Color and Appearance Measurement in the Plastic Industry

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Plastics

The plastic industry is separated into two sections, thermoplastics[1] and thermoset[2]. The Thermoplastics is the majority of the plastic industry. Each section is further divided into highly specialized industries that are responsible for all the plastic things you might commonly see every day. Plastic families in each group are listed in Table I. Four groups are involved in the process of making the final product: raw material manufacturer, processor, converter and equipment manufacturer. At each phase of product processing, quality control (QC) and in some instances computer color matching (CCM), play an integral part in ensuring success of the final product.

Table I

Thermoplastics	Thermosetting
Vinyls	Phenolics
Polystyrene	Amino plastics
Polyethylene	Polyesters
Polypropylene	Epoxies
Polyamide	Silicones
Fluorocarbons	Alkyds
Acrylics	
ABS Acrylonitrile Butadiene Styrene)	
Acetal	
Cellulosics	

A listing of the plastic industry broken into specific industries is displayed in Table II and a list of the typical color and appearance measurements is displayed in Table III. Raw material manufacturers, processors and to an extent converters, would have the most need for QC and CCM capabilities. In these areas, research and development (R&D), technical services, CCM, and QC laboratories are most prevalent. Personnel involved in these areas must have expertise encompassing the entire industry, especially when the product is absorbed throughout the entire mainstream from raw material to converter. Evaluation of resins and additives becomes important as we determine the performance at each stage. In particular, processors preparing color concentrates applicable to a customers needs, have many variables to consider: colorants, resins, stabilizers, dispersing aids, processing aids, loading, and processing equipment.

Most converters and equipment manufacturers need limited color instrumentation. Converters depend upon suppliers to conduct testing and inform them on the "raw material" they will use. They may use basic QC instrumentation to ensure the quality of raw material is maintained within shipping specification.

Table II. Raw Material

Resin manufacturers
Additives: stabilizers
Colorants
Fillers
Processing aids
Flame retardants

[1]Thermoplastics become fluid when heated sufficiently and harden again when cooled.
[2]Thermoset resins become permanent in shape when first cured and cannot be re-formed by further heat or pressure.

The user needs a wide range of equipment due to thorough testing of the end-use product. The user evaluates the raw material using a full range of QC and CCM instrumentation, and physical test equipment.

Processor

Masterbatch/concentrate house
Compounder
Liquid color house
Dry color house

These manufacturers are involved with custom color matching, pigment and additive dispersion for the convertor. They are very knowledgeable in all end-use applications. The instrumentation used are, QC and CCM instrumentation, and physical test equipment.

Convertor - End User

Blown film
Blow molding
Injection molding
Sheet extrusion
Rotational molding
Gel molding
Casting
Thermoforming (vacuum forming)
CalenderingCompression
Transfer molding

Typical evaluation methods are QC instrumentation and physical test. Some companies may use CCM if they do their own color matching. In this case they are a processor and convertor.

Processor and Converter Equipment

High speed dry mixers
2-Roll mill
Internal intensive batch mixer (Banbury)
Single and twin screw extruders
Compounding extruders
Extruder – moldingTumblers

Table III. Color and Appearance Measurements

Color Measurement	Raw Material	Processor	Convertor
Color – reflectance	✓	✓	✓
Color – transmission	✓	✓	✓
CCM – 2 constant math	✓	✓	✓
CCM – Transparent	✓	✓	✓
OPL	✓	✓	✓
Waste Work-off	✓	✓	✓
Batch correction	✓	✓	✓
Absorption measure	✓	✓	
Log K/S	✓	✓	
Opacity	✓	✓	✓
Whiteness Index	✓	✓	
Yellowness Index	✓	✓	
% Trans. Haze	✓	✓	✓
Strength	✓	✓	
Spectral Curves	✓	✓	
Tolerancing	✓	✓	✓
CMC	✓	✓	✓
Metamerism index	✓	✓	
Statistical charts	✓	✓	✓

A selective listing of major companies in this industry that dominate the market or has a significant involvement in market trends is displayed in Table IV.

