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Fine grinding of ceramics with attritors

A rising demand for high quality ultra-fine ceramic powders makes fine grinding one of the most important operations in ceramic processing. Three types of mill are commonly used: ball, vibratory and attrition. This article addresses attritors and their applications.
By Arno Szegvari

The author is the son of the late Dr Andrew Szegvari who invented the Szegvari attritor and founded Union Process Inc. He graduated in chemistry from Harvard College.

The attritor was conceived by Dr Andrew Szegvari in the 1920s. He kept the idea to himself until 1946 when he founded his own company, Union Process Inc in Akron, Ohio. Since then, over 40 years of on-going research and development have made the attritor one of the most efficient types of fine grinding and dispersing equipment.

Within the past several years, attritor technology was introduced to the ceramic industry. As the industry could not take steel contamination, the mill had to be designed to minimise it. This was accomplished by lining the mill and sleeving the agitator arms.

Principles. Although there are three types of attritor (batch, continuous, circulation), the basic principles remain the same. The attritor is a grinding mill containing internally agitated balls. For this reason, the attritor has been referred to generically as a stirred ball mill.

The material to be ground is charged or pumped into the stationary tank filled with grinding media. Both material and grinding media are agitated by a rotating vertical central shaft with horizontal agitator arms.

Generally, the tip speeds of the attritor agitator arms are 18 000-30 000cm/min, but the high speed attritor, the latest development, operate 4 to 5 times faster. Grinding media sizes used in attritors range from 2mm to 10mm. For the ceramic industry, grinding media commonly used include alumina, zirconia, zirconium silicates, steatite, silicon nitride, silicon carbide, tungsten carbide, mullite and glass. With these combinations of speed (arm tip speed) and masses (media weight), the attritor action creates powerful impact and shearing forces. This combined momentum energy results in efficient size reduction. Final product size can be a few microns, or even sub-micron, with very narrow distribution.

The most important concept in attritor grinding is that the power input is used

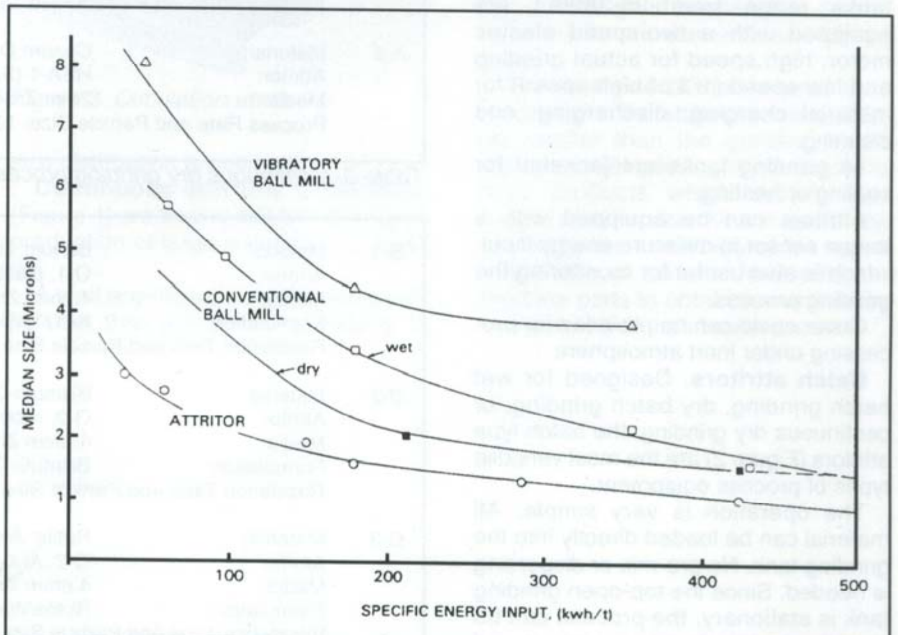

Figure 1. Comparisons of the effectiveness of grinding devices for the ultrafine grinding of Pima chalcopyrite concentrate.

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.

A comparison of the attritor, vibratory mill, and conventional ball mill used for ultrafine grinding of pima chalcopyrite concentrate can be seen in Figure 1. The top curve represents data from the vibratory ball mill, the middle two curves from conventional ball mills, and the bottom curve represents the attritor. At a specific energy input around 100kwh/T, the median particle size achieved in the attritor (2.1μm) is nearly half that obtained in the conventional ball mill (4.9μm), and about one-third that from the vibratory mill (6μm). At a specific energy input exceeding 200kwh/T, attritors continue to grind into the sub-micron range, while the ball mill and vibratory mill can no longer effectively produce smaller particles. Consequently, in fine grinding, the time required with the attritor is much shorter.

