VERSATILITY OF ATTRITION MILLING (WET OR DRY PROCESS; BATCH OR CONTINOUS MODE)

by

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INTRODUCTION

The Attritor was invented by Dr. Andrew Szegvari in the 1920's. The first concept of agitated media mills started from here.

In 1946, Dr. Szegvari founded his own mill manufacturing company, Union Process Inc. After almost 50 years of continuous research and development, the Attritor become one of the most efficient and versatile types of grinding and dispersing equipment. Figure 1 shows a brief history of the attrition mill's development over the years.

Fig. 1

PRINCIPLES

Although there are many types of Attritors (batch, continuous, circulation, dry or wet process), the basic principles are the same. The Attritor is a grinding mill containing internally agitated media. Therefore, the Attritor has been generically referred to as a "stirred ball mill".

This is also one of the most important design concepts of attrition mills 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.

The material to be ground is charged or pumped into the stationary tank filled with grinding media, then both material and media are agitated by a rotating central shaft with a set of horizontal arms which imparts irregular movement of the grinding media, as shown in Figure 2.

Fig. 2

In general, the tip speeds of the Attritor arms are 18,000 to 30,000 centimeter per minute, but the HSA (newly designed High Speed Attritor) is operated 4 or 5 times faster. The media sizes used in the Attritor are from 2mm to 10mm. The media types used in attrition include various types of steel and ceramics. With these combinations of speed (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.

GENERAL FEATURES AND OPTIONS

* Various types of Attritors can be used in wet or dry grinding process.
* A series of metal-contamination-free machines are specially designed for the ceramic 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 are designed with variable speed drive for different RPM selections. Grinding tank sizes from 100 ml to 9.5 L.
* 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.
* A torque meter can be equipped to measure the energy input, also by using the total power consumption, one can monitor the grinding process.
* Cover seals can be provided for processing required under inert atmosphere.

WET GRINDING ATTRITOR SYSTEM AND PROCESS APPLICATION EXAMPLES:

BATCH ATTRITORS ("S" Machines) (Fig. 3)

Fig. 3

The operation of the batch Attritor is very simple. All the material can be loaded directly into the grinding tank; no premixing or pre-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.

MATERIAL	ORIGINAL SIZE	FINAL SIZE	MACHINE MODEL/ RESIDENCE TIME
Zircon sand/water (60% solids)	100 mesh	50% < 1.08μ 90% < 3.00μ	1-S / 3 hrs.
Silicon carbide/isopropanol (60% solids)	-80 mesh	50% < 1.55μ 90% < 3.98μ	1-S / 5 hrs.
Silica/water (63.2% solids)	60 mesh	50% < 2.5μ 90% < 5μ	200-S / 3.5 hrs
Rice hull ash/water (52.5% solids)	1mm+	50% < 2.05μ 90% < 4.42μ	200-S / 3.5 hrs

CIRCULATION ATTRITOR ("Q" Machines) (Fig. 4)

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 finer. (See Fig.5)

Fig. 4

Fig. 5

MATERIAL	ORIGINAL SIZE	FINAL SIZE	MACHINE MODEL/ RESIDENCE TIME
Barium titanate/water (50% solids)	Av. 100μ Max. 250μ	50% < 0.49μ 90% < 2.74μ	Q-25 / 36.33 min.
Nickel oxide/water (63.5% solids)	325 mesh	50% < 0.62μ 90% < 1.36μ	Q-100 / 62 min.
Bismuth oxide/water (50% solids)	150μ	50% < 1.31μ 90% < 4.38μ	Q-2 / 38 min.
Chocolate coating	380μ	22μ	Q-50 / 6 min.

CONTINUOUS ATTRITOR ("C" Machines) (Fig. 6)

C-machines are best suited for the continuous production of large quantities of material.

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 the top of the tank.

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

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

Fig. 6

MATERIAL	ORIGINAL SIZE	FINAL SIZE	MACHINE MODEL/ RESIDENCE TIME
Ceramic slip/water (70% solids)	6.9% +325mesh	50% < 0.5μ 90% < 1.5μ	C5 / 8.66 min
Alumina trihydrate/water (25% solids)	48% +325 mesh	50% < 4.11μ 90% < 10.43μ	C20 / 11.76 min
Latex coating dispersion	100μ	Av. 3-5μ	C20 / 5.8 min
Chocolate liquor	22% +200 mesh	99.04% -200 mesh 98.27% -325 mesh	C20 / 1.6 min

