Tips:

Controlling atomization in your spray dryer

Controlling the feed liquid's atomization in your spray dryer will ensure the dried particles meet your specifications. But how can you ensure the atomized droplets are properly sized to meet your drying goals? Read this article for information on how operating parameters and liquid properties influence the droplet size.

The heart of a spray dryer is the nozzle. The nozzle, which can be called an *atomizer, pressure nozzle, centrifugal pressure nozzle,* or *hydraulic atomizer,* is available in various types. [***Editor's note:*** Discussing differences in nozzle types is beyond this article's scope, but the following information can be applied to various types.][1]

The nozzle performs several functions. It meters the feed liquid, controlling its flowrate into the dryer. The nozzle breaks the liquid into droplets, a process called *atomization,* which creates greater liquid surface area. The nozzle also disperses these droplets into a specified spray pattern so the droplets contact the dryer's heated air.

The heated air typically flows in one of three patterns: *cocurrent* (typically downward with the droplets), *countercurrent* (typically upward against the droplets), or *mixed* (a combination of the other two patterns). Evaporation removes most of the moisture.

The right spray angle for your dryer depends on the airflow pattern.

The droplet size is usually measured in microns (1 micron is 0.001 millimeters; there are 24,500 microns per inch). The term *Sauter mean* defines the diameter of a droplet whose volume-to-surface-area ratio is equal to that of the entire spray pattern.

Using the right droplet size improves drying and is critical to achieving your dried product's specified properties. Oversized droplets increase the moisture level in the dryer, which can cause material buildup in the dryer or high moisture content in the final product. Such droplets can also keep the final product from reaching your specified bulk density. The moisture in undersized droplets can evaporate too quickly, changing the dried product's color or taste or producing dusty particles.

You can alter the droplet size — whether to accommodate a product change or improve your drying results — by controlling several operating parameters and liquid properties. The operating parameters include liquid pressure, flowrate, and spray angle. The liquid properties include viscosity, surface tension, and density.

Liquid pressure

A nozzle is typically rated at 1,000 psi for water. As you change this pressure, the flowrate varies to approximately the square root relationship:

$$Q_2 = Q_1\sqrt{\frac{P_2}{P_1}}$$

where Q_1 is the flowrate at an initial operating pressure P_1 and Q_2 is the flowrate at a second operating pressure P_2.

You can achieve smaller droplets by using a less viscous liquid.

As you increase this pressure, droplet size decreases approximately as follows:

$$\frac{D_2}{D_1} = \left(\frac{P_2}{P_1}\right)^{-0.3}$$

where D_1 is the Sauter mean at an initial set of conditions and D_2 is the Sauter mean at a second set of conditions. Be aware that this relationship is true only when the same nozzle is used and the liquid properties that can affect the mean droplet diameter are held constant.

Flowrate

If you hold the liquid pressure constant but modify the nozzle to increase the flowrate, larger droplets will result because the nozzle's hydraulic energy must now atomize more liquid. Figure 1 shows typical flowrate versus liquid pressure for a nozzle with an 80-degree spray angle (discussed in the next section). As you can see, droplet size increases as the flowrate increases and the liquid pressure drops.

Spray angle

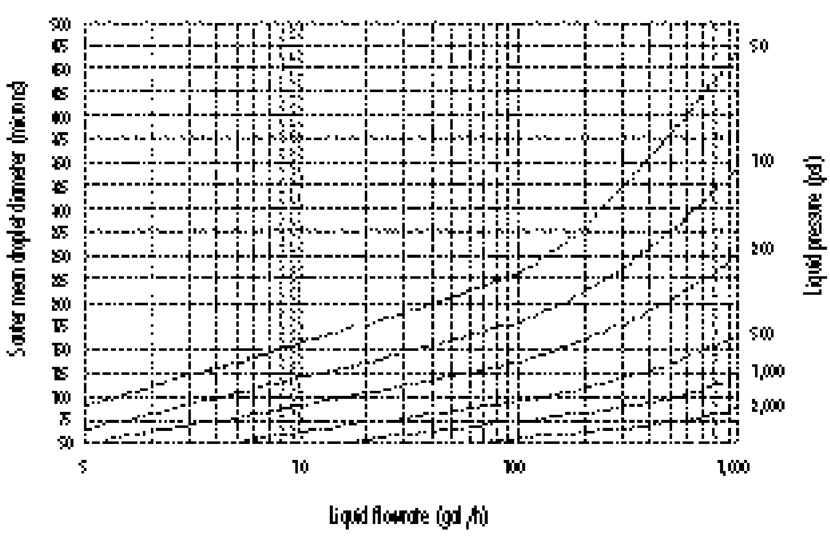
Spray angle is measured at the nozzle orifice and typically ranges from about 50 to 90 degrees. You can widen the spray angle and achieve smaller droplets by increasing the nozzle's *liquid tangential velocity* (the speed at which the liquid spins inside the nozzle before it sprays as droplets into the dryer). A narrow spray angle usually creates large droplets. By comparing Figure 1 with Figure 2, you can see that an 80-degree spray angle produces smaller droplets than a 65-degree spray angle. However, increasing the spray angle beyond about 90 degrees has a negligible effect on droplet size.