The general features and options available with attritors are as follows:

Attritors are available for wet or dry grinding.

A series of metal-contamination-free attritors is specially designed for the ceramics industry. 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 carbide, silicon nitride, tungsten carbide, rubber, polyurethane, and various plastics.

Laboratory size attritors (grinding tanks range from 110ml to 9.5L) are designed with variable speed drives for RPM variations.

Production size attritors (grinding tanks range from 35-3800L) are equipped with a two-speed electric motor: high speed for actual grinding and low speed (1/3 of high speed) for material charging, discharging, and cleaning.

All grinding tanks are jacketed for cooling or heating.

Attritors can be equipped with a torque sensor to measure energy input, which is also useful for monitoring the grinding process.

Cover seals can be provided for processing under inert atmosphere.

Batch attritors. Designed for wet batch grinding, dry batch grinding, or continuous dry grinding, the batch type attritors (Figure 2) are the most versatile types of process equipment.

The operation is very simple. All material can be loaded directly into the grinding tank. No pre-mix 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.

A-l	Material:	ZTA (Al_2O_3/ZrO_2): -50 mesh
	Attritor:	I-S, Al_2O_3 lined tank (5.7 L), ZrO_2 sleeved agitator arms
	Media:	4.8mm ZrO_2 balls
	Formulation:	Al_2O_3/ZrO_2/water
	Process Time and Particle Size: 3 hrs; 50% < 0.69 micron	
A-2	Material:	Zircon Sand: 100 micron
	Attritor:	1-S, Al_2O_3 lined tank (5.7 L), ZrO_2 sleeved agitator arms
	Media:	4.8mm ZrO_2 balls
	Formulation:	$ZrSiO_4$/water (65.8% solid)
	Process Time and Particle Size: 4 hrs; 50% < 1.01 micron	
A-3	Material: Silicon Carbide: -80 +325 mesh	
	Attritor:	1-S, Tefzel coated tank (5.7L), WC sleeved agitator arms
	Media:	4.8mm SiC Balls
	Formulation:	SiC / Isopropanol (60% solid)
	Process Time and Particle Size: 5 hrs; 50% < 1.55 micron	

Table 1. Batch wet grinding process data.

A-4	Material:	Dielectric formulations powders: 1-30 micron
	Attritor:	1-SDG, plastic coated tank and arms
	Media:	4.8mm ZrO_2 balls
	Process Time and Particle Size: 15 min; 50% < 1.52 micron	
A-5	Material:	Zirconia: 80 mesh agglomerates
	Attritor:	1-SDG, Tefzel coated tank, ZrO_2 sleeved agitator arms
	Media:	6.4mm ZrO_2 balls
	Process Time and Particle Size: 1 hr; 50 < 0.73 micron	
A-6	Material:	Glass: 10 mesh
	Attritor:	1-SDG, Al_2O_3 lined tank (5.fL), WC sleeved agitator arms
	Media:	6.4mm ZrO_2 balls
	Process Time and Particle Size: 45 min; 50% < 2.92 micron	

Table 2. Batch dry grinding process data.

A-7	Material:	Zirconia: -50 microns
	Attritor:	HSA-1, Al_2O_3 lined tank (5.3 L), ZrO_2 sleeved agitator arms
	Media:	2-2.5mm $ZrSiO_4$ beads
	Process Rate and Particle Size: 3.25 kg/hr; 50% < 0.46 micron	
A-8	Material:	Alumina: 325 mesh
	Attritor:	HSA-1 (5.3 L)
	Media:	2mm ZrO_2 beads
	Process Rate and Particle Size: 26 kg/hr.; 50% < 1.3 micron	
A-9	Material:	Cerium Oxide: 1.5mm
	Attritor:	HSA-1 (5.3 L)
	Media:	2mm $ZrSiO_4$ beads
	Process Rate and Particle Size: 10kg/hr; 50% < 1.2 micron	

Table 3. Continuous dry grinding process data.

