CHAPTER 12.36

Talc

Edward F. McCarthy and Jorge L. Yordan Hernandez

INTRODUCTION

The objective of this chapter is twofold: (1) to review the traditional mineral processing technology used by the talc industry and (2) to introduce and discuss the new technologies that are being implemented by talc producers in response to a changed marketplace.

Fifty years ago or so, talc processing was an easy manufacturing process because of an abundance of high-quality talc ores and relatively simple end-user applications. For instance, talc products were used as fillers in unsophisticated ceramic articles or in cosmetics and body powder. Nevertheless, the talc industry was reasonably profitable.

Today, the markets for talc have completely changed. Additionally, the good-quality ores are being depleted around the world, especially in China. Many simple end uses for talc are gone and have been replaced by applications that require the talc products they buy to be produced using state-of-the-art quality control programs and to comply with difficult-to-meet specifications. The talc industry worldwide continues to consolidate. The profitability of talc companies will be poor unless a substantial portion of their total revenues comes from value-added talc products that are targeted to enhance important properties of sophisticated end products manufactured by the plastics, specialty technical ceramics, and coatings industries.

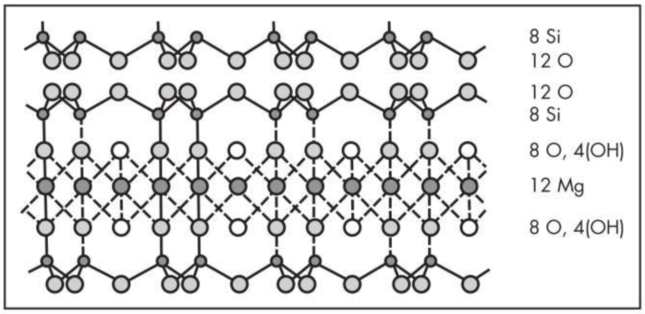
Even with major new world-class talc deposits being developed in Afghanistan and Pakistan in the last decade, it is challenging for talc producers to find talc ores that—when beneficiated the traditional way—would yield end products that meet the new market requirements. Consequently, talc producers have made significant investments to upgrade beneficiation, micronizing, and compaction capability to fulfill the market demands and also to alleviate the pressure of having to high-grade mines. These separation technologies, together with advances in wet grinding, fine particle sizing, surface coatings of talc particles, and talc synthesis, are discussed in this chapter.

The mining, processing, and applications of value-added talc products is a sophisticated process involving geologists, mining engineers, mineral processing engineers, chemical engineers, surface chemists, applications specialists, and a solid commercial group. In some instances, the applications are unique to talc and even to specific talc deposits. Indeed, for the most part, the market for talc is heavily dependent on the scientific research knowledge and technical skills of the producer. Without such application development efforts, new markets are very difficult to penetrate. This chapter borrows some content from the "Talc" chapter written by McCarthy et al. (2006) in *Industrial Minerals and Rocks* published by the Society for Mining, Metallurgy & Exploration (SME).

The Mineral Talc

Talc is a crystalline hydrated magnesium silicate of the general formula $3MgO\text{-}4SiO_2\text{-}H_2O$ (see Figure 1), which theoretically is 31.7% MgO, 64.5% SiO_2, and 4.8% H_2O. It is one of the layer silicates such as kaolin and mica. Talc ores can occur as a relatively pure mineral or as a mixture with other minerals. In its pure form, talc is colorless or appears white, but when the ore contains other minerals, it can also appear green, light green, yellowish, pink, or even black. Accompanying minerals include magnesite, dolomite, chlorite, calcite, and quartz.

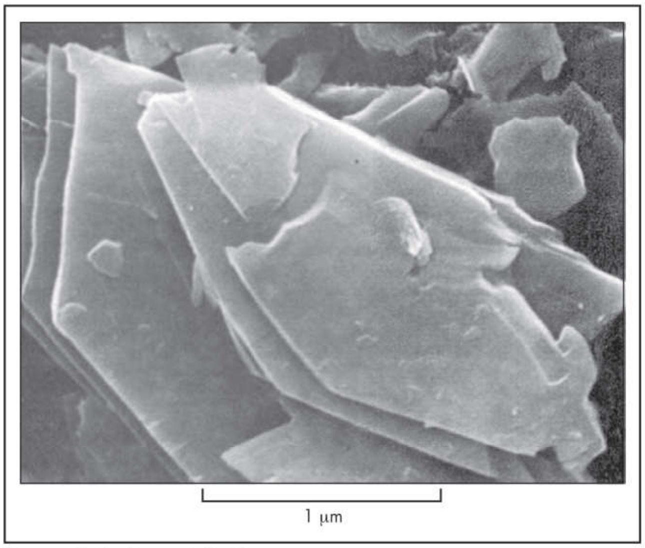
The adjacent layers of silica are very weakly bonded with only van der Waals forces, and this allows talc to be easily sheared along this plane. This gives talc its natural slippery



Source: McCarthy et al. 2006

Figure 1 Talc crystal structure

Edward F. McCarthy, Manager, Performance Minerals LLC, Morgan Hill, California, USA
Jorge L. Yordan Hernandez, Retired, Formerly with Rio Tinto Minerals, Parker, Colorado, USA



Source: McCarthy et al. 2006

Figure 2 Scanning electron micrograph of talc

feel as well as its platyness and softness (Figure 2). Talc is the softest mineral, with a Mohs scale hardness of 1. Additionally, talc is relatively inert and almost insoluble in conventional acids and bases but soluble in aqua regia and hydrofluoric acid. Talc has a pH in water of 9.0 to 9.5 and very little buffering capacity due to its insolubility. Regulatory authorities consider it a nuisance dust, but it has GRAS (generally recognized as safe) status as a cosmetics and food ingredient.

