SLOVENSKI STANDARD
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Analizna kolorometrija - 2. del: Saundersonova korekcija, rešitve Kubelka-Munkove enačbe, barvna jakost in kritnost (ISO/DIS 18314-2:2022)

Analytical colorimetry - Part 2: Saunderson correction, solutions of the Kubelka-Munk equation, tinting strength, depth of shade, hiding power (ISO/DIS 18314-2:2022)

Analytische Farbmessung - Teil 2: Saunderson-Korrektur, Lösungen der Kubelka-Munk-Gleichung, Farbstärke, Deckvermögen (ISO/DIS 18314-2:2022)

Analyse colorimétrique - Partie 2: Correction de Saunderson, solutions de l'équation de Kubelka-Munk, pouvoir colorant, profondeur de teinte, pouvoir masquant (ISO/DIS 18314-2:2022)

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Analytical colorimetry —

Part 2:
Saunderson correction, solutions of the Kubelka-Munk equation, tinting strength, depth of shade, hiding power

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 256, *Pigments, dyestuffs and extenders*.

This second edition cancels and replaces the first edition (ISO 18314-2:2015), which has been technically revised.

The main changes are as follows:

— the title has been amended by “depth of shade”;

— the terms and definitions in Clause 3 have been aligned with ISO 18451-1;

— the document has been editorially revised and the bibliography has been updated.

A list of all parts in the ISO 18314 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Analytical colorimetry —

Part 2: Saunderson correction, solutions of the Kubelka-Munk equation, tinting strength, depth of shade, hiding power

1 Scope

This document specifies the Saunderson correction for different measurement geometries and the solutions of the Kubelka-Munk equation for hiding and transparent layers. It also specifies methods for the calculations of the tinting strength including the residual colour difference with different criteria and of the hiding power.

The procedures for preparing the samples for these measurements are not part of this document. They are agreed between the contracting parties or are described in other national or International Standards.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
tinting strength
colour strength
measure of the ability of a colourant to colour other materials because of its absorptive power

[SOURCE: ISO 18451-1:2019, 3.122]

3.2
relative tinting strength
relative colour strength
percentage ratio of the *tinting strength* (3.1) of the colourant under test related to the tinting strength of a reference colourant

[SOURCE: ISO 18451-1:2019, 3.105]

3.3
tinting strength criterion
parameter that describes the colouring effect of a colourant, based on its absorption

Note 1 to entry: The tinting strength criteria used in this document are the following:

— value of the Kubelka-Munk function at the absorption maximum;

— weighted sum of the Kubelka-Munk function values;

— tristimulus value Y;

— the smallest of the tristimulus values X, Y, Z;

— shade depth parameter B.

Examples of other tinting strength parameters not used in this document are the following:

— unweighted sum of the Kubelka-Munk function values;

— chromaticity given by the three colour coordinates (L^*, a^*, b^*);

— reflectance factor at the absorption maximum.

3.4
residual colour difference
colour difference that remains between the white reductions of the reference and test samples when the tinting strength criterion values are the same or have been equalized

EXAMPLE Residual colour difference is given by ΔE^*.

3.5
depth of shade
shade depth
colour depth
measure for the intensity of a colour perception that increases with increasing chroma and decreases with increasing lightness

Note 1 to entry: Colourations having the same depth of shade appear to be prepared using the same concentrations of colourants having the same tinting strength.

[SOURCE: ISO 18451-1:2019, 3.26 modified: synonyms "shade depth" and "colour depth" added]

3.6
standard depth of shade
standard shade depth
standard colour depth
SD
depth of shade (3.5) level laid down by convention

[SOURCE: ISO 18451-1:2019, 3.113, modified: synonyms "standard shade depth" and "standard colour depth" added]

3.7
hiding power
ability of coating to obliterate the colour or colour differences of the substrate

Note 1 to entry: The use of the German expressions "Deckkraft" und "Deckfähigkeit" should be avoided.

Note 2 to entry: The term "coverage" is ambiguous because it is used in some instances to refer to hiding power and in others to mean spreading rate. The more precise terms hiding power and spreading rate should always be used.

[SOURCE: ISO 18451-1:2019, 3.47]

4 Symbols and abbreviated terms

a constant

a^*	CIELAB colour coordinate
$a(\varphi)$	factor
$a(\lambda)$	auxiliary variable
b^*	CIELAB colour coordinate
$b(\lambda)$	auxiliary variable
B	shade depth parameter
C_{rel}	relative tinting strength
D_{m}	hiding power value indicating the area of the contrast substrate concerned, in m^2, which can be coated with 1 kg
D_{v}	hiding power value indicating the area of the contrast substrate concerned, in m^2, which can be coated with 1 l
$F(\lambda)$	Kubelka-Munk function
$F'(\lambda)$	modified Kubelka-Munk function
$g(\lambda)$	weighting function (defined as the sum of the colour matching functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, and $\bar{z}(\lambda)$ for a 10° standard observer)
h	thickness
K	coefficient
$K(\lambda)$	absorption coefficient
$(K/S)_{\mathrm{r}}$	Kubelka-Munk value of reference sample
$(K/S)_{\mathrm{t}}$	Kubelka-Munk value of test sample
L^*	CIELAB lightness
m_{r}	mass fraction of coloured pigment reference sample
m_{t}	mass fraction of coloured pigment test sample
n	refractive index
r_0	reflection coefficient at the surface for directional light incident perpendicular from outside
$\overline{r_0}$	reflection coefficient at the surface for directional light incident parallel under 45° from outside
r_2	reflection coefficient for light incident diffusely from the inside of the specimen
$R(\lambda)$	reflectance spectrum
$R(\lambda)_{\infty}$	reflectance of infinitely thick layer
$R(\lambda)^*$	Saunderson-corrected reflectance spectrum
$R(\lambda)^*_{\mathrm{ob}}$	Saunderson-corrected reflectance of the black substrate