DRY GRINDING ATTRITOR SYSTEMS AND PROCESS APPLICATION EXAMPLES:

SDG SERIES:

The SDG Dry Grinding Attritors can be operated in both continuous and batch processing applications. In the continuous operation, the material is fed into the vessel at the top. It then falls through the agitating media bed where it is processed to a desired particle size, and is discharged through metering bar grids at the bottom of the tank. (See Fig. 7)

Fig. 7

The SDG Attritor is also used to make dispersion-strengthened metal (DSM). In this process (known as mechanical alloying or cold welding), the kinematic porosity results in the grinding media breaking the metals into small particles and beating them together to form agglomerates. By repeating the process, the various metals are evenly mixed and dispersed to form a new composition of alloy (DSM).

MATERIAL	ORIGINAL SIZE	FINAL SIZE	MACHINE MODEL/ BATCH TIME OR PROCESS RATE
Glass frit	-25 mesh	50% < 3.47μ 90% < 9.52μ	30SDG / 2 hr. 20 min.
Zirconium oxide	4-20 mesh	median 3.15μ	200SDG / 2 hr. 20 min.
Ferrite	6.9μ F.S.S.	1.9μ F.S.S.	100SDG / 800 lb/hr
Ion Exchange Resin	1/16" beads	Av. 4.36μ	200SDG / 25 min.

HSA SERIES:

The HSA High Speed Attritor is generally used in a continuous mode. The material is charged into the mill at the top and is discharged out the bottom side, making use of centrifugal force. The HSA is used when smaller particle size (generally 40 mesh) materials are fed into the machine and micron size end product is desired.

MATERIAL	ORIGINAL SIZE	FINAL SIZE	MACHINE MODEL/ PROCESS RATE
Calcium carbonate	90% +325 mesh	50% < 2.28μ 90% < 5.81μ	HSA30 / 500 lb/hr
Barium sulfate	325 mesh	50% < 2.82μ 90% < 9.88μ	HSA30 / 1000 lb/hr
Pumice	270 - 325 mesh	50% < 4.83μ 90% < 11.33μ	HSA30 / 750 lb/hr
Talc	200 mesh	45% < 1μ 61.4% < 2μ 78.8% < 4μ	HSA30 / 580 lb/hr

SUMMARY

ADVANTAGES AND LIMITATIONS OF USING ATTRITOR MILLING FOR INDUSTRIAL MINERALS

- **ADVANTAGES**
  * Fast and efficient fine grinding
  * Versatile and simple process
  * Low power consumption
  * Good temperature control
  * Low maintenance
  * Smaller plant area requirements

- **LIMITATIONS**
  * Used most efficiently for fine grinding (final product -200 mesh to sub-micron).
  * Feed size of the material to be processed in the Attritor should typically be smaller than the Attritor media diameter.
  * Wet grinding is necessary for most products which require majority under sub-micron particles.
  * The availability of the appropriate type and size of media for contamination-free grinding of a particular product.
  * Dry grinding processes do generate higher internal heat up to 300-350°F.

Fig. 1

WET GRINDING ATTRITORS

1940's
"S" TYPE BATCH MACHINE

1960's
"C" TYPE CONTINUOUS MACHINE

1970's
"Q" TYPE CIRCULATION MACHINE

1980's
METAL FREE MILLING MACHINES (Lined tank, sleeved arms)

