FINE GRINDING OF HIGH-VALUE-ADDED INDUSTRIAL MINERALS BY ATTRITION MILLING

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ATTRITOR®

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I. INTRODUCTION

In today's high technology environment, almost every product is facing higher standards and requirements. A large percent of the products are in some sort of particle form, such as particle and liquid (pastes or slurries), particle and gas (aerosols), particle and particle (mixed powders or filled polymers). Therefore, particle technology has become a key requisite for many material producers.

Methods of producing fine particles can be done either by chemical reactions, phase transformations or mechanical forces, such as milling.

There are quite a few different types of mills, even several different types of attrition mills, but today we are going to discuss the media attrition mill — the Attritor.

The Attritor was invented by Dr. Andrew Szegvari in the 20's. He kept the idea to himself until 1946. He founded his own company — Union Process Inc. After 40 years of continuous research and development, the Attritor became one of the most efficient types of grinding and dispersing equipment.

II. PRINCIPLES

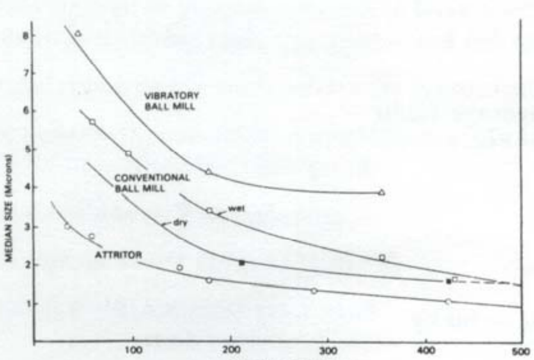
Although there are three types of Attritors (batch, continuous, circulation), the basic principles are the same. It is a grinding mill containing internally agitated balls. Therefore, the Attritor has been generically referred to as a "stirred ball mill."

The material to be ground is charged in the stationary tank filled with grinding media, both material and media are then agitated by a rotating central shaft with a set of horizontal arms.

In general, the tip speeds of the Attritor arms are 18,000 to 30,000 centimeters per minute. The media sizes used in the Attritor are from 3mm to 10mm. The media types include steel, alumina, zirconia, steatite, tungsten carbide, silicon nitride, silicon carbide, mullite, glass, even flintstones. With these given speeds (arm tip speed) and masses (media weight), the Attritor action creates both powerful impact and shearing forces. This combined momentum energy results in size reduction very efficiently. The final product size can be a few microns or even sub-microns, and with a very narrow distribution.

The most important concept in the Attritor is that the power input is used directly for agitating the media to achieve grinding and is not used for rotating or vibrating a large, heavy tank in addition to the media.

Figure 1 shows the comparison of the effectiveness of various grinding devices for the ultrafine grinding of pima chalcopyrite concentrate.



Comparison of the effectiveness of various grinding devices for the ultrafine grinding of pima chalcopyrite concentrate. Herbst and Sepulveda, "Fundamentals of Fine and Ultrafine Grinding in a Stirred Ball Mill," Proc. Powder & Bulk Solids Conf., Chicago, IL, May 1978.

Figure 1

The top curve represents data from the vibratory ball mill; the middle two curves are obtained from conventional ball mills; the bottom curve is obtained from the Attritor. As you can see, for specific energy input around 100 kwh/T, the median particle size achieved through the use of Attritors is nearly 50% smaller than that obtained from conventional ball mills, and is about 33% smaller than that obtained from vibratory mills.

Moreover, for specific energy input exceeding 200 kwh/T, Attritors continue to grind into the sub-micron range, while the other two machines can no longer effectively produce any smaller particles. Consequently, the time required in the Attritor is much shorter.

III. GENERAL FEATURES AND OPTIONS

- The lab size Attritors are designed with variable-speed drive for different RPM selections. The grinding tank sizes are from 110 ml to 9.5 L.
- The production size Attritors are equipped with a two speed electric motor — high speed for actual grinding, and low speed (1/3 of the high speed) for charging, discharging and cleaning procedure. The machine capacity ranges from 35 L to 3800 L.
- All the grinding tanks are jacketed for cooling or heating.
- For metal-contamination-free products several types of ceramic and polymer materials have been developed to line or sleeve the machine's internal parts. These materials include alumina, zirconia, silicon nitride, silicon carbide, tungsten carbide, rubber, polyurethane and various plastics.
- A torque meter can be equipped to measure the energy consumption.
- Cover seals can be provided for processing required under inert atmosphere.

IV. ATTRITOR SYSTEMS AND MINERAL PROCESS APPLICATIONS

A. Batch Attritor (S machines)

These are the most versatile types of process equipment. They can be used for wet batch grinding, dry batch grinding or continuous dry grinding.

The operation of the batch Attritor is very simple. All the material can be loaded directly into the grinding tank; no premixing or dispersing is needed. Since the top-open grinding tank is stationary, the process can be visually observed and corrections and additional ingredients can be introduced at any time.

The maximum feed material size can be up to 10mm, provided the material is friable; otherwise, any 10 mesh down material is feasible to be processed in this machine.

When used as a dry grinding machine, the S machine can be operated in either batch or continuous mode.

