

Drying Of Fine Sand In A Pilot Plant Unit Provided With A Draft-Tube Conical Spouted Bed

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A study has been conducted on the performance of a draft tube conical spouted bed for drying fine particles. Batch operation has been performed with different draft tubes (non-porous and open-sided) in order to ascertain the optimum configuration of this internal device. Continuous operation has been carried out with the device of best performance (open-sided draft tube) in a pilot plant provided with this type of bed.

1. Introduction

The applicability of the spouted bed technique lies in its ability to treat (drying, coating, encapsulation and so on) granular products that are too coarse for fluidized bed, or solids that are heat sensitive (Brennan, 1989; Ando and Maki, 2002; Rosiane et al., 2000). This is the case in the food and pharmaceutical industries. Thus, the spouted bed regime is an alternative contact method that is especially interesting when the conventional regimes have limitations imposed by the physical characteristics of the solid and by gas residence time (Rosiane et al., 2000; Olazar and San José, 1992).

Spouted beds with fully conical geometry combine the features of the cylindrical spouted beds (such as the capacity for handling coarse particles, small pressure drop, cyclic movement of the particles and so on) with those inherent to their geometry, such as stable operation in a wide range of gas flowrates (Olazar et al., 1992, 1994a, 1999). This versatility in the gas flowrate allows for handling particles of irregular texture, fine particles and those with a wide size distribution and sticky solids, whose treatment is difficult using other gas-solid contact regimes (Aguado et al., 1999; Olazar et al., 1993b, 1994b). Moreover, operation in the dilute spouted bed can be carried out with short gas residence times (as low as milliseconds) (Olazar et al., 1993b, 1994a, 1997).

A crucial parameter that limits the scaling-up of spouted beds is the ratio between inlet diameter and particle diameter. In fact, the inlet diameter should be no more than 20-30 times the average particle diameter in order to achieve spouting status. The use of a draft tube is the usual solution to this problem. Nevertheless, solid circulation, particle cycle time, gas distribution and so on, are governed by the space between the bottom of the bed and the draft tube. Moreover, minimum spouting velocity and operating pressure drop are also functions of the type of draft tube used.

A conventional spouted bed with draft tube has proven to be an efficient dryer of simple construction (Passos and Mujumdar, 1989). Thus, it provides a high interface area for gas and solid contact, high heat and mass transfer coefficients and high production rates.

Moreover, the use of a porous draft tube allows for gas percolation to the annular zone (Claflin and Fane, 1983). Nevertheless, large beds in cylindrical contactors (flat or conical bottom) record low particle circulation rates. In this paper, a conical spouted bed provided with draft tube has been studied to verify their potential application in the drying of fine particles.

2. Experimental

2.1 Equipment

Based on the knowledge acquired in previous studies about the hydrodynamics of conical spouted beds (Olazar et al., 1992, 1993a, 1993b), a new pilot plant dryer has been designed and built. This pilot plant is made of 304-L stainless steel, Figure 1, and consists of a blower, a solid feeding system, the contactor and a fabric filter for fine particle retention.

The blower supplies a maximum air flowrate of $300 \text{ Nm}^3 \text{ h}^{-1}$ at a pressure of 1500 mm of water column. The flowrate is measured by two computer-controlled mass flow-meters in the ranges $50\text{--}300 \text{ m}^3 \text{ h}^{-1}$ and $0\text{--}100 \text{ m}^3 \text{ h}^{-1}$. The blower supplies a constant flowrate, and the first mass flow-meter controls the air flowing into the contactor (in the range $50\text{--}300 \text{ m}^3 \text{ h}^{-1}$) by acting on a motor valve that reroutes the remaining air to the outside. When the flow required is lower than $50 \text{ m}^3 \text{ h}^{-1}$, it passes through the first mass flow-meter, being regulated by the second one placed in series, which also acts on another motor valve that adjusts the desired flowrate. The accuracy of this control is 0.5% of the measured flowrate.

