

# Attrition Dry Milling In Continuous And Batch Modes

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## ABSTRACT:

This paper will try to answer the WHY, WHAT, and HOW of attrition fine dry milling using Attritors in continuous or batch type modes. The principle of Attritor dry grind processing is achieved by an expanded moving bed of media. This condition is described as kinematic porosity. The dry particles are subjected various forces such as impact, rotational, tumbling and shear. Therefore, micron range powders can be easily achieved. Additionally, combinations of these forces create a more spherical particle than other impact-type milling equipment.

The Attritor's versatility is gained by the ability to operate under a broad range of conditions. For example, grinding media type, size and amount; different machine speeds; variable loading or feed rate of raw material. In addition to reducing particle size, Attritors also can create the highest intensity intimate blending of dissimilar materials. Specific chemicals or additives can also be introduced to the mill during the grinding process and achieve the ultimate dispersing or coating on the dry solid particles.

## WHY ATTRITOR DRY MILLING?

*Process Economics:* Attritors are energy efficient, easy to operate and require low maintenance.

*Versatility:* Attritor design allows modification of numerous variables to adjust changing specifications and meet the final product requirements.

*Reduced Transportation Costs:* In many wet slurry processes, 50% of the gross weight is liquid.

*Energy Saving:* Removal of the liquid from a wet grinding process involves not only another process step, but also requires large amounts of energy.

*Eliminate Liquid Waste Disposal:* Following stricter environmental regulations, the disposal of any waste liquid (water or solvent) is very costly.

## WHAT ARE SOME COMMON APPLICATIONS FOR DRY GRIND ATTRITORS?

Ceramic Powders	Ferrite
Glass Frits	Pigments
Metal Powders	Minerals
Mechanical Alloying	Coal & Coke
Metal Oxides	Graphite
Fibers & Cellulose	Plastics & Rubber
Food Products	Chemicals

## HOW DOES ATTRITOR DRY MILLING WORK?

The Attritor dry grind process is achieved in a stationary tank by means of rotating shaft and arms that agitate the media and arms that agitate the media into a random state of motion of internal porosity called "kinematic porosity". (Figs 1 & 2)

## KINEMATIC POROSITY

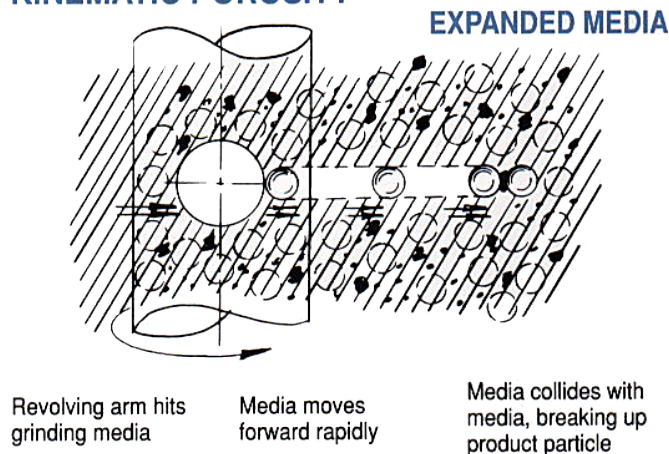


Figure 1

## MEDIA AT REST

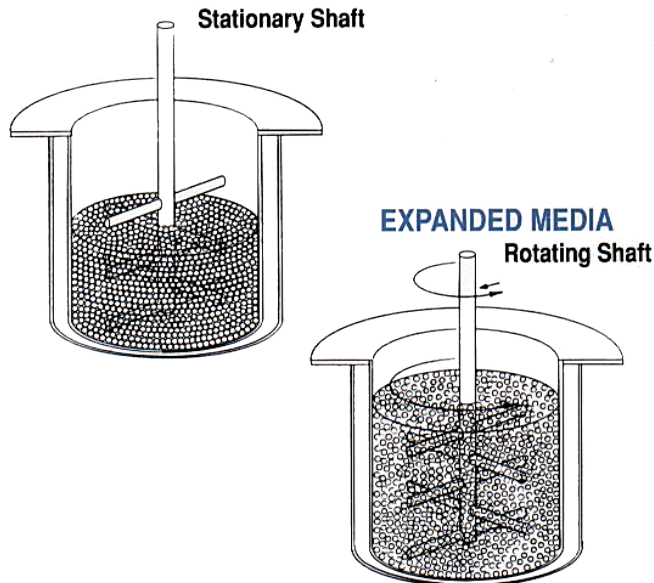


Figure 2

In this expanded condition, the media and particles are free to move, collide and impinge on each other, thus generating high shear and powerful impact for efficient grinding. (Fig. 3)

