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AP42 Section:	11.7
Background Chapter:	2
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CERAMICS
REF 2-8

Grinding Glazes: A Comparison of Milling Methods

Ball milling and attrition were investigated to determine optimum grinding times and particle size distribution for milling ceramic glazes for electrical porcelains

By: H. John Dowdle III, Senior Ceramic Engineer, Southern Devices Div., Leviton Mfg. Co., Morganton, N.C.

Southern Devices, a division of Leviton Mfg. Co., Morganton, N.C., applies a ceramic glaze on some of the low-tension electrical porcelain products it produces.

Since many of the characteristics of a glaze are determined by grinding time and particle size distribution, engineers at Southern Devices conducted a comparison of ball milling and attrition.

Under normal production requirements, Southern Devices grinds 300 gal of glaze/day. The ball mill has a 150-gal capacity, which requires making two grinds/day. The attritor offers the capability of making one grind/day and, at the same time, decreases the time it takes to produce the required amount of glaze.

Quick comparison

A quick comparison of a ball mill and an attritor yields several differences. A typical ball mill uses grinding media ½ in. or larger and turns from 10-50 rpm.

An attritor uses grinding media ranging from ⅛-⅜ in. with a shaft speed of 60-350 rpm. The power input is used directly for grinding, not for turning or rotating a tank with grinding media.

Some of the advantages of the attritor include:

- Fine homogeneous dispersions;
- Short grinding times;
- Temperature control;
- Easy inspection;
- Low power consumption;
- Minimum floor space required;
- Simple to operate;
- Narrow particle size distribution;
- Reproducible results.

Since almost everyone is familiar with the traditional ball mill, the following information will provide some insight on the operation of an attritor.

The attritor can process dispersions much faster than conventional ball mills.

Dispersions can be ground much finer than with conventional ball mills, and narrow particle size distributions are easy to obtain.

The attritor has a stationary grinding tank, compared to the revolving cylinder of conventional ball mills. The attritor tank is filled with grinding media ⅛-⅜ in. in size. As the dispersion passes through the tank, an internal shaft with arms rotates, resulting in an intensive grinding action.

A jacket surrounds the grinding tank, which helps to provide good temperature control for heating or cooling.

The dispersion can be inspected continuously, and additions or corrections made at any time.

The energy requirement in attrition is less than that required in ball milling.

There are three types of attritors:

- Batch—each batch to be processed is charged into the unit;
- Continuous—used for easy-to-grind and disperse materials, and for large quantities/hr;
- Circulation—used for hard-to-grind materials, with a big advantage in being able to obtain narrow particle size distribution in large quantities.

Attritor efficiency

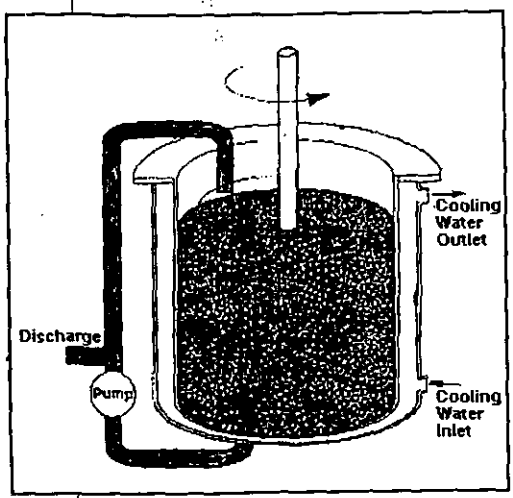
As the shaft rotates in the attritor, the arms force the grinding media to tumble randomly throughout the tank. This results in the media moving in all directions instead of a group movement as in a ball mill.

In order to achieve efficient grinding—especially fine grinding—both impact action and shearing forces must be present. With the random movement of grinding media in the attritor, both forces are present. This random movement also aids in dispersing and mixing of the slurry at the same time.

