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# Advanced technology in spray-dried ceramic slip conveying: Design, process simulation and test facility

A. Bianchini *, M. Pellegrini, C. Saccani

*Department of Industrial Engineering (DIN), University of Bologna, Viale Risorgimento no 2, 40136 Bologna, Italy*

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ABSTRACT

Spray-dried ceramic slip (hereinafter "atomized slip") conveying is mainly carried out by belt conveyors. The bulk solid is picked up from the spray dryer bottom and then covers long distances, crossing the working environment and rising up to feed final stocking silos. Conveyor belts, without specific powder confinement devices, spread out fine particles, causing dust pollution and generating risk for workers' health (silicosis).
Atomized slip pneumatic transport solves a problem of dust pollution caused by atomized slip belt conveying. However, atomized slip pneumatic conveying can be suitable only if some fluid-dynamical and thermo-hygrometric parameters are effectively under control. In fact, both solid maximum conveying velocity and speed gradient (i.e. the variation of solid velocity, in m/s, per meter of pipe length) need to be limited to guarantee product integrity and quality. Moreover, atomized slip humidity must be kept within a range (4–7% in weight) to give some specific characteristics to the final product. So, compressed air humidity, pressure and temperature need to be controlled all along the pipeline to avoid relevant atomized slip humidification or drying.
The paper describes the design process and realization of an atomized slip pneumatic conveying test facility carried out to confirm fluid-dynamical conveying parameters. A finite element software simulator (TPSimWin) was used to evaluate and control atomized slip velocity, speed gradient, humidity and temperature along the pipeline.


## 1. Introduction

Generally, the terms "ceramics" or "ceramic products" are used for inorganic materials with some organic content made up of non-metallic compounds that become permanent as a result of a firing process. In addition to clay based materials, ceramics could include different powder components to give the final product particular characteristics. Depending on the specific production processes, product manufacturing causes emissions to be released into the air, water and land. Fig. 1 shows an example of a ceramic production process plant.

The raw materials are mainly clay and feldspar. In the first phase, a mix of raw materials and water is poured into mills (grinding) to obtain slip with a specific granulometry according to the requested final product characteristics. The slip is then stored in special tanks with a blender to maintain product homogeneity and solid in suspension, while waiting to be sent to a spray dryer. By means of a plunger pump, slip slurry is fed into the spray dryer, where it meets a hot air flow: a uniform density flow finely balanced in the two phases (air and solid) is conveyed around the central vertical axis of the spray dryer, the output is an atomized dry bulk solid whose particles are between 100 and 600 μm. The atomized slip particles are now empty and very fragile. The atomized slip is conveyed by belts between the spray dryer and the warehouses and from the latter to the presses. Finally, molds, drying, glazing and firing processes are developed on the same line and they contribute in differentiating the final product by mechanical characteristics, size, quality and artistic details.

The development of industrial processes that ensure a healthier and safer working environment is a key factor for all enterprises. In the last few years in particular, the European Union stressed these aspects [1], that had become considerable also for the public opinion.

The ceramics industry has been dealing with these problems since the '70s–'80s, but some aspects are still unsolved [1,2]. One of the main problems comes from atomized slip conveying, that is currently carried out by conveyor belts that cross the working environment. This involves a lengthy exposure of the atomized slip in the working environment, with dangerous dust pollution from the diffusion of fine particles in workplaces. This can lead to silicosis, a respiratory disease caused by the inhalation of dust containing crystalline silica [3,4]. According to the American Conference of the Governmental Industrial Hygienists (ACGIH), the only parameter that regulates the maximum concentration of silica ($SiO_2$) in the working environment (i.e. in breathing fraction) is TLV-TWA (Threshold Limit Value–Time Weighted Average), that is the average over a work shift of up to 10 h per day, 40 h per week. In Italy, in the last twenty years, this parameter has decreased from 0.1 mg/m$^3$ in 1995, first to 0.05 mg/m$^3$, to the current 0.025 mg/m$^3$. Fig. 2 shows an example of a conveyor belt starting from spray-dryer outlet.

* Corresponding author. Tel.: +39 0512093403; fax: +39 05 12093411.
*E-mail address:* augusto.bianchini@unibo.it (A. Bianchini).

