HDPS: AN ECO-FRIENDLY AND SUSTAINABLE TECHNOLOGY

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Abstract

HyperDense Phase System (HDPS) is a leading conveying technology used for feeding alumina to electrolytic cells in aluminium smelters across the world. This technology was developed for the transport of fluidizable powdered products to eliminate alumina spillage and wastage and to achieve energy and space savings when compared to other conveying technologies.

This patented technology has recently undergone new improvements in relation to the powder proportioning and conveying over long horizontal distances.

The implementation of a HyperDense dosing system (HDPS Doser), for feeding the gas treatment centres (GTC) inside the aluminium pot lines, is resulting in a tremendous reduction of the alumina flow rate variation at the reactors inlet. This ensures a much more efficient adsorption of the fluorinated gases, which are emitted during the electrolysis processing; resulting in a significant reduction of harmful gas emissions into the atmosphere.

An upgraded mathematical model of the HDPS transportation of alumina to the electrolytic cell has created an "optimal alumina conveying design". Modelling is based on an original concept of interaction between fluidization velocity and powder/vacuum ratio, providing theoretical tools for units' conception and optimization. This results in the virtual elimination of alumina feeding breakdown, which can lead to anode effects and green house gas (GHG) generation.

With its energy saving benefits, dust free qualities, proven pot feeding reliability and recent improvements in GTC alumina proportioning, HDPS is reinforcing its unsurpassed position in the market place, while satisfying the highest of environmental and sustainable requirements and standards in the process.

Notation and Units:

ρg:	density of the gas phase (kg/m^3)
ρp:	density of the solid particle (kg/m^3)
µg:	kinematic viscosity of the phase gas (Pa.s)
At:	duct section (m^2)
Dt:	duct diameter (m)
dp:	particle diameter (m)
Fpt:	maximal mass flowrate conveyed in the gas cloud (kg/s)
g:	gravity (m/s^2)
Uc, Uk:	limit velocities of the turbulent regime (m/s)
Uf:	fluidization velocity (m/s)
Umf:	minimal fluidization velocity (m/s)
Umb:	minimal fluidization bubbling (m/s)
Usalt:	saltation velocity (m/s)
Utr:	transport velocity (m/s)
Ar:	Archimede number $Ar = \frac{d_P^3 \rho_G (\rho_P - \rho_G) g}{\mu_G^2}$
Re:	Reynolds number $\mathrm{Re} = \frac{\rho_G U_f d_P}{\mu_G}$

1. Introduction

B&A Engineering and Plant Projects- Gardanne, which is located in the south of France beside the Gardanne Alumina Plant, proposes engineering solutions for design, implementation and supply of technology and equipment in various fields including alumina production and handling.

Owing to 50 years of experience, B&A Engineering and Plant Projects are aluminium industry leaders in handling technology for base materials, particularly alumina, and has developed original feeding technology for pots and gas treatment centres: the HyperDense Phase System

The HDPS technology was first installed in 1985 and since then never stopped improving to achieve unsurpassed reliability and environmental standards.

This paper outlines the characteristics of the HDPS technology and indicates how, based on the fundamentals of the potential fluidization principles, a mathematical model was developed in order to optimise the HDPS operating parameters.

Industrial smelters results clearly indicate the contribution of the HDPS technology to the reduction of the fluorine and GHG atmospheric emission.

2. HDPS technology

This technology called **HyperDense Phase System** (**HDPS**) is based on the **potential fluidization principle**, which is the ability of powder materials that contain low air pressure to become fluidized when this air pressure is released. HDPS is a unique technology using the fluidization principle under pressure.

The main application for HDPS technology presently occurs during the **pot feeding process in aluminium smelters. The HDPS design** may vary from one site to another. However, the standard HDPS device usually consists of a fluorinated alumina silo which feeds the main HDPS air conveyor along the length of each potroom from where lateral outlets feed the hoppers within the electrolytic cells' superstructure by means of insulated and individual air conveyors.

The air pressure provided by a fan is equalized by the level of alumina in balancing columns installed on the main HDPS duct. This system is permanently full of alumina, from the silo to the pot hoppers. Any need for alumina in a pot hopper is quickly met by local fluidization of alumina through air pressure release. This flow of alumina is transmitted back along the duct up to the silo in the same way.

The Main characteristics of the HDPS technology are:

- The system is "on load", permanently full of product due to the potential fluidization principle
- The main feeding system is horizontal, allowing the transport of alumina up to hundreds of metres
- HDPS is a multipoint feeding system; thousands of points can be fed with a single system.