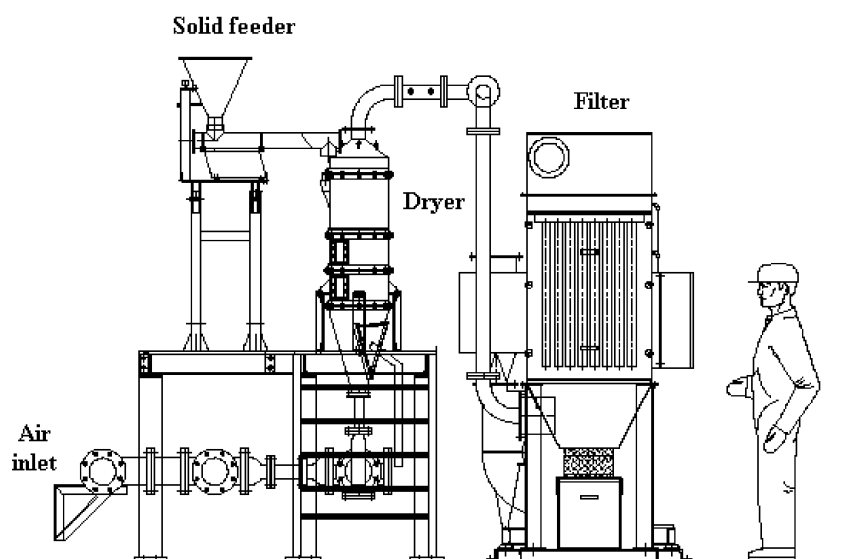


Figure 1. Scheme of the conical spouted bed pilot plant drier.

The solid feeder is made up of a hopper and a vibrating device. The solid flowrate into the dryer is controlled by the vibration level.

The measurement of bed pressure drop is relayed to a differential pressure transducer (Siemens Teleperm), which quantifies these measurements within the 0-100% range. Two thermocouples located at the bed inlet and outlet measure the temperatures of the air supplied by the blower before entering the contactor and at the exit. In addition, there are thermal conductivity detectors (Alhborn MT8636-HR6) for measuring air moisture content at both inlet and outlet. Temperature and moisture contents are stored in an Alhborn Almeno 2290-8 data logger, which allows for monitoring their evolution over time. The gas stream leaves the dryer and passes through a fabric filter for removing any entrained matter.

The pilot plant main component is the contactor, Figure 2, which has a conical geometry. Figure 2a shows the different zones in the bed with a standard non-porous draft tube and particle movement. The dimensions of the contactor, Figure 2b, are: Diameter of the upper cylindrical section, D_c , 0.35 m, conical section height, H_c , 0.51 m, included angle of the cone, $\gamma/2$, 36 degrees, inlet diameter, D_o , 0.04 m and base diameter, D_i , 0.068 m. The total height of the contactor (conical plus cylindrical section) is 1.16 m. In addition to the stainless steel contactor, an exact poly-methylmethacrylate replica has also been constructed for carrying out hydrodynamic studies.

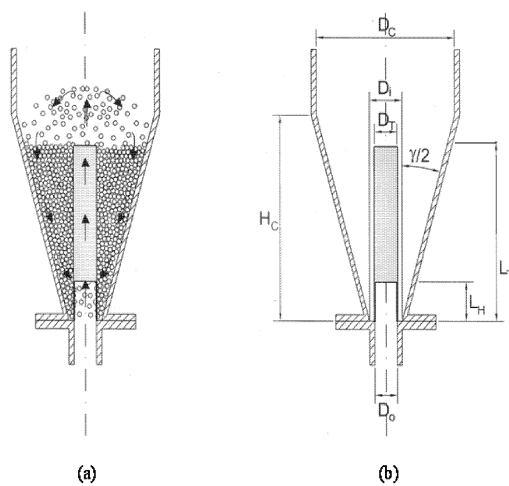


Figure 2. Conical contactors with (non-porous) draft tube. (a) Zones in the bed. (b) Geometric factors

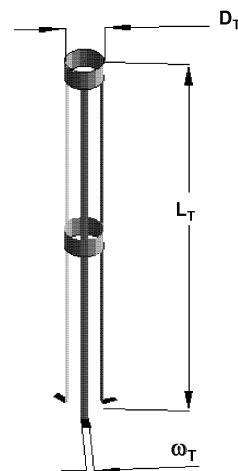


Figure 3. Scheme of the open-sided draft tube

Draft tubes with different configuration have been used: non-porous and three open-sided ones. The diameter of all the tubes, D_T , is the same as the inlet, 0.04 m. The length of the non-porous draft tube, L_T , is 0.27 m and the height of the entrainment zone (distance between the gas inlet nozzle and bottom of draft tube), L_H , is 0.07 m. The open-sided draft tubes are of different aperture ratios with three slots, Figure 3. The widths of the faces on the open-sided tubes, ω_T , are 0.025, 0.018 and 0.010 mm, which mean aperture ratios of 57, 65 and 78%. Moreover, the total length of the open-sided tubes is 0.50 m, which means they stand 0.20 m above the bed surface. This length has been chosen according to previous experimentation in which lower and denser fountains

were observed when the tube end was above the bed surface. In fact, the height above the bed must be at least 2/3 of the stagnant bed height.

Continuous and batch operation has been carried out using air at ambient conditions (25 °C).

2.2 Material

The material used for drying is building sand. The initial moisture content (as received) is between 7 and 10%, and the specification is that it should be dried to approximately 0.005 kg of water/kg of dried solid for subsequent use. The particle size distribution is shown in Table 2. As is observed, it is a fairly wide distribution, which is a major inconvenience when using a fluidized bed, and the average particle diameter is below 1 mm (0.45 mm), which hinders operation using plain spouted beds. In fact, this solid is usually dried in rotary driers where mass transfer and efficiency are low.