Talc has a specific gravity of 2.78, a refractive index of 1.58, a specific heat of 0.208 cal/g/°C, a thermal conductivity of 5 cal/g/s/°C, and a surface-free energy of 30–40 mJ/m^2 (Yordan et al. 2002) that makes talc a hydrophobic or water-hating mineral. Interestingly, when talc is split along the silica surface, the surface created is hydrophobic. When the talc is fractured across the silica–brucite–silica layers, the surface created is ionic (electrically charged) and hydrophilic. Materials that have both hydrophobic and hydrophilic components are surface active, and this gives talc its unique surface-active properties. Recently, Yan et al. (2011) confirmed and quantified the hydrophobicity of the planar talc surface as well as the hydrophilicity of the talc edges using a modified atomic force microscope. In water, the talc particles have a negative zeta potential with a maximum of –40 mV at a pH of 9. Its point of zero charge is around pH 2.5–3.0.

Geology of Talc Deposits

Talc can be formed in different geological environments or processes. The most commercially important deposits are metasedimentary-type deposits that are formed from the reaction of dolomite or magnesite host rocks and silica-containing fluids. Such deposits are common in the United States, China, and South Asia. They are amorphous when first formed but become progressively more crystalline when they are sheared into thinner lenses by geological tectonic movements. Such deposits will have carbonates or chlorite as the major co-minerals.

Also of significant commercial importance are serpentine-derived, ultramafic talc deposits typical of eastern Canada (Ontario) and Finland. These deposits are formed from the reaction of CO_2 with a host serpentine. Such deposits will always have high levels of divalent iron substitution in the talc lattice along with a magnesium–iron carbonate isomorph as the major co-minerals. Also, a second type of metasedimentary deposit is found in France, where magnesium-rich fluids-altered mica schists to form chlorite, and the silica released during this reaction altered overlying dolomite to talc. These deposits have 25% to 75% chlorite along with the talc and are often referred to as chloritic talc. Table 1 summarizes the typical mineralogy of the aforementioned ores.

Table 1 Typical mineralogy of North American and international talc ores

Ore Location	Talc, %	Carbonates, %	Chlorite, %	Quartz, %
Montana, United States	95	2	1	0.5
Ontario, Canada	45	50	5	Trace
Finland	55	40	1	Trace
France	55	2	40	1
China	93	3	3	0.5

Adapted from McCarthy et al. 2006

The value of a talc deposit is a function of its purity, color, and location relative to the market. The purity issue is not related to the absolute percentage of talc present but more a function of specific mineral or metal impurities. Asbestiform minerals and metals such as arsenic and lead are particularly deleterious even at parts-per-million (ppm) levels, and quartz, serpentine, chromium, and pyrite are harmful at levels greater than 1,000 ppm. However, carbonates and chlorite (magnesium–aluminum silicate) can be beneficial at levels up to 50%, especially when they are white and the quality is consistent.

The profitability of a modern talc operation mining a world-class talc ore such as the ones found in Montana (United States), Ontario (Canada), Finland, France, and China depends on minimizing the mining, beneficiation, and processing costs and maximizing the production of value-added talc products.

Exploration

Despite the availability of many modern geophysical techniques, the most effective talc exploration techniques are traditional field diagnostic, sampling, and mapping methods. Although talc is physically weak, it is chemically very stable, and the presence of talc in outcrops and in the overlying soils is the best diagnostic tool. After the deposits are sampled and mapped, if the quality is acceptable, the deposit is drilled, the quality is confirmed, and the reserve is estimated. The value of any talc deposit is a function of its color, purity, and location, along with the availability of appropriate markets. Nowhere is this more true than in Finland, where relatively low-purity and low-color ultramafic deposits were developed successfully to serve the local paper market and to replace expensive imported kaolin.

Mining

Most talc is mined today by conventional open pit, drill-and-blast, and shovel-and-truck techniques. The major difference from conventional technology is that blasting is minimized to avoid breakage of the soft talc ore, and all shovel work is accompanied by a high level of selectivity to minimize cross-contamination of high- and low-grade material. Many producers analyze blast-hole cuttings to delineate ore grades and select blast patterns accordingly. Experienced shovel operators can select ore or waste by color or texture for different grades. Equipment such as 10-m^3 shovels and 150-t trucks are common in North America and Europe, whereas 1-m^3 shovels, 20-t trucks, and even hand-carried baskets are used in Asia.

A typical western talc deposit is drilled on 30- to 50-m spacing, and the ore body is characterized by mineralogy, color, and chemistry. From this, the ore body is defined and a computer-aided mine plan is generated. Overburden is removed and stored elsewhere for eventual use in mine reclamation. Mining is typically done on 5- to 10-m benches. Before each blast, drill holes are analyzed and, if necessary, the shot is reconfigured to remove potential waste or segregate a better quality of ore. After the blast, the shovel operator will selectively scoop the rock into haul trucks and designate it as waste or as a low or high grade of ore.

