Advances in Pin Mill Technology

Improvements provide finer grinding at lower energy costs compared to air-swept classifying mills that have long reigned supreme in particle-size-reduction efforts

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For decades, the ultimate performance in fine mechanical milling performance has been provided by the air-swept classifying mill (ASCM). Perfectly suited to a broad range of nonabrasive milling applications, the air-swept classifying mill is a single machine used to carry out a twostep process. The process both reduces particle size and limits the output of particles using mechanical classification — only delivering those particles of a predetermined, easily controlled, fine size as the finished product exiting the mill. Historically, this technology has offered performance advantages over other options, in terms of its ability to deliver highly controlled particle sizes for a broad range of applications, from powder coatings to paper fillers. Until recently, the air-swept classifying mill has been widely held as the gold standard in milling technology.

Today, those processors seeking to upgrade or purchase new milling equipment have several different types of impact milling technologies to select from. The pin mill is one option that has seen major advancements over the last decade, enabling performance that rivals that of the air-swept classifying mill. Until recently, significant differences between air-swept classifying mills and pin mills were obvious. In general, air-swept classifying mills provided the ultimate milling performance, but also carried a large capital investment, as they required the purchase of a baghouse filter (to separate the milled material from the air stream), a high-static-pressure blower and auxiliaries. These auxiliaries and the operation of the mill increased the cost per ton of material processed by the mill, and contributed to a more sizable ongoing investment.

Historically, while pin mills have always used less energy, been simpler to operate, and been more economical overall, they were not as effective in terms of their ability to reach the same levels of fine-particle size. A primary goal of mill manufacturers over the last decade has been to close this gap in particle-size capabilities, to take advantage of the improvement in cost-per-ton figures that a pin mill can yield. To help readers better understand a comparison of the economics, a brief introduction to each of these two technologies is presented below.

FIGURE 1. The air-swept classifier mill carries out size reduction and classification in a single process, and particle size can be controlled by adjusting such variables as airflow rate, feed rate, classifier speed and residence time in the chamber.

Air-swept classifying mills

Air-swept classifying mills (Figure 1) are impact mills that can grind materials into very fine powders. The products range in size from about 100 µm (the diameter of a human hair), down to 5 µm (the diameter of a red blood cell). Despite being relatively costly to operate and requiring an experienced operator, users throughout the chemical process industries (CPI) have tended to gravitate toward them, thanks to several unique features beyond fineness. Such desirable attributes include the following:

- The air-sweeping feature can cool materials
- These systems have the ability to hold and control particles through mechanical classification
- The design allows operators to remove oxygen from the process using inert gases, such as nitrogen or argon, thereby reducing the risk of spark or ignition
- Air-swept classifying mills can produce particles in small sizes that other mechanical mills cannot

How air-swept classifying mills work. Air-swept classifying mills perform both milling and air-classifying functions in a single step. As the inlet product comes into contact with a series of spinning impact blocks, the material is smashed into fine particles that pass through a cage of spinning blades called the airclassifying wheel. The wheel acts as a screen and only lets the particles that are small enough through. The larger particles remain in the mill for

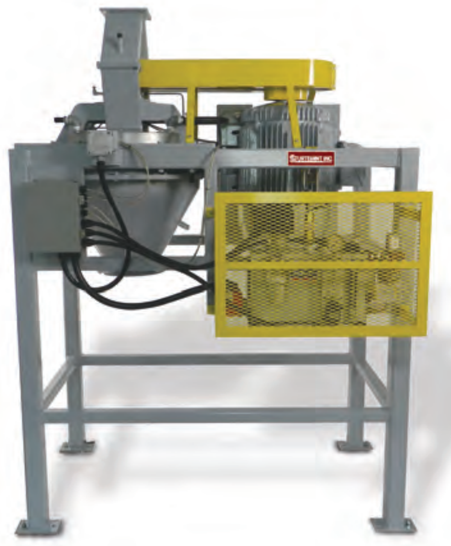

FIGURE 2. Pin mills can be configured in many ways to suit the needs of the application (for instance, using vertical or horizontal shaft, pneumatic or gravity-feed options, varying materials of construction and pin configurations) and more

additional grinding. In its simplest form, fine particles exit the mill and are collected in a baghouse product collector. Particle size is adjusted by increasing or decreasing the classifier speed. Airflow rate and feed rate affect the residence time in the chamber, and the action of the sweeping air prevents heat buildup.

Types of air-swept classifying mills. Air-swept classifying mills vary by size, speed and air flow. Different systems use various impact elements, materials of construction, impact walls, impact area geometries and directions of material flow. These options are used in combination to produce smaller particles, or a product with greater uniformity, less contamination, or any such characteristics that may be deemed desirable for a particular application. Most manufacturers of air-swept classifying mills offer a standard industrial version and customized versions. Customization options typically include specific, duty-purpose innovations to suit individual markets.

