Design, Construction, and Start-Up of an Inclined Sheet Continuous Powder Dryer

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Abstract

It was designed a continuous powder dryer of inclined metal sheets that is an alternative for the drying of lactose in the pharmaceutical and food industry where there are high control requirements for moisture content. However, the dryer can be used to dry any type of wet solid. The dryer was designed to process the granular material over a wide range of particle sizes. The air velocity used in the experiments were lower terminal particle velocity to avoid particle drag. The experiments were compared with CFD simulations. The results of the simulations helped to explain the results obtained experimentally. The best contact air-solid were obtained using the configuration of 60° inclination angle. With this arrangement, the air reduces the loss of energy caused by the sheet friction maintaining its high velocity.

Keywords: Drying, powder, air velocity, moisture

1. Introduction

In general dryers are equipment commonly used to remove water or certain solvents from powders such as those used in industries such as pharmaceutical [1], chemical [2], metallurgical [3], food [4], ceramics [5], agriculture [6], among others. Most of
them use a continuous flow of gas to disperse the particles through a confined space to increase the surface area of contact increasing as well the drying. Although the drying process has been studied in most dryers, research is still being done to make optimization of the equipment to get better results in the process. The factors that are wanted to improve are the rate of drying and the solid flow profiles in the fluidized bed. It is necessary to avoid granulometric changes in the particles [1] and dead zones that cause dust adhesion. There are other important factors to consider when selecting the type of drying method such as the type of material to be dried and the conditions that are required for the process, such as production time, costs, final product conditions, among others. Drying processes in fluidized beds are usually preferred, to favor the fluidity of the final product and obtain high production through a reduction in operating times.

To enhance the quality of drying in industrial applications that demand specific moisture content and knowing the complications to control the humidity in discontinuous dryers, a novel continuous powder dryer with adjustable angular sheets has been designed. The working angle of inclination were 40°, 50°, and 60°. The purpose was to create a new dryer that causes a uniform drying in a short time without altering the granulometry of the powder.

2. Methodology

After the results obtained with the simulations of a CFD software, it was built a continuous powder dryer with inclined metal sheets. Figure 1 shows the feeding module to pour the solids. The dimensions of the dryer where determined considering a powder flowrate of 25.2 Kg/h. The powder used to dry was granulated anhydrous lactose with an average particle size of 1 mm.

![Figure 1. Feeding module of the dryer](image)

Figure 2 a and b shows the bottom of the column which is a hopper discharge of the dried powders. Figure 2 c and d, shows the top of the column which is a dust filter to avoid powder escape.
Figure 2. Dimensions of hopper discharge of the dryer in mm (a) Top view (b) side view. Dust filter at the top of the dryer (c) top-side view (d) side view.

Figure 3 shows the different degrees of inclination of the metal sheets. As can be seen, all the sheets have different lengths depending on the inclination.

Figure 3. Dimensions of the dryer modules in mm a) front view b) side view

Figure 4 shows the system designed to heat the air to reduce its relative humidity. It consisted of eight heat resistances- coil type. The outlet of this heater has eight air exits that were connected to the dryer in different inlet sections.

Figure 4. Heater scheme
3. Results And Analysis

The design was initially assembled as shown in figure 5a with the air inlet in one side of the tower. The results of drying were extremely low near 1% of humidity removal. After analyzing the system, it was noticed that the air velocity profile obtained did not help the mechanism of drying. The CFD simulation help to create another assembling of the section of the tower as shown in figure 5b. With this configuration, the air enters in direct contact with the solids improving the drying.

![Diagram of drying system](image)

Figure 5. Continuous drying system a) with air inlet in one side of the tower b) with air inlet in opposite side in front of the sheets.

Figure 6 shows the air velocity vectors that helped the final design of the drying sections. There is a continuous direct contact with the solid with an air recirculation that increases the time of contact increasing the capacity of water removal. The disadvantage here is the low velocity found in each section. The area corresponding to velocities near 1 m/s correspond only to less than 5% of the entire section. The best result of air velocity profile is found in figure 6c for an inclination of 60°.
Table 1 shows the real average velocities found in all the sections. They were taken with some anemometers and they range from 1.53 to 2.28 m/s. These velocities are higher than the simulated.

<table>
<thead>
<tr>
<th>Module</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average velocity (m/s)</td>
<td>1.53</td>
<td>2.13</td>
<td>1.98</td>
<td>1.85</td>
<td>2.55</td>
<td>1.94</td>
<td>2.28</td>
</tr>
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</table>

Equation 1 determines the terminal velocity of the smallest particle. $r$ is the particle radius (0.0005 m), $g$ is the gravity, $\rho_p$ is the particle density (1520 Kg/m$^3$), $\rho_a$ is the density of the air (0.97 Kg/m$^3$) and $Cd$ is the drag coefficient (0.47).

$$U_t = \sqrt{\frac{8rg\rho_p}{3\rho_aCd}}$$

With the given parameters it is obtained a terminal velocity of 6.6 m/s. As can be seen in table 1, the average velocities in all the sections are lower than the terminal velocity indicating that there is no loss of powder in the dryer.

Figure 7 shows the results of the powder drying at a different degree of inclination of the sheets. As can be seen, at an inclination of 40° it is obtained the lowest removal of water which is in agreement with the results found in the CFD simulations that shows the worst contact air – solid at an inclination of 40°. It can be seen that at this inclination the air gets immediately in contact with the solid
causing a change of direction of the air to the down section increasing the friction of the air reducing its velocity, and the mass transfer as well.

![Graph showing humidity change vs. metal sheet inclination](image)

**Figure 7. Humidity removal for the different sheet inclination**

At an inclination of 50°, the air gets in contact with the solid at a short distance reducing the air velocity immediately by a normal force. It causes a decrease in water removal because of the low convection in the area. At an inclination of 60°, it can be found the longest separation regarding the sheet letting the air to spread easily all over the area increasing the contact with the solid enhancing the water removal. 60° was the best working angle. However, the general results are not the best because all the water removal was low for the three shown configurations, only the 10.5% of the total humidity was retired. It means that it is necessary to work at different operating conditions to get a better drying.

**Conclusions**

It was designed a novel continuous powder drying with inclined metal sheets. A CFD simulation was run to see the behavior of the possible best configuration of the sheet inclination.

Giving the results of the CFD simulations, the best configuration of inlet air flow resulted when the sheet inclination was 60° because of the length of the metal sheets. It was the highest length that makes the air to move along the metal sheets causing the highest contact with the solid. With this arrangement, the air reduces the loss of energy caused by the sheet friction maintaining its high velocity.

The powder drying was not as expected. All the water removal was low for the three studied inclinations. The maximum water removal was about 10.5%. It means that it is necessary to work at different operating conditions to get a better drying.
References


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