Controlling Conveyor Dryer Operation

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Understanding how to control and monitor critical process parameters such as air temperature, humidity and exhaust rate will allow you to maximize the economic payback of your dryer.

In many industries, drying a product is often a necessity for improved shelf life, palatability or to create a chemical change in the product. Conveyor dryers are well suited for food products that consist of individual pieces in the 0.04 to 4" (1 to 100 mm) size range. The conveyor dryer continuously moves the product on slats or bedplates through a series of individually controlled zones or stages to optimally remove moisture. Multiple stages or passes often are included in the dryer configuration to ensure uniform drying. Conveyor dryers are used in many applications within the food, pharmaceutical, chemical and animal feed industries.

The final moisture content of a dried product will have a major impact upon the yield and quality of the final product. Drying is often the largest energy consumer in the production process. Therefore, it is critical that the conveyor dryer is operating at its optimal level in order to achieve the desired product quality and minimize energy costs. Typically, this can be difficult to achieve given the variability in the product being dried and the generally poor understanding of drying operations. This article highlights methods for improving operation and control of conveyor dryers, ultimately leading to improved product quality, increased yield or lower energy consumption.

The basic operation of a conveyor dryer is relatively simple. Air is forced through a bed of material that is conveyed through the dryer. The air provides the heat necessary for the evaporation of water (or other materials) from the product being dried. Air also is the carrier for the removal of the water (or other materials) from the product bed. The velocity and temperature of the air moving through the product bed will determine the drying rate. Conveyor dryers also can be designed with multiple conveyor beds.

Although the basic dryer operation is straightforward, the challenge is to optimize airflow distribution and control through the product bed for uniform product drying and efficient operation. Methods of distributing this air will vary among dryer manufacturers. For example, flow vanes and diffuser plates are some of the mechanical methods that can be employed to attempt to control the airflow through the product bed.

Another concern when optimizing airflow in dryers is leakage. The airflow must be forced through the product bed and not allowed to leak by the sides. Sealing methods along the sides of the product bed will vary among manufacturers, who may have different sealing methods for a range of products or temperatures. One method is traveling guides, which are attached along the side of the product bed and can be used to seal against fixed guides mounted to the dryer structure. Or, to eliminate the need for traveling side guides, manufacturers may use seals that are attached to fixed side guides and make contact with the bed conveyor.

After the air has moved through the product bed, some or all of the air can be exhausted. Typically, some of the air is recycled to improve the energy efficiency of the drying process. The flow of exhaust and makeup airstreams in the dryer is controlled by dampers or fan operation. The recycled air is combined with fresh makeup air and mixed to ensure uniformity through the drying process.

Mechanical Operating Parameters

To effectively control the process parameters in a conveyor dryer operation, all aspects of the mechanical operation of the dryer need to be functioning correctly.

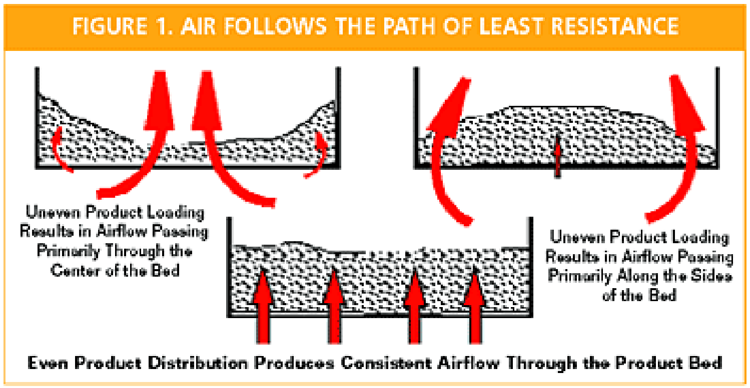

Figure 1. The product must be distributed evenly across the width of the conveyor or airflow distribution and drying rate will be affected.

