EFFECT OF TEMPERATURE ON THE DRYING OF SAWDUST IN A CONICAL SPOUTED BED

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Abstract: The drying of sawdust has been studied in a conical spouted bed pilot plant dryer using air at different temperatures and particle sizes. Batch operation has been performed without internal device and with non-porous and open-sided draft tubes. Although the non-porous draft tube requires the lowest minimum spouting velocity, its performance is poor due to the deficient gas solid contact. The open-sided draft tube and the contactor without internal device have shown higher efficiencies because of their better contact. An increase in the air temperature provokes a reduction in the drying time.

Keywords: Biomass drying, sawdust, conical spouted, draft tube

INTRODUCTION

The growing demand of alternative sources of energy has promoted the interest on the biomass in the last decades. Biomass represents one of the main renewable energy resources available. Moreover a wide variety of biomass derived fuels can be obtained (gases, liquid, and solid) (Bridgwater et al., 1999). The moisture content is one of the most significantly disadvantageous features of using biomass as a fuel that produces low combustion temperatures, low energy efficiency and high emissions of hydrocarbons and particles (Moreno et al., 2004). Furthermore the water content should be reduced for a more efficient transportation to the place of consumption in terms of energy density.

Different technologies have been applied to biomass drying and rotatory dryers are the most commonly used. However the performance of the rotatory dryers is poor due to the low heat and mass transfer rates and, consequently, long residence times and high contactor volumes are required (Berghel et al., 2008). Regarding the drying medium the most usual solutions are steam dryers and air or flue gas dryers. The superheated steam dryers have some advantages compared to air dryers such as the higher drying rates and the possibility of avoiding the risk of fire and explosions. The main disadvantage of steam dryers is the more complex design and expensive construction.

For more than 50 years spouted beds have been successfully applied to the drying of different solid materials such as sawdust (Berghel et al., 2008), grain (Markowski et al., 2007), seeds (Ando et al., 2002) and inert materials (Altzibar et al., 2008). In addition, the spouted bed with inert particles has been commonly used for the drying of liquid materials such as pastes suspensions and solutions.

The advantage of the spouted bed technique in drying is the capacity for handling granular products, which are difficult to be readily fluidized and where good heat and mass-transfer and favourable gas solid contacting are important. Moreover spouted beds are suitable for operations using heat sensitive materials due to their good heat transfer and isothermcity (Freitas and Freire, 2001).

Conical spouted beds have low segregation and can operate under stable conditions in a wide range of gas flowrates. However the ratio between the inlet diameter and particle diameter may limit the scaling up of spouted beds (the inlet diameter should be smaller than 20–30 times the particle). To overcome that limitation the use of a draft-tube is a usual and simple solution (Altzibar et al., 2009).

In this paper, pine wood sawdust has been dried in a conical spouted bed pilot plant. The bed height used is 27 cm and a good stability is achieved operating without draft-tube. However, the use of internal devices is mandatory for the scale up. Consequently the results obtained without draft-tube have been compared with those obtained using two different types of draft-tubes, i.e., non-porous and open-sided draft-tubes. Moreover the effect of temperature over the drying kinetics have been studied, the results obtained at 20 ºC have been compared with those obtained at 40 and 50 ºC.
EXPERIMENTAL

The pilot plant dryer used in this work has been designed with the knowledge acquired in previous studies about the hydrodynamics of conical spouted beds (Olazar et al., 1992). In fact, this plant has previously been used for the drying of building sand (Altzibar et al. 2008; Olazar et al., 2011). The plant is made of 304-L stainless steel, Figure 1, and consists of a blower, a cartridge for heating the air, a solid feeding system, the contactor and a fabric filter for fine particle retention.

The blower supplies a maximum air flowrate of 300 Nm$^3$ h$^{-1}$ and is measured by two computer-controlled mass flow-meters. The measurement of bed pressure drop is relayed to a differential pressure transducer (Siemens Teleperm).

Fig. 1. Scheme of the pilot plant dryer

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 also stored in the 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, which has a conical geometry. The dimensions of the contactor 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 the present paper the performance of the conical spouted bed without tube has been compared with the results obtained using two draft tubes with different configuration, a non-porous and an open-sided ones.

Runs have been carried out in batch mode using air at 20, 40 and 50 ºC. The bed was initially made up of 27 cm of wet sawdust. The initial moisture content is between 70 and 90 % on dry basis. This sawdust has a wide size distribution and has been divided into two different fractions by sieving. The gross fraction has a particle diameter between 4 and 2 mm and the fine one between 2 and 0.7 mm. The solid density of this material is 525 kg m$^{-3}$.

RESULTS

Prior to the drying operation with sawdust, the performance of the spouted bed regime and the minimum spouting velocity ($u_{min}$), operating pressure drop ($\Delta P_{op}$), and peak pressure drop ($\Delta P_{pm}$) must be determined. Dry biomass has been used in all cases for this purpose. The minimum spouting values are a bit lower for the contactor fitted with an open-sided draft-tube compared to the conventional conical spouted bed. However, the values obtained for non-porous draft tubes are lower for both sawdust samples. Moreover, minimum spouting velocity is greatly influenced by sawdust particle diameter. Thus, increase in the 60 to 80 % range was observed when the coarse sawdust is used.

Figure 1 shows a comparison of the evolution of the air moisture content at the outlet of the dryer for the three different systems studied. As observed the drying performance is very similar using open-sided draft tube and without draft tube. The open-sided draft tube allows for the gas percolation from the spout to the annulus region and getting a similar performance to the results obtained without draft tube. The time required for drying is around 60 minutes in both cases.

Fig.1. Comparison of the drying performance of different experimental configurations, 40 ºC, fine sawdust.

The performance using a non-porous draft tube is poorer due to the bad gas-solid contact, which is almost inexistent in the annulus region (Ishikura et al., 2003). The drying time obtained operating with a non-porous draft tube is longer than 80 minutes.
Figure 2 shows a comparison of the evolution of the air moisture content at the outlet of the dryer at 20 ºC without draft tube for both sawdust particle diameters. The major effect of particle size on the drying process is observed during the falling rate period in which mass transfer is controlled by the internal diffusion. In fact, the slope of the curve at the end of the falling rate period is lower in the drying of coarse particles, which is due to moisture diffusion limitation inside the sawdust particle.

Moreover, the time required for drying the solid decreases as the drying temperature is increased. In fact the time required for the drying is approximately (it depends on the system) three times shorter in the experiments carried out at 50 ºC in relation to those performed at 20 ºC.

CONCLUSIONS
The conical spouted bed is an interesting technology for drying sawdust due to its easy design and good performance. This contactor has shown a good performance either fitted with a draft tube or without internal device, given that the beds used in the study are stable in a wide range of operating conditions.

Conventional spouted beds without a draft tube provide a vigorous gas-solid contact. However, the gas flow rate required for the drying is too high and, moreover, instability problems arise when scaling up the process, and the use of an internal device is required. The non-porous draft tube is very stable and the gas flow rate it requires is the lowest of the three systems analysed, but performs poorly due to gas bypassing through the spout.

A slight increase in the drying temperature from 20 to 50 ºC causes an important reduction in the time required for the drying.

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REFERENCES


Berghel J. L. Nilsson and R. Renstrom (2008), Particle mixing and residence time when drying sawdust in a continuous spouted bed, Chemical Engineering and Processing, 47, 1252-1257.


Ishikura T., H. Nagashima and M. Ide (2003), Hydrodynamics of a spouted bed with a porous draft tube containing a small amount of finer particles, Powder Technology, 131, 56-65.