Waste-to-ore ratios are often quite high, especially for massive steatite deposits. Typical values range from 5:15 for massive ores and 1:3 for the lower-purity ultramafic grades. Underground mining is now less common and is declining rapidly in importance. Pure talc is a very soft, noncompetent rock, which is often highly fractured, of varying thickness, and in steeply dipping bodies. Where veins are thin and the surrounding rock is competent, overhand mining is acceptable with limited timbering. In thicker veins, underhand mining is necessary; where the veins dip steeply, shrinkage stoping is used. Some low-grade deposits can be mined by room-and-pillar methods, for which equipment is much smaller, blasting and mucking much more selective, and waste-to-ore ratios much lower than in open pit mining. Continuous miners can be used on softer high-grade veins.

Reclamation

In contrast to past practice, reclamation is now an integral part of all talc mining in developed countries. Waste piles are graded, covered with topsoil, seeded, and monitored for a return to natural vegetation. For both surface and underground mining, both surface and subsurface water flow is measured, monitored, analyzed, and, if necessary, treated to meet local and national discharge standards. Some pits are backfilled or converted to a beneficial long-term use, such as recreation.

Manufacturing of Value-Added Talc Products

The manufacturing of value-added talc products from talc ores can be viewed as a two-stage process: a beneficiation stage and a finishing stage. The goal of the first stage is to remove, using mineral processing technology, as much of the deleterious mineral impurities from the ore as possible to produce a high-quality talc concentrate. The goal of the second stage is to manufacture high-quality products by properly milling or micronizing the talc concentrate, removing additional impurities, sizing, compacting, deaerating, and packaging and shipping the finished goods.

BENEFICIATION STAGE

The beneficiation stage can be a dry or a slurry process. If dry, the predominant technology is sorting; if it is carried out wet, it involves unit operations such as froth flotation and wet high-intensity magnetic separator (WHIMS).

Sorting

In reality, the sorting of the talc ore starts at the mining front; after the blast, the shovel operator will selectively scoop the rock into haul trucks and designate it as waste or as a low or high grade of ore.

Typically, the ore selected to be processed any given day is crushed with a jaw crusher, and the crushed ore is conveyed to the sorting plant. The sorting technology used to separate talc from dolomite and other impurities includes hand sorting of lump ore, mechanized optical sorting of pebble-sized ore, and slide or friction sorting of lump ore.

Hand sorting usually takes place in sheds at process plants. Screened ore (5–25 cm in size) is run across belts, and if low grade, talc is picked from the ore; if high grade, waste is picked from the talc.

Optical sorting processes usually require talc to be washed and screened into narrow pebble-sized (1–2 cm) range. A camera scans each particle as it falls through a testing zone, and then jets of air remove either ore (for low grade) or waste (for high grade). This type of sorting is suitable for higher-value products such as those required for cosmetics or plastics applications.

This technology has now been extended to mineral-based separations based on using near-infrared and X-ray transmission sensor technologies instead of color meters (Bergmann 2014).

A slide sorting process conducted on friction plates and chutes to replace hand sorting was patented (Nichols et al. 1991). It is based on the fact that a talc-rich rock has a much lower coefficient of friction than dolomite or quartz rocks, so when dropped on a rotating plate, the talc rocks will quickly slide off the plate, whereas the dolomite or quartz rocks will be carried around and removed by a scraper. This type of sorting is particularly useful for high-grade talc that occurs in narrow (<1 m) veins in a carbonate host rock.

Froth Flotation

Talc concentration by froth flotation is usable for almost any talc ore, but it is particularly useful for ores where the talc is intercalated with the waste, such as talc ores of ultramafic origin (talc–carbonate ores). Ore is crushed and then milled to liberation size, typically about 50% passing 325 mesh. It is slurried in water at about 25% solids, and a frother, such as methyl isobutyl carbinol, is added at very low levels (<100 ppm). It is then passed through two to five stages of conventional flotation, where the talc content is upgraded to >95% purity. Carbonates, quartz, chlorite, and serpentine are selectively removed by this process. Most operations use traditional agitated float cell technology; flotation columns have not found extensive application, even when they are used as cleaner devices.

After flotation, the flotation concentrate is usually gravity thickened and then filtered to dewater to <20% moisture on a rotary vacuum filter. A Finnish producer uses a continuous Larox belt press to minimize the residual moisture. The cake is then flash-dried with hot air, sometimes in combination with milling. If the cake is too difficult to feed, it is premixed with some dried powder to improve its handling. The drying is usually done in a doughnut-type fluid mill at lower hot air pressure; machines such as the Bepex Pulvacron mill or the Hosokawa pin mill can also be used, as can more sophisticated fluid energy mills.

Wet High-Intensity Magnetic Separators

If a problematic level of dark, magnetic minerals is still present, WHIMS can be used to remove these from the floated product. Even stronger cryogenic magnets developed for the kaolin industry are being used in Finland. By using flotation and WHIMS together, it is possible to produce a higher-quality talc concentrate but also to use lower-quality talc ores that normally would be rejected as waste.