Process Data of Batch Wet Grinding

A-1. Material Name: zircon sand ($ZrSiO_4$) -12 mesh

Attritor Used: 1-S; ceramic-lined tank
tank volume: 5.7 L
shaft RPM: 350

Grinding Media Selected: 4.8mm ZrO_2 balls — 12.7 kg

Formulation: zircon sand — 3.3 kg
water — 1.8 kg
(65% solid)

Process Time and Particle Size: 3.5 hours; average 1.84μ

A-2. Material Name: alumina (Al_2O_3) -200 mesh

Attritor Used: 10-S; ceramic-lined tank
tank volume: 70 L
shaft RPM: 180

Grinding Media Selected: 6.4mm Al_2O_3 balls — 80 kg

Formulation: Al_2O_3 — 32.7 kg
distilled water — 10.9 kg
dispersant — 175 g
(75% solid)

Process Time and Particle Size: 4 hours; average 2.65μ

Process Data of Batch Dry Grinding

A-3. Material Name: graphite -200 mesh

Attritor Used: 1-S; stainless steel tank
tank volume: 5.7 L
shaft RPM: 300

Grinding Media Selected: 6.4mm WC balls — 54.5 kg

Formulation: graphite — 1 kg

Process Time and Particle Size: 2 hours; average 6.75μ

A-4. Material Name: garnet -35 mesh

Attritor Used: 1-S; ceramic-lined tank
tank volume: 5.7 L
shaft RPM: 350

Grinding Media Selected: 6.4mm ZrO_2 balls — 12.7 kg

Formulation: garnet — 2 kg

Process Time and Particle Size: 1 hour; 100% < 325 mesh

Process Data of Continuous Dry Grinding

A-5. Material Name: limestone ($CaCO_3$) -200 mesh

Attritor Used: 200-SDG; stainless steel tank
tank volume: 970 L
shaft RPM: 75

Grinding Media Selected: 6.4mm steatite balls — 950 kg

Process Rate and Particle Size: 1500 kg/hr
(50% < 3.5μ; 90% < 7.6μ)

A-6. Material Name: barite ($BaSO_4$) -200 mesh

Attritor Used: HSA-1; stainless steel tank
tank volume: 3.8 L
shaft RPM: 1600

Grinding Media Selected: 1mm zircon beads — 6.4 kg

Process Rate and Particle Size: 20.8 kg/hr
(50% < 3.35μ; 90% < 11.45μ)

B. Continuous Attritor (C machines)

To be able to use this type of process, one has to have a well premixed slurry. The slurry is pumped up through the bottom of the tall, narrow grinding tank and discharged out at the top of the tank.

The residence time required for certain fineness is controlled by the pumping rate.

The C Attritor can be set up in a series, using larger media and grid opening for the coarser feed, then the subsequent unit with smaller media to achieve the finer grind.

Process Data of Continuous Wet Grinding

B-1. Material Name: gold ore (19% +325 mesh)

Attritor Used: C-10; stainless steel tank
tank volume: 47 L
shaft RPM: 265

Grinding Media Selected: 4.8mm carbon steel balls — 209 kg

Formulation: gold ore/water (55% solid)

Process Rate and Particle Size: 97 gph; average 7.30μ
(3.5 min. residence time)

60 gph; average 4.97μ
(5.5 min. residence time)

B-2. Material Name: yellow iron oxide < 400 mesh

Attritor Used: C-3; stainless steel tank
tank volume: 12 L
shaft RPM: 350

Grinding Media Selected: 3.2mm stainless steel balls — 54.5 kg

Formulation: yellow iron oxide — 26.5 kg
water — 26.5 kg
(50% solid)

Process Rate and Particle Size: 59 gph; average 3.38μ
(1.2 min. residence time)

4.7 gph; average 0.88μ
(15.3 min. residence time)

C. Circulation Attritor (Q machines)

This system is a combination of an Attritor and a holding tank which is generally 10 times the size of the Attritor.

One of the essential requirements of the Q Attritor system is the high circulation (or pumping) rate. The entire contents of the holding tank are passed through the Attritor at least once every 7-8 minutes. With this rapid speed, the premixed slurry is pumped through a confined media bed, the media act as a dynamic sieve, allowing the fines to pass through quickly, while the coarser particles follow a more tortuous path and are ground more finely.

Process Data of Circulation Wet Grinding

C-1. Material Name: barium titanate ($BaTiO_3$) — 20μ

Attritor Used: Q-25; rubber-lined tank
tank volume: 83 L
shaft RPM: 245

Grinding Media Selected: 4.8mm ZrO_2 balls — 254 kg

Formulation: $BaTiO_3$/water (70% solid)

Process Time and Particle Size: 16 min. residence time
average 1.30μ

32 min. residence time
average 0.74μ

C-2. Material Name: steatite mixture (talc, clay, alumina, feldspar) -400 mesh

Attritor Used: Q-2; ceramic-lined tank
tank volume: 7 L
shaft RPM: 350

Grinding Media Selected: 6.4mm Al_2O_3 balls — 8.2 kg

Formulation: steatite mixture — 11.36 kg
water — 6.25 kg
dispersant
(64.5% solid)

Process Time and Particle Size: 36 min. residence time
average 2.55μ and uniform
dispersion.

V. SUMMARY (ADVANTAGES AND LIMITATIONS OF USING ATTRITOR MILLING FOR INDUSTRIAL MINERALS)

A. Advantages

1. Fast and efficient fine grinding
2. Low power consumption
3. Easy to operate
4. Good temperature control
5. Low maintenance
6. Smaller plant area requirements

B. Limitations

1. Used most efficiently for fine grinding (final product 200 mesh on down to sub-microns)
2. Feed size of the material to be processed in the Attritor should typically be smaller than the Attritor media diameter.
3. Wet grinding is necessary for most of the products which require sub-micron particles.
4. The availability of the appropriate type and size of media for contamination-free grinding of a particular product.
5. Dry grinding processes do generate some internal heat.