Title of Paper:

ADVANCES IN POWDER PROCESSING TECHNOLOGIES FOR CHEMICAL, FOOD AND MINERAL APPLICATIONS

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Abstract:

Powder producers in chemical, mineral and pharmaceutical markets are exploring new processing methods to isolate smaller average particle sizes and tighter overall particle size distributions. Consumer demand for higher quality end products is driving these producers to explore new technologies in the area of powder processing. Manufacturers of powder processing equipment have, in turn, developed new and improved methods for producing powder products that meet/exceed these stringent parameters.

This paper will review the basics of particle size reduction and classification, and describe recent developments in powder manufacturing technologies. A summary of available technologies will assist the participant to determine the optimal powder processing method for his/her specific application. The presentation will conclude with an overview of recent case studies within the powder processing industry.

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INTRODUCTION

Solid particle size reduction and classification techniques have been used for a number of years, in order to modify particles for a variety of chemical, pharmaceutical, food and mineral applications. Virtually any powder used in commercial production has passed through some type of machine to alter its size or shape. Practical examples include the powdered sugar on confectionery products; the toner used in copy machines; the powder coating material used for automotive finishes; the talc used in baby powder; the starch used in a variety of food products; the active ingredients used in prescription drugs. These represent a small sample of the applications were the raw material has been altered in some way to improve the quality of the finished product as well as the efficiency of the manufacturing method.

The science of size reduction and grinding has changed dramatically in order to keep up with the demand for improved consumer products. In addition, this demand is derived by the desire of the manufacturer to produce a product more efficiently, with less off spec material to recycle or discard. This paper will review size reduction and classification methods, in addition to the advances made in this area.

PARTICLE SIZE REDUCTION

Three main principles govern the size reduction of solid particles: Impact, compression and shear. Mechanical-impact grinding mills utilize the impact principle of grinding; either impacting a particle with an outside force or accelerating the particle against a particle. Compression involves size reduction caused predominantly by pressure but also by friction from the surfaces of the neighboring particles. Shearing, or stressing by cutting, is used for soft or fibrous materials such as plastics and animal and vegetable products. These machines make use of rotary knife cutters, which consist of rotating and stationary knives that cut materials on the shearing edges.

Mechanical-impact mills are ideal for easy to grind ("soft") materials requiring "medium" fineness (see Table 1). Harder materials (typically defined as solids with a harness of the Mohs scale of greater than 3) require special processing techniques which will be described in a later section.

TABLE 1

Degree of Hardness	Mohs Scale	Example
Soft	1	Talcum
Soft	2	Gypsum
Soft	3	Calcite
Medium-hard	4	Fluorite
Medium-hard	5	Apatite
Medium-hard	6	Feldspar
Hard	7	Quartz
Hard	8	Topaz
Hard	9	Corundum
Hard	10	Diamond

Mechanical impact mills are limited in their usage to relatively soft materials. Harder materials will cause wear and abrasion to occur rapidly inside and impact mill.

Types of Impact Mills

Technological advances have led to a whole host of machine configurations designed to reduce particle size. These mills include (but are not limited to): Cutting Mills/Crushers, hammer and screen mills, universal and pin mills and mills with classifiers. Each machine offers its own unique processing characteristic in order to achieve a specific product upon discharge.

Cutting Mills/Crushers

Cutting mills or crushers utilize shear for size reduction and are used when material is required in a coarse to medium fine product range (see Table 2). Cuttting mills (also known as granulators) make use of rotating and stationary knives that cut materials on the shearing edges. Sets of rotor-knives rotate inside a set of stationary knives, thus mimicking the action of high-speed scissors doing hundreds of cuts per minute (See Figure 1). The knife design can be varied depending on the material to be processed.

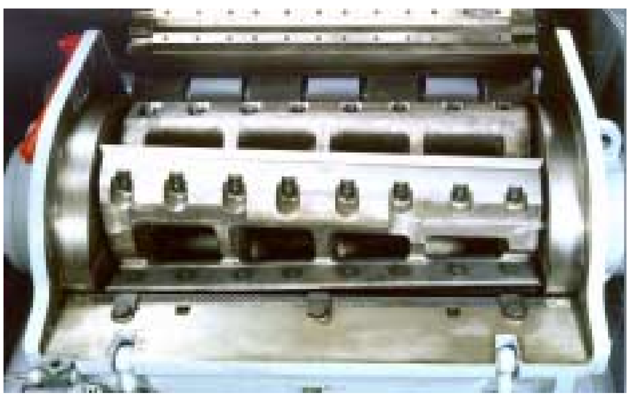

Figure 1: Rotary-knife Cutting Mill

Applications for cutting mills include the size reduction of fibrous materials such as vegetable matter, spices, herbs, plastic bottles and film, automobile components (bumpers, dashboards and door linings) for end-product particle size in the range of 1-6 mm.

