Roller mills: Precisely reducing particle size with greater efficiency

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This article introduces roller mills and explains how they efficiently grind friable materials to a uniform final particle size while using relatively little energy and minimizing waste.

Dry bulk solids processors are demanding more from their equipment today than ever before. Processors who use size reduction equipment have especially rigorous demands: improved product characteristics, higher process efficiencies, and lower energy usage. Roller mills can answer all of these demands for a wide range of chemical, pharmaceutical, food, mineral, and other products. The mill is suited to reducing friable or fragile and breakable materials — that is, any material that breaks rather than flattens under pressure — in applications that require a uniform particle size with minimal fines.

Consider coffee grinding, an application in which the most important goal — as in many bulk solids size reduction applications — is to maximize particle uniformity for better control of the final particle characteristics. In the US, most coffee beans are ground to achieve a maximum particle yield between 1,170 and 590 microns with minimal fines (particles under 417 microns), while some beans are ground finer, depending on the final use. For instance, beans are ground to 1,170 microns for use in percolators, 590 microns for fine drip grinds used in filter coffee, 300 microns for espresso, and 100 microns for Turkish coffee.

After grinding, the coffee goes directly to packaging without being classified. This streamlined process demands precise grind uniformity. If the grinding produces variations in the coffee's particle size or creates fines, the coffee overextracts during brewing. This overextraction increases the coffee's bitterness — a characteristic that all coffee producers try to minimize.

Skipping the classifying step isn't an option with many other size reduction methods. For most applications, the ground particles must be classified to ensure that the final particles meet strict size requirements. What's more, the fines removed during classifying cost the producer money and waste energy because the fines must be discarded, reprocessed, or used in a secondary market.

The roller mill minimizes such costs by precisely reducing feed materials with an average particle size up to ¾ inch to a uniform average size typically between 100 and 2,000 microns. The roller mill's ability to reduce materials to a uniform particle size provides more control of product characteristics and minimizes waste, as shown in Figure 1. The mill's controlled reduction action requires less energy than other grinding methods, improving production efficiency and saving energy dollars.

Roller mill components and operation

A typical roller mill has from one to four pairs of counter-rotating rolls mounted horizontally in a rigid frame, with a feeding device positioned above the top roll pair. One roll in each pair is mounted in a fixed position, and the other can be moved closer to or farther from the fixed roll to adjust the space between the rolls (called the *roll gap*). The roll gap size is based on the desired particle size reduction.

How the mill works. In operation, the feeding device gravity-feeds material at a constant rate to the roll gap between the top pair of rolls. The material enters the *nip point* (where the gap between the rolls is smallest) and is crushed into smaller particles as the rolls counter-rotate. If the mill has multiple roll pairs, the reduced particles will fall into the next pair's nip point, be crushed into smaller particles, and pass to the next roll pair, until the desired-size particles are discharged by gravity from the bottom roll pair, as shown in Figure 2.

Figure 1

Particle size distributions: Roller mill versus other grinding methods

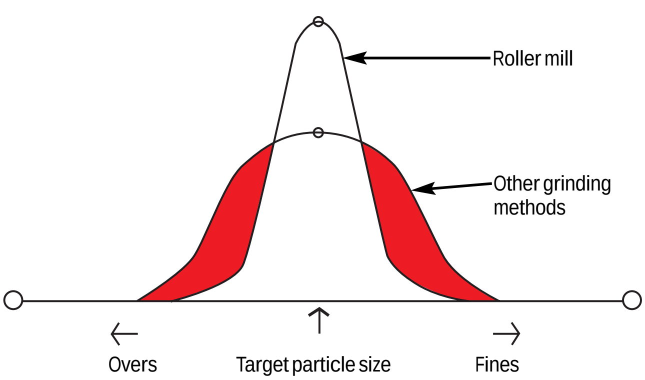
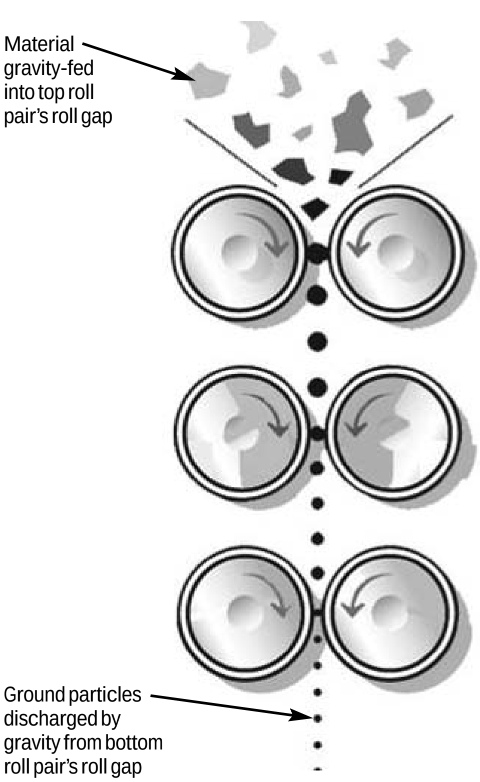


