# AGGLOMERATION ADVISOR

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## Choosing agglomeration technologies

Agglomeration is the process of converting fine powder particles into larger ones through the introduction of external forces. Size enlargement can be accomplished by a variety of means, including mixing with a liquid, applying pressure, and heating. In this column, we'll explore the basic types of agglomeration mechanisms, the technologies and equipment involved, and how to choose the process most suitable for your necessary end results.

### Agglomeration mechanisms

Particles are held together by a number of mechanisms. Liquid bridges in spaces between individual particles can form strong agglomerates as a result of capillary forces that develop when the voids are filled with the liquid. Binders, such as lignosulfonates, mineral oil, and kaolin clay, that readily adhere to solid particles can be effective agglomerating aids. Solid bridges between particles can also be formed as a result of sintering, partial melting, and recrystallization during drying. Attractive forces such as van der Waals forces, valence forces, and hydrogen bridges can also hold solid particles together. If adjacent particles interlock, very strong agglomerates form.

Technologies available for size enlargement fall into three general categories, tumble-growth agglomeration, pressure agglomeration, and agglomeration by heat or sintering. When deciding what process is best for your agglomeration needs, there are a few things to consider. Tumble-growth agglomeration equipment tends to have a low capital cost but may have a high capital cost if drying is a required part of the process. Pressure agglomeration equipment and equipment that agglomerates particles by heat or sintering generally have high capital costs but low operating costs.

Simple tests can be used as screening tools to determine the most suitable agglomeration process for a particular powder. Liquid can be added to a fine powder in a small kitchen blender to determine if the liquid will indeed wet the powder without the addition of a surfactant, which would lower the surface tension, allowing the liquid to spread over the solid surface. Alkylbenzene sulfonate and lauryl sulfate are just two examples of commonly used surfactants and are inexpensive to incorporate into your agglomeration process. A simple test can also give the investigator a sense of how much liquid must be added to avoid producing a slurry or paste. Hydraulic presses can be used to gauge the likelihood that pressure agglomeration is a suitable technology. Differ-

**FIGURE 1**

Pin mixer

Courtesy of FEECO International.

**FIGURE 2**

Disk pelletizer

Courtesy of Eirich Machines.

**FIGURE 3**

Rotary drum agglomerator

Courtesy of FEECO International.

ential scanning calorimetry (DSC), a technique used to study the thermal transitions of a polymer, can be used to estimate the temperature required to agglomerate a fine powder by melting or sintering.

Many suppliers of agglomeration equipment have test facilities for conducting feasibility studies with pilot-scale agglomerators. Often the equipment is available for rent, and customers can perform thorough in-house evaluations to find out if the agglomeration process achieves the desired result.

## Tumble-growth agglomeration

Tumble-growth agglomeration can be either wet or dry. In a wet agglomeration process, the fine particles are mixed with a liquid, usually water. In some cases, a surfactant or other chemical is added to improve the wettability of the solid particles. The optimal amount of liquid added to a powder — the level that gives an agglomerate its greatest strength — is typically 40 to 90 percent of the powder's full saturation.

Binders are frequently added to improve an agglomerate's strength. Examples of organic binders are starch, waxes, and rosin. Inorganic binders include sodium silicate, bentonite, and various aqueous solutions. The choice of binder depends on its cost, compatibility with the powder, and ability to give an agglomerate a certain amount of strength.

Common wet agglomeration equipment includes pin mixers, disk pelletizers, plough mixers, fluidized beds, and other technologies.

Wet agglomeration processing of fine powders occurs in three stages. The first stage is mixing and combines the fine powder, liquid, and binder. The particles are joined together to form green or uncured agglomerates, which is the second stage. Nuclei are first formed and then grow into larger aggregates by layering or coalescing with other particles. The final stage is drying or curing the agglomerate, which takes place in a separate device. In some cases, nucleation and aggregate growth take place in two separate pieces of equipment; for example, agglomerates formed in a pin mixer, like the one in Figure 1, are then fed into a disk pelletizer, like the one shown in Figure 2, to increase the agglomerate's size.

Since it is critical to produce a green pellet with an optimum saturation state, meticulous control of the solids and liquid feedrates is required. Providing a steady liquid feedrate is generally straightforward and easy to achieve; however, ensuring a constant solids feedrate for some powders relies heavily on the

**FIGURE 4**

Fluidized-bed agglomerator

Courtesy of Freund-Vector Corporation.

type of powder, the powder's flow properties, and the feeder design.

Dry agglomeration can be a misnomer because the method often requires moisture, although significantly less than the amount needed for wet agglomeration processes. The most popular equipment used in dry agglomeration is a rotary drum agglomerator, shown in Figure 3. In this process, nozzles inside the drum coat particles with liquid to promote adhesion.

