International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.11 No.09, pp 142-146, 2018

Thermo-energetic study of a continuous fluid bed dryer with vertical sectioning

Luis Obregón Quiñones[1]*, Lawer Acevedo Castro[1] and Alvaro Romero Estrada[1],

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

Abstract : At present, there are fluid bed dryers with high residence times higher than 20 minutes for the thermal treatment of granular materials in the pharmaceutical and food industry. In the present work, a continuous fluid bed dryer was designed with a very low residence time (2 seconds) to improve production. A thermo-energetic study was carried out using the infrared thermography method, which allows the analysis of the thermal profile along the bed, letting the determination of the energy losses based on the heat supply, considering the lack of isolation of the system. The dryer consisted of vertical sectioning with countercurrent flow air-solid. The results show an air temperature decrease higher than 50°C as it goes along the bed, resulting in approximately 1% in heat losses through the walls of the equipment. Therefore, the losses of thermal energy do not guarantee a uniform drying regarding the solid that flows through the bed causinga low energy efficiency.
Keywords : Infrared thermography, powder dryer, continuous drying, energy.

1. Introduction

Drying is a unitary operation that helps to reduce the moisture content of solids to levels that are safe for storage and transport, prolonging theirshelf life and stopping the microbial growth. Although the drying process is already established in most dryers, there is still a need to optimize these equipment to achieve a better drying homogeneity, to increase the mass transfer rate, to avoid granulometricchanges in the particles and to avoid dead zones to finally achieve uniform drying[1-3].

Some research has been made to find new highly efficient methods in the thermal treatment by convection for granular materials. Gravity machines with vertical sectioning in the interior space are one of the most promising designs. They occupy an intermediate position between fluidized bed devices and pneumatic tubes[4].

Infrared thermography (IRT) has received lots of attention due to its advantage of being generally contactless, safe and highly efficient[5]. According to how the test sample is heated, IRT can be classified into

DOI= http://dx.doi.org/10.20902/IJCTR.2018.110918

optical thermography, vibro-thermography, inductive thermography among others. An infrared thermographic camera registers an abnormal temperature distribution and emits a sequence of thermograms that can be used to observe the presence of cold and hot spots producing a thermographic profile[5]. It is an excellent technique for drying evaluation[6].

In this work, it is presented the study of the thermographic profile and energy losses when drying wet powders with hot air in a continuous powder dryer with vertical sectioning.

Methodology

The research device for the thermo-energetic study is a multistage platform model, whose experimental configuration is presented in figure 1.

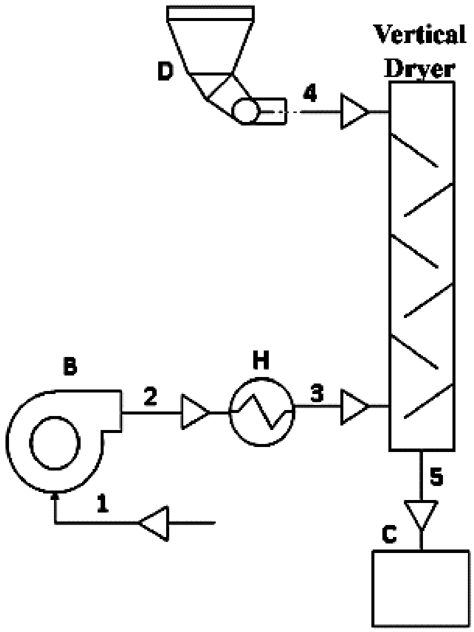

Figure 1.Schematic of the continuous powder dryer with inclined sheets.

In figure 1, B is the air blower, H is the heater, D is the solid dispenser, and C is the container for solid discharge. 1, 2 and 3 refer to the air flow in the different sections. 4 refers to the solid inlet, and 5 refers to the solid discharge.

