Defining colour tolerance

Introduction

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

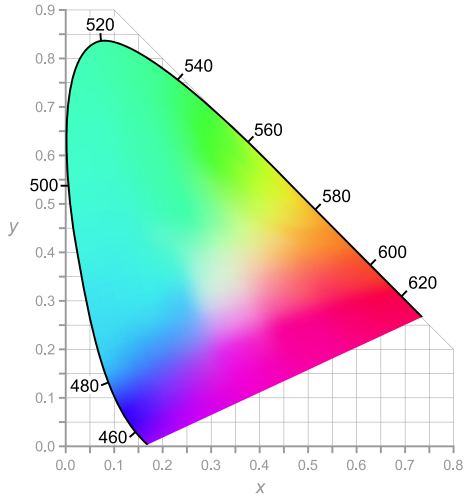
The goal for manufacturers in implementing colour to a product is to make it appealing or to match the company's image. Colour is used to stimulate the design of a product and excite customers, making them interested in acquiring the product. Should there be a discrepancy in colour, customer's satisfaction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

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

Colour tolerance is a limit set to control acceptance of the difference in colour 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 colour of the sample meets the requirement.

Colour difference

Colour difference is a distance metric used in the world of colour to determine the difference in colour quantification.



CIE Chromaticity Diagram describes colour as seen by the human eye in full daylight. Two-dimensional diagram of colours with same brightness (intensity). All colours of visible spectrum are represented.

The most common CIE colour space CIE L*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 colour in the L*a*b* colour space system. To effectively define colour difference tolerance, here are some points to take note of.

Define a colour standard:
What colour 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 colour of the master product.

Colour assessments:
What colours are acceptable?

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

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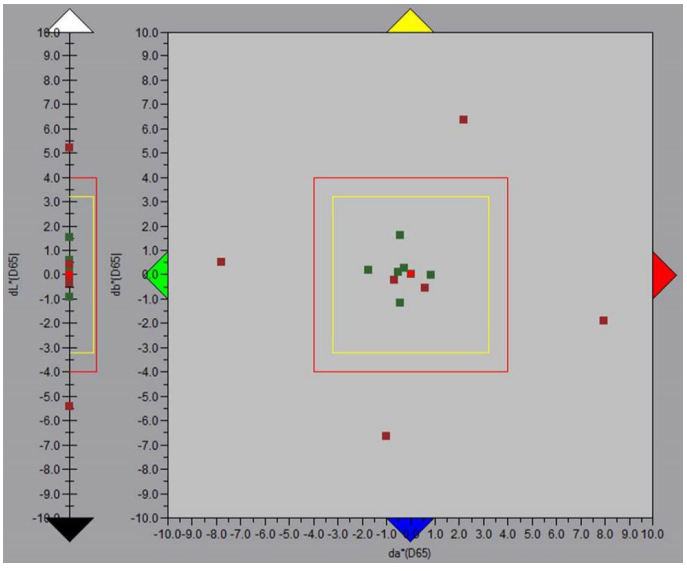
Define tolerance values:
Are the values in the range of acceptability?
Take the measurements of the samples from the visual colour assessments using a colorimeter or spectrophotometer. The difference in colour between samples and the master should be compared using a colour difference system (e.g. ΔE*ab or ΔL*,Δa*,Δb*). With the data collected, establish the maximum range of the tolerance limit (+ and -) using the values furthest from the master colour. These values are re-evaluated throughout the process to continuously refine and obtain the ideal tolerance values for the correct colour.

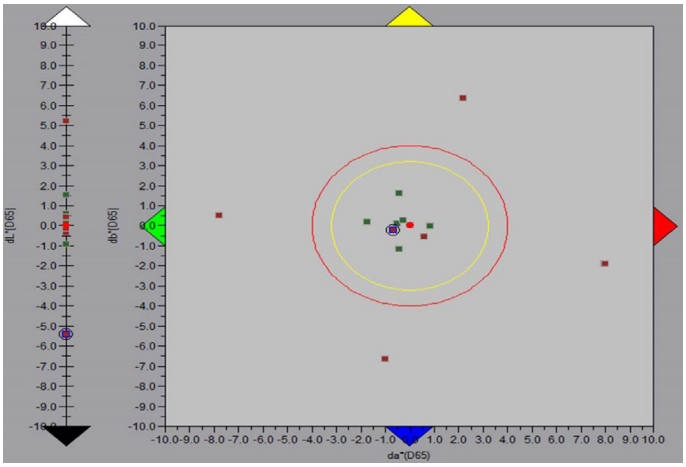
Establish a colour difference system:
Eectangular, circular or elliptical?
Tolerance values should correlate well with the human eye so that colour is both numerically and visually acceptable. This ensures consistency from each batch to the next. There are several types of colour difference systems ranging 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 colour 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 colour 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 colour difference. The tolerance established will form a sphere in the L*a*b* colour 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* colour 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 (RT)
2. Compensation for neutral colours (The primed values in the L*C*h differences)
3. Compensation for lightness (SL)
4. Compensation for chroma (SC)
5. Compensation for hue (SH)

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

This is a system that is based on the colour 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 colour. Data that falls inside the defined tolerance ellipsoid is graded pass, while colour that falls outside of this ellipsoid is rejected.

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

Konica Minolta offers a wide range of instruments for measuring and quantifying colour. From hand-held colorimeters to high precision all-in-one bench top systems, we can help you find a solution to suit your specific needs and throughput.

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