## ACTION OF MEDIA

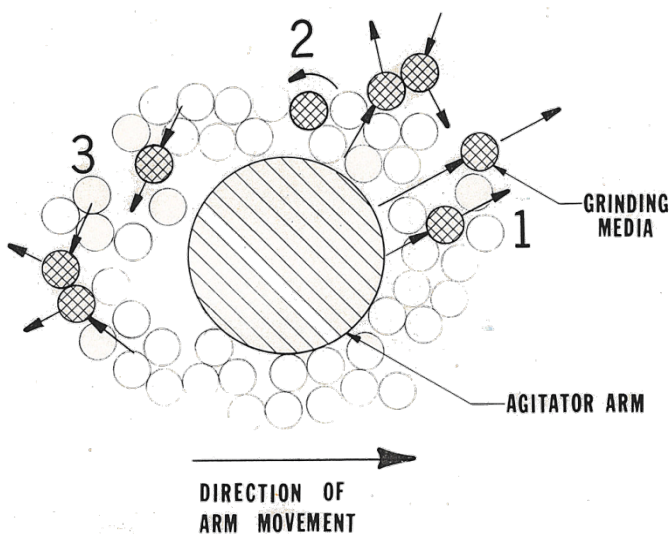


Figure 3

## Dry Grind Attritor Types:

### I. SDG Series

The SDG Series ("Regular" Speed Dry Grind Attritors) can be operated in continuous or batch grinding processes. In the continuous operation, the material is feed into the grinding chamber at the top, then falls through the agitated media bed where it is ground to desired particle size and discharged

through a metering type valve assembly at the bottom of the tank. (Fig. 4)

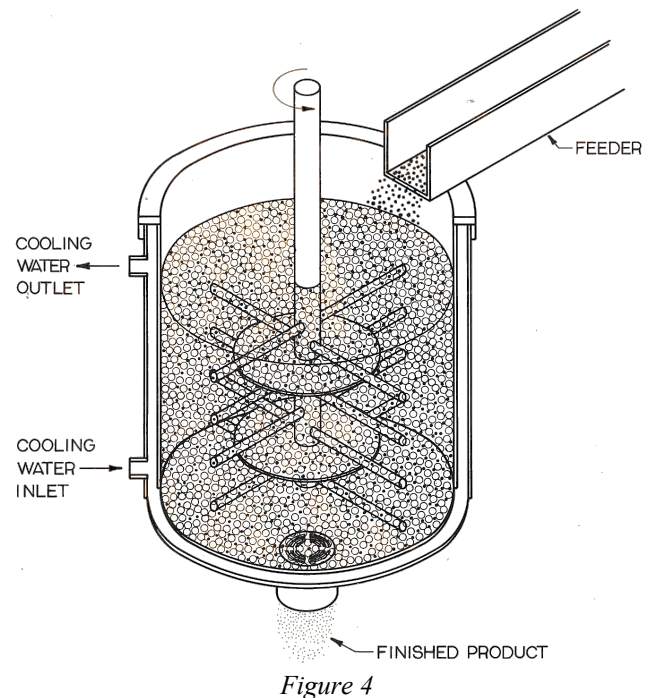


Figure 4

In the batch mode, material is charged into the mill at the top, ground to the required size, then discharged through grids at the tank bottom.

The SDG Attritors can easily be sealed for grinding under inert gases such as nitrogen or argon. The system can also be constructed with ceramic materials for metal-free grinding processes.

The SDG Attritors use grinding balls from 5mm to 13mm. The shaft RPM generally runs from 75 to 500. This series of Attritors are suitable for harder-to-grind materials such as metal powder, metal carbides and glass chunks. The feed material size for these machines can be quite coarse, but generally smaller than the grinding media chosen. If the material is very friable, larger flakes can be feed into the machine.

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 grinding media breaking the metals and additives into small particles first, then 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).