The right spray angle for your dryer also depends on the airflow pattern. A wide spray angle is usually best with a cocurrent pattern, because the downward flow of heated air tends to narrow the spray angle. A narrow spray angle is commonly used with a countercurrent pattern because the downward spray flows back up with the heated airflow, widening the spray angle.

Although increasing the liquid pressure doesn't have much effect on the spray angle, the pressure increase will narrow the spray pattern's diameter at some distance from the nozzle. This is caused by a low-pressure zone — the "hollow core" of air that forms in the spray pattern's center — that *pulls in* the spray pattern's outer edges. However, this doesn't affect the droplet size.

Figure 1

Typical flowrate versus liquid pressure (80-degree spray angle)*



*Note: Test conducted on pressure nozzle at Delavan's Lexington, Tenn., facility. For more information, contact the author.

Viscosity

As the feed liquid's viscosity increases, the energy supplied to your nozzle must overcome larger viscous forces. This reduces the energy available for breaking up the droplets, resulting in larger droplets. As a result, you can achieve smaller droplets by using a less viscous liquid.

The liquid viscosity also affects your spray pattern: A more viscous liquid typically produces a narrower spray angle. Increased viscosity can sometimes increase the flowrate and contribute to even larger droplets. As a rule of thumb, you can assume droplet size will vary as the 0.25 power of the viscosity.

Surface tension

To create droplets, the nozzle must overcome the liquid's surface tension. Thus a liquid with a higher surface tension (such as plain water) is more difficult to atomize than one with a lower surface tension (such as a water-solid suspension). You can assume droplet size will vary as the 0.33 power of the surface tension. In some applications, you can reduce the surface tension by adding a surfactant to the liquid.

Density

Using a higher density liquid typically increases the droplet size. But the liquid's density usually doesn't vary without also changing other liquid properties, so use caution in interpreting the liquid density's relationship to droplet size. The following formula helps to explain the relationship:

$$\frac{D_2}{D_1} = \left(\frac{D_2}{D_1}\right)^{-0.5}$$

where D_1 is the Sauter mean at an initial density and D_2 is the Sauter mean at a second density. Again, this relationship is true only when the same nozzle is used and the liquid properties that can affect the mean droplet diameter are held constant.

Some final advice

As you can see, these operating parameters and liquid properties are interrelated. Because anything that changes the droplet size can change the dried product's properties, change your spraying conditions with care.

Also be aware that proper dryer maintenance will help you maintain droplet size. Nozzle wear, typically at the orifice, can increase the liquid flowrate and generate a streaky spray that greatly enlarges the droplets. To maintain dried product quality, regularly check your nozzle for wear as part of your normal spray dryer maintenance program.

—Chuck Trullinger, product manager, Delavan-Delta, Inc., Lexington, Tenn.; 901/968-8152.

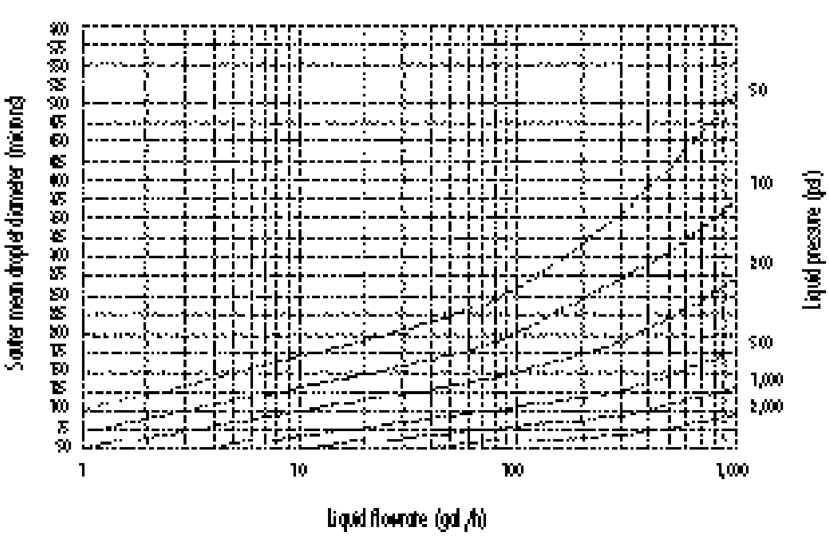
Contact him for information about software to calculate how altered spraying conditions can improve spray drying.

Reference

1. For more detailed information on spray dryer components (including the nozzle), operation, and applications, see articles listed under "Drying" in *Powder and Bulk Engineering*'s comprehensive "Index to articles," December 1996, page 108.

Figure 2

Typical flowrate versus liquid pressure (65-degree spray angle)*



*Note: Test conducted on pressure nozzle at Delavan's Lexington, Tenn., facility. For more information, contact the author.