Coarse crushers utilize the compressive force between two solid surfaces to cause size reduction. These crushers are used mostly for the size reduction of minerals, gravel and ores resulting in particle size distributions in the range of 1 mm-100 mm. A specialty use is as a pre-crusher, to provide a uniform feed material for the next step in size reduction. Most crushers are located at mine sites, for immediate size reduction prior to being loaded for transportation.

Universal and Pin Mills

Universal mills are often referred to as fine-grinding impact mills. Particle size reduction occurs by impact against the grinding media, and through inter-particle collision and attrition. These mills typically utilize a variety of grinding media within the same milling chamber to allow for complete flexibility in the resulting particle size distribution (see Figure 2).

Figure 2: Universal (pin) Mill

A universal mill equipped with pin discs consists of one stationary set of pins and one rotating set of pins. Material enters the center of the grinding chamber via gravity, and is accelerated by centrifugal force against the meshing pins. The speed of the discs sets the strength of this force. The feed rate and the peripheral speed of the pin discs determine particle size. These mills do an ideal size reduction when the desired particle-size distribution is narrow. Milling of pharmaceuticals, food confectioneries, animal feeds, mineral powders, pesticides, paints pigments as well as the cryogenic milling of herbs and spices can be accomplished using the universal mill.

Hammermills

Size reduction in a hammermill is accomplished by impacting the solid particles against a rigid surface, namely the mill housing. A retaining screen on the discharge end of the mill "rejects" oversized particles and prevents them from exiting the grinding chamber. Three basic variables affect the grinding process: hammer type, screen hole size and peripheral speed of the hammers.

Hammermills (see Figure 3) are ideal for a wide variety of particle sizes in the medium to medium-fine particle size range (20-150 microns). Applications include the grinding of pigments, various industrial chemicals and food ingredients. Hammermills are ideally suited for a cryogenic impact-milling set-up that embrittles the material prior to size reduction. This makes possible the grinding of tough, fibrous materials or thermoplastics as well as heat-sensitive products.

Mills with Classifiers

A recent advancement in the area of impact milling has been the incorporation of a classifier wheel as an integral part of the grinding machine. The classifier acts as a rejection mechanism that only allows particles below a specified size to pass through the wheel. Material to be ground is conveyed into the mill chamber to a rotor equipped with pins or hammers. As particle size reduction occurs, the particles are picked up by the airstream and eventually pass through the classifier wheel to the product collector. Those particles that are rejected by the classifier are continuously recycled back to the hammers for further size reduction (See Figure 4).

Rotor speed, classifier wheel speed and airflow control particle size in an air-classifier mill. Due to the constant airflow passing through the air-classifier mill, the overall temperature remains relatively low, allowing for low-melting or softening point materials to be ground with this device.

Figure 3: Hammermill

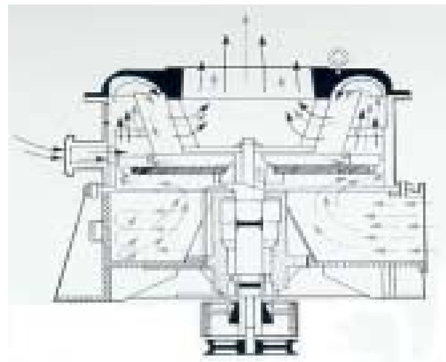

Figure 4: Air-classifier mill

Application examples for the air-classifier mill include a variety of heat-sensitive materials and minerals such as kaolin, talc and diatomaceous earth. Powder coating materials are ideally suited for this grinder, due to the need for temperature control in the mill as well as control of particle size on the top end of the distribution. Average particle sizes as fine as 30 microns are possible, depending upon the material and application.

Long-gap Mills

A further advancement in the area of impact milling has been the development of the long-gap mill. The design of the long-gap mill includes a variable rotor height to diameter ratio well as an adjustable gap clearance between the impact hammers and the mill liner (See Figure 5).

Figure 5: Long-gap mill

The unit includes an independent or single shaft classifier, for controlling the top end of the resulting particle size distribution. Grit-reduction in the processing of carbon-black is a popular application for the long-gap mill, as well as the simultaneous drying/grinding of a variety of minerals and metal oxides.

Fluid Energy Impact Mills

Fluid energy impact (jet) mills utilize the principle of size reduction via particle-to-particle collision. Particles are accelerated in a high-velocity gas stream and are reduced by inter-particle collision or impact against a solid surface. Unlike impact milling devices, fluidized bed jet mills are suitable for the fine and ultra-fine size reduction of any material up to a hardness of 10 that can be fluidized by the expanding compressed gas in the grinding chamber. In addition, heat sensitive and abrasive materials can be easily processed in this type of mill.

Two general types of jet mills exist: those that do not have an internal classifier and those that do. A pancake or spiral jet mill has no internal classifier (See Figure 6). A fluidized bed jet mill incorporates an internal air classifier which allows material of a given fineness to exit the mill, while rejecting over-sized particles back into the grinding chamber for additional size reduction (See Figure 7).