## II. HSA Series

HSA (High Speed Attritors) feature a unique patented design concept that includes a new grinding tank internal configuration and side discharge screen which allows mills to run at higher speed, using smaller media, and continuously discharges product out of the mill by centrifugal force (Fig. 5)

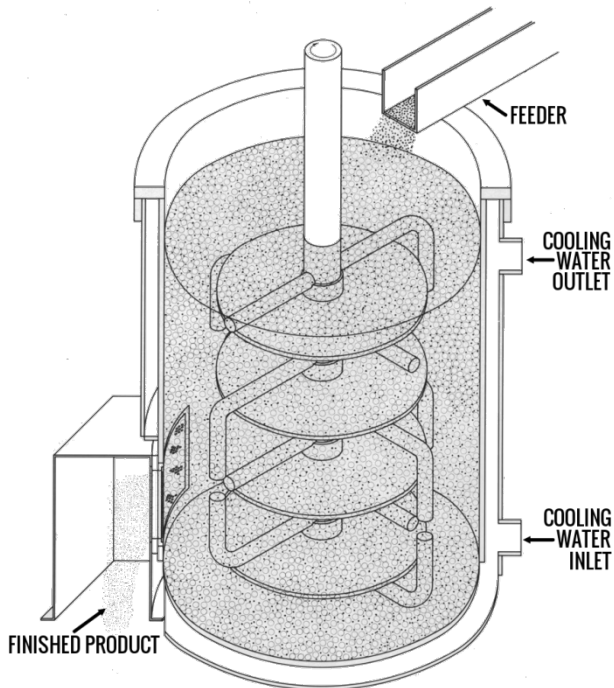


Figure 5

HSA Attritors generally operate from 400-1800 RPM using grinding beads from 1-3mm. This combination of high velocity and increased grinding media surface area insure much finer grind of the processed material.

The HSA Attritor is generally used in a continuous mode. The material is charged into the mill at the top by a pre-set rate feeder and discharged out the lower side of the grinding tank. HSA Series Attritors are generally used for finer feed material (-40 mesh), and produce large quantities of ultra fine powders in micron size. Applications include various minerals such as calcium carbonate, talc, barium sulfate, iron oxide, rice hull ash and flyash. The HSA is also often used for fibrous and polymer types of materials.

## III. System Setup Options:

The SDG and HSA Attritors also can be set-up as two-stage process, using larger media in the SDG Attritor to pregrind coarse feed material, then continuously run through the HSA Attritor with mini media to achieve ultrafine products (Fig. 6)

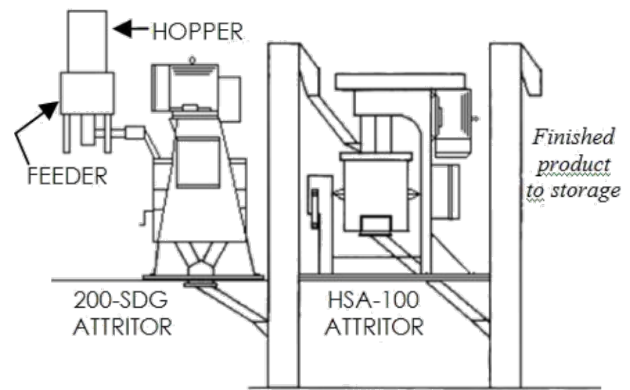


Figure 6

An air classifier or screen can be incorporated with SDG or HSA Attritors to form a closed grinding process loop. By constantly taking out the fine product and reloading the oversize particles, very efficient, narrow distribution fine grinding is achieved. (Fig. 7)

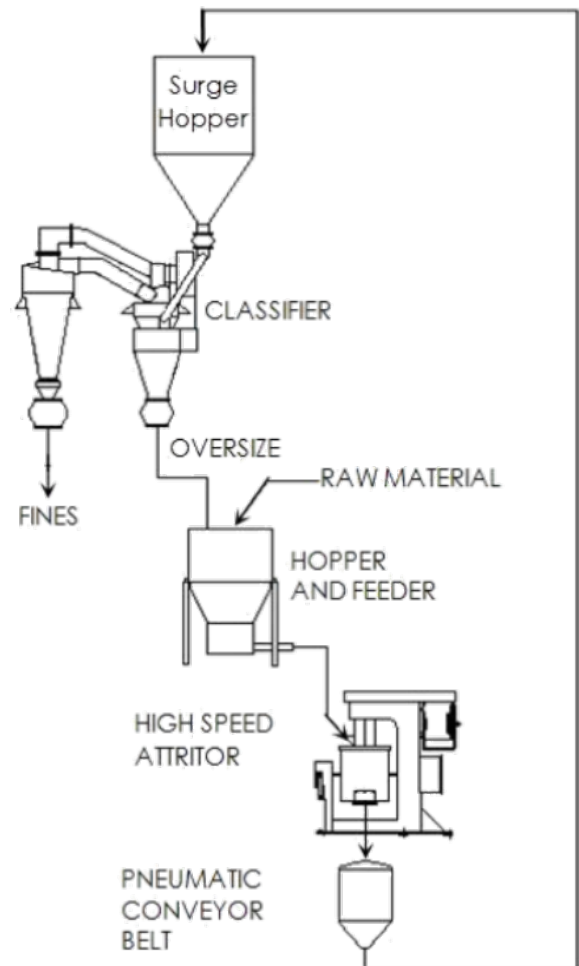


Figure 7

## ATTRITOR GRINDING MEDIA TYPES:

Selection of grinding media depends upon several factors, some of which are interrelated.

