Understanding Pigments: The Third Step to Higher Quality and Consistency

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Putting great color in your product is part of the systems approach for resolving issues of sub-standard properties and appearance.

This article on pigments is the third in a four-part series about the interrelationship of the material components used in marble and solid surface manufacturing. These AOC-authored articles respond to the challenge that the cast polymer industries aspire to higher standards of quality and consistency. Because resolving cast polymer issues requires a systems approach, other articles in this series address resins, gel coats and processing. All articles begin with background information on the main subject matter, followed by ten related issues and guidelines.

A BACKGROUND ON COLORANTS

In their natural state, cast polymer resins meet a variety of performance requirements but are lacking in the color that draws the customer to the end product. Achieving a marketable color requires the addition of one or more pigments. Each pigment type or chemistry has an inherent property for imparting color to the final formulation.

Most of the primary pigments used in the cast polymer industry are listed in Table 1. The first pigment listed, Titanium Dioxide, is often referred to as "tee-eye-oh-two" after its chemical symbol, $TiO2$. Titanium dioxide is the most widely used white pigment because of its unique ability to provide exceptional opacity and to lend whiteness and brightness. Because of this opacity property, Titanium Dioxide is better able to "hide" the color of the base resin than other commercially available white pigments. For example, Zinc Oxide (ZnO) or zinc sulfide (ZnS) can be employed as white pigments. However, they are less opaque and would have to be used at higher loading levels to achieve similar whiteness and opacity.

Titanium Dioxide is used in the majority of the products made by the cast polymer industry. Titanium Dioxide-based colors include most whites, pastels, earth tones and off-whites such as bone, ivory, beige or biscuit. As noted in Table 1, non-white synthetic oxides are combined with Titanium Dioxide to create pastels and earth tones for cultured marble and solid surface applications.

Phthalocyanine pigments, or "Phthalos," impart deep colors such as the automotive "Hunter Green" of a sport utility vehicle or the high strength Blue used in ballpoint pens. Because they are so deep when used by themselves, Phthalo Blue and Phthalo Green are normally blended with other pigments, many times Titanium Dioxide.

Among black pigments, Iron Oxide Black is used to achieve a "jet" black look in cast polymer products. Carbon blacks are used judiciously in many Gray and Platinum colors, and as a shading component in many other formulations. Ultramarine blues, which have a deep "royal blue" color, can be blended with Titanium Dioxide to create the appearance of "Bright White" colors.

ANALYZING COLOR AND CONSISTENCY

At AOC, scientists and technicians generally employ the CIE L*a*b* Color Scale for analyzing color. The Scale is a three-dimensional "map" that determines the location of a specific color by locating the intersection of three different axes of color values. By using this system, a color analyst can numerically express or analyze if a product's color is on target or if it is getting too blue or yellow, too green or red, too light or dark. See the sidebar report, "The CIE L*a*b* Scale 'Elevator,'" for details on this color evaluation system.

While several different instruments are available for measuring color, visual assessment is still a very powerful and important technique. Cast polymers are not the only products where sight is used to make a subjective appraisal. Thus it is important the human observer agrees with and sophisticated color computer. Many important purchasing decisions, such as homes, clothes and automobiles, are influenced entirely by visual color assessment.

GUIDELINES TO BETTER COLOR

Establishing color parameters and maintaining color consistency is a complex proposition. A list of basic troubleshooting tips has a useful purpose but do not always address individual shop preferences and routines. In an alternative approach, let's look at key issues and guidelines for optimizing color quality and consistency. These guidelines are not presented in any particular order of importance.

Three of these guidelines - on record keeping, manufacturing repeatability, and communicating with your suppliers - may look familiar. These universal principles are important enough to be included in all four articles of this series.

1. Judging the color that meets the eye.

The way a color is judged can vary by the lighting environment. The same sample will take on a different appearance under a conventional incandescent light bulb, outdoor daylight, and fluorescent office lighting. There are even more variables to consider for a company that has more than one visual inspector and when color-critical parts are manufactured and shipped from several locations.

The appearance of some parts may change simply by changing the angle of illuminating light. Normal wear, scuffing, chalking or surface erosion on a part can also significantly alter the way overall color and appearance is judged. Surface gloss plays a huge role in the perceiving color and appearance of finished parts.