The device is built with high impact acrylic walls of 4mm thick. It has a cross-sectional area of 225 cm^2. It was assembled with 7 identical modules organized in such a way that the sheets are inclined with different angles, 40°, 50° and 60°. The air inlet duct has a diameter of 3.175 mm. The sheets are inserted 2 cm below the top of the edge of each module. The top of the dryer has a filter that avoids the loss of fine particles. The equipment has a dosing system designed with an endless screw so that the flow of wet material was constant and uniform. The wet material enters to the top of the tower by means of a conveyor belt and exit falling on another conveyor belt located at the bottom of the tower. The residence time was approximately 2s. In addition, it has an On-Off control system for adjusting the hot air intake temperature to the tower.

The infrared thermography mechanism, made with a thermal imager, allows capturing the infrared radiation of the electromagnetic spectrum to determine temperatures in Celsius without the need to make contact with the granular solids in the dryer. With the data of the environmental conditions (humidity and air temperature), the distance of the Thermography camera to the powder dryer, the incident radiation and the characteristics of the thermo-graphed surface (acrylic 4mm), it is converted the radiated energy detected by the thermal camera to temperatures.

Based on thethermographic mechanism, several radiometric images were taken to the entire verticaldryer at different air inlet conditions (85°C and 100°C). The thermal energy loss ratio over time was calculated.

2. Results

The results of the thermographic equipment shown in figure 2, let to see the temperature profile along the height of the dryer or at any point of interest. In addition, it is possible to find surfaces where the dryer loses a lot of heat due to the lack of an insulation system. It can be inferred that the low resistance acrylic material used for the manufacture of the equipment for illustrative purposes, decreases the drying potential, and consequently, contributes to a low energy efficiency.

Figure 2 shows the decrease in air temperature as it rises toward the top, decreasing as well the potential of moisture removal for the first stages through which the solid crosses. The above, indicates that a single entry is not enough to make a uniform distribution of air and maintain a constant temperature throughout the equipment. Therefore, several air inputs and a high strength acrylic material must be considered to ensure a steady state between solid-gas with a high potential of moisture removal.

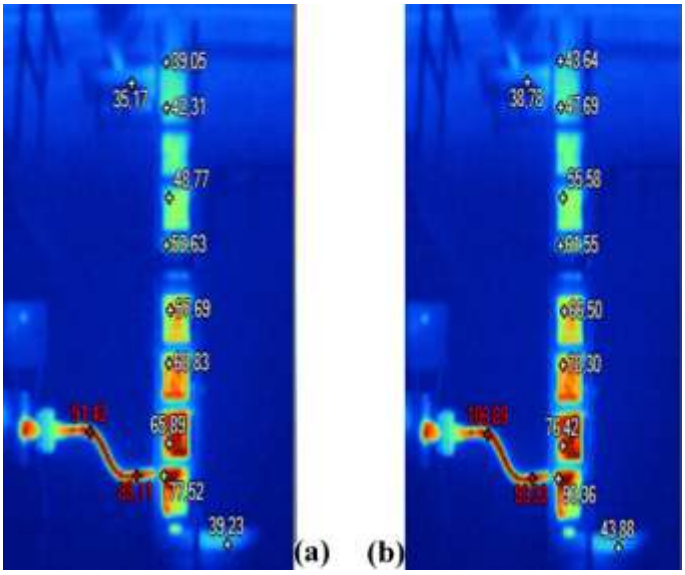

Figure 2. Thermographic profile of the entire vertical dryer in steady state. a) air inlet, 85°C and b) air inlet at 100°C.

Figure 3 a and b, shows the temperature profile in the hose connected to the dryer. As can be seen the temperature in this zone is high near 100°C. There is a loss of energy in this section that must be considered when determining the efficiency of the dryer.