**Specific gravity.** In general, high density media give better results. The media should be more dense than the material to be ground. Also, highly viscous materials require media with higher density to prevent floating.

**Initial feed size.** Smaller media cannot easily break up large particles.

**Final particle size.** Smaller media are more efficient when ultrafine particles are desired.

**Hardness.** The harder the media the better the grinding efficiency and consequently, the longer the wear.

**pH.** Some strong acid or basic material may react with certain metallic media.

**Discoloration.** For instance, white material should remain white.

**Contamination.** The material resulting from the wear of the media does not affect the product or can be removed by a magnetic separator, chemically, or in a sintering process.

**Cost.** Media that may be 2-3 times more expensive may wear better, sometimes 5-6 times longer, therefore, well worth their extra cost of the long run.

Following is a list of types of media used in Attritors:

- through-hardened carbon steel
- chrome steel
- 440C stainless steel
- steatite
- zirconium silicate
- silicon nitride
- silicon carbide
- aluminum oxide
- zirconium oxide (MgO or Yttria stabilized)
- tungsten carbide

## CONTINUOUS OR BATCH GRINDING PROCESS?

Batch dry grinding is employed when the material requires longer residence time (over 30 min and more), and the prime consideration is the finest particle size possible, tighter distribution.

Another important reason for choosing batch grinding is ability to control the milling atmosphere. The grinding tank cover can be equipped with a mechanical shaft seal. Purging with inert gas allows material to grind under an oxygen free condition. A specially designed, sealed discharge container also can be equipped with the machine.

Continuous dry grinding is chosen for the following reasons:

1. Large production quantity is required.
2. Material is temperature sensitive. With continuous processing, all the material passes through the grinding chamber quickly without overheating inside the mill.
3. Material has a tendency to cake. Constantly moving material through the media bed prevents material build-up against the tank wall.

The continuous grinding process requires a stable condition be maintained inside the mill at all times. The objective is to precisely control the retention time in the mill long enough to reduce the particles to the size desired. Special accessories are used to control the process.

1. An accurate feeding system dispensing material into the top of the mill.
2. A special shaft and arm configuration plus diverter discs. These diverter discs prevent unground material from short-circuiting through the grinding chamber and discharging prematurely.
3. A specially designed metering discharge can be adjusted to dispense the exact amount of material from the mill as is being added to the top of the mill. The adjustable discharge also allow one to easily maintain or change the bed amount of material inside the mill.

4. With the controller on a VFD system one can monitor the power going into the mill. By observing this power readout and operating within a narrow range of variation, you can be assured that the material bed in the mill and process conditions are stable. As a result, all the material passing through the grinding chamber is being processed with similar amounts of grinding energy.

The results from this kind of process procedure show very tight quality control specifications. All the process data can be sent to a computer printout and used for ISO requirement documentation.

If the system is shut down overnight, it is generally not necessary to drain the material from the mill prior to start-up. Since the bed of processed material already exists inside the mill, start-up involves only turning on the mill and feeding equipment.

## PROCESS DATA EXAMPLES:

Data are collected from our pilot plant tests of 30-SDG and HSA-30. Instruments used to determine particle size include Tyler mesh sieve, Fisher sub-sieve, laser defraction device, and sedigraph.

## II. SDG SERIES ATTRITORS

MATERIAL	PARTICLE SIZE		PROCESS MODE
	ORIGINAL	FINAL	
Alumina	MV 104μ	MV 1.6μ	C
Coral Glaze (Fe <sub>2</sub> O <sub>3</sub> /ZrO <sub>2</sub> )		Mixing & Blending	C
Ferrite	FSS 9.4μ	FSS 1.6μ	C
Glass Frit	-12 mesh	MV 4.09μ	B
Glass Ribbon	1" Sq.	50% 3.29μ	B
Ion Exchange Ribbon	-200 mesh beads	50% 4.30μ	B
Iron Mill Scale	2-3" chunks	FSS 2.4μ	C
Iron Oxide Beads	1/8"-1/16" beads	50% 1.113μ	B
Nickel Oxide	FSS 8.3μ	FSS 1.45μ	C
Petroleum Cake	Up to 3/16" chunks	50% 4.70μ	B
Phthalocyanine Blue Pigment	20-40μ	Color Development	B
Quinacridone Pigment	-325 mesh	Color Development	B
Silicon Metal	80 mesh	-325 mesh	B
Sodium Bicarbonate	50 mesh	90% -325 mesh	C
Synthetic Graphite	90% -70 mesh	Av. 5-7μ	B
Waste Bottle Glass	¼" pieces	75.5% -165 mesh	C
Zircon Sand	-40 mesh	Median 4.19μ	C
Zirconium Oxide	4-20 mesh	Median 3.15μ	B