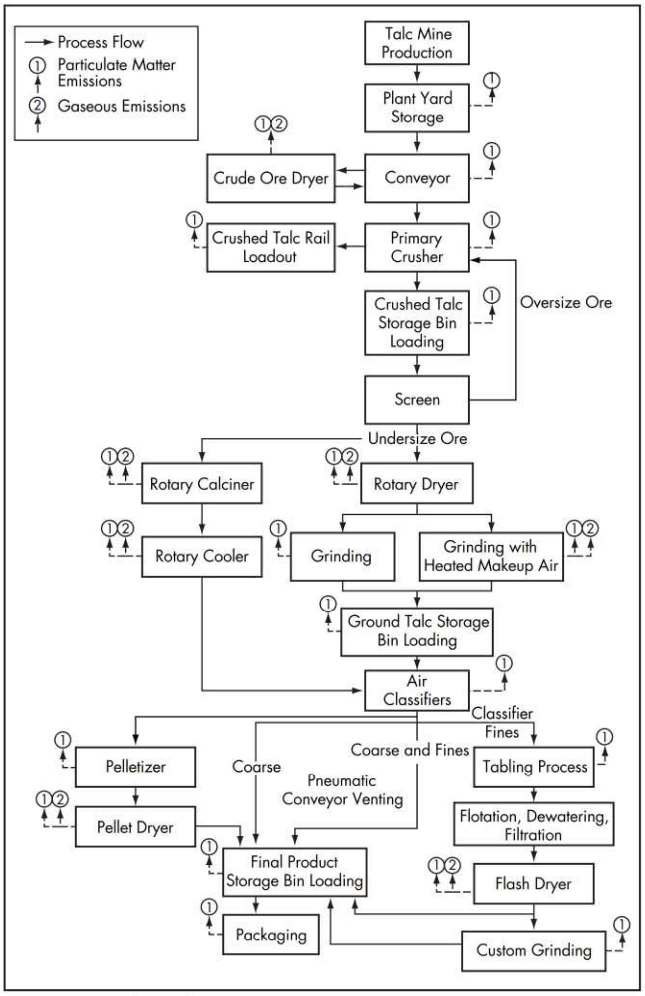
Leaching and Acid Washing

Leaching of floated talc for removal of yellow iron stains found on the surface of the talc particles was practiced in the past in the United States as a way to further increase the whiteness of floated talc concentrates. The leached talc products were mainly used in cosmetics. However, as the cosmetic talc market became smaller, this costly and environmentally problematic technology was eliminated and the talc requirements for cosmetic applications were replaced by very white, double-sorted, imported talc ores.

Acid washing to remove both carbonate and sulfide impurities for products used in chewing gum or pharmaceuticals was also used, but this has also been replaced by more environmentally acceptable separation technology such as slide sorting.

FINISHING STAGE

This stage includes milling the talc concentrate, additional magnetic impurities removal, sizing, compacting into pellets or powder densification, and packaging and shipping of finished products. The flow scheme of a typical multiproduct talc plant is shown in Figure 3.



Source: McCarthy et al. 2006

Figure 3 Typical flowchart of a talc operation manufacturing multiple products

Analytical Techniques and Measurements Nomenclature

In describing the physical and chemical properties of milled products, a substantial number of analytical techniques and measurements with a unique nomenclature are used. In this section, the techniques and measurements are described and the nomenclature is defined.

Among the most notable measurements are the median particle size and the top size. Median particle size is most often measured by sedimentation techniques using an instrument called a sedigraph. The sedimentation technique assumes that all particles are spherical; talc particles are not. A sedimenting talc platelet will behave like a much smaller sphere, skewing the reported distribution toward the fine end. The technique is generally used only for subsieve particles (100% finer than 100 mesh [150 µm]). The technique will give a full distribution and is accurate down to approximately 0.4 µm. The other major subsieve technique is laser particle size analysis with instruments made by several companies, including Malvern and Horiba. Unlike the sedimentation technique, the laser analyzer measures the long dimension of the talc platelet, and thus the distribution reported by the laser will be different and larger than that reported by the sedigraph.

For top-size measurements, sieving and Hegman drawdowns are used. Sieves from 40 to 325 mesh are common. The Hegman bar, also called the fineness-of-grind gauge, is a technique borrowed from the paint industry. A small quantity of talc powder is dispersed under high shear in linseed oil. A small portion of the talc in oil dispersion is placed on the Hegman bar, which has a very accurately machined groove with a depth of 100 µm at the top end and 0 µm at the bottom. When the talc in oil dispersion is drawn down through the groove, the coarsest particles will show somewhere in between, and the material is given a Hegman rating based on the largest particles in the sample. For instance, particles of 70 µm would give a 3 Hegman and particles of 25 µm would give a 6 Hegman.

Other critical properties that are measured include surface area, bulk density, and color. Surface area is measured by the Brunauer, Emmett, and Teller (BET) method. It consists of adsorbing a monolayer of nitrogen on the surface of the sample and weighing it. Values vary from 1 m^2/g for the coarsest macrocrystalline products to 20 m^2/g for the finest microcrystalline products. Bulk density is reported as either loose bulk density (LBD) or packed bulk density in grams per cubic centimeter. LBD is measured in a very simple piece of equipment called a Scott volumeter in which the powder is cascaded over a series of glass plates into a 1-in. cube. After the cube fills, it is smoothed off and weighed. LBD values range from 1 to 1.2 g/cc for coarse roofing products to <0.15 g/cc for the finest paint and plastic grades. LBD strongly correlates with median particle size and in many plants is used as a primary control parameter because it is quicker to run than a median particle size.

The science of color measurement as it affects talc is quite complex and constantly evolving. Most producers measure powder color, which is achieved by pressing the powder into a pellet at standard conditions (3 bar pressure) and then measuring the color and brightness on the surface. A wide variety of measurement systems are available. The most commonly used today is the Y reflectance system, whereas the General Electric brightness (GEB) method is used only in the paper industry. Y reflectance and GEB are quite close in value and are measured on a simple scale of 0 to 100 on a brightness tester. Products vary from about 60 for coarse products with low talc content to 96 for the finest, whitest talc products. Almost always, as talc products are milled more finely, dry brightness values increase.

