Tips:

How to apply an attrition mill for fine, dry grinding

This article explains how a dry attrition mill can finely grind materials, how to select grinding media for the mill, and how to improve milling performance.

A dry attrition mill is a versatile fine-grinding unit that can handle several materials under many conditions. Common applications include grinding ceramic powders, pigments, chemicals, food products, plastics and rubber, minerals, metal powders, glass frits, fibers, and cellulose. The mill can also blend dissimilar materials, coat particles with additives or disperse the additives during grinding, and provide mechanical alloying. Conditions that can be varied during mill operation include the grinding media type, size, and ratio to material; material feedrate; and grinding speed.

The attrition mill's dry operation saves the process step and energy required to remove waste liquid from a wet-milling chamber and eliminates having to dispose of the liquid, which can be costly. The compact mill also allows you to adjust operating variables to meet your product spec.

The dry attrition mill typically provides size reduction finer than that of a vibratory mill and comparable with that of a jet mill.[1] A regular-speed dry attrition mill typically can handle feed materials 40 mesh and finer; a high-speed unit can handle feed materials 75 microns and finer.[2] In continuous mode, the regular-speed mill can typically reduce particles to –44 microns; the high-speed unit can reduce them to about 5 microns and, with air classification, to about 3 microns. In batch mode, the regular-speed mill can typically reduce particles to between 1 and 2 microns; the high-speed mill can reduce them to about 80 percent less than 1 micron.

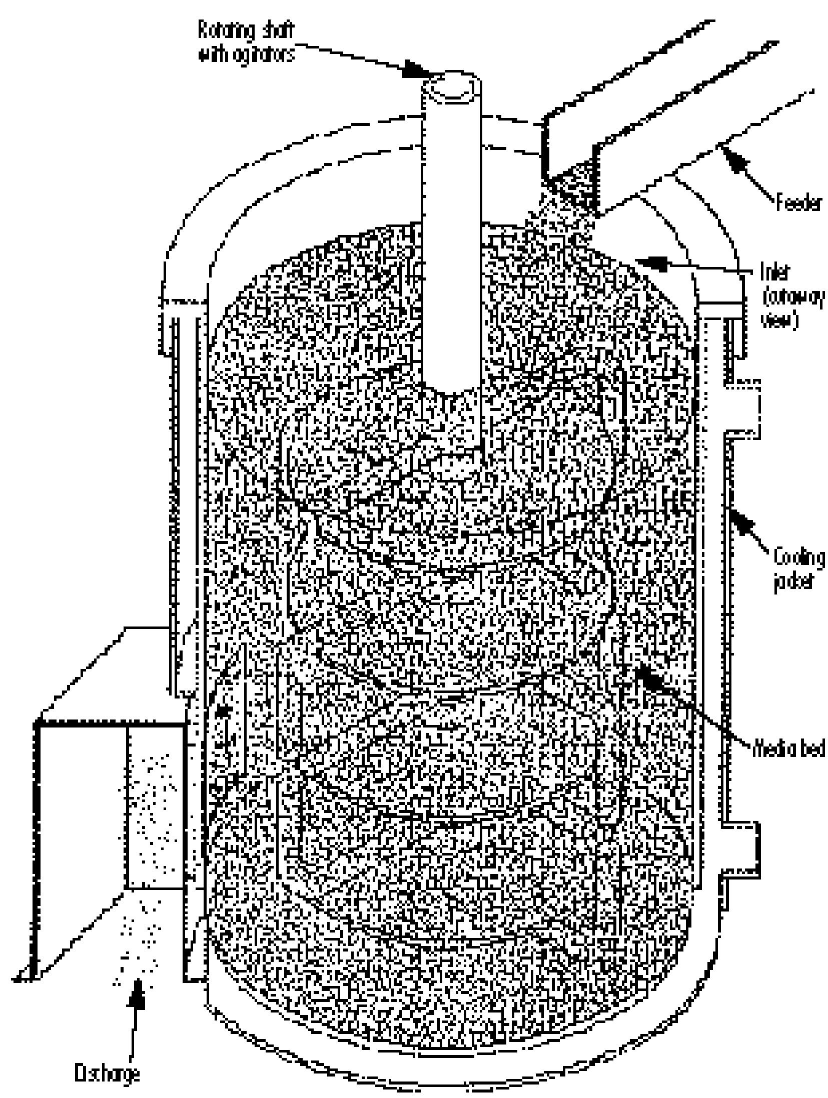
However, the mill is typically not suited to reducing materials to superfine submicron particles, which requires wet grinding.[1] The dry attrition mill also generates more internal heat than a wet mill and can require running a refrigerated coolant through the mill's cooling jacket. Adjusting the mill's material-to-media ratio and retention time also can limit heat generated during grinding.