B-1	Material:	Barium Titanate: 10-20 Micron
	Attritor:	Q-1, plastic-lined tank (5.7 L), plastic-sleeved arms
	Media:	4.8mm ZrO_2 balls
	Formulation:	$BaTiO_3$/Distilled H_2O (70% solid)
	Residence Time and Particle Size: 32 min; 50% < 0.67 micron	
B-2	Material:	Bismuth Oxide: 150 micron
	Attritor:	Q-2, rubber-lined tank (8 L), polyurethane sleeved arms
	Media:	4.8mm ZrO_2 balls
	Formulation:	Bismuth Oxide/Distilled H_2O (50% solid)
	Residence Time and Particle Size: 38 min; 50% < 1.31 micron	
B-3	Material:	Rutile: Average 15 micron+
	Attritor:	Q-2, Al_2O_3 lined tank (8 L), plastic sleeved arms
	Media:	4.8mm ZrO_2 balls
	Formulation:	Rutile/Water (50% solid)
	Residence Time and Particle Size: 32 min; 50% < 1.50 micron	

Table 4. Circulation wet grinding process data.

C-1	Material:	Alumina Trihydrate: 48% +325 mesh
	Attritor:	C-3, Al_2O_3 lined tank (11.4 L), WC sleeved arms
	Media:	6.4mm Al_2O_3 (95%) balls
	Formulation:	Alumina Trihydrate/Water (45% solid)
	Residence Time and Particle Size: 12 min; 50% < 4.11 micron	
C-2	Material:	Ceramic Slip: 6.9% +325 mesh
	Attritor:	C-5, Al_2O_3 lined tank (23 L), WC sleeved arms
	Media:	2-3mm $ZrSiO_4$ beads
	Formulation:	Ceramic Slip/Water (70% solid)
	Residence Time and Particle Size: 1.09 min; 50% < 0.49 micron	

Table 5. Continuous wet grinding process data.

Figure 4. Continous attritor.

Maximum feed material size can be up to 10mm, provided the material is friable. Otherwise, any -10 mesh material can be processed in the batch type attritor. When used for dry grinding, the batch attritor can be operated in either a batch or continuous-feed mode.

Circulation attritors. This grinding system is a combination of an attritor and a pre-mix/holding tank which is generally 10 times the size of the attritor.

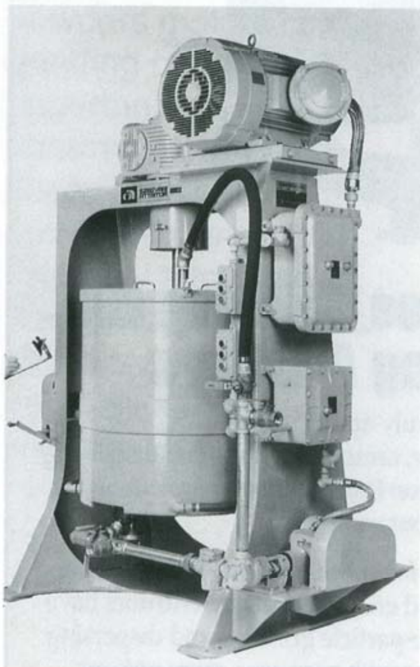

Figure 2. Batch attritor.

Figure 3. Circulation attritor.

One of the essential requirements of this attritor system is the high circulation (or pumping) rate. The entire contents of the pre-mix/holding tank is passed through the attritor at least once every 7-8 minutes. At this rapid speed, the pre-mixed 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 finer. A sharp particle size distribution is obtained.

Continuous attritors. C-machines (Figure 4) are best suited for continuous production of large quantities of material.

A well pre-mixed slurry is necessary to use this process. The slurry is pumped up through the bottom of the tall, narrow grinding tank and discharged out the top of the tank. Residence time required for obtaining specific fineness is controlled by the pumping rate. The slower the pumping rate, the longer the residence time, hence size reduction is obtained.

These attritors can be set up in series, using larger grinding media and grid openings for coarser feed than a subsequent unit with smaller grinding media to achieve the finer grind.

Pros and cons. Attritors are fast and efficient in fine grinding applications, consume little power, are easy to operate, provide good temperature control, require little maintenance and factory space.

The feed size of the material to be processed in the attritor should typically be smaller than the grinding media diameter. Wet grinding is necessary for most products which require submicron particle size. Attritor use is also limited by the availability of the appropriate type of material for media and machine parts to obtain contamination-free grinding of a particular product. □

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For more information on Attritor Grinding Mills, contact:

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The only way to truly appreciate the fast, contamination-free, ceramic grinding and dispersing capabilities of Union Process Attritor systems is to let us test grind your sample.

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Union Process Attritors are being used to successfully grind:

- alumina
- barium titanate
- ceramic pigments
- glass frits
- silicon carbide
- silicon nitride
- zircon
- zirconium oxide

Wet or dry grinding systems are available.

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