A New Powder Feeder for the Transport of Ultrafine Powders

Abstract

Advanced spraying technologies as High Pressure-HVOF Spraying or Cold Gas Spraying as well as new concepts for the next generation of plasma sprayed TBC's demanding spray powders with strongly decreased powder grain sizes (< 15 µm or even less). Although, with decreasing powder grain size the flowability of the powder is also decreased, causing finally problems in the transport of powder. Within this paper a new powder feeder design will be presented, that makes the precise feeding of ultrafine powders possible, even through feeding lines several meters in length.

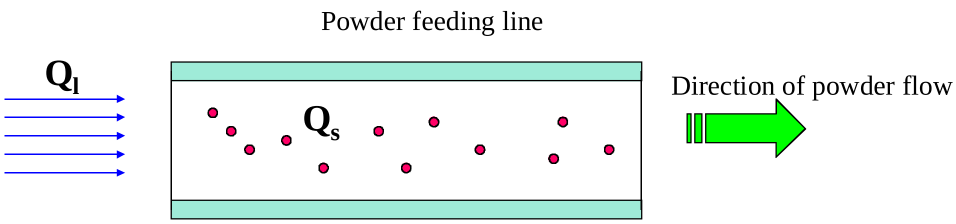
All known powder feeders for thermal spraying use the pneumatic convey for powder transport through the feeding line. In opposite, the new developed powder feeder is using the dense phase convey of powders. The powder transport can be compared with the transport of a liquid in an hydraulic system.

The new powder feeder shows no restrictions in the flowability of a powder. The feeding of normal spray powders (carbides, oxides, metals) as well as submicron powders were successfully tested. Feeding rates from several grams per hour to hundred kilogram and more per hour can be realised, depending on the design of the system. The transport through feeding lines longer than 10 meters also causes no difficulties. The system is self-cleaning and there are no mechanical parts in contact with the powder.

Introduction

Traditional Powder Feeder Concepts

The design of a powder feeder for thermal spraying is defined by two essential points. First, the principal to feed a powder from a powder container into the powder feeding line. Second, the principal to transport the powder in the powder feeding line from the feeder to the spraying torch. In the first point available feeders for thermal spraying are quite different in their design. Here, one can differ into two different design concepts: fluidised bed feeders and mechanical feeders. Both concepts having their advantages and disadvantages as function of application. Although, all conventional powder feeders for thermal spraying are using without exception the pneumatic convey for powder transport in the feeding line. Pneumatic convey means, that the powder particles are kept floating in a gas stream. Therefore, the powder feeding gas flowrate and the feeding gas velocity have to be adjusted in that manner, that the powder particles in the feeding line having no tendency for plugging, that finally requires relative high gas flow rates to guarantee a continuos and pulsefree powder transport. The basic principle of pneumatic conveying is given in the following fig. 1.



Feeding gas velocity > powder velocity
Feeding gas velocity = 20- 35 m/s
Typical ratio between powder massflow and powder feeding gas massflow in the line: Qs / Ql = 10-30

Q_s = Powder mass flowrate
Q_l = Feeding gas flowrate

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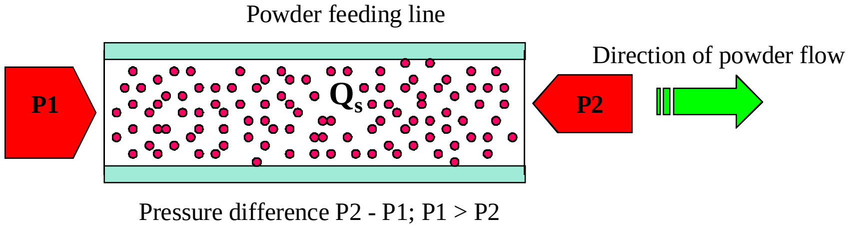
Figure 1: Pneumatic conveying of powders [1]

The classical feeder design causing following problems/restrictions in thermal spraying:

- Limits in the maximum feeding line length
- The powder has to have a flowing behaviour
- Limits in minimum powder grain size to be feeded
- Limits in feeding precision
- Limits in feeding very low quantities
- Limits in feeding very high quantities

Dense Phase Conveying

The new developed powder feeder is using the dense phase conveying mode of powders, as demonstrated in fig. 2. The powder transport can be compared with the transport of a liquid in an hydraulic system. Meaning the powder line is all time completely filled with powder. Therefore, not the flowrate of the feeding gas is responsible for feeding the powder; instead of that the pressure difference between the begin and the end of the feeding line.



The pressure difference determine the powder transport and not the feeding gas velocity!