- Because of the very low velocity of the conveyed alumina (typically 0.05m/s), neither wear nor product attrition is expected
- HDPS needs low air fluidization pressure (typically 0.1 bar) which leads to a low maintenance cost and dust free equipment
- Energy consumption is as low as 2 kWh/t of alumina conveyed
- The HDPS is self-balanced, with no electronics and no moving parts within the alumina stream
- Fully sealed system, ensuring no alumina losses into the environment.

The **main components** of the pot feeding HDPS are the longitudinal air conveyors and the pot air conveyors on hoppers as illustrated in Figure 1.

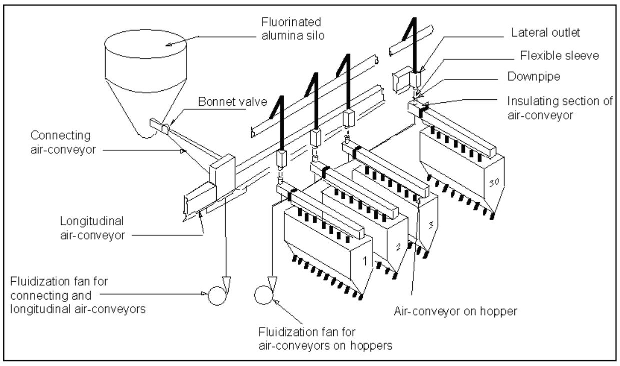

Figure 1. General HDPS pot feeding arrangement

With respect to the main characteristics of the HDPS, the **proven advantages** of this technology are:

- This is a safe technology as it involves very low air pressure (0.1 bar)
- HDPS is "eco-friendly" for two reasons: (i) the device is entirely closed and is consequently dust free; and (ii) the device is permanently full of alumina with hours of autonomous operation, thereby avoiding any alumina shortage to the pots and the associated anode effects
- It is possible to feed continuously and simultaneously thousands of different outlets
- The HDPS technology is horizontal and made of pre-assembled modules, therefore easy to install
- Unlike other systems which use valves within the alumina stream to divert the flow to the many destinations, HDPS does not use valves at all; which ensures a significant reduction in the pieces of equipment known to experience wear and provides the HDPS a significant advantage, as alumina is very abrasive
- There is no product breakage due to attrition and no impurities due to equipment wearing thanks to the low velocity of the conveyed alumina
- Air is supplied by low pressure fans which lead to low energy consumption and little maintenance
- The system is fully automatic, self balanced and does not need any operator intervention, which equates to low operating costs.

3. Modelling

The model used today for the design of HDPS technology was created in the 1980's. The cumulative length of 100km of HDPS installed in smelters all around the world by B&A Engineering - Gardanne (formerly Pechiney, then Rio Tinto Alcan Engineering), has been designed using this model. However, in order to be more confident in future designs of which the capacity tends to be more and more important, a "refreshment" of the modelling tool was necessary. Indeed, some parameters of the model were tuned with industrial tests and the limits of the model were not known precisely. Consequently, a three year R&D program (PhD thesis) was conducted in collaboration with the University of Toulouse (INPT) in France.

1) Operating conditions fluidization regime

During the PhD thesis, an experimental study was completed on a laboratory pilot, on an industrial sized pilot and in a few industrial sites in order to increase the knowledge about the alumina fluidization operating conditions in HDPS. All these experimental observations added to the determination of the characteristic fluidization velocities, enabling the establishment of a new modelling tool.

First of all, it's important to notice that sandy alumina powder (the alumina used in modern smelters) belongs to group A of the Classification of Geldart (Figure 2). This classification, used to classify the powder in term of fluidization aptitude, shows the ability of this kind of particle to be fluidized.

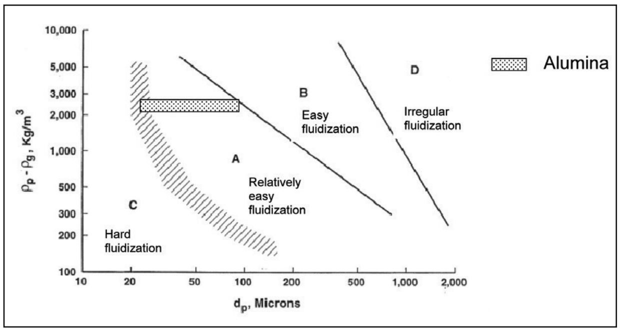

Figure 2. Classification of Geldart

Moreover, the experimental study enabled a determination of the fluidization regime of the HDPS alumina fluidized bed at the optimal operating conditions of the equipment. The knowledge of the optimal operating conditions is essential to modelise and optimise the solid flow in the HDPS.

The evolution of the void fraction with the fluidization velocity (Figure 3) shows that the operating alumina fluidization regime of the HDPS is situated between smooth regime (homogeneous fluidization) and bubbling regime (heterogeneous fluidization). The smooth regime is a particularity of the group A particles (Figure 4).

