

Color and Appearance of Composites – the Future of Instrumental Measurement

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Abstract

Instrumental practices for the assessment of color and appearance have been in place for many years. Manufacturers use handheld and benchtop spectrophotometers, measuring samples both in contact and non-contact configurations. Users compare colorimetric data from these measurements to visual assessments performed in lightbooths, controlled harmony rooms, and in front of the HR manager's window. In addition, we may sometimes use image data to assess the color or appearance of samples. These colors and images may be displayed on web sites, in soft catalogs, or anywhere else, and browsing users assume they are faithful renditions of the actual item. This presentation will review current tools and solutions for assessing color and appearance of composite materials. The paper will also outline projected future developments and needs for rigorous, critical assessment.

Introduction

Current practices in industrial color measurement have include spectrophotometers of several types (handheld vs. benchtop, contact vs. non-contact, sphere vs. 45/0 geometry, pulsed xenon vs. tungsten illumination). Software tools in industrial use have included systems for color difference assessment, recipe formulation, production management, allocation, and communication.

In order for color assessment to be successful, procedural details and definitions must be clearly established, and their practice shared among multiple users or sites. Finally, communication of color assessment results must be uniform, objective, and quantitative in order for manufacturers and sourcing companies to track their quality and color compliance.

Current Color Difference Assessments: Visual and Instrumental

Color difference assessment, whether visual or instrumental, is composed of hardware, software, and "humanware" factors. In the case of instrumental assess-

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ment, the hardware includes such items as spectrophotometer geometry, source illumination, and area of view. The software includes choice of color difference metric, illuminant, and observer. The humanware factors include sample presentation and other procedural details. In addition, the environmental conditions (temperature, humidity) can affect the assessment for some colors and materials.

For visual assessment, the hardware includes tools such as standardized lighting environments. The software includes the control or calibration of the lighting environment, and the humanware includes the use of sound and consistent procedures. For example, procedural details that need to be identified for visual assessment include specifics of positioning the sample and standard, and any backing or thickness for non-opaque materials. Also, the scope of the assessment task needs to be framed carefully, on order for multiple parties to make assessments which correlate with each other. For example, the following thresholds could result in different judgments or the same sample-standard pairs: "is this color development submission an acceptable match to the on-screen color standard?" vs. "is this production lot acceptable with previously accepted lots for distribution to end-users?"

The humanware aspect can have unintended consequences, because it is harder for a manufacturer to quantify the cost of false-negative decisions. False-positives are easy to detect and charge – and no one wants to be responsible for a container-load of off-shade product being received (and rejected!) by the customer. However, when well-intentioned QA staff reject goods because they can *perceive* a color difference (a difference which may in fact be *acceptable*), then the manufacturer is burdened with un-shipped first-quality goods.

Once the color difference assessment has been completed, the results must be communicated to interested parties (supply chain partners, QA manager, or whoever). The form of this communication in present practice may be qualitative or qualitative, electronic or Post-it note.

Future Assessments: Visual and Instrumental

Future improvements in color and color difference assessments might still fit the above model of hardware, software, and humanware. Let's consider this model for instrumental assessment, first.

The sensors used for measuring samples in the future will permit greater flexibility for measuring on a production line, or off-line in a lab. They will also support assessment of color or appearance, or both. (At present, users must choose between sphere or 45/0 geometry, when both measurements may be desired.) Sensors may

need to permit control over the spectral power distribution of the source illumination for the measurement of fluorescent materials, rather than simple adjustment of UV cutoff as is the current practice. Industrial users will also require the ability to capture a high-resolution image of the same, as well as multi-angle spectral data. Extended wavelength range for military applications and separation of true reflectance from fluorescent emission are both crucial needs for niche markets. If these needs can be met by the versatile engineering of non-niche sensors, then the state of industrial color measurement will improve for even more markets and products. These sensors will communicate wirelessly with PDAs, computers, and various other micro-electronics. These sensors will model the color changes driven by temperature, humidity, or other factors.

The software which supports these devices will run on any commercially-available OS, and will be immune to viruses, yet totally portable. It will include color difference metrics with outstanding correlation to visual assessment, and will alert the user to issues of color inconsistency. The systems will transform data from disparate sensors or color spaces into a common platform for comparison and communication. The software will automatically adapt tolerances, batch sizes, and acceptance criteria according to appropriate history, yet will drive manufacturing hysteresis by “learning” from occasional manufacturing error. The software will support multiple user interfaces (voice, touch screen, graphic, etc), and will accommodate users with different use habits (similar to voice recognition systems today). Users will not have to learn a single, foreign procedure, but will find that the systems fit seamlessly into their existing workflows. The software will support full implementation of color appearance models, including luminance levels, colors of surround, and complexity of design.

The humanware aspect of my future vision involves people doing the tasks for which humans are uniquely suited: using experience and judgment to reduce a large, complex problem to its simpler elements. Measurement systems can perform the repetitive tasks which form 90% of a robust color program. Humans will execute the most difficult processes which are not readily modeled. (Customers of the future are expected to be as fluid and flexible as ever!) People with skill and training will bring their innovation and expertise to solve the problems identified by the process of color measurement.

For visual assessment, the environments for controlled color assessment will be “tunable” to different spectral power distributions whose data may be transmitted from a PDA or other wireless device. Temperature, humidity, and other parameters will be controlled by the environment. Three-dimensional products and complex aesthetics will be viewed both separately and as components of the whole. The observer’s acuity for color assessment

will be tracked by the viewing environment, and the user alerted to samples which lie outside her optimal range. Regular scaling assessments will be used to qualify the observer for particular tasks.

The Communication Piece

When we collect color and color difference data on production goods, we can quickly be overrun with quantitative data. Rigorous reduction of these data is crucial, followed by appropriate communication of the results. Otherwise, the improved systems described above only serve to drown us more quickly than at present. So, we can all either sign up for swimming lessons, or we can reduce the data by mining for the most useful information.

As an example, overall trends of acceptable goods should be modeled for each customer or application. When production variation is aligned with acceptance limits, then manufacturing can be informed in real-time of the high percentage of shippable units. However, if production variation is not aligned with acceptability, then manufacturing needs to know be notified even faster. Sourcing managers need access to timely information regarding the performance of suppliers, both for color development and manufacturing. These same results need to be tabulated by product and market, season, and other parameters.

Communication will take the form of electronic messaging, updating on-line databases containing summarized results of PLM systems, and closed-loop correction systems. As long as humans are the ones to purchase products, there will be some inconsistencies in color difference assessment. The challenge of any color program is to establish a regimen which generates an acceptable number of “wrong” decisions (however “wrong” is defined), with the benefit of speedy, accurate, quantitative measurement of color performance.

Conclusion

Our final snapshot of color measurement in the future will include an integration of technologies we can glimpse today – nanotechnology for measurement and wireless communication, seamless databases and the mining tools for efficient PLM, self-improving manufacturing processes. The result of such systems will be to provide netter tools for trained color managers to control and steer their processes to produce the desired products for our world.