Figure 6: Spiral Jet Mill

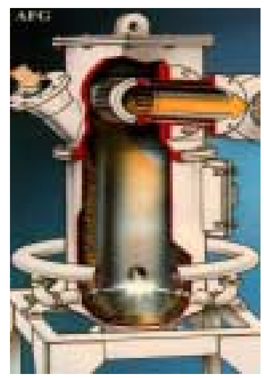

Figure 7: Fluidized-bed Jet Mill

Applications for these fluid energy mills include fine chemicals, ceramic materials including oxides, pharmaceutical powders, resins, waxes pigments, dyes, pesticides and rare earth powders. The fluidized-bed jet mill is specially suited for toners due to their requirement for very fine particles in narrow, overall particle size distribution.

AIR CLASSIFICATION OF POWDERS

Air classification is used in processing industries where a high degree of uniformity is required in the finished product. Oversized particles can spoil the surface finish of plastics, paints and coatings, cause failure of electronic components and profoundly affect the flow or packing characteristics of powdered products. Particles that are too fine can also cause problems in powder performance and handling: flow properties deteriorate, airborne dust increases and process loss and waste can become a serious factor. In addition, very fine particles may cause ruboff in coating applications or cannot be recycled upstream in the process.

While the simplest means of separating a powder into two distinct fractions is through sieving, developments in air classification have resulted in more economical classification processes. Sieves depend on the size of the screen mesh to divide material into a coarse and a fine fraction. Screens are susceptible to blinding when high throughput rates are desired or if the product being classified contains moisture. Air classification is used where when screens cannot effectively make the separation, increased throughput is desired, plant space is limited or when the cutpoint is more easily varied with air classification.

Air classification relies on the fact that there are always two forces that affect particles in an airstream: mass force is exerted on the particle by acceleration due to gravity, inertia or centrifugal force. Drag force is always the force exerted on a particle by the surrounding medium as affected by its aerodynamic properties. Drag force depends on several variables including velocity of the particles in the surrounding medium, the density of the fluid and the drag coefficient of the particles.

Dispersion of solid particles is often the most critical material characteristic affecting classification. A classifier cannot effectively classify the individual particles into fractions f the particles cannot be physically separated and distributed evenly in the fluid. Moisture, oil or fat content or electrostatic interaction can inhibit dispersion and negate classification. Advancements in the dispersive capabilities of classifiers have been made which improve the performance and efficiency of these machines.

Centrifugal Classifiers with Mechanical Dispersion

A centrifugal classifier with mechanical dispersion (Figure 8) uses low energy dispersion to disperse material. Material enters the classifier and is dispersed at the top of the classifier wheel prior to actual classification. A further result of this dispersion is the equal dispersion around the classifier wheel. Airflow and classifier wheel speed determines the cutpoint for the material being classified.

A further method for improving the performance of classifiers by operating two classifiers in series. The first classifier's coarse fraction is highly dispersed as it is immediately fed to the second classifier. This results in improved product quality and especially higher product yield. A unique tandem classifier design has advanced the principle and applied it to a single unit. This new development in high performance classification (Figure 9) is intended for products that are from the coarse classification fraction.

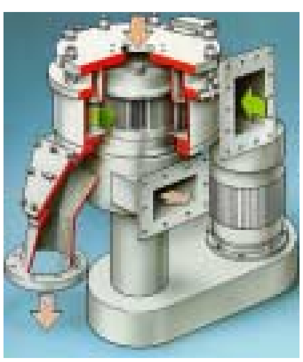

Fig. 8:Centrifugal classifier w/mechanical dispersion

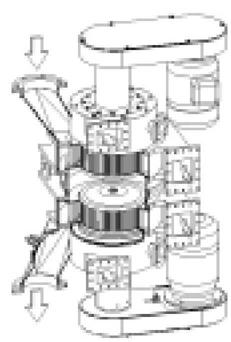

Figure 9: Tandem Classifier

The tandem classifier has become an ideal machine for use in toner manufacture. In recent years, the particle size requirement has become finer, as the demand for higher image quality in terms of resolution and color saturation has increased. An extremely sharp top size cut (d97~12 micron) and a very sharp fines cut at 3 microns or less is required to achieve these desired parameters. The tandem classifier is capable of achieving these specifications in the finished product. Powder coating material, while slightly coarser than toner, also requires tight particle size control. While powder-coating materials are typically ground on a mechanical air classifier mill to control maximum particle size, further classification is required to remove the fraction of fine particles that remain after grinding.

CONCLUSION

Manufacturers of powder products continue to innovate in order to increase product quality and manufacturing efficiency. These product innovations have led to unique machine configurations designed to process materials to the more exacting specifications required in the marketplace.

The applications and examples outlined in this paper represent a small sampling of those that have been optimized through the use of new processing technology. In order to keep up with the changing demands of the powder processing industry, the science of size reduction and classification has advanced dramatically. All industries have been affected and can benefit from improved particle size distributions of powders and better overall control of the process.

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