Using functional fillers in coating powder formulation

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Although fillers are used in coating powder formulation to control cost and to extend prime pigments, they are also used to improve or modify many functional properties of a coating powder. This article examines three popular fillers—barium sulfate, calcium carbonate, and wollastonite—as well as a few other fillers used in coating powder formulation. It also looks at how the fillers are made and how they affect the functional characteristics of a coating, specifically gloss.

Fillers are widely used in coating powder formulations to modify functional properties, such as hardness; modulus; permeability; corrosion, abrasion, and chip resistance; gloss; texture; flammability; and electrical characteristics. The term *filler* comes from liquid paint technology, where it refers to materials that are included in a coating composition to take up space and to reduce cost. The term has a similar meaning in powder coating technology, which is unfortunate because fillers for coating powders can actually improve or modify the functional characteristics of the coating.

Many in the powder coating industry also refer to fillers as *extenders*. In the paint industry, extenders, or extender pigments, show some degree of wet or dry hiding and extend the hiding of titanium dioxide (TiO_2). This distinction isn't usually made in the powder coating industry.

Manufacturers use fillers to ensure that all powders of a formula type cost about the same and offer consistent coverage. For example, many suppliers offer a standard coating powder formulation that comes in many colors. The white powder in this formula class may need a level of 35 to 40 parts of TiO_2 per hundred parts of resin (PHR) for adequate hiding at a nominal thickness of 2 mils (50 microns). But the black powder of the same formula class may need only 2 to 3 PHR of carbon black to get complete opacity at the same thickness. If the powders were formulated and sold on this basis, the black powder would have a lower specific gravity, higher flow, higher cost per pound, and a higher gloss than the white powder.

By adding the appropriate type and amount of filler to the black powder, the white and black formulations will be about equal in cost, coverage, and gloss.

Filler makeup and properties

Most fillers used in coating powders are inorganic and are usually based on naturally occurring mined minerals that are beneficiated—in some cases—and ground to a fine particle size. Particle size varies with the filler's specific grade, but can range from relatively coarse particles—a median particle size of 15 microns or more with 1 to 2 percent retained on a 325-mesh screen—to very fine particles with a median particle size of less than 1 micron.

Some fillers are made synthetically, usually by precipitation from a solution of soluble salts. For example, barium sulfate is precipitated from a solution of barium chloride and sodium sulfate (see Table 1). The precipitated fillers usually have a finer and more narrow distribution of particle size than the ground fillers. Ground fillers are prepared by mechanically grinding—either wet or dry—and by classifying to a consistent particle-size distribution.

Most fillers are inorganic, usually in their fully oxidized state. They are heat stable, resist ultraviolet degradation and chemical attack, and don't interact with the binder system. Table 2 shows the characteristics of an ideal filler. Other important characteristics that affect the smoothness, texture, and gloss of a coating powder are as follows:

- Particle shape, which also affects gloss, smoothness, texture, and permeability of a coating powder
- Oil absorption, which has a significant affect on flow and smoothness of a coating powder
- Specific gravity, which affects the coverage and applied cost of a coating powder

Three popular fillers

Because different fillers have different properties, powder manufacturers use many types of fillers in their powders. Table 3 shows the most widely used fillers: cal-

TABLE 2

Characteristics of an ideal filler

Inert
- Noninteraction with binder system
- Lightfast and colorfast
- Resistant to solvents, acids and alkalies, chemicals, and stains
- Heat stable
- Insoluble in water and organic solvents

Constant properties, such as composition, particle size, and distribution

Low specific gravity

Nontoxic and nonhazardous

Nonabrasive

Low cost

TABLE 1

The synthetic preparation of barium sulfate by precipitation from a solution of barium chloride and sodium sulfate

Barium chloride +	sodium sulfate	Barium sulfate +	sodium chloride
(aqueous solution)	(aqueous solution)	(insoluble)	(aqueous solution)

TABLE 3

Properties of typical fillers used in coating powders

Common name	Barytes	Calcite	Wollastonite	Clays
Chemical type	Barium sulfate	Calcium carbonate	Calcium metasilicate	Aluminum silicate
Particle shape	Granular	Granular	Acicular	Platy/lamellar
Specific gravity	4.45	2.65	2.90	2.58
Oil absorption (g/100 g)	12	16-30	20-33	40-115
Refraction index	1.64	1.57	1.63	1.62
Source	Natural/synthetic	Natural/synthetic	Natural	Natural

Common name	Talcs	Hydrated alumina	Silica	TiO_2 (comparison)
Chemical type	Magnesium aluminum silicate	Hydrated aluminum oxide	Silicon dioxide	Titanium dioxide
Particle shape	Platy/fibrous	Tabular	Granular	Granular
Specific Gravity	2.80	2.42	2.65	4.0
Oil absorption (g/100 g)	25-50	30-40	20-45	14-18
Refraction index	1.59	1.56	1.55	2.70
Source	Natural	Natural/synthetic	Natural	Synthetic

cium carbonate, barium sulfate, and silicates. The table lists data for TiO_2 for comparison.