Feeding gas velocity = 3-10 m/s
Typical ratio between powder massflow and powder feeding gas massflow in the line: Q_s / Q_l = 30-100

Q_s = Powder mass-flowrate
Q_l = Feeding gas mass-flowrate

Figure 2: Dense phase conveying of powders [1]

The Powder Pump

The principle design of the idea of such a " powder pump " is shown in fig. 3. A powder pump contains a vacuum source (1), a pressure source/powder feeding gas (2), a powder aspirating line (3), the powder feeding line (4), 4 valves (5, 6, 7, 8) made of special elastic tubes that can be opened and closed mechanically by pistons and a defined volume (dose) (9). If the valves 7 and 8 are closed and the valves 5 and 6 are open, the powder will be aspirated through the aspirating line (3) out of a container into the dose (9) due to the pressure drop produced by the vacuum pump (1). The dose can have a calibrated volume in the range of 10 to 1000 mm3 as a function of application. After that, the valves 5 and 6 will be closed and valves 7 and 8 will be opened. Now the powder will be pressed out of the dose into the powder feeding line (4). The special design guarantees a 100 % filling and cleaning of the dose. Under atmospheric conditions the working pressure will be less than 0.2 MPa depending on the powder to be feeded and the feeding line length. The powder container can be even a open box, where the powder will be aspirated perpendicular out of it. Although, a well designed powder silo is of advantage regarding feeding regularity and precision.

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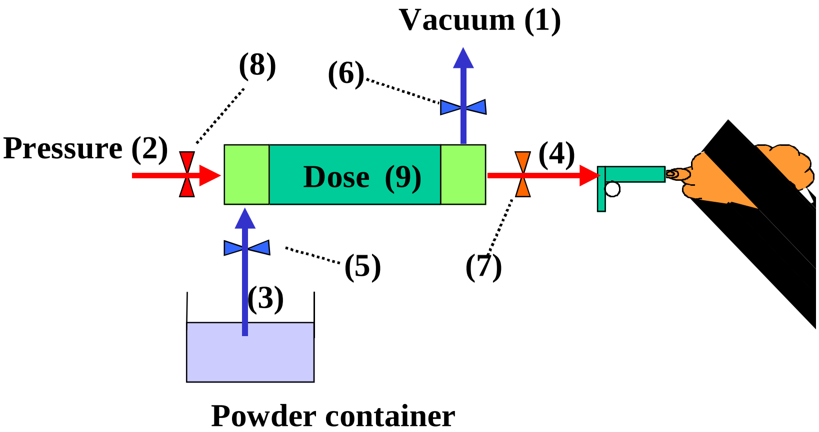

1 = Vacuum source; 2 = Pressure source;
3 = Powder aspiration line; 4 = Powder feeding line;
5,6,7,8 = valves; 9 = defined filling volume (dose)

Figure 3: Scheme of a powder pump

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Running at least at minimum two " powder pumps " parallel with the following, simplified time scheme, a pulse-free powder feed results. The cycle time for a pump is normally situated below 0,4 s per pump, see fig. 4.