One manufacturer offers a variant of the traditional air-swept classifying mill that is specifically designed for food ingredients. It presents material directly to the classifying wheel first, to reduce the energy used for grinding "on specification" material, and then uses hammer blocks to grind the material. The standard materials of construction change to stainless steel and the fasteners are changed to no-tool access (this feature has helped the design to gain U.S. Dept. of Agriculture (USDA) acceptance). Another manufacturer offers a variant that is specifically designed for grit reduction of low-density materials, such as carbon black. The feed stream is introduced below (rather than above) the rotor, and the mill incorporates an external coarse recycling system.

Pin mills

Modern impact pin mill technology. Pin mills use varying degrees of impact and agitation to process many types of materials. They perform a variety of functions, helping users to reduce the size of bulk solids, deagglomerate materials, break apart fibers in natural materials, densify, fluff, mix, blend, disperse and homogenize the product. They provide a range of speeds. Relatively slow mixing and blending typically has rotor speeds on the order of 6,800 ft/min; high-impact grinding may have speeds up to 36,000 ft/min. Today's designs are sealed to provide controlled atmospheres. Constructed from stainless steel, carbon steel, and many other materials, they are available for applications in the chemical process, food, pharmaceutical, grain milling and mineral industries.

How pin mills work. There are several types of pin mills, but all of them achieve the same end: producing homogeneous products. They work by introducing the feed product onto various spinning rotors with different configurations of pins or blocks that act as impactors. The number and orientation of the pins determines how material is processed, and the rotor speed determines the force of impact.

Size reduction results when materials flow through a maze of pins that have many interactions at higher speeds (Figure 2). Gentle handling, such as mixing and blending, happens at lower speeds so more of the energy can be efficiently directed into the product without degrading it. Individual pin mill designs feature different types of rotors and rotor diameters, varying types, numbers, and orientations of pins, different capacities, feed options and liners to produce different results.

Types of pin mills

The type of pin mill to consider for an application depends on the size, density and type of product that is supplied and desired, and the environment the mill will be working in.

Pin mills can be customized to fit with pressure-pneumatic or gravity feed systems, and they can be constructed from different materials according to the application.

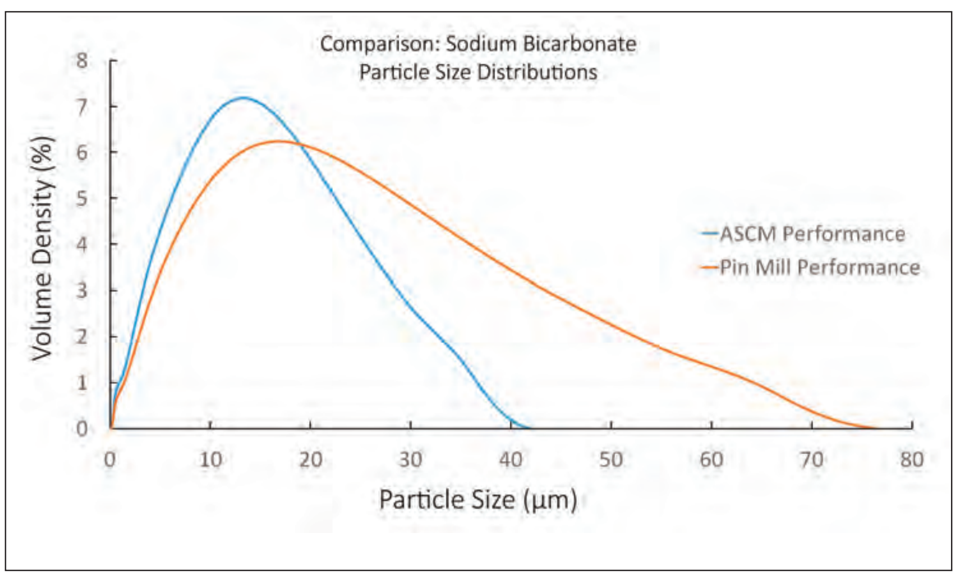

FIGURE 3. Shown here is a comparison of the particle-size distribution for a pin mill versus an airclassifying mill handling sodium bicarbonate. As shown, the pin mill was not able to achieve the same maximum fineness as the final product produced by the air-swept classifying mill

FIGURE 4. In recent years, pin mills, such as this one milling trona, have become competitive with airswept classifying mills on performance, but also can yield reduced capital, energy and operating costs

Horizontal and vertical pin mills. The name indicates the orientation of the rotor. Some applications have special requirements so they can only use one or the other. For instance, those that need a screen at the bottom require a vertical mill.

Centrifugal impact pin mills. These mills are used to reduce medium- to low-density materials to fine, uniform sizes of 50–325 mesh (300–44 microns, μm), for applications where low wear is critical. They are widely used in many low-wear markets, including food-product processing, such as corn fractionation, flours, starch densification, corn slurry, sugar and sweeteners, and semi-abrasive material applications, such as aluminum sulfate, fertilizer, gypsum, soda ash, tungsten and other powder de-agglomeration (including tungsten), talc, clay and kaolin.

