International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.11 No.08, pp 213-218, 2018

CFD analysis of a continuous powder dryer with inclined metal sheets

Luis Obregón Quiñones[1]*, Martín Guerrero Pérez[2], Kevin Mendoza Salgado[3]

[1]Research Group on Sustainable Chemical and Biochemical Processes, Universidad del Atlántico, km 7 Antigua vía Puerto, Colombia

Abstract: A continuous powder dryer of inclined metal sheets was designed and simulated using computational fluid dynamics. This dryer suggests an alternative for the drying of lactose in the pharmaceutical and food industry where there are high control requirements for moisture content. The dryer was designed to process the granular material over a wide range of particle sizes. The dryer dimensions are calculated by the particle entrainment theory to obtain the terminal particle velocity. CFD simulations were performed by feeding the air in the front and the back of the metal sheets with inclination angles of 40°, 50°, and 60° angles.The results of these simulations indicate that the velocity profiles with the best contact air-solid were obtained using the configuration of 60° inclination angle.
Keywords : CFD, simulations, drying, tower.

1. Introduction

Drying is a unitary operation of great importance used in industries of different fields worldwide in sectors such as pharmaceutical[1], chemical[2], metallurgical[3], food[4], ceramics[5], agriculture[6], among others. Although the drying process is already established in most dryers, research is still being donemake 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[7] and dead zones that cause dust adhesion.

The problem is that this unit operation is affected by multiple factors like the thermal conductivity of solid and liquid, the latent heat of vaporization, the effect of solutes in the liquid, the pressure and temperature of the drying atmosphere, the speed and relative humidity of the air, the vapor pressure of the liquid, the solid-liquid surface tension, the size of the particles and their internal porosity, and the vapor diffusion coefficient in the pores, which make tedious the understanding of drying phenomena.To solve this problem, equipment are designed,andexperimentsare rununtil optimal operating conditions are obtained[8]. However, the problems in the output product continue due to the many variables affecting the drying directly and indirectly.

Luis Obregón Quiñones *et al* /International Journal of ChemTech Research, 2018,11(08): 213-218.

DOI= http://dx.doi.org/10.20902/IJCTR.2018.110825

With the goal of improving the quality of drying in numerous industrial applications that demand specific moisture content and knowing the complications to control the humidity in discontinuous dryers, a novel continuous dryer with adjustable angular sheets has been designed and simulated using a CDF software to know the velocity profile of the air inside the dryer and understand the possible phenomena that can occur during the powder drying to achieve an optimization eventually. 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

In this stage the entire internal volume of the structure. The modules or sections were drawn (figure 1) and then assembled to have a complete dryer (figure 2). Each module has the dimensions shown in figure 1 a and b. According to the geometry of the tower, the symmetry of the dryer has computational benefits reducing the time to obtain results because it does not contain many obstacles in its interior that prevent the movement of fluids. A specialized CFD software was used,and the CAD files were imported to run the simulations.

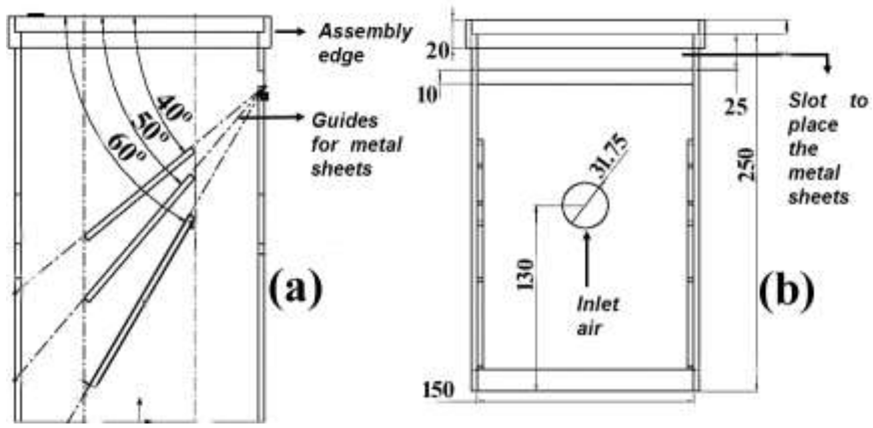

Figure 1.Dimensions of the dryer modules in mm a) front view b) side view

As shown in Figure 2, the air has several inlets on the side of the drying column. The entry of particulate material is at the top. There are three different angles to place the sheets where the powder is going to slide. Each sheet has different lengths depending on the angle. Figure 2 shows seven sections. The top is an additional section where the air exits andat the same time enters the particulate material.

