ATTRITORS AND THERMAL SPRAY POWDER APPLICATIONS

Robert E. Schilling , M. Yang
UNION PROCESS INC.
Akron, Ohio

Presented November 3, 1999

by

Robert "Bob" Schilling

Thermal Spray Symposium
Session 12
Research on Thermal Spray Technology
Equipment, Consumables, and Processes
Cincinnati Convention Center
Cincinnati, Ohio

ATTRITOR MILLING AND THERMAL SPRAY POWDER APPLICATIONS

Robert E. Schilling , M. Yang
UNION PROCESS INC.

INTRODUCTION

Thermal spraying is an important and fast developing surface engineering technology. The primary applications for thermal spray coatings that we are seeing include wear resistant coatings, corrosion protective coatings, and thermal barrier coatings. Thermal spray technology finds relevance in a broad spectrum of industries, such as aerospace, automotive electronic, chemical, oil, gas petroleum, paper and textile machinery and many more.

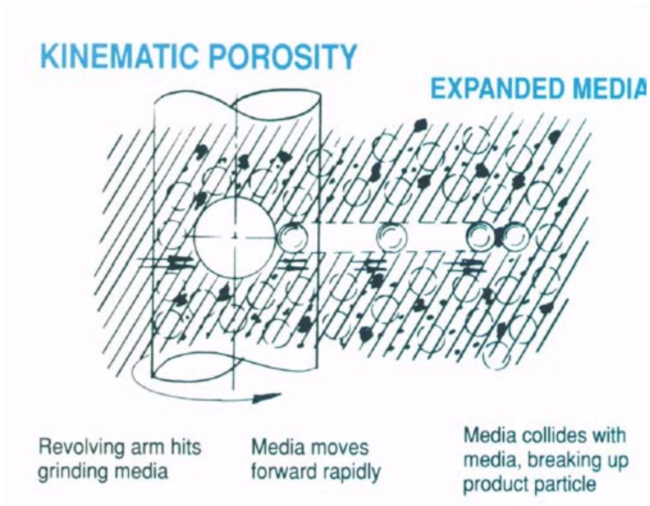
Regardless of the complicated techniques in the thermal spraying process, one of the most important factors in obtaining a superior sprayed coating is the use of high quality powders. Among the requirements of high quality powders are homogeneity of the mixture, uniformity of the morphology and relatively narrow particle size distribution. Herman and Sampath stated in their paper on Thermal Spray Coatings, "There have been debates concerning the part played by powder characteristics on deposit properties. It can be said, generally, that spherical, mono-sized and chemically homogeneous powder particles are preferable to particles having faceted shapes, wide size distributions, and a non-uniform distribution of components. Variations in particles size will affect the melting points of the polymer powders, which in turn will affect the coating's surface characteristics. For instance, fine particles will pyrolize while larger particles may remain unmelted."[i] Ross Lunato, writing for Sulzer Metco, said "With powders the two major elements to be concerned with are the particle size distribution and the materials chemical composition. For example, if the particle size distribution is considerably large, problems with unmelted particles, porosity and poor particles cohesion will occur."[ii]

Attritor dry milling technology has been shown to be useful in producing a wide range of powders for thermal spray applications, which includes various mechanical alloying powders and many different metal matrix composites (metal alloys with oxides, or carbides reinforcements.)

SD ATTRITORS AND DRY MILLING PRINCIPLES

The Attritor was invented by Dr. Andrew Szegvari in the 1920's. Later in 1946, Dr. Szegvari founded Union Process Inc. to manufacture Attritors. The first generation of the Attritor was designed for wet grinding and dispersing. After many years of continuous research and development, the first dry grinding type – **SD Attritor** was introduced in the early 1980's.

The SD Attritor is a dry grinding mill that consists of a stationary tank and an internal rotating shaft /arm assembly. The tip speeds of the agitator arms range from 600-1000 fpm (180 to 300 meters per minute).

