KONICA MINOLTA | SENSING ASIA

THE STANDARD IN MEASURING COLOR

Defining Color Tolerance

Introduction

Most manufacturing, research & development (R&D) and quality assessment (QA) process for products will come to a stage where color is involved. Color surrounds us and we associate color with quality. There is no escaping from the fact that color has an effect on our thoughts and how we perceive these products.

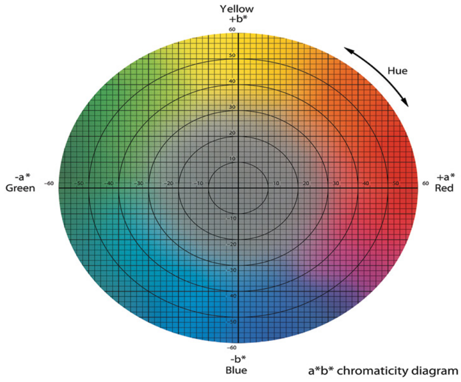
The goal for manufacturers in implementing color to a product is to make it appealing or to match the company's image. Color is used to stimulate the design of a product and excite customers, making them interested in acquiring the product. Should there be a discrepancy in color, customer's satisfaction may be compromised. And the branding of the company may also be compromised.

To get the right color, color quantification is used and color tolerance established to effectively keep the color of a product with limits to meet color specifications.

Color tolerance is a limit set to control acceptance of the difference in color between the sample and the master target. Tolerance values are defined between the suppliers and client. It is usually employed in the R&D and QA/QC process to determine if the color of the sample meets the requirement.

Color Difference

Color difference is a distance metric used in the world of color to determine the difference in color quantification.



a*b* chromaticity diagram

The most common CIE color space CIEL*a*b* uses the euclidean distance (delta E_{ab}) or the box tolerance (expressed as + or – limits on L*, a*, b*) to determine the difference in color in the L*a*b* color space system. To effectively define color difference tolerance, here are some points to take note of.

Define a Color Standard:
What Color Is Intended For the Finished Product?

This is a standard that should be defined within the company or between the suppliers and client. To set the standard, colorimeters are used to measure the color of the master product.

Color Assessments:
What Colors Are Acceptable?

Color assessments are performed to select the correct or closest color to match the master sample. Firstly, gather samples or color batches that appear similar in color to the master and visually assess them by using a light booth. Next, select the colors that are visually different from the standard but are still within the range of acceptance in matching the master. Once the color assessments are completed, gather the samples for measurement. Note that the sensitivity of the human eye varies from person-to-person, which may cause color to appear differently to each individual. It is recommended to use a committee to conduct these color assessments to maintain consistency.

Define Tolerance Values:
Are The Values in the Range of Acceptability?

Take the measurements of the samples from the visual color assessments using a colorimeter or spectrophotometer. The difference in color between samples and the master should be compared using a color difference system (e.g. ΔE^*ab or $\Delta L^*, \Delta a^*, \Delta b^*$). With the data collected, establish the maximum range of the tolerance limit (+ and -) using the values furthest from the master color. These values are re-evaluated throughout the process to continuously refine and obtain the ideal tolerance values for the correct color.

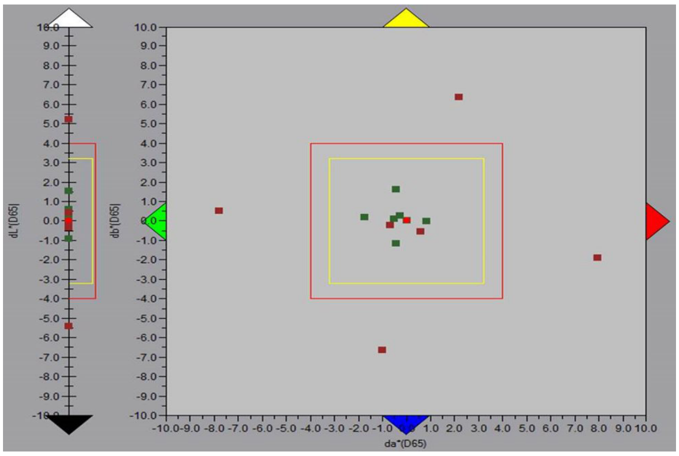
Defining Color Tolerance

Establish a Color Difference System: Rectangular, Circular or Elliptical?