Barium sulfate. This probably comes as close to an ideal filler for high-gloss systems as any available. The filler has a low oil absorption, which means the coating has only a slight reduction in flow and smoothness even at higher levels, such as 50 PHR or 33 percent loading.

All pigments and fillers reduce to some extent the melt-flow and smoothness of a coating powder as well as its physical properties, such as flexibility and impact resistance. But barium sulfate, or barytes, reduces melt-flow and smoothness less than other fillers. The filler is very inert and doesn't react with the binder or with outside environmental factors, such as acid rain. Barium sulfate only slightly reduces coating-powder gloss and doesn't adversely affect the physical properties of the binder system as much as other fillers.

Both the ground mineral (barite) and the precipitated synthetic filler (blanc fixe) are widely available. The precipitated grades have a finer particle size and a purer chemical composition than the ground grades. The ground grades are usually coarser than the precipitated grades and may contain other minerals, such as silica or silicates. The high specific gravity of barium sulfate, 4.4, means the specific gravity of the coating powder will also be high. This reduces the coverage on a cost-per-square-foot-per-mil basis.

The coverage of a powder in square feet per pound per mil is inversely proportioned to the specific gravity and can be easily calculated from the equation:

$$\frac{192.3}{\text{sp gr}} = \text{coverage in sq ft/lb/mil}$$

[Author's note: For a more detailed discussion of coverage and specific gravity, see "Misconceptions about the applied cost of wrinkle finishes and other textured powder coatings," by Thomas P. Frauman and Michael Correll, *Powder Coating,* vol. 8, no. 6 (September 1997): pp. 75-81, and the Powder coatings clinic, by Douglas S. Richart, in this issue.]

Calcium carbonate. This is another filler widely used in coating powders. Many grades are available based on

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the ground mineral (calcite), with precipitated grades also available. As with barium sulfate, the precipitated grades have a finer particle size and a purer chemical composition than the nonprecipitated grades.

Depending on the ore body that the calcium carbonate comes from and on the degree of beneficiation, or upgrade, most ground grades of calcium carbonate contain levels of magnesium carbonate, iron, and silica (quartz). Calcium carbonate, not as inert as barium sulfate, is attacked by acids. It's slightly alkaline and can adversely interact with binder systems that contain strong acid catalysts.

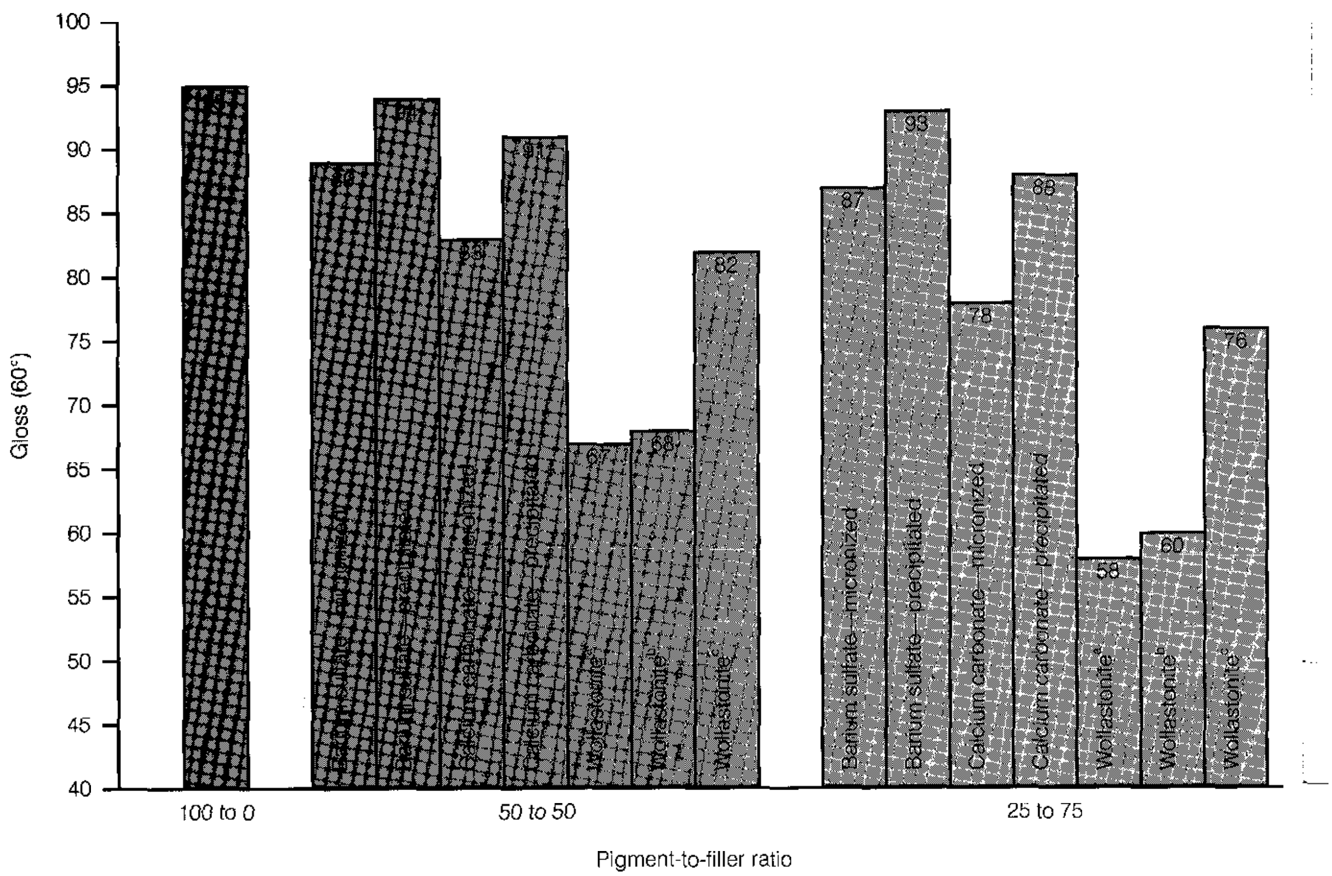
On the one hand, this filler has a somewhat higher oil absorption than barium sulfate, which usually means slightly more orange peel at the same loading. On the other hand, calcium carbonate has a lower specific gravity and better coverage at equal weights than barium sulfate. Calcium carbonate only slightly affects coating gloss (see Figure 1).