1990's
"CLS" TYPE CONTINUOUS SLAKING MACHINE

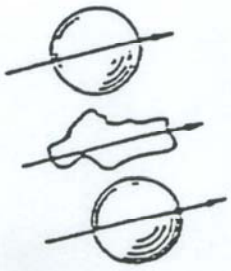
DRY GRINDING ATTRITORS

1980's
"SDG" TYPE BATCH OR CONTINUOUS MACHINE

1990's
"HSA" TYPE CONTINUOUS MACHINE

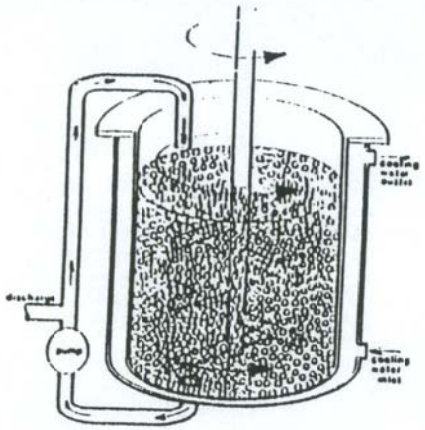
Fig. 2

IRREGULAR MOVEMENT



GROUP MOVEMENT

Fig. 3



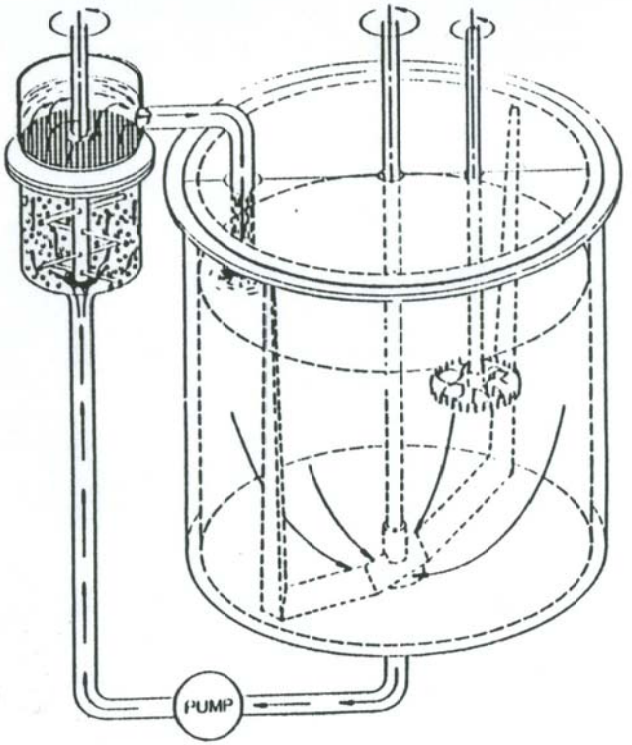


Fig. 4

Fig. 5

Passage Of A Small & Large Particle Through A Layer Of Agitated Media

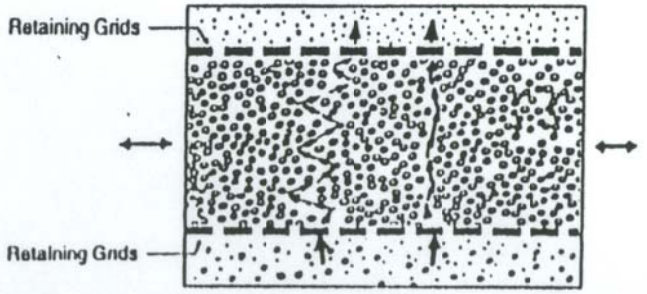


Fig. 6

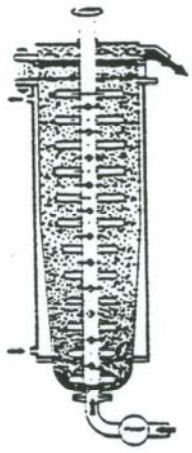
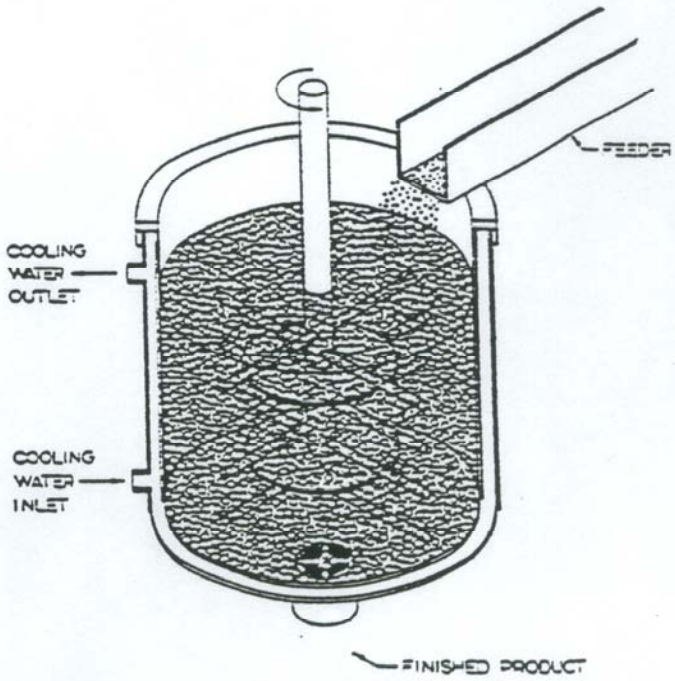


Fig. 7


FEEDER
COOLING WATER OUTLET
COOLING WATER INLET
FINISHED PRODUCT