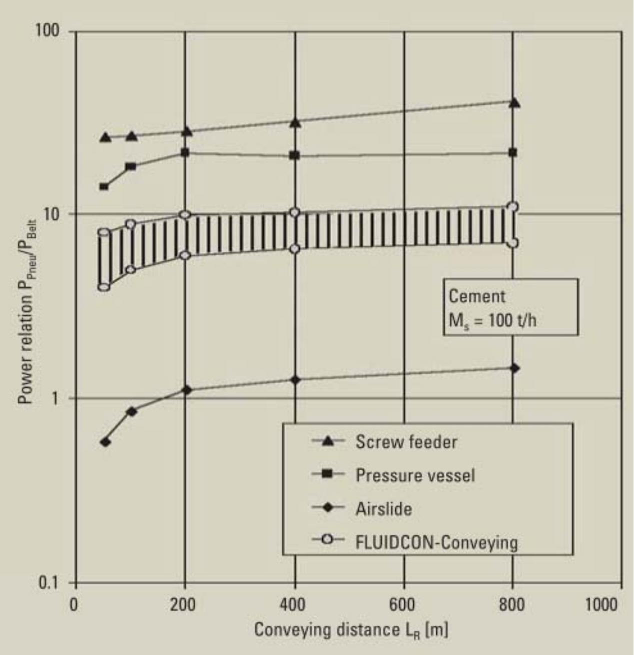

Figure 5. Installed power of different conveying systems (reference basis belt conveyor).

Due to the low conveying velocities the attrition rate is quite low as well. At the mentioned installation a test of the attrition rate was carried out and the attrition was found to be in a good range (**Figure 6).**

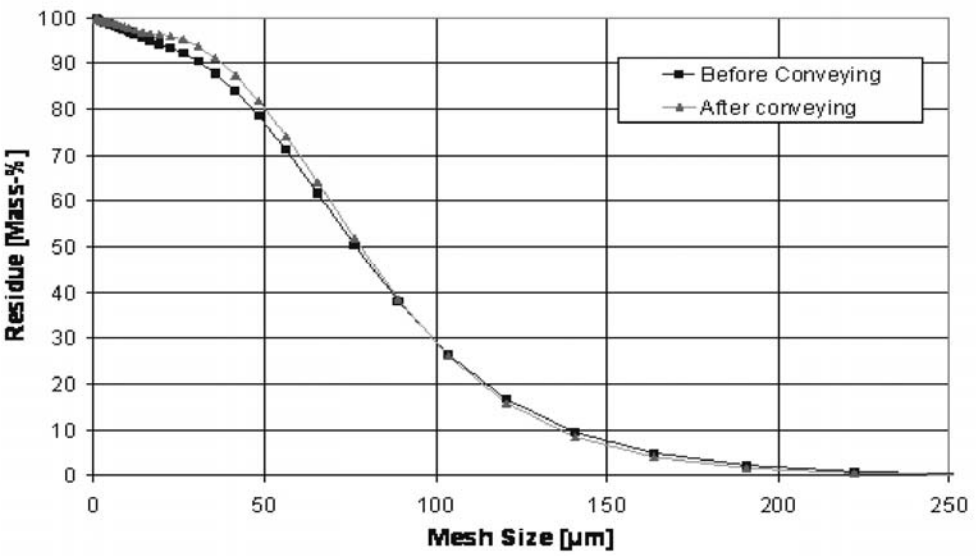

Figure 6. Evaluation of particle attrition, taken from [7].

4. Conclusion

A description is given of a simple dense phase conveying system that combines the advantages of aeroslide conveying and pneumatic pipe transport. The characteristics of the FLUIDCON conveying system are an extremely low transport velocity and a low power requirement. The design of the conveying pipe, the layout of the system as well as the requirements to the bulk materials which are conveyable with FLUIDCON are discussed. The operating behaviour of FLUIDCON in the case of the transport of "sandy alumina" is represented with the aid of the results of extensive systematic measurements carried out in a test plant in the Claudius Peters Technologies research centre and is applied to a real plant implementation.

4. References

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