Figure 2

Material passing through multiple roll pairs



More about the rolls. Common roll diameters are from 6 to 10 inches, and roll lengths — which vary with the roll diameter to ensure that the roll will be mechanically robust — are from 8 to 52 inches. Longer rolls provide greater grinding capacity.

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The rolls typically have a cast-iron core with a ⅝- to ¾-inch-thick outer layer made of alloy steel. The outer layer's surface is typically corrugated with grooves or other patterns, depending on the application. For some very fine size reduction applications, the roll surface is smooth.

The more roll pairs the mill has, the greater the size reduction it can achieve. For instance, reducing salt feedstock to coarse road salt requires a roller mill with one roll pair, while reducing the material to table salt requires a mill with two or three roll pairs.

More about the feeding device. The feeding device is integral to the roller mill. Common feeding devices include rotary feeders (for granular feed with an average particle size from ¼ to ¾ inch) and vibratory feeders (for powder feed with an average size up to about 400 microns). To provide a constant feedrate, the feeding device must be positioned precisely above the top roll pair's roll gap and maintain a falling curtain of feed material into the gap.

How the mill achieves uniform particle size

To achieve a uniform final particle size with minimal fines, the roller mill must have the right roll surface, roll speed ratio, and roll gap for your application.

Roll surface. Typically, the roll surface is corrugated rather than smooth to achieve efficient size reduction, as shown in Figure 3. Thousands of different corrugation configurations are available to suit your material hardness and desired final particle size. For instance, rolls can have *longitudinal corrugations,* which run along the roll's length, or *circumferential corrugations,* which run around the roll's circumference. Each corrugation can also incorporate several flutes (small grooves) of various profiles and sizes. To determine which corrugation style is right for your application, the manufacturer will typically conduct roller mill tests of your material in the manufacturer's test facility with various roll corrugation styles and under conditions that duplicate your operating environment.

Roller mill demand grows with

Growing markets for uniformly reduced particles

Market demand for the uniform particles produced by roller mills is growing as bulk solids processors strive to improve product characteristics, achieve higher process efficiencies, and use less energy.

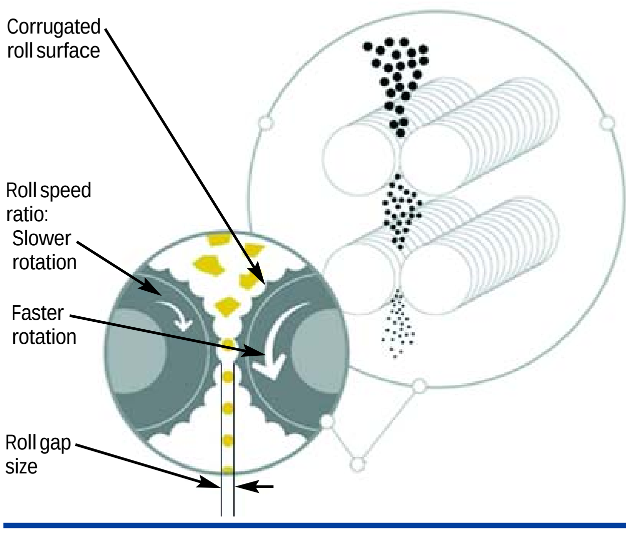
Prime examples are the markets for carbon and super-absorbent materials, which are expected to grow in the next few years. Demand for carbon is growing because of the increasing market for activated carbon (for purifying air and water) and for carbon electrolytes (used in steel manufacturing). The market for super-absorbent polyvinylacrylate (PVA) materials (for use in diapers, moisture-release soil additives for agricultural uses, and other products) is also maturing. The increasing use of these materials as commodities is driving competition among carbon and super-absorbent materials producers to manufacture the materials more efficiently and with more consistent product quality. The roller mill's ability to reduce particles to a uniform size with low energy usage and minimal waste makes it ideal for both applications.