Before startup, the operators should inspect the dryer internally to ensure that all panels and doors used to seal or direct air are in the proper position. If these panels or doors are not correct, air may be allowed to bypass the product and result in inefficient dryer operation.

The successful operation of a conveyor dryer begins with feeding the material to the dryer. Upstream processing can affect dryer operation significantly because uniform feeding of the conveyor bed is important for drying uniformity. Surges or pulses in the feed rate to the dryer will result in changes in the product depth on the dryer's conveyor. The air velocity through the bed of material on the conveyor is indirectly proportional to the product height. The air velocity will have a direct impact on the drying rate.

Typically, the material to be dried is delivered to a center point of the dryer conveyor and then distributed using an oscillating-type feeder. The type of feeders used depends upon the flow characteristics and the friability of the material to be dried. The oscillation speed of the feeder must be fast enough to prevent a furrowed look to the product bed. The oscillation width must be wide enough to evenly distribute the product across the drying surface. If the product is not distributed evenly, then the local product height will vary, and this will result in uneven airflow (figure 1).

The conveyor speed should be set to provide a bed depth consistent with the process design parameters from the manufacturer. Typically, the recirculation fans are designed for a specific air velocity through the bed. A bed depth of material that is too small may result in underdrying or high product temperature due to not enough retention time. This small bed depth will have lower resistance to airflow than the design value, which will place the recirculation fan operation in a different position of the operating curve. The pressure drop through the product bed normally aids in the distribution of air through the material. A lower pressure drop may allow localized areas of high air velocity that will result in overdrying and poor final moisture uniformity.


Figure 2. When the product

In a multiple-pass dryer configuration, the bed depth on the first pass typically is set at a low height to avoid clumping and product deformation. As the product dries, the later passes may be operated at a deeper bed depth because the drying rate will be lower and more dominated by diffusion in the material. Also, as the product dries, it can be stacked more deeply without causing product deformation (figure 2).

enters a multiple-pass dryer, it is set at a low height on the conveyor to avoid clumping and deformation. During successive passes, the product bed depth is designed to be deeper to allow good air velocity and air residence time in the product bed.

A conveyor dryer will be divided into individual drying zones. These zones can be designed to operate with different recirculation airflow rates, air temperatures and humidity levels. The process parameters may be product specific. During dryer operation, the parameters should be checked to ensure they are within the correct operating range for the product.

Recirculation airflow rates can be difficult to check directly and normally will be checked by ensuring that the correct number of fans are operating, the fans are rotating in the correct direction and the fan speeds are correct.

Process air temperatures typically are monitored after the air has been reheated and passed through the recirculation fans. The turbulent area through the heat source and fans will provide the most uniform readings to ensure that the correct process temperature is used in each drying zone.

Humidity levels typically are checed by using wet-bulb measurements in the dryer airstream. Due to the psychrometrics involved in drying, the wet-bulb reading can be taken in the airstream either before or after contact with the product. The humidity level in the dryer is directly related to the wet-bulb reading and the air temperature. The humidity level can be controlled by adjusting the exhaust flow rate from the drying zone. In a multiple-zone dryer, the exhaust flow rate can be adjusted using airflow dampers positioned at the inlet to the exhaust ducting. The humidity level in the drying zones will impact the energy efficiency of the dryer and may also affect the drying rate.

Overall operating pressure in the dryer is another parameter that should be checked. Conveyor dryers are designed to operate at or below atmospheric pressure to ensure that either fumes or dust do not escape into the plant environment. The dampers that are used to control the makeup air flow rate to the dryer need to be balanced with the exhaust dampers. For correct operation, the mass of the makeup air should be set lower than the mass of the exhaust air so the dryer operates at a slight negative pressure. The negative pressure will ensure that the drying air will not leak from the dryer enclosure to the surrounding environment (figure 3).

