In many bulk solids manufacturing operations, drying is part of the agglomeration process. In this column, I’ll explain what agglomeration is and the basic steps involved, then I’ll describe several commonly used agglomeration methods.¹

Agglomeration basics
Agglomeration is the joining together of small particles (or fines) to make a larger particle. The fines stick to each other by surface bonding, creating a larger, extended structure while retaining their individual shapes, similar to a cluster of grapes. This is different from granulation, where an evaporating solution deposits dissolved solids onto a suspended particle bed during drying. The granules become larger and larger as fines are continuously added to their surfaces, similar to the way hailstones are formed and built up by successive updrafts and downdrafts during a thunderstorm.

There are several reasons for agglomerating fine particles in manufacturing:
• To create a “nondusting” final product. Herbicides, pesticides, and powdered detergents, for example, are agglomerated to prevent dusting.
• To create a final product that will rapidly disperse when dissolved in a liquid. Instant soup, for example, requires that the agglomerated particles dissolve quickly, whereas a granulated fertilizer requires that the particles dissolve slowly to release the nutrients over time.
• To create a final product with an aesthetically pleasing appearance. For example, agglomerated instant coffee more closely resembles flavorful freeze-dried coffee than instant coffee that’s simply been spray dried.

The binding mechanism, or “cement,” that holds the particles together can be any one or more of the following:

- A binder material, such as a starch solution, which acts like mortar, joining the particle surfaces together as the moisture evaporates during drying.
- Surface crystallization of dissolved solids, which adheres adjacent particles to each other as the moisture evaporates during drying.
- Solidification of particle surface melt (or fusion).

Agglomeration and drying

Agglomeration steps
Whatever the mechanism you use to bind the particles, the basic steps to agglomeration remain the same and are shown in Figure 1. In the first step, feed material and recycled fines are preconditioned. For example, if the feed material is free-flowing, a binding agent is typically added and mixed with the material. Solids-liquid mixing creates intimate contact between the...
material and the wetting agent, allowing agglomerates to form. The mixing equipment might be a horizontal ribbon or paddle mixer or a vertical paddle or pin mixer. A horizontal mixer can provide additional residence time, if necessary, to allow for agglomeration, while a vertical pin mixer can prevent material hang-ups and lump formations in the equipment. You can maximize particle contact and minimize agglomerate breakage by adjusting the orientation of the flat sides of the pins or paddles and by using a variable-speed motor to drive the mixing shaft.

The next step is drying, which cures the binder and sets the agglomerated particles. Which dryer type you should use depends on the application and is discussed further in later sections of this column.

A postconditioning step may also be necessary. For example, you may need to cool the agglomerated material to prevent lumps from forming during downstream handling or storage.

The final step is size separation, where the correct-sized product is separated from fines and oversized material. Oversized agglomerates are milled and then recycled along with the fines back to the first step.

**Agglomeration methods**

The following figures illustrate several common agglomeration methods. Which method you should use depends on your application.

**Vertical pin mixer.** The agglomeration process shown in Figure 2 uses a vertical pin mixer and a fluid-bed dryer. Feed and recycled fines enter the mixer along with binder solution. The vertical pin mixer provides intensive shear mixing in a relatively short (just seconds) residence time. The wetted agglomerates then drop into the fluid-bed dryer. In the dryer, heated air flows up through the gas distributor (a perforated or slotted screen) and evaporates the liquid from the binding solution, causing the binder-dissolved solids to crystallize and cement the fines into agglomerates.

Agglomerate strength will determine which dryer type you should use. If the cement bonding is strong, you may be able to use a stationary fluid-bed dryer. Otherwise, you should be able to use a vibrating fluid-bed dryer, which uses less violent fluidizing action. If the wet agglomerate is very weak, however, you may need to use a continuous belt-conveyor dryer, which is even more gentle on the agglomerates than a vibrating fluid-bed dryer since the particles are at rest on the moving belt during drying. Each dryer type can be zoned to incorporate a cooling stage prior to discharging the dried agglomerates, if necessary.

**Figure 2**

Vertical pin mixer system
**Spray dryer.** In the agglomeration process shown in Figure 3, the material feed is a liquid solution that’s being spray dried prior to agglomeration. Atomizing nozzles at the top of the dryer spray the solution into the tall cylindrical spray tower, and cocurrent heated airflow removes much of the moisture, leaving fine particles, which fall to the spray tower’s bottom and are discharged into the vibrating fluid-bed dryer below.

By adjusting the drying chamber’s humidity and outlet-air temperature, you can control the discharged material’s moisture content to form surface-wetted, “sticky” particles. As moisture evaporates from these sticky particle surfaces during fluid-bed drying, dissolved solids crystallize and bridge the fine particles into agglomerates. Agglomerates formed by this method are typically not very strong, so you should use either a vibrating fluid-bed or continuous belt-conveyor dryer to avoid damaging the agglomerated particles. Again, either dryer type can easily be zoned to include a cooling stage.

**Falling curtain/steam agglomerator.** Falling curtain/steam agglomeration is shown in Figure 4. In this process, dry feed material and recycled fines are fed into a distributor at the agglomerator’s top and then fall, as parallel curtains of particles, through a sparged (or sprayed) steam zone and into a vibrating fluid-bed dryer below. The sparged steam is used as a wetting agent to dissolve the particle surfaces, making them sticky. To maximize the steam’s effectiveness, the material can be chilled before being fed into the distributor. The sticky particles then form wet agglomerates, which set in the downstream vibrating fluid-bed dryer. This agglomeration method is used for fine, water-soluble powdered materials, such as spray-dried instant coffee, dried fat emulsions, and milk powder.

A second-generation falling curtain/steam agglomeration process is shown in Figure 5. This method uses surface melt fusion to bind the particles. To increase the agglomerates’ strength, the drying air in the fluid-bed dryer is heated to a higher inlet air temperature, causing the agglomerates’ surfaces to begin to melt and become tacky. The agglomerates then cure during the subsequent cooling stage, and the particles fuse together. A vibrating...
fluid-bed dryer should be used to keep the agglomerates in motion during drying. A continuous belt-conveyor dryer isn’t suitable for fusion agglomeration because the stationary agglomerates would fuse together on the belt during drying.

Using fusion to agglomerate organic foodstuffs can be challenging because higher drying temperatures tend to degrade the final product’s taste, aroma, and color. To slow the drying rate but allow the particle surface temperature to increase high enough for melting, humidifying steam is injected into the drying airstream, increasing its moisture content and raising the drying air’s wet-bulb temperature. Since the particle surface needs to reach the drying air’s wet-bulb temperature before evaporation can occur, the evaporative cooling effect at the elevated wet-bulb temperature protects the organic particle at the higher fusion drying temperature.

With a higher moisture content in the drying air, the partial pressure driving force for evaporation is decreased, slowing the evaporation rate. Without humidifying steam, moisture would evaporate at a lower wet-bulb temperature and a higher rate, exposing dried particle surfaces to the higher fusion drying air temperature without the protection of the evaporative cooling effect. This could degrade the material.

References
1. For more information about the equipment, components, and terminology used in this column, see previous “Drying Desk” or “Agglomeration Advisor” columns. All columns are available through the Article Index on our website, www.powderbulk.com. You can also contact the author at jwalshpe@ameridrycon.com.

2. For more information about fusion agglomeration, see US patent numbers 3695165 A and 3740232 A, which were assigned to General Foods Corp. in the early 1970s.

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