The CIELAB scale measures color on three scales: *L* ranges from 0 to 100 on a white or black scale; *a* ranges from red to green on a similar scale; and *b* ranges from blue to yellow. A typical talc product with a GEB of 80 might have an *L* value of 86, an *a* value of 0.5, and a *b* value of 3. The *b* value, sometimes called *tint*, is the most critical, as it is often reflective of iron staining. A lower *b* value is almost always better.

The powder brightness does not always reflect how the product performs in an end use. In plastics and bar soaps, for instance, the brightness of talc is typically lowered significantly as the talc surface is wet out by resin, which changes the optical image. To measure this, the powder is wet out in mineral oil and the color is measured on the paste.

The other major analyses involve the mineralogy and chemistry of the ore and products. In its simplest form, talc mineralogy is estimated from loss on ignition (LOI) data. The pure mineral talc loses its (4.75%) water of crystallization at 960°C. Thus, the closer the 1,000°C LOI is to this, the purer the talc. If the major impurity such as dolomite or magnesite is known, the purity can be accurately estimated. Mineralogy is measured more accurately by X-ray diffraction (XRD) techniques. An X-ray beam is sent through a pressed sample of the powder, and the beam is scattered at a specific angle by each mineral present. The location and intensity of that scattered beam are characteristic of the mineral and its level in the sample. Talc, chlorite, carbonates, amphiboles, and quartz are readily identified and quantified down to concentrations of approximately 0.1% (1,000 ppm) using this technique. Asbestiform minerals can be measured down to <10 ppm sensitivity using transmission electron microscope analysis (Pier 2016).

A method to quantify the crystalline nature of talc was proposed by Holland and Murtagh (2000). They measured the intensity of the 004 and 020 XRD peaks and combined them in the following equation:

$$\mathrm{MI} = I_{004}/(I_{004} + 2I_{020}) \qquad \textbf{(EQ 1)}$$

where

MI = morphology index

I = beam intensity

Their MI varied from 0.98 for the more macrocrystalline and platy Ontario talc to 0.45 for the microcrystalline Montana ores.

Chemistry is determined by either X-ray fluorescence (XRF) techniques or by more detailed wet chemistry techniques, such as inductively coupled plasma (ICP) or atomic adsorption (AA). XRF is done on a pressed powder sample and is accurate for silica, magnesium, calcium, iron, and aluminum down to perhaps 0.2%. The wet chemistry techniques are much more accurate but require that the samples be digested in a very strong acid, such as aqua regia or hydrofluoric acid, before they are run through the ICP or AA instruments. This makes the technique much more expensive and time-consuming.

Talc Milling

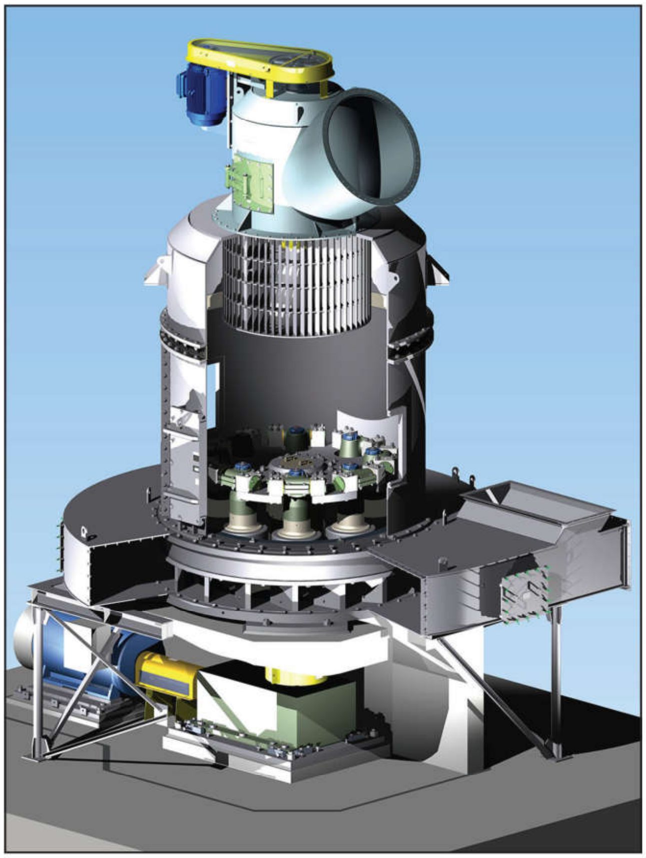
Talc is an extremely soft mineral and generally very easy to mill or to reduce in particle size, although the aspect ratio or platy nature of the talc can complicate matters. Preserving that aspect ratio is difficult in some milling processes, and a fine talc platelet is very difficult to handle and "manage" in an airstream, where almost all talc milling occurs. Very little wet milling is used. But it is slowly becoming more popular, as it is one of a few milling techniques that can increase the aspect ratio of the talc being milled. If the ore is wet, the process will typically start with drying. Direct-fired rotary dryers are the most common. The coarsest talc products can be produced by crushers run in closed circuit with vibrating screens. Roofing products are produced in this fashion by running crusher discharge over a 35-mesh screen.