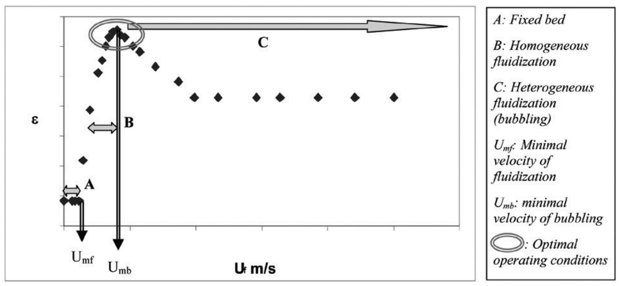

Figure 3. Evolution of the alumina fluidized bed void fraction (ε) with the fluidization velocity (U_f)

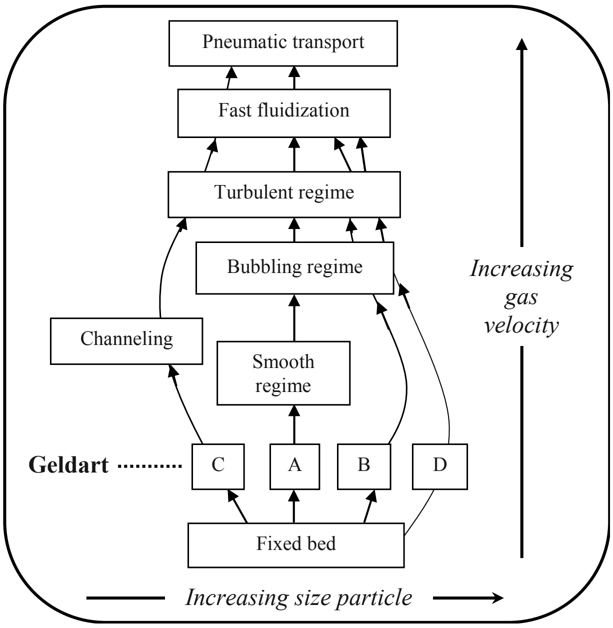

Figure 4. Progressive change in gas contacting with change in gas velocity

In fact, this industrial operating condition corresponds to a regime with reduced inter-particle friction (rubbing). This low rubbing added to a low horizontal solid velocity is at the origin of the absence of alumina attrition in HDPS.

2) Modelling tool

Further to this experimental study, a new modelling tool was created in order to model the solid flow in HDPS. The new model is based mainly on the calculation of the rubbing factor of the particles on the HDPS walls. This parameter is tuned to industrial values recently measured in HDPS at several aluminium plants. Moreover, the model is based on the determination of the fluidization characteristic velocities. These velocities enable definition of:

- The hydrodynamic behaviour of the powder in the equipment with the determination of the minimal velocity of fluidization (Umf), the minimal velocity of bubbling (Umb), the solid transport velocity (Utr) and the limit velocities of the turbulent regime (Uc and Uk)
- The hydrodynamic behaviour of the HDPS gas cloud (the bubble). For this, we defined a solid transport in diluted phase, which is the bubble, characterised by the saltation velocity (Usalt). This velocity corresponds to the minimal velocity of solid deposit. In the HDPS, this velocity corresponds to a critical level in terms of solid transport in the bubble. When the gas velocity becomes superior to this saltation velocity, solid particles at the surface of the fluidized bed are carried.

All these velocities are calculated with the following correlations:

- Re_{mf} Reynolds number at minimal velocity of fluidization (Thonglimp)

$$\mathrm{Re}_{mf} = (31.6^2 + 0{,}0425\,Ar)^{1/2} - 31.6 = \frac{\rho_g U_{mf} d_p}{\mu_g}$$

- Minimal velocity of bubbling (Abrahamsen and coll.)

$$U_{mb} = 33 d_p \left(\frac{\mu_g}{\rho_g}\right)^{-0.1}$$

- Limit velocities of the turbulent regime (Mori and coll.)

$$\mathrm{Re}_c = 0{,}36 Ar^{0{,}472} = \frac{\rho_g U_c d_p}{\mu_g}$$

$$\mathrm{Re}_k = 1{,}46 Ar^{0{,}472} = \frac{\rho_g U_k d_p}{\mu_g}$$

- Transport velocity (Mori)

$$\mathrm{Re}_{tr} = 1{,}41 Ar^{0{,}56} = \frac{\rho_g U_{tr} d_p}{\mu_g}$$

- Saltation velocity (Rizk)

$$\frac{F_{pt}}{\rho_g U_{salt} A_t} = \left(\frac{1}{10^{(1440 d_p + 1{,}96)}}\right)\left(\frac{U_{salt}}{\sqrt{g D_t}}\right)^{(1100 d_p + 2{,}5)}$$

More than the calculation of HDPS, the new model enables design of:

- Dosing HDPS. This equipment enables precise feed (+/- 5% in mass flowrate) of alumina to the gas treatment centre (GTC) of the smelters. The aim of the GTC is to reduce the fluorine emissions by adsorption of the fluorine onto the alumina: monitoring the alumina feeding flowrate entering the GTC is of primary importance for fluorine emission control
- Powder transport lines: powder conveying between two points in a plant. This equipment has the ability to transport alumina along several hundred metres at high mass flowrates with low energy consumption.