Table IV.

RAW MATERIALS		
GE Plastics	Pittsfield, MA	resins, additives
BASF	Bridgeport, NJ	pigments, additives
Bayer	Pittsburgh, PA	resins, additives, pigments
Dow Chemical	Midland, MI	resins
Union Carbide	Danbury, CT	resins, film, additives
Degussa Corp	Ridgefield Park, NJ	pigments
DuPont	Wilmington, DE	resins, additives, pigments
General Polymer Div.	Columbus, OH	resins
Ciba Geigy	Hawthorne, NY	additives, pigments
Sun	Cincinnati, OH	pigments
Eastman Chemical Products	Kingsport, TN	additives, resins
Amoco Polymers	Apharetta, GA	resins
Clariant Corp	Coventry, RI	pigments
PROCESSOR		
Ampacet	Tarrytown, NY	masterbatch
Chroma Corp	McHenry, IL	dispersions, concentrates
Reed Spectrum	Holden, MA	concentrates
Ferro	Stryker, OH	masterbatch, concentrates, liquid & dry color
PMS	Somerset, NJ	concentrates
CONVERTER		
Huntsman Packaging	South Deerfield, MA	film
3M	St. Paul, MN	film
Allied Signal, Inc.	LaCrosse, WI	sheet laminates
Polytec Plastics	St. Charles, IL	extruded tubes.
MANUFACTURER OF EQUIPMENT		
Battenfeld	E.Providence, RI	compression, injection, transfer mold
Krauss-Maffei	Munich, Germany	extruders, Injection molders.
Boy Machines	Exton, PA	injection molders

Berstorff Corp.	Charlotte, NC	extruders
American Leistritz Corp.	Somerville, NJ	extruders
Cincinnati Milacron	Batavia, Ohio	injection & blow molders, pelletizers, RIM

Color

There are many factors affecting color in the plastic industry. The main considerations are colorant selection, processing temperature, and dispersion method. Due to the nature of colorant manufacturing, we have lot-to-lot variation. In order to maintain standard quality lots or batches, manufacturers must qualify the inherent color characteristics with standard material. Basic QC measurements allow colorant manufacturers the ability to set-up tolerances for color control.

Colorant selection is probably the single most important item in the color process. Colorants are either dyes or pigments. Pigments are subdivided into organic and inorganic. Dyes are very strong, good heat stability, and transparent. These colorants are typically used to tint or shade a resin. Dyes solubility only allows it to be used in selected resins. Pigments are more widely used due to its opacifying ability, wide chroma range, and good heat stability for most resins. Pigments are dispersed within a resin matrix, and dyes solubilize in the resin. Colorant selection will depend upon the resin type, processing conditions, and the end-use application requirements.

Within the plastic industry, the 2 biggest problems concerning colorants are, heat stability and dispersion. Typically, organic pigments are very difficult to disperse, while inorganic pigments are easy to disperse. Without good dispersion, we fail in characterizing the inherent color. A large majority of the industry will use pre-dispersed colorants for their operation. This is the reason for processors. The makers of finished plastic products do not have to face the problems of adequate dispersion and proper mixture.

Exceeding thermal limitations of colorants, causes the colorants to degrade. Organic pigments tend to fade in color, inorganic generally turn dark and dull, and dyes sublime. Evaluating heat stability of pigments is typical by the manufacturer and the processor. The area in which the colorant is subject to heat is the processor and the converter. The processor is not subjecting the colorants to excess heat. Their main concern is dispersion and distribution of colorants. The convertor is manufacturing the end product. The rule of thumb is "higher temperature, higher yield". The raw material supplier to the convertor must know and make correct colorant recommendations based on the end use requirements. Again, basic QC measurements for color comparison allow the user to calculate pigment degradation as a function of temperature.