Figure 2 is imported into the CFD software to run the simulations. Figure 3 and b shows the different configurations of air intake to the column. Figure 3a shows when the air flow and hits directly on the front of the plates in each of the modules being in full contact with the particulate material when falling.

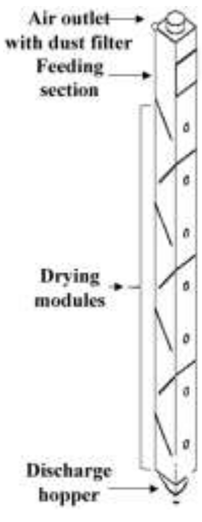

Figure 2.Scheme of the continuous dryer with adjustable angular sheets

Figure 3b shows when the air flows and hits directly on the back of the plates in each of the modules just where there is no direct contact with the particulate material.

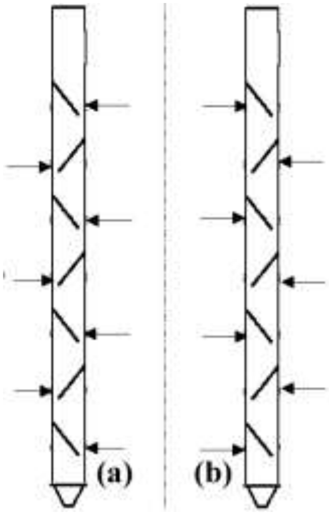

Figure 3. Air inlet (a) on the front of the inclined metal sheet, (b) at the back of the inclined metal sheet.

The equations solved by the laminar flow interface are the Navier-Stokes equations for the momentum conservation (Eq.1) and the continuity equation (Eq.2) for the conservation of the mass. The system was considered in steady state, allowing to analyze the variables of velocity and pressure.

$$\rho D\mathbf{v} / Dt = -\nabla p + \mu \nabla^2 \mathbf{v} + \rho \mathbf{g} \quad \textbf{(1)}$$

$$\partial \rho / \partial t + \left(\nabla \cdot \rho \mathbf{v} \right) = 0 \quad \textbf{(2)}$$

3. Results

3.1. Air inlet behind the metal sheets. Sheet inclination angle: 40°, 50°,and 60°

Figure 4a shows the flow of air inside the dryer movinghorizontally in the vicinity of the inlet causing a high reduction of the kinetic energy of the air avoiding direct contact of the air with the solid.

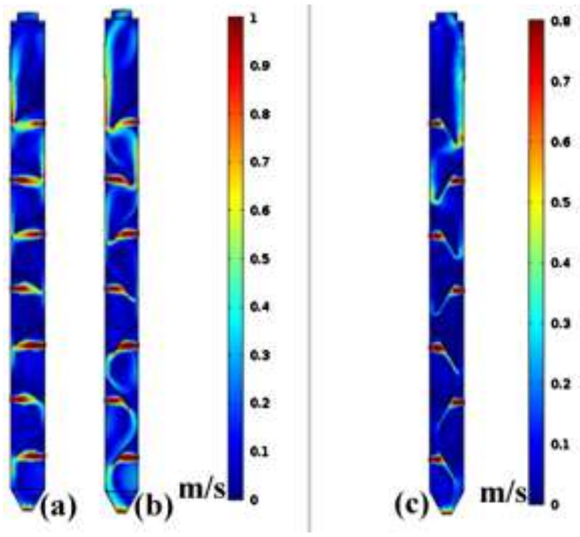

Figure 4. Velocity profiles of the inlet air at the back of the metal sheet with inclinations of (a) 40° (b) 50°, and (c) 60°

According to the color scale, the air velocities are low in the zones defined as potential for drying. The results of the simulation shown in figure 4b indicate that the effect of the velocity is higher in the back of the metal sheets because the air makes direct contact with the solid that will eventually slide in the next sheet. It happens in the three first sheets. In the fourth sheet, this effect decreases indicating a zone of poor drying. However, in the zone of the five, six, and seven sheets the velocity of the air increases letting a better contact with the solid increasing the drying as well. There is a complication in the first sheet because most of the air that enters in the first sectionexit in the outlet of the solids through the hopper decreasing the efficiency of the entire dryer.