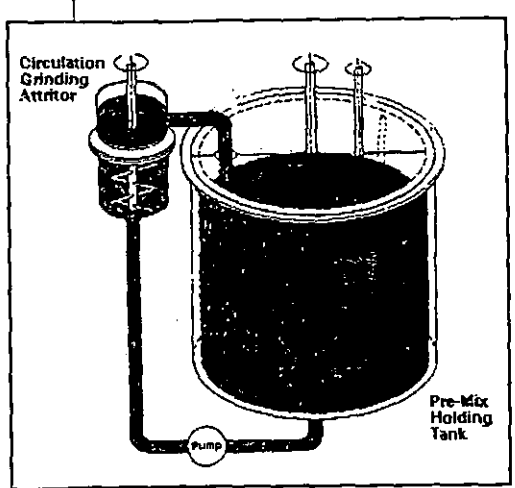
As the shaft and arms rotate, most of the grinding action is achieved at ≈⅔ the radius of the arms. This results in less wear of the tank walls.

Another consideration is the selection of the type of grinding media. Things to consider are: specific gravity of slurry, initial feed size, final particle size, hardness, pH, discoloration and contamination.

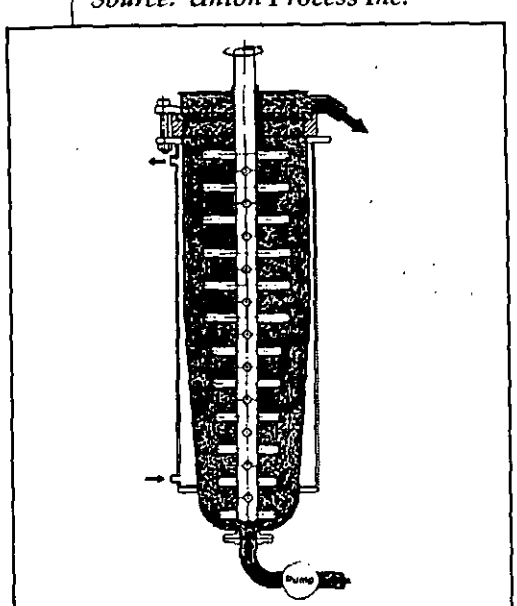
The attritor continues to grind into the submicron range as size reduc-



Batch attritors for wet grinding. Source: Union Process Inc.



Circulation attritors. Source: Union Process Inc.



Continuous attritors. Source: Union Process Inc.

tion in other devices has almost stopped. The attritor has a high power input per unit volume of vessel, giving a much higher grinding potential.

Energy-efficient grinding

Actual values from our process conditions yielded the following numbers:

(0.8% residue retained on 325 mesh screen)
Ball mill. . . . 0.009 kw/gal
Attritor . . . . 0.025 kw/gal

Remember, we must grind in the ball mill two times/day to get the equivalent of one grind/day in the attritor.

As a result, the time required for grinding in the attritor is much shorter for a fixed specific energy input or to a certain desired particle size. Again, the advantage of the power input goes directly toward the grinding of the slurry.

Process conditions

At Southern Devices, we grind 300 gal of glaze/day or 72,000 gal/yr. We use a circulation-type attritor with a 300-gal premix holding-tank capacity.