As the demand for custom color matching grows, we need to expedite the time it takes to make a match and display it to the customer for approval. Most colorant manufacturers, processors, and some converters, require the need of CCM. A large majority of the colorants have opacifying abilities, such as inorganic pigments. It is those colorants that are translucent and transparent, such as, some organics and dyes, which are very difficult to characterize within the same software as opaque colorants. Often different letdown methods are necessary to characterize those types of colorants. Applications Engineers also should be consulted with for additional advice.

Measurement of Appearance Attributes

Plastic resins are evaluated for yellowness and haze. Optically, resins vary from clear to cloudy and from colorless to light yellow, amber, and brown. During servicing, many resins tend to yellow due to heat or as a result of chemical degradation. In the case, of clear plastics, haze and yellowness by transmission are the two attributes most regularly measured. Instruments used are sphere based spectrophotometers and hazemeters.

White pigments are regularly tested for whiteness and opacity. The most popular white is titanium dioxide (TiO2). The best measurements are made when the pigment is dispersed in the resin of intended use since both resin and pigment are responsible for whiteness. Instruments used are sphere based and 45°/0° spectrophotometers for both measurements.

Color pigments should be dispersed in the resin before evaluation. A single pigment, or pigment

blend should be evaluated with a known standard. We can determine the colorants shade and strength. For testing strength, the colorant is prepared as a tint[3]. To determine the inherent color, we prepared the colorant as a masstone[4]. Instruments used are, spectrophotometers, and colorimeters for shade. For color measurement correlating to a visual agreement, 45°/0° spectrophotometer is often recommended. To measure irregular shapes, i.e., pellets and powder there are cell holders and cups used to fit on the entrance port of the instrument.

Gloss measurements on flexible plastic films and molded parts are commonly conducted. Time, temperature, processing conditions affect the surface conditions.

CCM is used for matching concentrates, film, molded parts, and fiber to name a few. Typically, plastic surfaces have a semi-gloss to high gloss finish. For this reason, we highly recommend sphere-based spectrophotometers.

Organizations

In the plastic industry, the measurement of appearance is governed by the American Society for Testing Materials or commonly referred as ASTM. Some specific test methods used in the plastics industry are instruments for measurement of color, yellowness, gloss, and geometric transmission of light by plastics, and applications of methods of appearance measurement.

Other organizations which have an influence on the plastic industry are Food and Drug Administration (FDA) which publishes the Code of Federal Regulations Title 21, Environmental Protection Agency (EPA), California Proposition 65, Superfund Amendments and Reauthorization Act of 1986 (SARA), Occupational Safety Health Act (OSHA), Resource Conservation Recovery Act (RCRA). These organizations make sure the industry maintains and complies with their guidelines. They all basically deal with regulation of "hazardous material".

The Society of Plastics Engineers (SPE), The Society of the Plastics Industry, Inc. (SPI), the Dry Color Manufacturers' Association (DCMA), and the Cadmium Council, are organizations used for presenting papers, conducting studies, education, and general support to the industry and its products.

Publications

Journals and magazines are an effective way to communicate the latest technology and current information on products and services. These are the most common publications:

- Modern Plastics
- Plastics Compounding
- Plastics Technology
- Plastics World
- Plastics Engineering
- Plastics News

Conclusion

The plastics industry is not a mature market. It is still growing and innovative. New resins, processing equipment, colorants, and additives are constantly being developed. At every stage in this industry, require some form of color control to assess the product being produced.

The raw material supplier, processor and convertor, may require color instrumentation for all types of appearance evaluations. The nature of their application will dictate which instrument(s) is best for their process. Follow the “color trail”; you will find many opportunities from start to finish. Use the publications for references and your Minolta applications and sales support staff for additional information.

[3]The term tint is associated with the colorant letdown with TiO2 or with another colorant.
[4]Masstone is a term associated with a colorant and a base vehicle at 100% colorant concentration.