In "Process Mode" column: C = "continuous" process/B = "batch" process.

## II. HSA SERIES ATTRITORS:

MATERIAL	PARTICLE SIZE		PROCESS MODE
	ORIGINAL	FINAL	
Barium Sulfate	400 mesh	50% 2.82μ	C
CaCo <sub>3</sub> (Stearic Acid Added)	90% 41.84μ	50% 2.68μ	C
Carbon Fiber	¼" Long	80-100μ	C
Cement Grout	90% 40μ	50% 3.29μ	C
Channel Carbon Black	90% 248μ	50% 2.4μ	C
Flyash	-10 mesh	50% 2.51μ	C
Hematite		1 <sup>st</sup> Pass 50% 4.15μ 2 <sup>nd</sup> Pass 50% 2.88μ	C
Hydrated Lime	21.6% +270 mesh	50% 4.96μ	C
Magnetite Ore	10% +325 mesh	50% 3.77μ	C
Manganese Dioxide	60 mesh	50% 0.62μ	C
Oat Fiber	91% +200 mesh	98% -200 mesh	C
Potato Powder	100 mesh	55% -200 mesh	C
Pumice	50% 22.52μ	50% 4.80μ	C
Rice Hull Ash	+50 mesh	50% 4.51μ	C
SBR Rubber Compound	¼" Chips	85% -325 mesh	C
Sodium Antimonate	90% 97.15μ	50% 2.37μ	C
Talc	200 mesh	45% <1μ/61.4% <2μ	C
Waste Pencil Core	2-5" Long	99% -325 mesh	C
Wheat Bran	½" x ¼" Flakes	99% -60 mesh	C
Wheat Fiber	<1/8"	70% -200 mesh	C
Wood Fiber	20% +80 mesh	96% -325 mesh	C

In "Process Mode" column: C = "continuous" process/B = "batch" process.

## A FEW DRY GRINDING TIPS:

1. Minimize moisture content in the raw material: high moisture content (Over 5%) can cause material to cake inside the grinding chamber. Operating at higher temperature can drive off some moisture.

2. Maintain a proper material to media ratio: If the ratio of material-to-media is too high, the velocity and impact force of the media will be reduced and inefficient particle size reduction will result. On the other hand, if the ratio of material-to-media is too low, the media will impact itself causing wear of the media. Optimizing material and media ratio results in efficient particle size reduction.

3. Try to obtain uniform size feed material: Raw material with broad size range often results in wide size distribution final product. It also makes choices of process mode,



machine type, media size, etc. very difficult.

4. Add grind aid and additives: Chemical additives can be continuously added to the process while size reduction is taking place. These additives can be dry powders or liquids. Their function is do one or more of the following:

- Minimize the effects of moisture that may be inherent to the material processed
- Change the electrical charge on 3. Try to obtain uniform size feed the surface of the particle
- Reduce negative effects of any static charge that may develop during the size reduction process
- Act as a portioning agent between particles to prevent agglomeration
- Function as a lubricant between particles
- Frequently there are some additives or ingredients added downstream which can be added during the milling stage and save one more process step

## **SUMMARY: ADVANTAGES AND LIMITATIONS OF DRY GRIND ATTRITORS**

### **ADVANTAGES:**

1. Fast, efficient and reliable fine grinding
2. Versatility of the process
3. Low power consumption
4. Machine tanks are jacketed for cooling or heating temperature control
5. Easy and safe to operate
6. Low maintenance
7. Compact design, small plant area required

### **LIMITATIONS:**

1. Feed material size are limited to less then 13mm for SDG Attritors, 40 mesh for HSA Attritors
2. For most of the sub-micron superfine powders, wet grinding still is necessary
3. Dry grinding process does generate more internal heat than wet grinding
4. The availability of the appropriate type of material for HSA machine parts and screen to obtain metal-free grinding

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