In the configuration of sheet inclination of 60^o shown in figure 4c, the velocity profile along the entire dryer is near to zero indicating that the drying by forced convection is null. Therefore, it is concluded that these configurations do not favor the eventual drying process in the equipment.

3.2. Air inlet in front the metal sheets. Sheet inclination angle: 40°

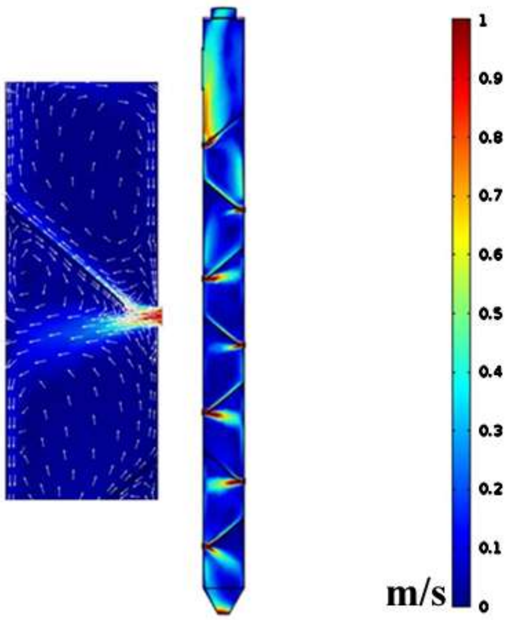

Figure 5. Air velocity profile in front of the metal sheets with an inclination of 40°.

The results shown in figure 5 indicate that there are potential drying areas on the front surface of the sheets where the speed was between 0.3 and 0.5 m/s and compared to the previous results, an improvement is observed because of the circulation of the air inside the dryer. As can be seen in figure 5 the air rotates around each section letting an increase in the contact air-solid improving at the same time the possible drying of the powders.

3.3. Air inlet in front the metal sheets. Sheet inclination angle: 50°

The results of figure 6 indicate that there are potential drying areas on the front surface of the metal sheets in the average velocities between 0.4 m/s and 0.7 m/s. This configuration can benefit the heat and mass transfer with the solid that will slide through the sheets.

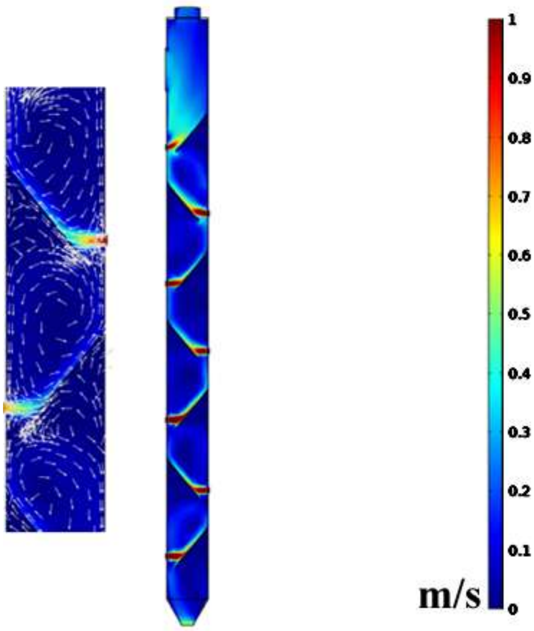

Figure 6. Air velocity profile in front of the metal sheets with an inclination of 50°.

The rotation of the air is clockwise, contrary to the obtained with the sections of 40° of sheet inclination (counterclockwise). The air moves up through the metal sheets getting direct contact with the powders allowing a higher degree of drying. It happens because the length of the metal sheets is higher at 50° than at 40° causing the air to change their direction along the metal sheets.