4. Industrial results

Some typical data and records of achievement can illustrate what HDPS represents today.

- **Pot feeding**

A cumulative length of 100km of HDPS, designed and installed by B&A Engineering - Gardanne, was reached last year. The number of pots equipped with HDPS technology exceeds 5,300 pots.

30t/h is a typical value for product flow rate in HDPS, but can be increased up to hundreds of t/h if needed. 0.1 bar and 0.05 m/s are the typical data for air pressure and product velocity respectively.

The HDPS prospects are promising because this technology is no longer exclusive to Aluminium Pechiney pots. HDPS can be adapted to pots from 90,000 to 500,000 Amps and available for “Greenfields” and “Brownfields” as well.

This technology can also be adapted to existing potlines. The latest retrofit example is at PNL (Pechiney Nederland in Vlissingen) where 512 pots are now equipped with HDPS technology.

Thanks to the new upgraded modelling tool, HDPS transportation of alumina to the electrolytic cell has created an “optimal alumina conveying design”. Modelling is based on an original concept of interaction between fluidization velocity and powder/vacuum ratio, providing theoretical tools for HDPS conception and optimization.

The simplicity of equipment and low velocities of transportation with the HDPS results in the virtual elimination of alumina feeding breakdown, which would otherwise lead to anode effects and green house gas (GHG) generation. Reliability of HDPS is one of the keys to eliminating “anode effects”.

- **Gas Treatment Centres (GTCs)**

B&A Engineering - Gardanne has developed some new HDPS applications. The GTCs can be equipped with the HDPS technology: HDPS feeding in GTCs is an innovative solution for improving alumina proportioning.

Implementation of HDPS in GTCs includes the newly patented (B&A Engineering – Gardanne) "HDPS dosing device" which:

- Reduces fluorine emissions by improving reactor performances due to the achievement of a constant and adjustable feed rate to the reactors; and
- Saves capital expenditure by reduction of the GTC steel structures.

This technology is available and currently implemented at an industrial scale on AP pots technology.

HDPS in GTCs is also based on the potential fluidization principle, with balancing columns, air conveyors and dosing devices as the main components.

The following curve (Figure 5) indicates the tremendous reduction in fluorine emission at a GTC (AP technology potline) after HDPS dosing technology implementation in 2003.

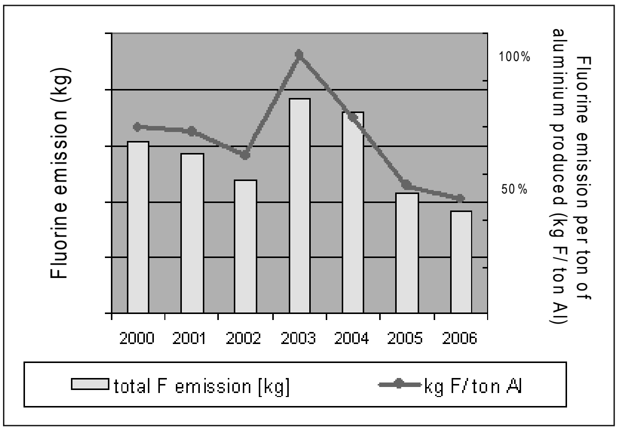

Figure 5. Contribution of HDPS dosing technology to Fluorine (F) emission reduction: GTC industrial results on AP potline technology

5. Conclusions

The new developments in potential fluidization conveying technology now allows optimized engineered solutions for electrolytic cell and GTC alumina feeding.

More than 5,300 electrolytic cells are fed today over the word with HDPS technology and recent industrial results show that GTC fluorine emission can be halved using the new HDPS dosing device.

A modelling tool based on the interaction between fluidization velocity and powder/vacuum ratio enables design of the HDPS equipment and operating parameters. The simplicity of the technology guarantees reliable and low cost operation.

Accuracy of GTC feeding flow-rate and reliability of pot hopper feeding, lead to significant fluorine and GHG emission reduction, making HDPS an eco-friendly unsurpassed technology.

Acknowledgements

Pr Mehrdji Hemati and Dr Cecile Plais (Institut National Polytechnique de Toulouse)

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