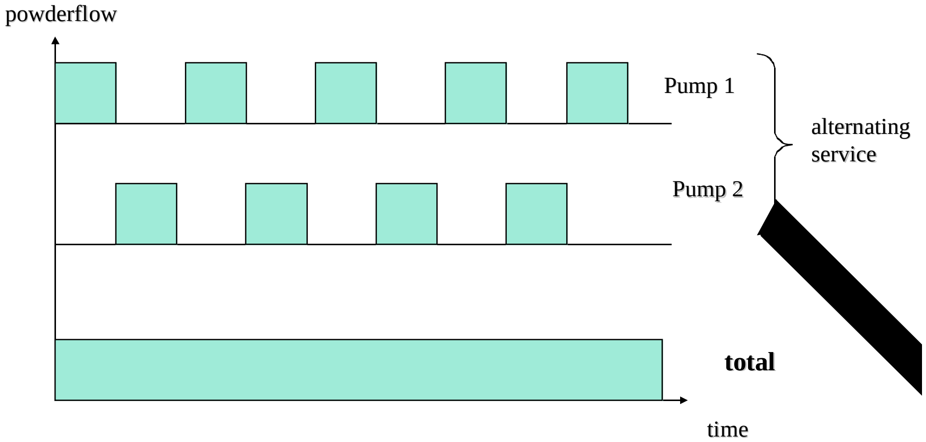

Figure 4: Time scheme of a puls free double powderpump for thermal spraying

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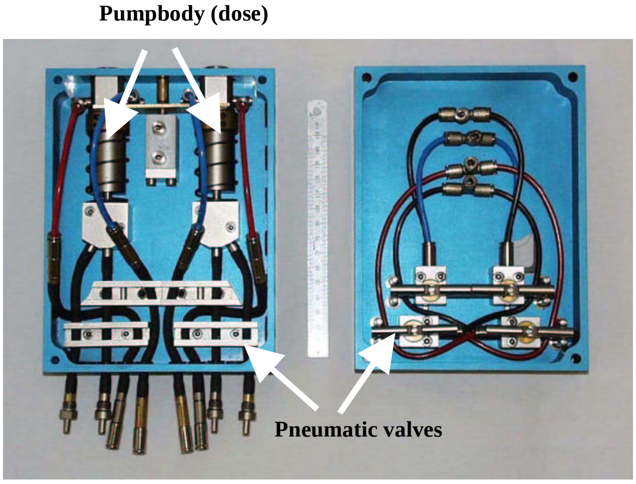

Figure 5: Body of a powder pump with two variable doses

A picture of a realised powder pump with two doses is given in fig. 5. Here the feeding quantity can be controlled by mechanical variation of the volume of the dose within in a given range.

The whole system is controlled by a microprocessor. A further advantage is that no mechanical parts are in the contact with the powder, so that it can come to no wear with the mechanical parts. Furthermore the system is self-cleaning. Patents are pending for the design of the powder feeder.

Due to the basic principle the new feeder need roughly by factor 3 to 10 lower powder feeding gas volume flow rates and there are by the same factor reduced powder feeding speeds in the line. This allows nearly the independent control of the powder feeding gas rate and the powder mass flow. Powder feeding rates from several grams per hour to hundred kilogram and more per hour can be realised, depending on the design of the system. A feeding line length of 20 m or more are normally no problem. If the pressure on the end of the line (gun) is less than 0.2 MPa or vacuum, the powder silo can be under atmospheric pressure, meaning there are no limitations in the size of the silo. Still now the feeding of common powders for thermal spraying (carbides, oxides, metals) were tested successfully. Even first trials with nano-sized powders were done without problems.

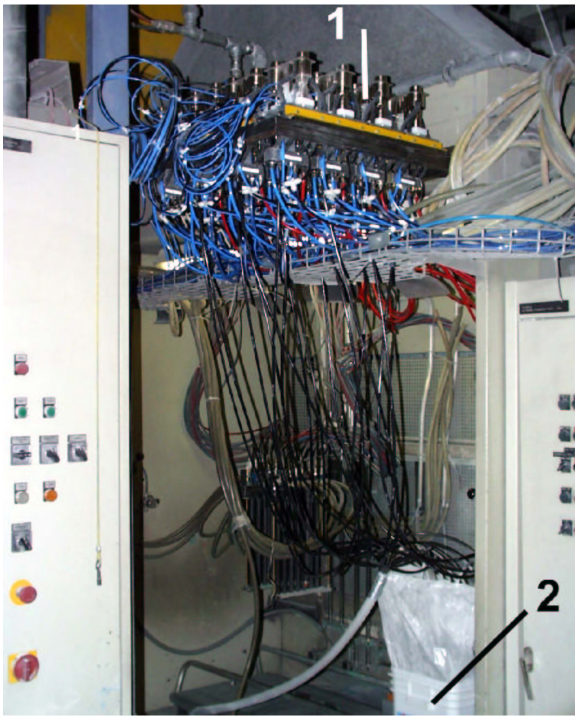

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Figure 6: Installation of 16 double powder pumps (1) for electrostatic powder spraying, aspirating powder out of a open box (2)

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Figure 6 shows a first industrial installation for electrostatic powder spraying of plastic powders. Here 16 powder pumps (top) running parallel aspirating the powder perpendicular out of a open box (bottom). The length of the aspiration lines is of about 2 m and the length of the different feeding lines is 20 m each. The working pressure is 0.08 MPa for a feeding line inner diameter of 6 mm. The feeding capacity of a single pump can be varied between 120 to 340 g/min for a powder with a apparent density of 0.7 g/dm3. The feeding repeatability is +/- 5 g/min for the maximum dose.

Summary and Conclusions

The actual state of knowledge allows to summarise the special properties and advantages of the new developed powder pump as follows:

- Feeding of ultrafine (nanopowders) up to coarse powders is possible
- The powder don't need any flowing behaviour
- The feeding rate can from several g/h to several hundred kg/h (depending on design)
- High feeding precision
- Pressureless powder container
- No limitations in powder container size
- Extreme long feeding lines can be realised (> 30 m)
- Limited electrostatic problems with the feeding line
- Independent control of the volume flow of the feeding gas and the powder mass flow
- Possibility of online blending

Literature

1. Wolfgang Siegel, "Pneumatic Feeding", Vogel-Fachbuch: Verfahrenstechnik, Würzburg: Vogel, Germany, ISBN 3-8023-0432-2, (1991) (in German)

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