Carbon and super-absorbent materials aren't the only materials that can benefit from roller milling. In thousands of applications, bulk solids producers who want to uniformly reduce friable particles, reduce energy costs, and minimize waste are discovering that the roller mill is the solution to their grinding problems. ***—D. Ephraim***

Roll speed ratio. In most applications, the rolls in each pair counter-rotate at different speeds (Figure 3). Both rolls are powered by one motor, and the speed difference is supplied by an HTD drive belt. Operating the rolls at different speeds applies shear to the material as it passes through the nip point. The difference in roll speeds for each pair is called the *roll speed ratio* (or *roll speed differential*). For instance, if one roll rotates at 1,000 rpm and the other at 500 rpm, the roll speed ratio is 2:1 (1,000/500). More shear — and thus a larger roll speed ratio — is required to crush less friable particles. Running the rolls at the ideal roll speed ratio will achieve the desired shearing effect as the material passes through the nip point; the higher the shear, the more tearing the crushed particle receives. As a result, the roll speed ratio can have a powerful impact on your final particle size distribution, depending on your material's friability and other properties and the roll surface. Roller mill tests can help determine the right roll speed ratio for your material.

Figure 3

Roll surface, roll speed ratio, and roll gap



Roll gap. Controlling the roll gap (Figure 3) is critical to achieving your required final particle size. This control has two components: the roll gap size and roll alignment. The roller mill operator can control the particle size by widening or narrowing the roll gap. For most roller mills, the roll gap is automatically adjusted through a PLC that's programmed to change the gap to match the specs for a new product or batch. This allows roll gap adjustments to be made in just seconds while the mill is operating, which allows fast changeovers between various grind settings and eliminates the need to shut down a continuous process. The operator can also adjust the roll gap to control the roll alignment: The rolls in each pair must be perfectly parallel to ensure that the roll gap is exactly the same along the roll length so the mill can achieve uniform size reduction. Tests at the mill manufacturer's facility can determine the best roll gap for your size reduction requirements.

How the mill saves energy and minimizes waste

The roller mill requires less energy than other attrition milling methods that rely on multiple high-speed impacts,

The roller mill can reduce materials to a uniform particle size, providing more control of product characteristics and reducing waste.

such as a hammermill, in which the hammers rotate at very high speed and repeatedly impact each particle. In the roller mill, each roll pair rotates at relatively slow speed and impacts each particle only once. In fact, the roller mill's energy efficiency typically allows it to reduce at least 40 percent more material (in tonnage per hour) at a given horsepower than a hammermill. The resulting energy savings is often the major reason for choosing a roller mill over a hammermill or other attrition milling equipment.

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The roller mill provides a particle size distribution that's from 50 to 100 percent more uniform, with 50 to 75 percent fewer fines, than distributions produced by other attrition milling equipment. This means that no classifying step is required after reduction in the roller mill, and the mill produces minimal waste in fines, eliminating a need to discard, reprocess, or sell the waste.

Some final advice

The roller mill isn't the best size reduction machine for every application. Nonfriable materials are best handled in other size reduction machines, and some very fine particle size distributions are better obtained by other methods. For instance, if you're looking to produce very fine particles in the 40-micron range, a pin mill may be your best choice. But for controlled reduction of friable particles to uniform size distributions in the 100- to 2,000-micron range, a roller mill is the best option. While it does have a relatively high capital cost (for instance, from 50 to 200 percent higher than most hammermills), its ability to precisely reduce particles while using less energy and producing little waste can provide a relatively fast return on investment.

When selecting a roller mill, work closely with the mill manufacturer to choose the optimal unit for your application. Ideally, you should observe roller mill tests of your material in the mill manufacturer's plant. The tests will help determine not only the best roll surface, roll speed ratio, and roll gap for your application, but the ideal number of roll pairs, motor size, feeding device, and other options. Expect the tests to demonstrate that the roller mill can achieve your final grind requirements.

Once you've selected the roller mill, make sure your operators receive training from the mill manufacturer. Ideally, a technician from the manufacturer should also be present for the mill's installation and initial startup at your plant.

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For further reading

Find more information on roller mills in articles listed under "Size reduction" in *Powder and Bulk Engineering*'s comprehensive article index at www.powderbulk.com and in the December 2005 issue.

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