$R(\lambda)^*_{ow}$ Saunderson-corrected reflectance of the white substrate

$R(\lambda)^*_{b}$ Saunderson-corrected reflectance of the sample on black substrate

$R(\lambda)^*_{w}$ Saunderson-corrected reflectance of the sample on white substrate

$R'(\lambda)$ modified reflectance spectrum including surface effects

s saturation

$S(\lambda)$ scattering coefficient

SD standard depth of shade

T weighted sum

x, y chromaticity coordinates

X, Y, Z tristimulus values

$''E^*$ residual colour difference

$''E^*_{ab}$ CIELAB colour difference

φ hue angle

φ_o closest angle in the table below the hue angle

5 Saunderson correction

5.1 General

For colorimetric calculation it is necessary to account for surface phenomena to obtain viable results. The formulas are known as Saunderson correction, their derivation can be found in References[1] and[2] The necessary coefficients are solutions of the Fresnel formulae[3] depending on the index of refraction for the given binder.

The formulae are derived assuming an ideal surface, a perfectly hiding layer and a perfectly diffuse scattering of light inside the interior of the specimen. Any deviation from these assumptions shall lead to consideration of the usefulness of the following calculations.

The formulae given here are for two of the most widespread geometries: diffuse incidence, 0° observation (d:0°) (Formula (1), Formula (2) and Formula (3)) and 45° incidence, 0° observation (45°:0°) (Formula (4) and Formula (5). In nearly every colorimeter used, the measurement angle is not 0° but 8°. This deviation is not considered problematic.

The constants necessary for the calculation are the following:

r_0: reflection coefficient at the surface for directional light incident perpendicular from outside. For n = 1,5 r_0 = 0,040.

$\overline{r_0}$: reflection coefficient at the surface for directional light incident parallel under 45° from outside. For n = 1,5, $\overline{r_0}$ = 0,050.

r_2: reflection coefficient for light incident diffusely from the inside of the specimen. For n = 1,5, r_2 = 0,596.

5.2 Incidence diffuse, observation 0° (d:0°)

The constant a = 1 if a gloss trap is closed and a = 0 if the gloss trap is open and the specular reflection is excluded.

$$R(\lambda) = \mathrm{a}r_0 + \frac{(1-r_0)(1-r_2)R(\lambda)^*}{1-r_2R(\lambda)^*} \tag{1}$$

$$\text{for a} = 1: \qquad R(\lambda)^* = \frac{R(\lambda)-r_0}{1-r_0-r_2\left[1-R(\lambda)\right]} \tag{2}$$

$$\text{for a} = 1: \qquad R(\lambda)^* = \frac{R(\lambda)}{1-r_0-r_2+r_2\left[r_0+R(\lambda)\right]} \tag{3}$$

5.3 Incidence 45°, observation 0° (45°:0°)

$$R(\lambda) = \frac{(1-r_0)(1-\bar{r}_0)\frac{1}{n^2}R(\lambda)^*}{1-r_2R(\lambda)^*} \tag{4}$$

$$R(\lambda)^* = \frac{n^2R(\lambda)}{1-r_0-\bar{r}_0+r_0\bar{r}_0+n^2r_2R(\lambda)} \tag{5}$$

6 Solution of the Kubelka-Munk equations

The Kubelka-Munk theory describes the reflection of a pigmented layer by two constants: absorption [$K(\lambda)$] and scattering [$S(\lambda)$]. It is based on the following assumptions:

a) ideally diffuse radiation distribution on the irradiation side;

b) ideally diffuse radiation distribution in the interior of the layer;

c) no consideration of surface phenomena resulting from the discontinuity in refractive index.

For an infinitely thick, respectively hiding layer with a reflectance of $R(\lambda)_\infty$, the following solutions (Formula (6) and Formula (7)) are found, which allow the determination of the relation between the scattering and the absorption coefficient:

$$\frac{K(\lambda)}{S(\lambda)} = \frac{\left(1-R(\lambda)_\infty\right)^2}{2R(\lambda)_\infty} \equiv F\left(R(\lambda)_\infty\right) \tag{6}$$

respectively the inverse:

$$R(\lambda)_\infty = 1 + \frac{K(\lambda)}{S(\lambda)} - \sqrt{2\left(\frac{K(\lambda)}{S(\lambda)}\right) + \left(\frac{K(\lambda)}{S(\lambda)}\right)^2} \tag{7}$$

For the determination of the scattering and absorption coefficient, two different methods can be applied (the Saunderson correction shall be used):