Tolerance values should correlate well with the human eye so that color is both numerically and visually acceptable. This ensures consistency from each batch to the next. There are several types of color difference systems ranging from box tolerance (ΔL* Δa* Δb*), ΔE*ab, CIE94 or CIE dE2000 that are available for selection that best suits the application.

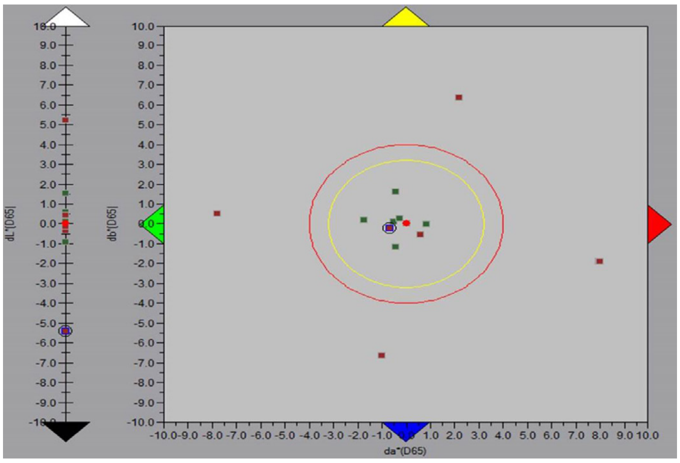
Box Tolerance (Rectangular)

This is the color difference system using either a singular or dual to triple values to establish the tolerance in a line form (singular data), box form (dual data) or cube form (triple data) from each individual L*, a*, b* data. For line form, all data that falls on the line are accepted while the remaining that falls out of the line are rejected. The same goes for the box and cube form, all data within the box or cube are accepted awhile the remaining that are not within the box or cube are rejected.



Delta E*ab or ΔE*ab (Circular)

The ΔE*ab is a circular or sphere type of color difference system. This system uses the calculation and averaging of all the 3 values from the L*a*b* system to derive a single ± value that determine the color difference. The tolerance established will form a sphere in the L*a*b* color space. Data that is within the sphere is accepted while data out of the sphere is rejected.



$$\Delta E^*_{ab} = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2}$$

CIE94

In 1995, CIE published an equation called CIE94. It uses the L*a*b* coordinates to calculate the differences in lightness, chroma and hue (L*C*h* color space system). The equation's weighting functions are mostly based on tolerance data attained from automotive coating samples experiments where the surfaces of the sample are smooth.

$$\Delta E^*_{94} = \sqrt{\left(\frac{\Delta L^*}{K_L S_L}\right)^2 + \left(\frac{\Delta C^*_{ab}}{K_C S_c}\right)^2 + \left(\frac{\Delta H^*_{ab}}{K_H S_H}\right)^2}$$

CIE dE2000 (Elliptical)

The CIE dE2000 or dE*00 is a revision since 1994 (CIE94) by CIE to help address the perceptual uniformity issues. This revision is refined by the addition of 5 compensations into the formula. The 5 compensations are:

1. A hue rotation term (R_T)

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2. Compensation for neutral colors
   (The primed values in the L*C*h differences)
3. Compensation for lightness (S_L)
4. Compensation for chroma (S_C)
5. Compensation for hue (S_H)

$$\Delta E^*_{00} = \sqrt{\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T \frac{\Delta C'}{K_C S_C}\frac{\Delta H'}{K_H S_H}}$$

This is a system that is based on the color discrimination threshold of the human eye. This tolerance is established to address the weaknesses of those other tolerance systems and at the same time, help improve accuracy.

The limit values defined forms an ellipsoid around the master color. Data that falls inside the defined tolerance ellipsoid is graded pass, while color that falls outside of this ellipsoid is rejected.

To establish and define a good color tolerance effectively, the use of highly accurate color measurement instrumentation (spectrophotometers) and color analysis software (SpectraMagic NX Software) are required as users will then be able to define the tolerance and quantify color inconsistencies between the sample and the master easily.

Konica Minolta offers a wide range of instruments for measuring and quantifying color. For more information on color measuring instruments, please visit our Konica Minolta website at http://sensing.konicaminolta.asia/

Alternatively, you can email to us at ssg@gcp.konicaminolta.com for a free copy of 'Precise Color Communication' educational booklet or call us at +65 6895 8685 to find out more on our product range or solutions that we offer for your specific application.