The major advantage of dry tumble-growth agglomeration over wet agglomeration is reduced drying costs. However, disadvantages include the long residence time required to granulate the powder, the need for seed particles to be fed into the drum during startup, and the high material recycle rates that are generally necessary.

Other tumble-growth agglomeration equipment includes mixers that are equipped with spray nozzles and fluidized beds, such as the fluidized-bed agglomerator, as shown in Figure 4. The equipment provides a turbulent environment where particles come in contact with liquid and each other, coalesce, layer, and form agglomerates.

If the solids are initially dissolved or suspended in a lot of liquid, agglomeration can be achieved by feeding partially dried particles from a spray dryer into an integrated fluidized-bed dryer. Because the drying is incomplete in the spray dryer, particles fed into the fluidized bed are slightly cohesive, and size enlargement will occur during fluidization. The final drying also takes place in the fluidized bed.

**FIGURE 5**

Roller compactor

Courtesy of Komarek.

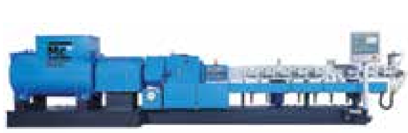
**FIGURE 6**

Ring die mill

Courtesy of CPM Roskamp Champion.

**FIGURE 7**

Screw extruder



Courtesy of Coperion.

### Pressure agglomeration

Pressure agglomeration falls in two general categories, roller compaction and die compaction. In a roller compactor, like the one shown in Figure 5, mechanical forces are used to press the powder. Fine powder is fed between two counter-rotating rolls, where it is compressed into a sheet or strips. The sheet or strips are then fed through a flake breaker, which shears and crushes the material into manageable sizes.

The equipment works best when the powder fed into the compactor is deaerated before it reaches the rolls. This can be accomplished by equipping the roller's feed hopper with a screw to compress the material as it is conveyed downward. Another technique is to apply a vacuum on the clean side of gas-permeable hopper walls or rolls.

Die compaction equipment, such as briquetters and pellet mills, produces agglomerates with a desired shape. A briquetter is a roller compactor that has pocketed rolls, allowing the material to be molded by pressing it into the recessed cavities on the rolls.

Pellet mills are devices that force fine powders into dies. Flat dies and ring dies are two common types of pellet mills. A flat die mill is similar to an extruder as the powder is screw-conveyed against an orifice plate. A cutter at the opposite side of the plate is then used to make pellets. In a ring die mill, like the one in Figure 6, the powder is fed into the inside of a cylindrical chamber where rollers inside the cylinder compress the powder through the die holes. Cutters outside the cylinder then cut the pellets as they leave the mill.

### Melting and sintering agglomeration

Agglomeration by melting or sintering is accomplished using ram extruders and screw or auger extruders. The extruder is usually heated externally, although the temperature of the equipment will rise without the introduction of heat because of friction between the particles themselves and friction between the particles and the extruder walls.

Ram extrusion is a batch process. A volume of powder is fed into the ram extruder's barrel, and then a hydraulically driven piston forces — or rams — the materials toward a die. The piston is then reversed, and a new batch of powder is fed into the barrel.

Screw extrusion differs in that it's a continuous process. The screw extruder is comprised of a feed section, conveying section, melting or sintering section, and pumping section, as shown in Figure 7. In the screw extruder, friction or a heated barrel increases the temperature of the conveyed powder. Pressure is generated by pumping the materials through a die plate or restricted orifice. The extrudate leaving the die plate or orifice is often immersed in a water bath to reduce the extrudate temperature to below its melting point before converting it into pellets.

In conclusion, powder agglomeration can be accomplished by a variety of technologies. The end product's intended use often dictates the choice of agglomeration equipment. For example, many applications require the agglomerates to return to their initial particle size, which usually eliminates pressure and sintering as possible agglomeration methods. Some customers require a narrow particle size distribution, in which case a tumble-growth process is possible but will require auxiliary-classification equipment to sift out the desired particle size. If you're having trouble deciding, simple screening tests using a small blender or hydraulic press can provide insight to the most suitable choices. However, once the screening tests have been completed, larger-scale tests should be conducted at a manufacturer's facility, or rental equipment should be evaluated at your site. **PBE**

**Author's Note:**
The article "Agglomeration Processes: Phenomena, Technologies, Equipment" by Wolfgang B. Pietsch from July 2008 is an excellent reference for further investigating agglomeration technologies. Also, design methods for reliable powder feed systems are discussed in depth in the article "Designing Hoppers, Bins, and Silos for Reliable Flow" in *Chemical Engineering Progress*' April 2018 issue.

**For further reading**

Find more information on this topic in articles listed under "Agglomeration" in *Powder and Bulk Engineering*'s article index in the December 2019 issue or the article archive on *PBE*'s website, www.powderbulk.com.

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