Table 1. Particle size distribution of the sand.

Particle size (mm)	0.1	0.23	0.47	0.81	1.5	3	5
Weight (%)	2.51	17.12	33.94	29.36	16.15	0.91	0.01

3. Results

Batch drying has been carried out in the poly-methylmethacrylate unit, in order to compare the performance of different types of draft tubes. In all runs, 0.5 kg of wet sand (0.07 kg of water/kg of dry sand) were added to a bed containing 7 kg of dry sand. Figure 4 show the evolution with time of the air moisture content at the bed outlet for the non-porous and one of the open-sided tubes ($\omega_T = 0.018$ mm, 65% aperture ratio). As is observed, the drying time required with the open-sided draft-tube is much shorter than with the non-porous draft tube. Thus, the spouted with the non-porous draft tube requires 1200 s to dry the solid to the specification given, whereas the spouted bed with the open-sided draft tube requires only 450 s. This is explained by air percolation from the spout in the annulus and the consequent better contact with the porous tube (Claflin and Fane, 1983). Furthermore, the fountain obtained with the open-sided draft tubes is much lower and denser than with the non-porous, which is due to the length that protrudes above the bed surface (0.23 m). Consequently, there is an important additional gas-solid contact in the fountain, which shortens the drying time.

Concerning the results for three open-sided tubes, the time needed for drying the solid to the specification given decreases as the aperture ratio is greater, from 500 s for the tube with 57% aperture ratio to 350 s for that with a 78% ratio. The reason for the better performance lies in the much higher solid circulation rate, which helps air percolation to the annulus and provides a better gas-solid contact.

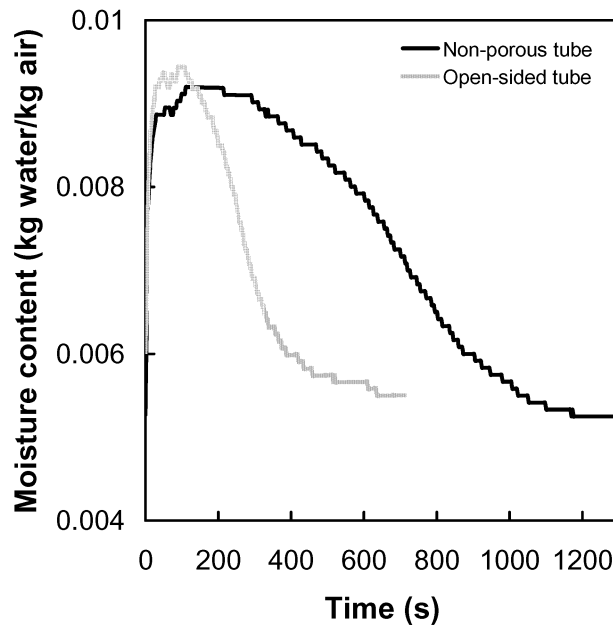


Figure 4. Evolution of air moisture content with drying time using the non-porous and an open-sided draft tube ($\omega_T = 0.018$ mm, 65% aperture ratio)

The open-sided tubes require higher minimum velocity and operation pressure drop than non-porous draft tube but the solid circulation rate is much higher. In addition to the higher solid circulation rate, open-sided tubes also allow for a better distribution of the gas to the annulus and, consequently, more air is required to open the spout. In other words the higher solid circulation rate (turbulence in the annulus) helps air percolation from the spout into the annulus.

Based on the results obtained in the batch drying an optimum open-sided draft-tube has been designed for the continuous operation, whose dimensions are: the length of the tube, L_T , is 0.72 m, the diameter of the tube, D_T , is 0.04 m and the width of the faces on the open-sided tubes, ω_T , is 0.018 m.

Several runs have been carried out in order to ascertain stable operation of this bed in the drying process and the amount of sand that this pilot plant is able to dry using air at ambient conditions. In each run, a given flowrate of wet sand (0.08 kg of water/kg of dry sand) has been fed into a 34 kg dry sand bed (0.52 m stagnant bed height). The flowrates of wet sand were in the 12-60 kg/h. The main conclusion drawn from this runs is that specification (moisture content below 0.005 kg of water/kg of dry sand) is met when the air flowrate is lower than 24 kg/h.

4. Conclusions

Conical spouted beds fitted with a draft tube perform well in the drying of fine solids, given they allow for stable operation in a wide range of operating conditions.

Conventional non-porous draft tubes are very stable, but have a poor performance due to gas bypassing through the spout. Open-sided draft tubes perform much better than the non-porous ones, given that the time required for drying is around half or even less (450 s vs. 1200 s), although their pressure drop and air flowrate required are superior.

5. References

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