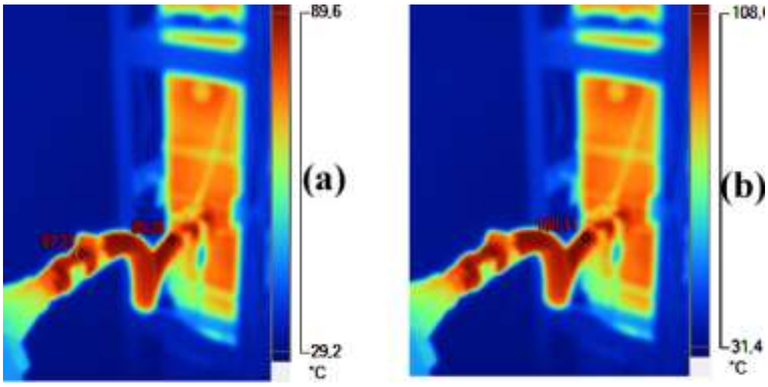

Figure 3.Thermographic view of the single air inlet to the dryer a) air inlet, 85°C and b) air inlet, 100°C.

Figure 4a shows the hottest point of air at the outlet of the heater, before entering the dryer. figure 4b shows the air temperature behavior inside the last two stages of the dryer when the inlet air temperature was 100°C. It can be seen that there is no uniformity in the temperature profile neither between stages nor inside stages.

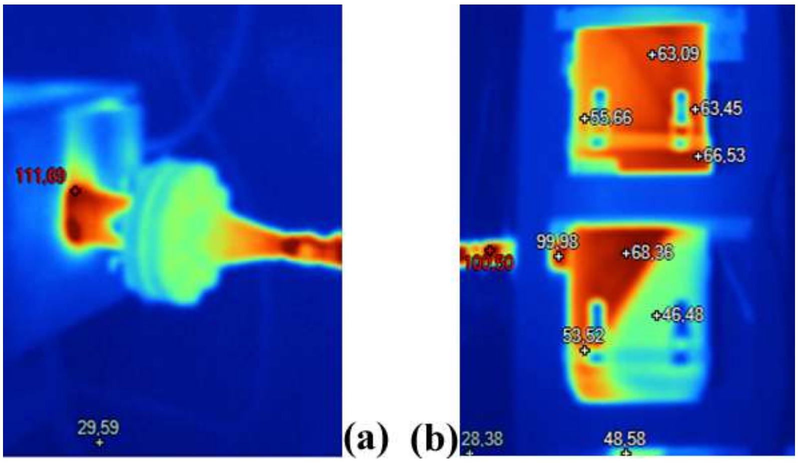

Figure 4. a) Thermographic view of the heater outlet, b) Temperature profile in the last two stages of the dryer for air inlet temperature, 100°C.

Table 1 shows the total energy consumption in kW-h of each conveyor belt, the powder feeder, the thermal resistances of the air heater and the blower for a continuous operation (24h/day).

Table 1. Energy consumption of each device of the continuous drying system

Device	**Potency (kW)**	**Quantity**	**Energy consumption (kW-h/day)**
Motorof powder feeder	0.06	1	1.44
Motor of conveyor belt1	0.08	1	1.92
Motor of conveyor belt 2	0.09	1	2.16
Motor of blower	0.37	1	8.88
Thermal resistances	2.00	8	384.00
Total			398.40

Due to the lack of a thermal insulation system on the dryer, there is an amount of heat loss that must be calculated with equation 1. This equation considers three types of heat resistances, two convective resistances, and one conductive resistance. It was considered the inside convective coefficient $h_{in}$of the hot air inside the dryer, the thermal conductivity of the acrylic *k*, and the outside convective coefficient h_o.

$$\dot{Q} = \frac{\Delta T}{\sum R_T} = \frac{T_{\propto 1} - T_{\propto 2}}{\frac{1}{h_{in}A_T} + \frac{L_{ac}}{kA_T} + \frac{1}{h_0 A_T}} \quad (1)$$

Where $T_{\infty 1}$ is the air temperature inside the tower, $T_{\infty 2}$ is the air temperature outside the tower, A_T is the total lateral area of the tower, L_{ac} is the width of the acrylic sheet of the walls, and K is the thermal conductivity of the acrylic walls.

$$\dot{Q} = \frac{\Delta T}{\sum R_T} = \frac{(67.5 - 30)°C}{\frac{1}{\left(17.6\frac{W}{m^2\,°C}\right)1.05m^2} + \frac{0.004m}{\left(0.17\frac{W}{m\,°C}\right)1.05m^2} + \frac{1}{\left(4.103\frac{W}{m^2\,°C}\right)1.05m^2}}$$

$$\boldsymbol{\dot{Q} \cong 121.5\,Watt = 0.122\,kW}$$

The thermal network of resistances through the 4mm acrylic wall is shown in figure 5.

