Agglomeration with fluid-bed conditioning: Three methods

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Agglomeration brings particles together to create larger particles. The resulting granules are easier to handle and less dusty than fine powders and have other desirable properties as well. This article discusses agglomeration methods for producing granules that can be quickly reconstituted in liquid. Each of the methods discussed here — fines-return, impingement, and re-wet agglomeration — is a form of growth-tumble agglomeration and incorporates fluid-bed conditioning. The techniques, sometimes classified as spray granulation or fluid-bed granulation methods, are commonly used to produce food and dairy products, food ingredients, and detergents.

Agglomération par conditionnement à lit fluidisé: Trois méthodes sont utilisées

L'agglomération regroupe les particules pour en créer de plus larges. Il en résulte des granulés plus faciles à manipuler et produisant moins de poussière que les poudres fines et possédant de surcroît d'autres propriétés souhaitables. Cet article discute des méthodes d'agglomération pour la production de granulés pouvant rapidement être reconstitués sous forme liquide. Chacune des méthodes discutées ici — retour de fines, impact, agglomération par retrempe — est une forme d'agglomération à croissance par culbutage incorporant un conditionnement à lit fluidisé. Les techniques, parfois désignées comme méthodes de granulation par pulvérisation ou de granulation par lit fluidisé, sont communément utilisées pour produire des produits alimentaires ou laitiers, ingrédients alimentaires ou détergents.

Agglomeration durch Fließbett-Konditionieren: Drei Methoden

Agglomeration can make a powder dustless, which helps keep plants and equipment clean, prevents bacteria and spores from spreading, and prevents proteins, enzymes, and other active substances in food products from becoming airborne and provoking worker allergies. The process can adjust a powder’s bulk density, which can help it fit into a certain package size or be measured volumetrically. Agglomeration can improve a powder’s flow properties, making it easier to convey and feed.

Making a powder easier to reconstitute by improving its ability to quickly dissolve and disperse in liquid is often achieved by growth-tumble agglomeration methods that incorporate fluid-bed conditioning. Such methods can produce granules ranging from about 100 to 2,000 microns in diameter, depending on the feed (or primary) particles’ diameter, which can range from a few to 200 microns. The final granules’ mean particle diameter is typically between 200 and 500 microns, and the granules have a narrow particle size distribution. In Figure 1, you can see the relatively small mean diameter of unagglomerated milk product particles (Figure 1a) compared with that of milk product granules formed by an agglomeration method with fluid-bed conditioning (Figures 1b and 1c).

In addition to milk powders, other common food products and food ingredients agglomerated by these methods include wheat flour, baby food, cheese, instant coffee, cocoa milk, coffee whitener, yeast protein, vitamins, and gum arabic. These granules consist of primary particles bound together into agglomerates. During reconstitution, capillary forces draw moisture into the cavities between the primary particles, humidifying and dispersing the granules by dissolving the bonds between the particles and then dissolving the particles themselves. Some granules, such as instant coffee and infant milk formula, are called instant products because they can be reconstituted extremely rapidly.

**Desired granule properties**

For best performance, granules produced by methods that incorporate fluid-bed conditioning must meet several criteria. The granules must be mechanically stable, with strong bonds between the individual particles so they don’t degrade or generate dust. The granules must also have a uniform particle size with a relatively large mean diameter and few fines. For instance, in an instant product such as infant milk formula less than 15 percent of the granules can have a diameter smaller than 90 microns.

The granules must be easy to reconstitute, with good wettability and dispersability. This ensures that gentle stirring with a spoon or fork will dissolve the granules in hot or cold liquid without leaving lumps or residue.

The granules must have good flowability so that they can be conveyed easily, an especially important property when the granules will be handled in automatic conveying and dosing systems. However, achieving good flowability can compromise other desired properties. For instance, producing larger, more flowable granules can reduce the granules’ bulk density and require more heat treatment during processing, which
Figure 2

Fines-return agglomeration systems

a. Two-stage spray dryer system

b. Three-stage spray dryer system

c. Spray-bed dryer system
can reduce the granules’ instant properties (that is, their ability to reconstitute quickly).  [Editor’s note: For more information on tests for measuring granules’ instant properties, contact the authors.]