Wollastonite. Another filler used in coating powders is calcium metasilicate, or wollastonite. This ground mineral is mined from a large ore body in New York. Its uniqueness as a filler comes from its acicular, or needle-like, shape.

The various grades available vary in aspect ratio from about 2 to 1 through 7 to 1. Aspect ratio is the ratio of length to diameter of the individual particles. The longer aspect-ratio grades are mainly used as a reinforcing agent in plastics; the lower aspect-ratio grades are used in coatings and ceramics. Coating powders made with wollastonite have a naturally lower gloss than powders made with barium sulfate or with calcium carbonate.

FIGURE 1

Affect of fillers on the gloss of an interior, white, epoxy-polyester hybrid coating powder



Notes: [a] Largest particle-size wollastonite
[b] Slightly finer than largest particle-size wollastonite
[c] Finest particle-size wollastonite

Other fillers. Clays, talcs, silica, and alumina are also used in coating powders, but not as often as the other three fillers. These fillers are more often used in the manufacture of liquid paint. Clays and talcs have high oil absorption values, which result in a lower coating flow. They're used in textured and special-effects coatings. In liquid paints, the high oil absorption doesn't detract from smoothness and provides desirable rheological characteristics.

Silica is used in functional coatings, especially electrical grades, but its use is diminishing because of its classification as a possible human carcinogen. Hydrated alumina is used primarily in functional coatings, where it imparts flame retardancy and arc and tracking resistance in high-voltage electrical insulation.

Fillers and coating gloss

To characterize the effects of several fillers widely used in coating powders, a series of powders were prepared[1]. The powders were based on a 50-to-50 epoxy-polyester hybrid binder pigmented white at a constant pigment-to-binder (P-to-B) ratio of 0.6 to 1.0. The ratio of the TiO_2 pigment to filler was varied from 100 to 0, 50 to 50, and 25 to 75 by using barium sulfate, ground and precipitated grades; calcium carbonate, ground and precipitated grades; and wollastonite ground to three different particle-size ranges.

Coating powders were prepared using standard melt extrusion methods and were sprayed on panels, cured, and then evaluated for gloss. Figure 1 shows results.

The powder with 100 percent TiO_2 showed the highest gloss level. The powders that contained barium sulfate and calcium carbonate, both of ground and precipitated grades, were somewhat lower in gloss, ranging from 78 to 94 on a 60° glossmeter, compared with 95 for the powder made with 100 percent TiO_2.

The coatings prepared from the ground grades and those prepared with the higher filler-to-pigment levels had slightly lower gloss than those prepared with the precipitated grades. This result was expected because finer-particle-sized pigments or fillers produce a somewhat higher gloss than the ground—or micronized—grades that have a larger average particle size. Larger-particle-size pigments and fillers tend to protrude through the surface of the coating, resulting in microscopic roughness. This causes a scattering of light, resulting in lower gloss. Higher concentration of fillers also increases surface roughness.