A tiny fraction of talc is sold in lump form for carving, machining, or decorative applications. A significant volume of Chinese and South Asian production is exported in lump form to the consuming countries. However, the vast majority of the ore must be reduced to a powder for end use. The size needed ranges all the way from –10 mesh (top size of 2.5 mm or 2,500 μm) to 1,250 mesh (top size of 10 μm). Obviously, in a milled talc, all the particles are not the same size; they have a distribution of sizes—sometimes called the granulometry—which also has end-use importance because some applications require a narrow particle size distribution and some require a broad distribution. Finally, the particle shape is critical in some applications and is affected by the grinding method as well.

The most common milling machine in the talc industry is the ring roller mill, with the Raymond roller mill being the most popular type (Figure 4). In this mill, ore up to 50 mm in size is swept into a grinding zone between a set of rotating rolls that grind the talc between them and a horizontal ring. The fine product is swept out of the milling zone up to an air separation zone. Here, a set of horizontal blades, called a whizzer, creates an airflow in a horizontal direction to the sweep air and forces the coarse particles out to the side and back down the circumference of the cylinder into the grinding zone. The fine product continues with the sweep air and is removed by centrifugal action in a cyclone. The air is recirculated with a large fan back into the grinding zone. A slipstream of air is pulled off after the fan into a dust collector. This keeps the whole system at a slight negative pressure and removes particles that are too fine for the cyclone to capture.

Roller mills are effective devices for milling softer (up to 3.5 Mohs hardness) materials down to 325 mesh top size (44 μm). They appear to preserve the aspect ratio and, if heat is applied, have the capability to do limited drying of wet feed. The primary control mechanism on the mill is the whizzer speed, with a higher speed giving a finer top size and a finer median particle size.

Newer mills use the more sophisticated cage classifiers in place of the whizzer, which is not an efficient separation device. Cage classifiers require a higher pressure drop and usually a bigger fan but will enhance both throughput and



Courtesy of Arvos Raymond Bartlett Snow LLC

Figure 4 Raymond roller mill

top-size control. Products as fine as 5 Hegman can be made with enhanced classifier systems.

Producers use ball mills in closed circuit with air classifiers, especially for harder chloritic talc or ore with a high carbonate content. In South Asia, it is common to use less expensive hammer mills for coarse milling, sometimes in open circuit with air classification.

To mill from a 325 mesh to a 6 Hegman, the most efficient machines are hammer mills with built-in classifiers, such as air classifying mills (ACMs). The ACM is a compact hammer mill with an integral, highly efficient cage classifier. The hammers are mounted on a plate in a cylindrical housing, and the rotation forces the particles to impact a serrated liner. They are then air-swept into the cage classifier zone, where the coarse particles are knocked back and the fine particles are sent on to collection in a baghouse. The ACM can accept feed up to approximately 6 mm. The primary control mechanism in the ACM is classifier speed, with a higher speed giving a finer top size and a smaller median particle size.

For ultrafine grinding, often called micronizing, fluid energy mills, alternatively called jet mills, are used. In this process, high-pressure (>10 bar) air or steam is expanded through nozzles into a grinding chamber. In some of these, the grinding chamber is a doughnut-shaped system, and the high-speed air flowing around the chamber in a centrifugal motion causes the powder to grind against itself. In the Aljet type, the fine product is taken off on a slipstream on the inside of the doughnut. In the Alpine type, the grinding is done by streams of opposing nozzles that inject pressurized air and powder into the base of a cylinder (Figure 5). The fines are taken by the milling air into the classification zone on the top of the cylinder where multiple cage classifiers reject coarse particles back into the mill. Product from all these systems is collected in baghouse filters, with care being taken to ensure that any cooling does not approach the dew point of the steam effluent.

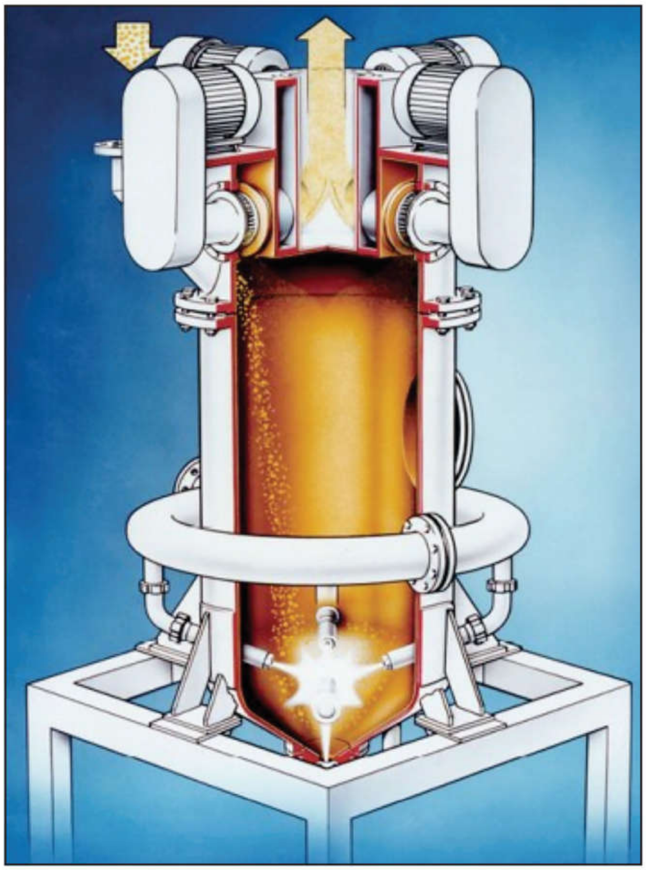
Fluid energy mills are effective for milling from approximately 4 down to 7 Hegman top-size products. At the same top size, they will give a much finer median particle size than the ACM. Furthermore, centrifugal-type mills are believed to be better delaminating devices than the ACM.