The granules must have enough heat stability to withstand the high heat required at processing’s start, when the feed moisture level is high. This will prevent the granules from becoming insoluble or slower to reconstitute, from scorching, discoloring, or crystalizing, and from losing amino acids or vitamin content. To reduce product loss and the need for frequent equipment cleaning, only minimal product residue can deposit on the equipment walls during agglomeration.

**How the methods work**

The agglomeration methods that incorporate fluid-bed conditioning are fines-return, impingement, and re-wet agglomeration. Systems for each method require various process equipment, such as spray dryers, spray-bed dryers (also called spray fluid-bed dryers and multistage dryers), fluid-bed dryer-coolers, and fluid-bed re-wet agglomerators. Additional equipment can include feeders, air heaters, sifters, cyclones, and dust collectors. Depending on the application, each system can be designed to operate in batch or continuous mode.

These systems share a common feature: Each incorporates one (or more) fluid bed. A fluid bed can provide drying and cooling, re-wetting (required for some applications), classifying (for removing fines), and gentle mixing and conveying (to prevent breaking the agglomerates).

Let’s take a closer look at these agglomeration systems, including the equipment they require, how they operate, and how various factors affect their performance.

**Fines-return agglomeration**

Fines-return agglomeration incorporates recycled fines into the agglomeration process and can be achieved in a two- or three-stage spray dryer system or in a spray-bed dryer system, as shown in Figure 2.

**Spray dryer systems.** A two-stage spray dryer system (Figure 2a) typically includes a liquid feed pump, air heater, spray dryer, fluid-bed dryer-cooler, cyclone, and dust collector. In operation, two feeds enter the spray dryer’s top: a feed solution (or slurry) that passes from the liquid feed pump and is sprayed through an atomizer, and dry fines returned from the downstream cyclone. Warm drying air also enters the dryer’s top and flows downward. After the liquid feed is atomized, it forms droplets that spray downward as a fine mist into the dryer. The droplets contact the warm airflow in what’s called the atomizing zone and begin to dry, forming individual particles. While these still contain enough moisture to stick to each other, they contact the returned fines, forming agglomerates. This completes the system’s first stage.

For the second stage, the granules flow from the spray dryer discharge to the fluid-bed dryer-cooler. The granules enter the dryer-cooler’s initial drying section, in which warm air flows upward through a perforated plate to gently dry the granules in a fluid bed. The granules then pass to a subsequent cooling section, in which water-chilled air cools them. As the granules dry and cool, the fluid bed simultaneously mixes them and conveys them toward the discharge. Fines are entrained in the spray dryer’s airflow and exit near the vessel’s bottom; the fluid-bed dryer-cooler separates additional fines, which exit with that unit’s airflow. The airflow from both units passes to the cyclone, which separates the fines from the airflow and returns them to the dryer’s top. The air exhausted from the cyclone is filtered by a dust collector.

A three-stage spray dryer system (Figure 2b) has similar equipment, but in this system the spray dryer’s bottom section incorporates an integral fluid bed. The system’s operation, including the fines returning to the spray dryer’s top, is similar to that of a two-stage system, with the first stage occurring in the spray dryer. But the integral fluid bed provides the second stage, which achieves more intimate mixing and more drying in the spray dryer. After the granules exit the spray dryer, they flow to the fluid-bed dryer-cooler for final drying and cooling — the third stage.

In both the two- and three-stage systems, agglomeration performance depends on the drying air temperature and on the quantity of returned fines and their position, flow direction, and velocity in the spray mist. A certain minimum quantity of fines must be recycled to the spray dryer to produce high-quality agglomerates. But too many fines can be a problem, because the fines pass through the warm air before they reach the spray mist and can be exposed to heat damage that degrades the granules’ functional properties. The fines must be directed toward a spot in the atomizing zone that’s neither too wet nor too dry, and they shouldn’t move so quickly that they blow through the spray mist without being agglomerated.

**Spray-bed dryer system.** A spray-bed dryer system (Figure 2c) includes a spray dryer with an integral fluid bed, called a spray-bed dryer. The main difference between the spray-bed dryer and a spray dryer is that the spray-bed dryer’s air outlet is at the unit’s top, so the returned fines pass with the exiting air upward along the walls of the dryer through the atomizing zone. This causes some of the air and the fines to be sucked into the spray mist, resulting in a higher degree of agglomeration that tends to produce larger and stronger granules. Depending on the application requirements, some or all of the fines separated by the cyclone can be returned to the atomizer.