Although the micronized grade of calcium carbonate produced a coating with a somewhat lower gloss than the coating made with barium sulfate in this study, the results could easily have been reversed if different particle-size grades had been used.

The gloss of coatings with wollastonite, however, is consistently lower than the gloss of coatings made with barium sulfate or with calcium carbonate. Gloss is lower at *higher filler-to-pigment ratios*, as Figure 1 shows.

Particle size and coating gloss

In coating powders, as in paints, gloss is a function of specular reflection. Smooth, planar surfaces reflect a large portion of incident light rays. In lower-gloss coatings, some of the light rays are scattered because of a macroscopically or microscopically rough surface, resulting in lower gloss. Chemists think that the microscopically rough surface seen with wollastonite is a result of its acicular particle shape, which disrupts the surface smoothness.

This is confirmed by the different degrees of gloss shown by the three wollastonite particle-size grades. The finest particle-size grade gives the highest gloss. The largest particle-size grade gives the lowest gloss. The middle grade is of slightly finer particle size than the largest grade and gives a slightly higher gloss[2].

The finest particle-size grade, which also has the lowest aspect ratio, yields a coating with a microscopically smoother surface with higher gloss than other grades. Wollastonite has an oil absorption similar to calcium carbonate and produces coatings equally as smooth as those made with calcium carbonate but with lower gloss (see Table 3).

If manufacturers want a *high-gloss coating*, they should use a fine-particle-size grade of calcium carbonate or barium sulfate as their filler. If they want a low-gloss coating, they should use wollastonite as their filler of choice, based on the results of this study.

Some of the other fillers shown in Table 3 produced reduced-gloss coatings, but that's because their high oil absorption resulted in rough, unattractive coatings with heavy orange peel. At low levels—such as P-to-B ratios from 0.05-0.15 to 1.0—these fillers usually yield coatings of higher gloss but with a textured surface.

This is also true for mica, which produces rough, unattractive coatings. In a few cases, manufacturers use mica in heat-resistant coatings because it helps prevent blistering at high temperatures.

Conclusion

Fillers are an important part of the raw materials available to the formulator to control many functional characteristics of a coating powder. The addition of fillers to a powder coating formulation results in some loss of the coating's physical properties, especially at levels of 50 PHR and higher. The difference between the coating with fillers and the coating without fillers depends a great deal on the base coating powder formulation as well as on the filler characteristics. **PC**

Endnotes

1. The study was done for NYCO Minerals, 124 Mountain View Drive, Willsboro, NY 12996-0368; 518/963-4262. Detailed copies of the study are available from the company.

2. The finest particle-size grade of wollastonite is NYAD® 1250. The largest particle-size grade of wollastonite is NYAD® 325, and the grade of wollastonite that is slightly finer than the largest particle-size grade is NYAD® 400.

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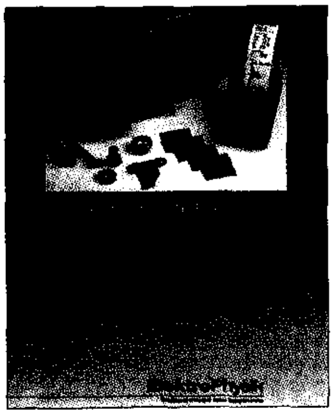

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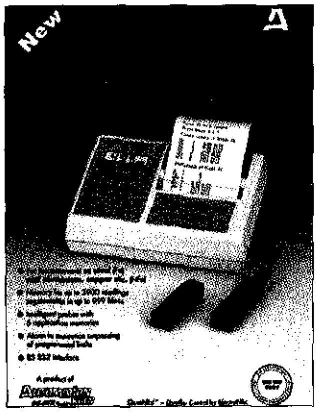

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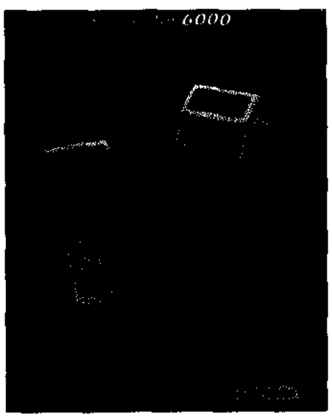

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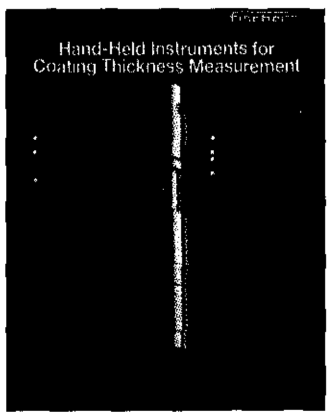

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