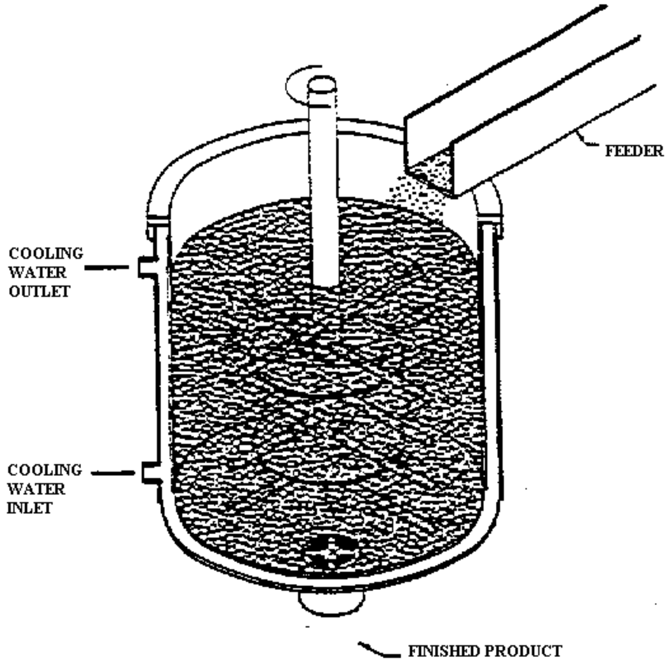


The grinding media inside the tank is agitated into a random state of motion called kinematic porosity. In this expanded condition, the media and particles move freely, colliding and impinging upon each other. This media movement creates impact and shear forces, which result in effective grinding and dispersing. The grinding media used in the SD Attritor can be various types of steel or ceramic balls, ranging in size from 3mm to 12mm. For processing thermal spray powders, most commonly used media are 6-7mm balls.

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. When grinding some slurries, media with higher density may be required 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 in the long run.

The SD Attritor can be operated in either batch or continuous modes. Batch dry grinding is employed when the primary concern is to achieve fine particle size or narrow size distribution. Batch processing is also the preferred method when intensive mixing of several materials is required.



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

Continuous dry grinding is more suitable for large quantities and easier to grind materials, and is generally 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 being overheated 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 this 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 allows one to easily maintain or change the bed amount of material inside the mill.
4. A torque sensor fixed to the rotating shaft and display readout indicates torque in inch-pounds. By observing this torque 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.

In batch mode of the attrition dry milling, materials are charged into the milling chamber and ground for a predetermined time, then discharged through grids at bottom of the tank. In continuous mode milling, material is fed into the tank at the top, and then it is ground down as it passes through the agitated media bed, discharged through a metering grid at the bottom or side of the lower portion of the tank. The particle size and residence grinding time is controlled by the shaft RPM, media size and quantity, and by the rate of material discharge.

SD ATTRITOR AND THERMAL SPRAY POWDER PROCESSING

To produce thermal spray powders or do mechanical alloying, a batch mode operation with the SD Attritor is often used. For process composites of metal matrix with ceramic reinforcements, various metals, alloys, oxides, carbides or nitrides are loaded into the SD Attritor tank, and the mill is turned on. After mixing, dispersing and grinding for an appropriate amount of time, the powder is discharged through grids on bottom of the tank. The final powder product is a very homogeneous mixture. The oxides, carbides or nitrides are uniformly embedded in the metal matrix.

The time required to process mechanical alloying varies depending upon the formulation. In general, metal matrixes with softer, ductile metals require less time to repeat cold welding process. In some instances, a very small amount of surfactant or lubricant is added as process control agent. These agents can prevent some low melting point metals from flattening and laminating too quickly, so that the second phase particles can be homogeneously distributed into the final matrix. The most commonly used agents are stearic acid, oleic acid, and some of the aliphatic solvents. Although the use of process control agents can be beneficial to grinding and dispersing, contamination concerns from these additives must also be carefully considered.

SUMMARY - ADVANTAGES AND LIMITATIONS

I. ADVANTAGES

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

II. LIMITATIONS

1. Feed material size is limited to less than 13mm for SDG Attritors.
2. For most of the sub-micron superfine powders, wet grinding still is necessary.
3. Dry grinding processes do generate more internal heat than wet grinding.

A Few Dry Grinding Tips:

1. Minimize moisture content in the raw material. Quite often high moisture content (say over 5%) can cause material to cake inside the grinding chamber and make the process impossible. Operating the mill at higher temperature can help to 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 excessive wear of the media. When the material and media ratios are optimized, efficient particle size reduction results.

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 the 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 functions are to 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 the surface of the particle.
   - Reduce negative effects of any static charge that may develop during the size reduction process
   - Act as partitioning agent between particles to prevent agglomeration
   - Function as 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

---

[i] H. Herman and S. Sampath, The Thermal Spray Laboratory - Department of Materials Science and Engineering, State University of New York, *Thermal Spray Coatings*

[ii] Ross Lunato. Sulzer Metco Field Service Engineer, *Troubleshooting the Thermal Spray Process,* http://www.sulzermetco.com/techtalk/tip9.html