In the spray-bed dryer, the degree of agglomeration depends to a great extent on the integral fluid bed’s fluidizing velocity. The agglomeration can also be controlled by fines return and impingement.
**Impingement agglomeration**

In a system for impingement agglomeration, two liquid feed sprays impinge on each other. The system typically includes equipment similar to that in fines-return systems, with either a spray dryer or spray-bed dryer. However, the dryer is equipped with two or more pressure nozzles that are turned toward each other. In operation, the liquid feed is split between the two nozzles, and when the spray mists flow through the warm air and contact each other, the partially wet droplets agglomerate and form granules. The granules flow to a fluid-bed dryer-cooler for final drying and cooling. The final granules tend to be coarse and firm and to re-wet less easily than those formed by fines-return or re-wet agglomeration. [Editor’s note: Be aware that this method is different than mechanical impingement agglomeration, such as that provided by a pin mill.]

Controlling the combination of three conditions — the distance between the nozzles, the nozzle angles, and the drying air temperature — ensures that the particles are wet enough to stick together but dry enough to avoid forming overly compact agglomerates that can’t be dissolved. This method can also be combined with fines-return agglomeration by returning fines to the dryer’s atomizing zone.

**Re-wet agglomeration**

A system that provides re-wet agglomeration, as shown in Figure 3, re-wets a dry powder feed to achieve agglomeration. The feed can be from a spray dryer that can’t achieve agglomeration (such as in an older one-stage system), or it can be a mixture of various dry powders.

The system typically includes a loss-in-weight feeder, a fluid-bed re-wet agglomerator (with agglomerating, drying, and cooling sections), a re-wet system in the agglomerator (consisting of spray bars equipped with two-fluid atomizing nozzles that are linked to a water supply and compressed-air supply), a sifter, one (or more) cyclone, and a dust collector. In operation, the feeder meters the dry powder feed into the fluid-bed re-wet agglomerator. The re-wet system’s two-fluid nozzles combine compressed air with water (or a suitable solution) to form a spray mist that contacts the particles in the unit’s agglomerating section and causes them to stick together. The resulting granules flow through the subsequent drying and cooling sections. Some fines exit the agglomerator in the air flowing to the cyclone, which returns the fines to the agglomerator. The granules discharge to the sifter, which removes additional fines and returns them to the agglomerator. The air exhausted by the cyclone is filtered by the dust collector.

To achieve high-quality granules with the right density and particle size distribution and to avoid leaving excessive deposits on the agglomerator walls, the ratio of water to feed must be correct. The ratio of water to air in the two-fluid nozzles also must be controlled to achieve the right droplet size, and the nozzles must be at the correct angles. Temperatures in each of the agglomerator’s sections must be suitable for the application, and the water from the spray bars must be equally distributed across the agglomerator’s width while the feed powder is equally distributed across and along the agglomerator. In the agglomerating section, the fluidizing velocity must suit the application. Fines returned from the sifter and cyclone must be well-mixed with the feed entering the agglomerator. When these conditions are right, re-
wet agglomeration allows wide adjustment of the granules’ bulk density, particle size distribution, and instant properties.

**Some advice**

Work with an agglomeration consultant or agglomeration equipment supplier to choose the right method for your application. In some cases, the form of your feed can be the determining factor. For example, if your feed is already a dry powder, re-wet agglomeration allows you to agglomerate the feed without the additional step of dissolving it or making a slurry.

In other cases, the choice will depend on your existing equipment and how much versatility you need. For example, a spray dryer can be used both for fines-return agglomeration and spray-drying fine powders.

Your choice can also depend on the final granule characteristics you desire. For example, you may need the larger, stronger granules produced by fines-return agglomeration in a spray-bed dryer or the greater range of bulk density, particle size, and instant properties provided by re-wet agglomeration to produce several different products.

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**For further reading**

Find more information on agglomeration methods and drying in articles listed under “Agglomeration” and “Drying,” in Powder and Bulk Engineering International’s comprehensive “Index to articles” in our November 2002 issue and at www.powderbulkintl.com.

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