2. Dry or wet...the choice is yours.

For some operations, adding dry pigment to the cast polymer batch can be cost and performance effective. However, dry pigment addition is much less "forgiving" of formulation and process variation. In dry form, a pigment is usually in a small particle size and irregular shape that causes it to stick on equipment and workers. Without strict attention to bin and hopper design, the handling of solid pigments can lead to "bridging" and "ratholing" problems. General maintenance and upkeep are also increased.

Dry pigments take longer to blend into the cast polymer system to ensure uniform distribution of color and to eliminate the possible appearance of undispersed pigment specks. Furthermore, the resin adsorption characteristics of dry pigments can lead to variations in gel time, higher catalyst demand and differences in green strength development.

Most operations prefer the convenience, simplicity and effectiveness of liquid or paste pigment dispersion. With pigment dispersions, the color is suspended in a "vehicle" of monomer free polyester resin. When added to the matrix resin of a casting formulation, the dispersion gives the finished part molded-in color. In pigment dispersions, potential clumps of solid color concentrate are broken down by high-shear premixing.

The wet dispersion is easily added and blended into the overall formulation for easier maintenance of color consistency from run to run.

This is especially important for "mix and match" components, such as a back splash that is produced at a different time and with a different batch than a vanity.

3. Veining without or with monomer.

Shop workers take pride in developing techniques that create just the right effect with veining pastes. When veining pastes are supplied without styrene monomer, the resulting veins tend to be more subdued. Veining pastes supplied with monomer tend to be bolder and brighter. However, the monomer-containing paste calls for closer attention to reaction and cure to ensure consistency and quality.

4. Master the art and science of blending.
Quality is improved when there is a greater understanding of the individual and total contributions of resin, catalyst, filler and pigment. To ensure formulation consistency, it is best to maintain consistent parameters for the mixing procedure. This includes: the order of ingredient addition, the time of addition, the length of each ingredient blending cycle, and the temperature during addition. Part quality is also enhanced when ingredients are blended with clean and well maintained equipment.

5. Optimize your formulation for color.
Test the pigment you intend to use at differing levels to achieve the best balance of cost and appearance. A general rule of thumb is to make and compare test specimens at 0.25% increments (0.25%, 0.50%, 0.75%, 1.00%, etc.). While higher pigment loading will help reduce color variability, pigment loadings are generally held to less than 2%. If any changes are made to a formulation, test the proposed formulation against the current formulation.

6. Not all pigments, resins, catalysts and fillers are created equal.
Every ingredient in a cast polymer formulation contributes to the color of the final part. It is extremely rare to find a "drop-in" replacement for an existing ingredient that will result in the identical finished part color. For titanium dioxide alone, our studies have shown that different grades can vary by almost 10% on the lightness (L*) scale. The most widely used fillers cast polymers are calcium carbonate and aluminum tri-hydrate. If a change in filler is made, a color shift is likely because of differences in color, particle size distribution and/or resin adsorption characteristics. Also expect changes in color if the amount or type of catalyst is changed.

7. The solution to your problem may be in the vehicle.
If color shifts because of a formulation ingredient change, share that information with all your formulation ingredient vendors. They may be able to provide information on how the formulation change affects their particular ingredient. It can be especially beneficial to work with a pigment dispersion supplier who offers the option of multiple vehicles for carrying the pigment. In some cases, changing the vehicle chemistry may be the most effective way to minimize the impact another change would have on existing shop preferences and practices.

8. Put it in writing.
Good record keeping starts by saving the manufacturing and quality control records that your pigment supplier provides. Combine that information with a record of any variables that may affect profitability and customer-acceptance. Keep a record of how changes and variations in the formulation and process affect the original optimized formulation.

9. Seek repeatability, and repeat it.
The key to color consistency is establishing consistency in your formulation and shop conditions. In a never-ending quest for improvement, you can make methodical and incremental changes to determine which factors increase quality, consistency and productivity.

10. Talk to your material suppliers.
Take advantage of outside technical expertise. A professional technical service representative can help you avoid or minimize "trial and error." Making good parts sooner saves time and money. Be specific about the make-up of your formulation and details about your process and shop. The enterprising supplier wants to join you on a path of mutual profitability and success.

ABOUT THE AUTHOR
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