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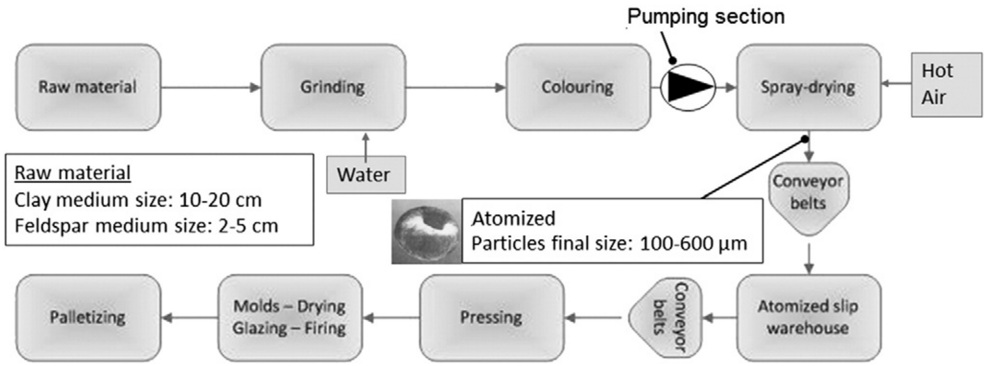


**Fig. 1.** Process flow chart in a ceramics plant.

The conveyor belts introduce in ceramic manufacturing three kinds of relevant problems:

1- lengthy exposure of the atomized slip in the working environment;
2- high capital and management costs, in particular if referred to air extraction/ventilation systems;
3- lay-out design constrained by belt conveyor obstruction.

Innovative transport technologies need to be introduced in ceramics industry to solve these problems.

## 2. Test facility

Pneumatic conveying of atomized slip should fully solve industrial problems due to bulk solid transport:

1- full confinement of atomized slip in transport phases;
2- low capital and management costs if compared to current technologies, including un-safety cost decreasing due to lower working environmental impact [5];
3- lay-out design fully free from constraints.

An atomized slip pneumatic conveying test facility has been designed and realized in industrial size to measure the atomized slip characteristic values, which are necessary for industrial plant design. First of all, the general lay-out of the plant was defined (see Fig. 3): the whole circuit is about 70 m long.

The test facility P&I is reported in Fig. 4. Air mass flow is measured by a differential pressure (DPZ) installed on an ISO 5167-2 designed orifice plate, while air density is computed by air temperature (TZ) and pressure (PL). Instead, atomized mass flow is controlled by frequency regulation of the rotary valve (EFSL) at the hopper discharge; atomized mass flow is measured by load cells (JBB). Atomized slip temperature inside the hopper (TTR) and the air filter temperature (TB) are measured. Pneumatic conveying develops following the lay-out of Fig. 3. At the air filter outlet, the atomized slip can be recirculated or discharged: once the atomized slip is discharged, it is measured in terms of density, granulometry and humidity content to evaluate atomized slip wear or atomized slip humidity change.

In addition, the pressure drop and temperature of pneumatic conveying are monitored. For this purpose, there are 12 more temperature transmitters (T#L) and 8 more differential pressure transmitters (PD#) with regard to the P&I of Fig. 4. The 8 differential pressure transmitters are able to acquire data from 29 pressure connections along the pipeline.

A "Multiplexer" system (Fig. 5), is able to switch differential pressure signal to the same pressure transmitter from one connection to another in a temporal succession. Every multiplexer is composed of a maximum of 8 solenoid valves: by alternate opening of a solenoid valve pair, in steady-state, it is possible to have a complete mapping of pressure drop along the pipeline. For example, by opening V1 and V2 valves, it is possible to read the pressure drop between connection 0 and connection 1. After V1–V2 are closed, V3 and V4 will open and measure the pressure drop between connection 1 and 2. The test facility is equipped with PC software that acquires and memorizes signals from transducers. Fig. 6 shows the atomized pneumatic conveying test facility.

Starting from the lay-out shown in Fig. 3, the simulation software TPSimWin was used to design the pipe diameter d and the loading ratio m, i.e. the ratio between the mass flow rate of solid and air. TPSimWin produces both a diagram and a spreadsheet for each simulation wherein total conveying pressure loss Δp, solid velocity, air velocity and voidage


**Fig. 2.** Spray-dryer outlet in the ceramics industry.

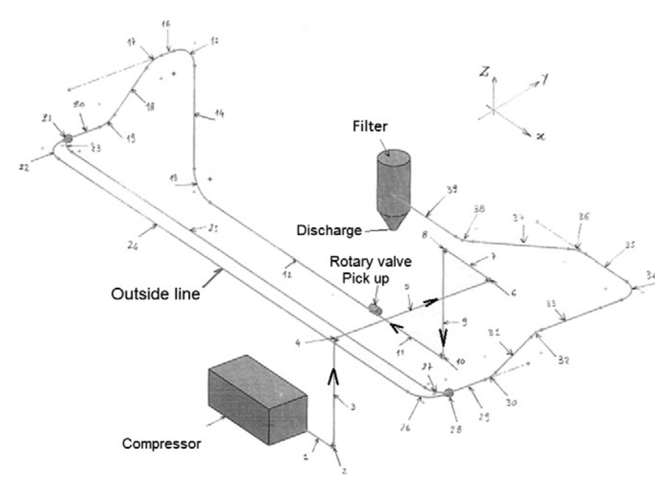


**Fig. 3.** Test facility lay-out. By diverter valves 21 and 28 it is possible to send the product to the outside line, while the rest of the plant is inside an industrial shed. At the air filter outlet, the atomized slip can be recirculated or discharged.