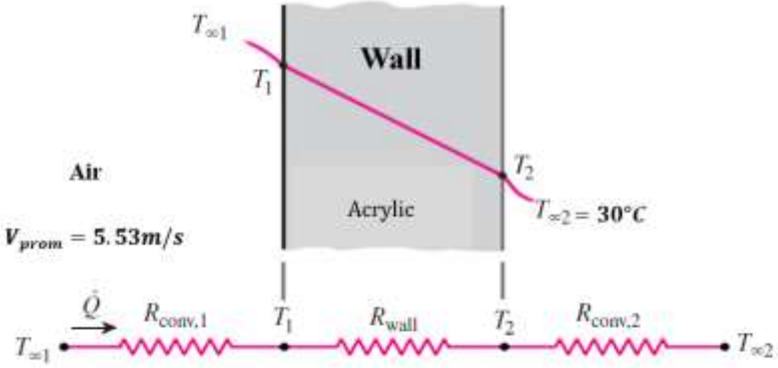

Figure 5. The thermal resistance network for heat transfer through a plane wall subjected to convection on both sides

Now it is calculated the percentage of energy lost in form of heat considering the total energy consumed by the thermal resistances shown in table 1.

$$\% \, \dot{\boldsymbol{Q}}_{lost} = \frac{0.122kW}{16kW} x100\% \cong \mathbf{0.76}\%$$

Consequently, 0.76% of the total energy supplied in the form of heat is lost through the walls.

Conclusions

It was designed a novel continuous vertical fluid bed dryer with a very low residence time (2 seconds). The thermographic view of the drying equipment shows that there is a difference in temperature of more than 50°C between the inlet and the outlet of the air implyinga high energy transfer to the solid that help the drying, with a heat loss by the surfaces of thedryer of about 0.75% due to lack of insulation. It implies anon-homogeneous temperature profile along the drying equipment which is a disadvantage of the dryer. It means that a single entry is not enough to make a uniform distribution of air and maintain a constant temperature throughout the equipment. Therefore, several air inputs and a high strength acrylic material must be considered to ensure a steady state between solid-gas with a high potential for moisture removal.

References

1. J. C. Ho, S. K. Chou, A. S. Mujumdar, M. N. A. Hawlader, and K. J. Chua, “An optimisation framework for drying of heat-sensitive products,” Appl. Therm. Eng., vol. 21, no. 17, pp. 1779–1798, 2001.
2. L. Obregon, L. Quinones, and C. Velazquez, “Model predictive control of a fluidized bed dryer with an inline NIR as a moisture sensor,” Control Engineering Practice, vol. 21, pp. 509-517, 2013.
3. C. L. Law, H. Chen, and A. S. Mujumdar, “Food Technologies: Drying,” in Encyclopedia of Food Safety, 2014, pp. 156–167.
4. N. Artyukhova, M. Yuhimenko, O. Shandyba, and A. Artyukhov, “Simulation of the particle motion in devices with vertical sectioning of workspace,” Processes and Equipment of Food Productions,vol. 3, no. 3, pp. 446–453, 2014.
5. Xie, C. Xu, G. Chen, and W. Huang, "Improving visibility of rear surface cracks during inductive thermography of metal plates using Autoencoder," Infrared Physics & Technology, vol. 91, pp. 233-242, 2018
6. E. Barreira and R. M. S. F. Almeida, "Drying Evaluation Using Infrared Thermography," Energy Procedia, vol. 78, pp. 170-175, 2015.

*****