Fine Grinding of Ceramics with Attritors

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Introduction

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 mills are commonly used: ball, vibratory and attrition. This article addresses Attritors and their applications.

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 OH. Since then, over 40 years of ongoing 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 minimize it. This was accomplished by lining the mill and sleeving the agitator arms.

Principles

Although there are three types of Attritors (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 rotating vertical central shaft and 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 4-5 times faster. Grinding media sizes used in Attritors range from 2mm to 10mm. For the ceramic industry, grinding media commonly used include alumina, zirconium steatite ceramic, silicon nitride, silicon carbide, glass beads, tungsten carbide. With theses combinations of speed (arm tip speed) and masses (media weight), the Attritor action creates powerful forces. This combined momentum energy results in size reduction. Final product size can be a few microns or sub-micron. The most important concept in the Attritor grinding is that the power input is used directly for agitating the media to achieve grinding and 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 ultra fine 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 the 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 (2.1u) is nearly half that obtained in the conventional ball mill (4.9u) and about one-third that from the vibratory mill (6u). 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 designed for the ceramic industry. Several types of ceramic and polymer materials have been developed to line or sleeve the machines 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 110cc to 9.5L) are designed with variable speed drives for rpm variations. Production size Attritors (grinding tanks range from 35-3800L) are equipped with 2 speed electric motor, high speed for actual grinding and low (1/3 of high speed) for material charging 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.

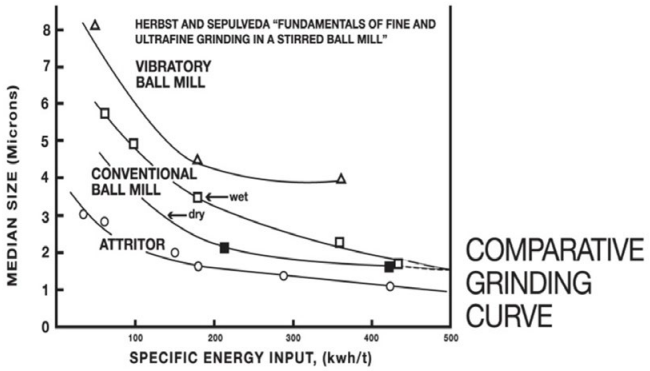

Figure 1

Comparisons of the effectiveness of grinding devises for the ultrafine grinding of Pima chalcopyrite.

Batch Attritors

Designed for wet batch or dry grinding or continuous dry grinding, the batch type Attritors (Figure 2) are the most versatile types of equipment. The operation is simple. All material can be loaded into the grinding tank. No pre-mixing is needed. Since the open top grind tank is stationary, the process can be observed and correction and ingredients can be introduced at any time.

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.

Figure 2

Batch Attritor

Table 1. Batch wet grinding process data

A1	**Material:**	**ZTA (Al203/Zr02) -50 mesh**
	Attritor:	1-S, Al_2O_3 lined tank (5.7L) ZrO_2 sleeved agitator arms
	Media:	4.8mm ZrO_2 balls
	Formulation:	$ZrSiO_4$/water (68.8% solids)
	Process Time:	3 hours
	Particle Size:	50% < 0.69µ
A2	**Material:**	**Zircon Sand 100µ**
	Attritor:	1-S, Al_2O_3 lined tank (5.7L) ZrO_2 sleeved agitator arms
	Media:	4.8 ZrO_2 balls
	Formulation:	$ZrSiO_4$/water (65.8% solids)
	Process Time:	3 hours
	Particle Size:	50% < 1.01µ

Table 2. Batch dry grinding process data

A3	**Material:**	**Dielectric formulation powder 1-30µ**
	Attritor:	1-SDG plastic coated tank and arms
	Media:	4.8mm ZrO_2 balls
	Process Time:	15 minutes
	Particle Size:	50% < 1.52µ
A4	**Material:**	**Zirconia 80 mesh agglomerates**
	Attritor:	1-SDG Tefzel coated tank, ZrO_2 sleeved agitator arms
	Media:	6.4mm ZrO_2 balls
	Process Time:	1 hour
	Particle Size:	50% < 0.73µ

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. One of the essential requirements of this Attritor system is the high circulation rate (pumping rate. The entire contents of the pre-mix holding tank are 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 torturous path and are ground finer. A sharp particle size distribution is obtained.

Figure 3

Circulation Attritor

Table 3. Circulation wet grinding process data

B1	**Material:**	**Barium Titanate: 10-20µ**
	Attritor:	Q-1, plastic lined tank (5.7L) plastic sleeved arms
	Media:	4.8mm ZrO_2 balls
	Formulation:	BaTiO/Distilled water (70% solids)
	Process Time:	32 minutes
	Particle Size:	50% <0.67µ
B2	**Material:**	**Bismuth Oxide 150µ**
	Attritor:	Q-2, rubber lined tank, (8L) polyurethane sleeved arms
	Media:	4.8mm ZrO_2 balls
	Process Time:	38 minutes
	Particle Size:	50% < 1.50µ

Continuous Attritors

C-machines (figure 4) are best suited for continuous production of large quantities of material. A well mix 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 is 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 the subsequent unit with smaller grinding media to achieve the finer grind.

Figure 4

Continuous Attritor

Table 4. Continuous dry grinding process data

A5	**Material:**	**Zirconia -50**
	Attritor:	HSA-1 Al_2O_3 lined tank (5.3L) ArO_2 sleeved arms
	Media:	2-2.5mm $ZrSiO_4$ beads
	Process Rate:	.25kg/hr
	Particle Size:	50% < 0.46µ
A6	**Material:**	**Alumina 325 mesh**
	Attritor:	HSA-1 (5.3L)
	Media:	2mm ZrO_2 beads
	Process Rate:	26kg/hr
	Particle Size:	50% < 1.3µ

Table 5. Continuous wet grinding process data

C1	**Material:**	**Alumina TriHydrate: 48% =325 mesh**
	Attritor:	C-2 Al_2O_3 lined tank, (11.4L) WC sleeved arms
	Media:	6.4mm Al_2O_3 (95%) balls
	Formulation:	Alumina TriHydrate/water (45% solids)
	Residence Time:	1.09 minutes
	Particle Size:	50% < 4.11µ
C2	**Material:**	**Ceramic Slip, 6.9% +325 mesh**
	Attritor:	C-5 Al_2O_3 lined tank (23L) WC sleeved arms
	Media:	2-3mm $ZrSiO_4$ beads
	Formulation:	Ceramic slip/Water (70% solids)
	Residence Time:	1.09 minutes
	Particle Size:	50% < 0.49µ

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. Wet grinding id needed for most products requiring sub-micron 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.

For more information, contact:

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