The primary control mechanism in fluid mills is the integral or external classifier speed, with a higher speed giving a finer product. For mills without a classifier, the product can be made finer with a higher fluid-to-talc ratio or a higher fluid pressure.

Mills are normally hardened steel construction, but grinding zones can be lined with urethane, ceramic, or ultra-high molecular-weight polyethylene for critical end uses (such as pharmaceuticals) where contamination, wear, and minimal color loss are important.

Size Classification of Talc Powders

Screens are excellent absolute-size separation devices, but their capacity and efficiency decline rapidly with finer meshes, and they are subject to rapid blinding and high maintenance



Courtesy of Hosokawa Micron Corporation

Figure 5 Hosokawa jet mill

with fine powders, platy materials, and agglomerates. In general, conventional screens are effective for separation of talc powders down to about 60 mesh. Below this, the powders agglomerate and blind the screens. For scalping-type applications (<0.5% oversize), air-swept screens can be used for powders in sizes down to 100 µm.

Air classifiers are devices in which a stream of air that contains fine particles (usually <100 mesh) is subjected to a velocity perpendicular to the direction of flow. This will cause the coarse particle to be deflected, allowing the fine particles to pass through. Two types of devices are used to create the perpendicular flow: blades (sometimes called whizzers) and cages that have a fan-like design. The latter are much more efficient, especially at fine particle sizes, but have higher pressure drop, lower capacity, and more potential problems. Typically, the flow is upward, and the whizzer is mounted vertically. When the separation points get finer (<20 µm), however, it is often advantageous to mount the unit horizontally.

Classifiers do not make a clean cut, and a platy particle behaves like a much smaller sphere. In addition, there are problems with bypassing, dispersion, and airflow control. In the most sophisticated units, all the accepted (fine) particles are forced through the vanes of the cage and exit through a hollow shaft on which the cage rotates.

The primary control parameter is the speed of the whizzer or cage, but other variables such as airflow, the air-to-solids ratio, and particle surface energy have significant effects. For any classifier, the higher the air-to-solids ratio, the better the classifier will work. But the operating cost is higher and the capacity is proportionally lower. Higher surface energy will have a detrimental effect in encouraging agglomeration, and this energy is an inevitable by-product of the milling process.

Classified products with fines removed are essential for use in solvent-based coatings today. All of these coatings have reduced levels of solvents to comply with volatile organic carbon emission regulations; thus, a pigment used in the formulation must minimize the viscosity build, and that is best done with talc by removing its fine particles.

Densification and Compaction

The fluffy nature and low bulk density of fine talc products make packaging and shipping difficult and expensive. To overcome this, producers use deaeration and agglomeration technology to increase the bulk density of fine products.

The standard deaeration technology uses a horizontal screw densifier to pull air out of powders. The powder is transferred through a horizontal screw that is surrounded by a filter cloth. A vacuum is pulled on the outside of the cloth, increasing the bulk density of a fine product by more than 100%, from 0.15 to 0.3 g/cc. The process has little effect on the talc itself, as the powder reaerates with minimal agitation. It does allow the product to be packaged in smaller sacks or to get 100% more talc in a regular sack. Such machines are manufactured by Carman in the United States, Alexanderwerk in Europe, and Kurimoto in Japan.

In compaction, the fine talc is wetted with about 20% water in a continuous mixer, and this paste is forced through a circular die to form pellets. Kahl and California Pellet mills are the most commonly used; some pellets are shipped wet, but most pellets are dried on a continuous tray or vibrating conveyor dryers. Typically, approximately 2% moisture is preferred for paper applications and <0.5% moisture is required for plastic and rubber. Bulk density is increased from 0.15 to 1 g/cc for fine products.

Dry compaction equipment is also available from Kurimoto, Bepex, and Hosokawa. In dry compaction, the fine powder is forced between two rolls and subjected to a high local pressure that agglomerates the fine particles. This process has the potential of making the agglomerates too hard to redisperse. Uetake (2002) patented a process that controlled the density between 0.7 and 0.9 g/cc to optimize density improvement and dispersion in polymer.

Densified and compacted products are now the standard product form in the plastics, paper, and rubber markets. Along with savings in transportation, the compacted grades are easier and faster to compound into polymers and disperse into water.

Packaging and Shipping

Talc products are shipped mainly in super sacks (400–1,200 kg) and, to an increasingly lesser degree, in paper bags (usually 25 kg) stacked on wooden pallets. Nowadays, packaging systems are increasingly automated and use robotics.

Transportation to the customer is a significant portion of the total cost of talc products, averaging 25% to 30% of the cost and, in some cases, more than 50%. Most talc products are now shipped by truck. The combination of faster, more reliable delivery and lower costs for most customers continues to favor this mode. Rail is used for larger-volume bulk customers when the haul distance is more than 500 km. Most trucks will deliver coast to coast in 4 or 5 days, whereas rail delivery will typically take 2 to 3 weeks. Bulk trucks are popular with customers because the truck driver unloads the material with a compressor on the truck, in contrast to bulk railcars where the customer has to supply the compressor and unload the material. Most product is shipped directly to customers. Smaller (less than truckload) customers typically purchase through chemical distributors who purchase from the producer and warehouse talc products locally.