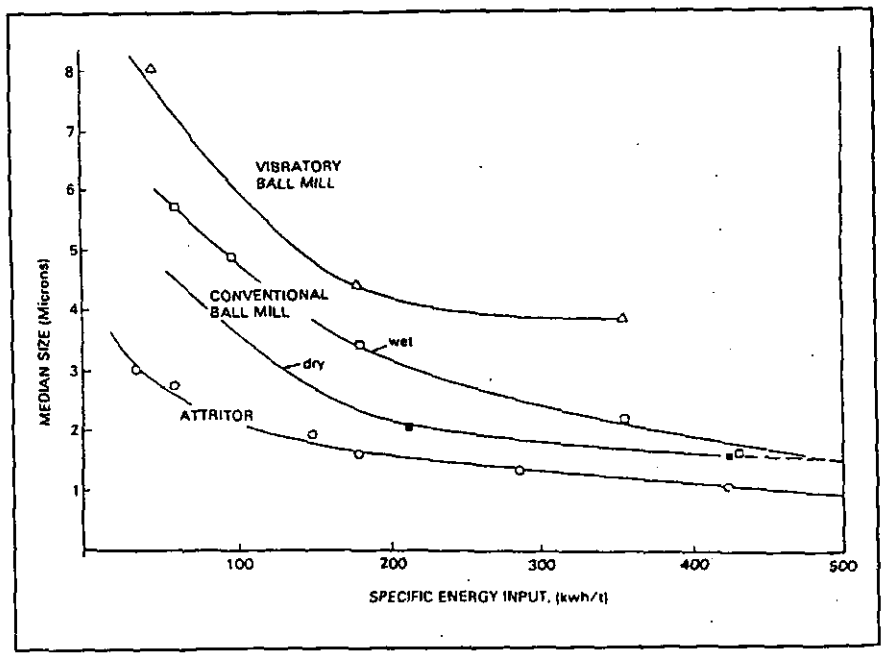
During the grinding process, we maintain a pump rate of 30-35 gal/min in circulation. The high pumping rate allows for a faster grind and a more narrow particle size distribution.

As the slurry circulates, the fines pass through easier, since the coarser particles spend more time in the grinding chamber.

Using the attritor, we produce twice as much glaze in 30 min less grinding time. If the attritor had had new arms and grinding media, the grinding time would have been about 90 min to reach 0.8% retained on 325 mesh for 300 gal of glaze.

Many ceramic glazes are abrasive, and as the arms and media begin to wear, the grinding time will gradually increase. A graph of grind time vs particle size can be plotted to determine the frequency that new grinding media needs to be added to the attritor.

It should be noted that it may be possible to shift the particle size distribution curve for the glaze. For example, instead of ball milling to 0.8% retained on 325 mesh, grind to 1.5% retained on 325 mesh using attrition. This would reduce wear on the grinding media, and the glaze might still have the same characteristics. It also would depend on how the percentage of fine and coarse particles react in different processes. This has to be determined by trial and error.



Comparison of the effectiveness of various grinding devices for the ultrafine grinding of Pima chalcopyrite concentrate.

Maintenance

When adding media, look for wear around the shaft, stainless steel sleeve and brass bushing. Abrasive material can penetrate these areas and cause wearing. As the grinding media wears, small pieces can penetrate into these areas and increase the wear on the sleeve and bushing and eventually wear on the shaft if not corrected.

If there is evidence of wear, the sleeve and bushing need to be changed. If and when the sleeve and bushing are changed, the grinding media should be purged and replaced with new media.

We are presently running tests on various hardnesses on the stainless steel arms to determine an optimum between the arms and grinding media.

We also are looking at redesigning the sleeve and bushing on the shaft with closed seals to prevent glaze and worn media from penetrating and causing them to wear.

Conclusion

We continue to use the attritor for glaze production and the ball mill as a backup, if needed. For our process, the attritor offers the advantage of faster grinding and increased glaze-producing capacity. There is some maintenance required several times a year, but we have our own toolroom and are capable of making our own replacement parts cheaply.

One of the biggest advantages we have using an attritor is in making multiple glaze colors. By developing a standard base glaze, the base can be mixed and ground in the attritor. Most color stain producers offer fast and easy dispersible stains. The standard base glaze can be pumped to a small holding tank where the stain is mixed and dispersed. This eliminates the need for separate ball mills for individual colors and can save a lot of room and time.

Annually, we spend several thousand dollars on replacement parts and grinding media for the attritor, but we make that back through the advantages and the improved glaze quality. □

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A list of references used in the preparation of this article is available upon request.

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