Pin mill advances

Most pin mill advances are based on specific needs of certain applications. As noted above with duty-purpose air-swept classifying mills, pin mills are also customized to meet user requirements, with the resulting designs and configurations then integrated to produce the desired products. Thanks to ongoing design and material improvements, pin mills are trending toward producing finer and finer cuts, now typically in the 30–300-μm range.

When manufacturers are able to combine a few of the features already discussed, an assemblage of key features can now be realized. For instance, a vertical-shaft pin mill that provides very fine particle distribution can now have low maintenance requirements, be cost-effective and simple to operate. A final comparison must be made on the tradeoff between the cost to operate in kilowatt hours and relative fineness of the same material, because a pin mill still cannot achieve the low, tight particle size distribution exactly like an air-swept classifying mill.

Comparing key attributes

To compare the energy usage, particle sizes, and operating cost of the two technologies, laboratory testing was carried out using a pin mill and an air-swept classifying mill. Both mills processed identical material with corresponding throughput settings. The simulation was based on an industrial fluegas-treatment application, where sodium bicarbonate would be used for dry sorbent injection. The resulting particle-size distributions and energy consumption were also observed so operating costs and performance could be compared between the two systems. The test was run under similar conditions and optimal horsepower set tings. Each mill design is flexible and horsepower can be adjusted for every application. Table 1 summarizes results from a side-by-side comparison test, showing energy consumption per hour on a kilowatt (kW) basis.

TABLE 1. OPERATING COST COMPARISON: PIN MILL VS. AIR-SWEPT CLASSIFIER MILL (SODIUM BICARBONATE FINE-CUT CAPACITY)

	Pin mill	Air-swept classifier mill
Fine-cut capacity	1,500 lb/h	1,500 lb/h
Exhaust fan	N/A	20 HP @ 460 V (15 kWh)
d10, d50, d90, μm	d10 = 2, d50 = 13, d90 = 48	d10 = 2, d50 = 9, d90 = 22
Resulting kWh used	18.35 kWh	51.84 kWh
Operating cost of 1,500 lb/h at $0.13/kWh	$2.39/h	$6.74/h

Energy cost per hour to mill 1,500 lb/h was calculated using a utility cost of \$0.13/kWh, by the following equations:

Horsepower formula (3-phase):

$$\frac{1.732(V)(Amps)(EFF)(PowerFactor)}{746} = \qquad (1)$$

$$\frac{\left(kW/HP\right)}{746} = HP$$

$$\frac{1.732(460V)(Amps)(0.9)(0.95)}{746}$$

Where:

EFF = Motor efficiency (typically expressed as percentage)

Conversion from HP to kW:

$$HP\left(\frac{0.746kW}{HP}\right) = kW \qquad (2)$$

Cost to operate:

$$(kW \bullet h)\left(\frac{\cos t}{kW \bullet h}\right) = \$ \qquad (3)$$

$$(kW \bullet h)\left(\frac{\$0.13}{kW \bullet h}\right) = \$$$

As demonstrated in the table, using \$0.13 per kWh, a \$5.78/ton savings is shown in this example.

To understand the savings, consider a single-shift plant, assuming 8-hour days and 250 d/yr, the annual savings would be \$8,700 using a pin mill versus an air-swept classifying mill.

However, observing the graph in Figure 3, it is also important to note that based on these results, the pin mill never achieved the maximum fineness that was possible with the air-swept classifying mill: 50% of the particles produced by the pin mill exceeded 13 µm, compared to 9 µm with the air-swept classifying mill; and 90% of particles from the pin mill passed 48 µm, versus only 22 µm for the air-swept classifying mill.

Regarding target fineness, the takeaway is that when fineness of 20 µm for 90% or more of the volume being processed is a key objective objective, pin mill technology may not be quite ready to handle the challenge. However, if there are allowances for particle size in the upper limits of the particle distribution, the pin mill performance is very close to that of the air-swept classifying mill. When looking at only the average of particles — the d50 value — fineness is almost identical.

In the past, pin mills (Figure 4) were only capable of producing top sizes down to 75 µm — the theoretical limit of fineness on a pin mill. Equally for an air-swept classifying mill, many believed the finest materials it could achieve were in the range of 20 µm. Today, the theoretical fineness in air-swept classifying mills is in the 5–10 µm range, with the practical limit being around 20 µm. Pin mills have achieved a practical range down to 40 µm, which is very similar to that of air-swept classifying mills so the gap is narrow.

For users who want narrow particle- size distributions, air-swept classifying mills do it well consistently, but advancements in pin mill technologies show that they are now able to produce comparable particle- size distributions, too. Although pin mills cannot do everything that air-swept classifying mills can, in some cases, the cost to operate the latter outweighs the benefits of milling performance. In these situations, the advancements in modern pin mill technologies can far outweigh the investment and cost to operate an airswept classifying mill.

Understanding the trade-off between energy, fineness, and the convenience features of a modern pin mill relative to an air-swept classifying mill may be an important step in any plant's next design review. ■

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