Other Processing Technologies

Wet Milling

Wet milling in stirred media mills is a patented technology by Fourty et al. (2002) for the manufacture of highly delaminated talc products. Water is the liquid phase that is most commonly used. The milling media are typically small steel or ceramic balls with a narrow size distribution in the 1- to 5-mm range.

The main control variables in stirred media mills are the type of talc feed; the talc-to-liquid-media ratio; the type, shape, size, and amount of the milling media; and the stirring speed, stirring energy input, and milling time. After milling, the wet slurry is screened to remove oversize and broken media and then spray-dried; alternatively, it can be centrifuged or filtered to dewater and then flash-dried. Highly delaminated talc products have had commercial success in the marketplace being used for improved reinforcing in thermoplastic olefins and for reduced permeability in rubber tire inner liners.

Submicrometer or nanosized talc products can be manufactured with a dry-stirred media mill, followed by wetting the talc with water to make products with a BET surface area in the range of 300–600 m^2/g. Although the process has been patented, the products have not been commercially successful, as the application performance is quite poor in markets such as plastics and coatings. There are also patents (Martin et al. 2012) issued on a process to make synthetic nano-talc via the high-pressure, moderate-temperature, water-based reaction of sodium silicate with magnesium chloride.

Surface Treatments

A limited amount of talc is surface treated to improve its performance in specific applications such as plastics, rubber, and cosmetics. Aminosilane, polyethylene glycol, and waxes are some of the materials used. In general, the level of coating on talc products is relatively low—in most cases, less than 1%. This is in contrast to carbonates, where stearate coatings reach 3 wt % for ultrafine products.

A wide variety of equipment is used to apply the coatings. When the volume is small, as it typically is in cosmetic applications, batch technology is used. Horizontal drum mixers with slow macromixing and high-speed micromixing are common, as are V blenders, Nauta-type mixers, and rotating drums. For larger-volume applications, continuous mixers such as Littleford or Hosokawa turbulizers are used. They provide a modest (5–30 s) residence time along with high-shear mixing. The additive is usually added via a spray nozzle.

Talc for use in cosmetic, food, or pharmaceutical applications must be bacterially controlled to <100 cfu/g. This is generally done in a heat-treating circuit, where the talc is heated to >170°C for 1 minute; this can be done in an air-conveyed system or in a conveying heat exchanger.

Talc Slurries

A major development, especially in northern Europe, is the delivery of fine talc to paper mills in slurry form for use in paper coating. Fine talc, which has low surface energy and hydrophobicity and a platy structure, is difficult to wet in water and extremely difficult to make into a stable, high-solids slurry. Nevertheless, close to 250,000 t/a was shipped in this form in Europe, but the paper coating market has been in decline. The talc is dry-milled and then made into slurry using high-energy mixers and a proprietary package of dispersants and stabilizers. The slurries have a solids content of 61% to 65% and a viscosity of approximately 200 cP. A limited amount of talc is also shipped for pitch-control applications in slurry form, but the solids content is much lower and no chemicals are used.

Other Innovations

There are applications where some of the properties of talc are detrimental (such as the viscosity build in solvent-based coatings). To address this, producers in Europe and the United States are selling blends of talc and calcium carbonate for the coatings and putty industries, and another producer is selling blends of talc and feldspar for film antiblock.

CONCLUSION

Talc producers are well aware of the changes in the end uses of talc as well as the significant reduction of high-quality talc ore reserve. Consequently, they are investing in mineral processing technologies that will allow them to manufacture value-added talc products from lower grades of ores. These new products will have to comply with very strict product specifications and provide the expected functional performance to the end user.

REFERENCES

Bergmann, J.-M. 2014. Innovative water free mineral processing. Presented at the 22nd Industrial Mineral Conference, Vancouver, BC, Canada.

Fourty, G., Jouffret, F., and Monnot, P. 2002. Lamellar filler process for the treatment of polymers. U.S. Patent 6,348,536.

Holland, H.J., and Murtagh, M. 2000. An XRD morphology index for talcs: The effect of particle size and morphology on the specific surface area. *Adv. X-Ray Anal.* 42:421–428.

Martin, F., Ferret, J., Lebre, C., Petit, S., Granby, O., Bonino, J.P., Arseguel, D., Decarreau, A., and Ferrage, E. 2012. Method for preparing a synthetic talc composition from kerolite composition. U.S. Patent 8,202,901.

McCarthy, E.F., Reade, E., and Genco, N.A. 2006. Talc. In *Industrial Minerals and Rocks*, 7th ed. Edited by J.E. Kogel, N.C. Trivedi, J.M. Barker, and S.T. Krukowski. Littleton, CO: SME.

Nichols, C.W., Lorang, M.J., Wold, M.O., and Rayfield, J.W. 1991. Method and apparatus for friction sorting of particulate materials. U.S. Patent 5,069,346.

Pier, J. 2016. Development of a new ASTM method to detect asbestiform minerals in talc. Presented at the 2016 SME Annual Conference and Expo, Phoenix, February 21–24.

Uetake, T. 2002. Manufacturing methods of polypropylene resin composition with talc content. Japanese Patent 3,241,746.

Yan, L.A., Masliyah, J.H., and Xu, Z. 2011. Determination of anisotropic surface characteristics of different phyllosilicates by direct force measurements. *Langmuir* 27(21):12996–13007.

Yordan, J., Kortmeyer, J., Yildirim, I., and Yoon, R.H. 2002. Studies of the interactions between talc and stickies during paper recycling. SME Preprint No. 02-152. Littleton, CO: SME.