3.4. Air inlet in front the metal sheets. Sheet inclination angle: 60°

Figure 7 shows the best configuration to get highest drying efficiency. It shows that in the vicinity of the front of the sheets, the air moves faster than 0.4 m/s and that in these areas there is a noticeable solid-air contact to favor drying.

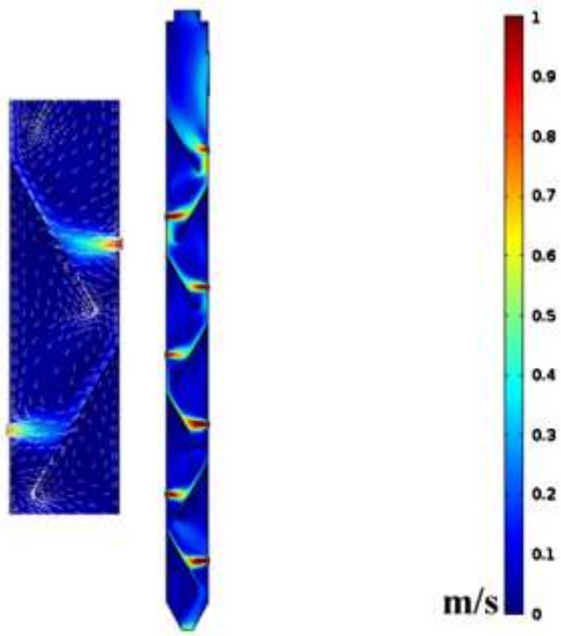

Figure 7. Air velocity profile in front of the metal sheets with an inclination of 60°.

The average velocity of the air in all the sections is the highest obtained because of the lowest friction obtained by the sheets. It makes the air move faster causing a better drying to the powders.

4. Conclusions

A novel continuous dryer with adjustableangular sheets was designedand simulated using a CDF software to know the velocity profile of the air inside the dryer.

Sheet inclination angles of 40°, 50°, and 60°, with air intakes behind the metal sheets, do not offer the possibility of direct contact between the solid and the air. Besides, the air velocities reduce approximately to zero reducing the possibility of obtaining a high drying.

Sheet inclination angles of 40°,with air intakes in front of the metal sheets,cause the air rotates around each section letting an increase in the contact air-solid improving at the same time the drying of the powders. The air rotation with sheet inclination angles of 40°is counterclockwise while at 50°, and 60°, the air rotation is clockwise.

According to the results of the CFD simulations, the best configuration of inlet air flow was obtained when the angle of sheet inclination was 60^{o} because of the length of the metal sheets. It was the highest length that causes the air to move along the metal sheets. With this arrangement, the airreduces the loss of energy caused by the sheet friction maintaining its high velocity.

References

1. Obregon, L., A. Realpe, and C. Velazquez, Mixing of granular materials, part II: effect of particle size under periodic shear. Powder Technology, 2010. 201(3): p. 193-200.
2. Wang, H.G., et al., Online measurement and control of solids moisture in fluidised bed dryers. Chemical Engineering Science, 2009. 64(12): p. 2893-2902.
3. Geng, F., et al., Simulation of dynamic processes on flexible filamentous particles in the transverse section of a rotary dryer and its comparison with video-imaging experiments. Powder Technology, 2011. 207(1-3): p. 175-182.
4. Savaresi, S.M., R.R. Bitmead, and R. Peirce, On modelling and control of a rotary sugar dryer. Control Engineering Practice, 2001. 9(3): p. 249-266.
5. Buschmuller, C., et al., In-line monitoring of granule moisture in fluidized-bed dryers using microwave resonance technology. European Journal of Pharmaceutics and Biopharmaceutics, 2008. 69(1): p. 380-387.
6. Fudholi, A., et al., Review of solar dryers for agricultural and marine products. Renewable and Sustainable Energy Reviews, 2009. 14(1): p. 1-30.
7. Obregon, L., L. Quinones, and C. Velazquez, Model predictive control of a fluidized bed dryer with an inline NIR as moisture sensor. Control Engineering Practice, 2013. 21(4): p. 509-517.
8. Moon, S.-H., et al., Optimization of drying of low-grade coal with high moisture content using a disc dryer. Fuel Processing Technology, 2014. 124(0): p. 267-274.

*****