How the attrition mill works

The dry, fine-grinding attrition mill consists of a stationary, cylindrical, vertical grinding chamber, as shown in Figure 1. A rotating vertical shaft

Figure 1

Dry attrition mill (high-speed unit)



with horizontal agitators is mounted at the chamber center. Grinding media, available in balls made of various materials, fill about two-thirds of the regular-speed mill's chamber and about one-third of the high-speed unit's chamber. A feed inlet is located at the chamber's top, and a metering valve assembly with either a grid or laser-drilled screen is located at the bottom. (A high-speed unit can be fitted with a side discharge near the chamber bottom for discharging by centrifugal force.) A secondary feeder for adding a dry grinding aid or additive or a metering pump for dispensing a liquid additive can also be located at the chamber top. A cooling jacket encloses the chamber and typically is filled with water.

In operation, feed material is metered through the inlet and falls into the media bed. (If required, a grinding aid or additive is dispensed by the secondary feeder or metering pump into the chamber.) The rotating shaft's agitators expand and move the media bed, creating a random motion in which the media and particles (and any grinding aid or additive) can freely move, collide, and impinge on each other. The action generates high shear and powerful impact for efficient grinding, creating small particles that are more spherical than those produced by other impact-milling methods. The on-spec milled particles flow by gravity through the media bed and out the metering valve, where the grid or screen prevents the media from exiting (or the particles are propelled by centrifugal force through the high-speed unit's side discharge).

How to select grinding media for the mill

Grinding media types for attrition mills include plastic pellets, through-hardened carbon steel, chrome steel, Type 440C stainless steel, zirconium silicate, zirconium oxide (MgO or Y_2O_3 stabilized),[3] aluminum oxide, steatite, tungsten carbide, silicon nitride, and silicon carbide. The media are available in a range of diameters to match your application.

Base your media selection on the following factors, which are often interrelated:

- ***Specific gravity.*** High-density media generally provide better grinding results. The media should be denser than the material being ground.
- ***Initial feed material size.*** Use large media if your material has large particles; small media can't break up the large particles.
- ***Final particle size.*** Use small media to achieve finer grinding.
- ***Hardness.*** Hard media will grind more efficiently and wear more slowly.
- ***pH.*** A strong acid or alkaline material can react with some metallic media.
- ***Discoloration.*** When your final product color is important, closely match the media color to the material color. For instance, use white media with a white material.
- ***Contamination.*** Because wear particles from the media can enter your material, choose media whose wear particles won't affect product quality or that can be removed by a magnetic separator, a chemical reaction, or sintering.
- ***Cost.*** Long-wearing media tend to be more expensive. But a media type that initially costs two to three times more than another can be a long-term bargain because it can last five to six times longer.

How to improve milling performance

Getting the most out of your attrition mill means controlling several operating variables.

Minimize your material's moisture content. A material with a high moisture content (over about 5 percent) can cake inside the grinding chamber and stop the process. Keep your material's moisture content as low as possible. In some cases, you can operate the mill at a higher temperature to drive off moisture.

Minimize particle size variation in the feed material. A feed material with a broad particle size range often produces a wide final particle size range. Such a feed material also can make your decisions about process mode, mill type, media, and other factors more difficult.

Control the feedrate. Although both gravimetric and volumetric feeders are suitable for feeding the mill, make sure the feeder is accurate. The more accurate the feedrate, the better your grinding results.

Maintain the right material-to-media ratio. If your material-to-media ratio is too high, it will reduce the media's velocity and impact and reduce the grinding efficiency. But if the ratio is too low, the media will impact itself and wear quickly. The optimal material-to-media ratio delivers efficient grinding.

Use grinding aids and additives. You can continuously feed a chemical grinding aid or additive to the mill during grinding. The chemical can do one or more of the following:

- Minimize the effects of any inherent moisture in the feed material.
- Change the inherent electrical charge on each particle's surface or reduce negative effects of any static charge that develops during grinding.
- Act as a partitioning agent between particles to prevent agglomeration (an example is fumed silica, whose abrasiveness separates particles).
- Function as a lubricant between particles (an example is fatty acid, which oils particle surfaces).

- Eliminate the additional process step of introducing an additive or ingredient downstream from the mill.

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References

1. Find more information on available equipment in the "Product summary" and "Resource catalogs" departments located elsewhere in this issue and in articles listed under "Size reduction" (pages 116-117) in *Powder and Bulk Engineering*'s comprehensive "Index to articles," December 1996.

2. SDG regular-speed and HSA high-speed dry grind attritors, Union Process, Akron, Ohio.

3. For more information, see "A comparison of zirconia ceramic grinding media" by Peter J. Donnelly, Hiroshi Ohnishi, and Kazuyo Inui in *Powder and Bulk Engineering,* June 1994, pages 42-50.