Product samples should be collected periodically at the inlet and outlet of the dryer. The samples should be checked for moisture content to ensure that the dryer is operating at the desired drying rate and that the finished product is within the desired specifications. If the inlet moisture content is above the dryer design value, the upstream process may need to be adjusted to ensure that the dryer will be capable of providing the desired product moisture content at the discharge. If the outlet moisture content is not within specifications, the dryer process air temperatures normally are adjusted to either increase or decrease the drying rate.

Dryer Control for Economic Payback

For most drying operations, a maximum allowable moisture content for the finished product is set. Because this is an important quality parameter, operations typically will tend to err on the safe side and overdry the product. The amount of overdrying normally is a function of the operators' understanding of the drying process and the amount of process information available.

Figure 3. Adjusting the makeup air and exhaust air dampers to ensure that the dryer operates at a slight negative pressure will prevent air from leaking from the dryer enclosure to the surrounding environment.

Sensors are available from a number of vendors that have the ability to measure the moisture content of solids after drying. The expense, calibration, accuracy and maintenance of these sensors can sometimes be prohibitive for some industries.

An alternative to measuring the moisture content directly is to develop a model of the dryer operation to predict the outlet moisture content based on temperature measurements within the dryer. Because drying is a process with simultaneous heat and mass transfer, the measurement of air and product temperature changes through- out the drying process can be related to the amount of water evaporated from the product.

Installing online measurement sensors or developing a predictive drying model will allow controls to be implemented that will reduce the variability of the outlet moisture content. This will allow the dryer outlet moisture content to be controlled closer to the maximum allowable quality parameter and eliminate the need to overdry the product. The increase in moisture content will result in an increase in the mass of the finished product and a lower evaporation load for the dryer. Also, the lower evaporation load will allow dryer throughput to be increased.

In many plants, it is possible to increase the average outlet moisture content by 0.5 percent wwb (wet weight basis). If this results in a 0.5 percent increase in the final product weight, then the payback for successful implementation (if the product is sold by weight) of a moisture control system is shown in the example below. Assume the current production rate is 10,000 lb/hr (4,535 kg/hr) and the value of the product is $1/lb ($2.2/kg). With those assumptions in this example, increasing the average outlet moisture content by 0.5 percent would result in:

If a conveyor dryer is divided into individual drying zones, the zones can be designed to operate with different recirculation airflow rates, air temperatures and humidity levels.

10,000 lb/hr (dry) x 0.5 x 24 hr/day x 250 day/yr x $1/lb = $300,000/yr

This example demonstrates a possible incentive for companies that operate dryers to implement controls that will improve the consistency of the outlet moisture content. These systems will then allow them to operate closer to optimal levels for product performance and revenue return.

Humidity Controls. The humidity level within the dryer zones can be controlled on a continuous basis by installing a humidity sensor in the airstream of the drying zone. A feedback controller then can be used to automatically adjust the damper positions for the makeup and exhaust levels of the zone.

The humidity controls will adjust the dryer exhaust based on evaporation loads in the dryer. During periods when the dryer is empty, the exhaust can be limited to minimum values. The energy that is saved by limiting exhaust levels will result in a lower energy cost of the drying system. For example, for the drying system as described above, limiting the exhaust levels during idle periods can save approximately $15/hr in fuel costs.

During operation, implementing humidity controls will keep the dryer operating at optimal humidity levels. For a dryer designed for a feed rate of 20,000 lb/hr (9,070 kg/hr) and an evaporation load of 3,700 lb/hr (1,680 kg/hr), an increase of 2 percent relative humidity in the dryer recirculating airflow will decrease yearly heating energy costs by approximately $50,000. This is based on fuel or heating costs of $0.8/therm ($0.0076/MJ). This also will decrease the exhaust airflow by more than 35 percent, which will reduce any expenses associated with treating the exhaust air.

The key to efficiently operating a conveyor dryer is to monitor and control significant operating parameters such as air temperature, flow rate and humidity and product distribution. Sensors, controllers and modeling systems are options for controlling these parameters. The payback for control of the conveyor dryer is significant in terms of both cost savings and product quality.