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Analizna kolorometrija - 2. del: Saundersonova korekcija, rešitve Kubelka-Munkove enačbe, barvna jakost in kritnost (ISO 18314-2:2015)

Analytical colorimetry - Part 2: Saunderson correction, solutions of the Kubelka-Munk equation, tinting strength, hiding power (ISO 18314-2:2015)

Analytische Farbmessung - Teil 2: Saunderson-Korrektur, Lösungen der Kubelka-Munk-Gleichung, Farbstärke, Deckvermögen (ISO 18314-2:2015)

Analyse colorimétrique - Partie 2: Correction de Saunderson, solutions de l'équation de Kubelka-Munk, force colorante, pouvoir couvrant (ISO 18314-2:2015)

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Analytical colorimetry —

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

Analyse colorimétrique —

Partie 2: Correction de Saunderson, solutions de l'équation de Kubelka-Munk, force colorante, pouvoir couvrant

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Foreword

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The committee responsible for this document is ISO/TC 256, *Pigments, dyestuffs and fillers*.

ISO 18314 consists of the following parts, under the general title *Analytical colorimetry*:

— *Part 1: Practical colour measurement*

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

— *Part 3: Special indices*

Analytical colorimetry —

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

1 Scope

This part of ISO 18314 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 part of ISO 18314. They are agreed between the contracting parties or are described in other national or International Standards.

2 Terms, definitions, symbols, and abbreviated terms

2.1 Terms and definitions

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

2.1.1
tinting strength
measure of the ability of a colorant, based on its absorption, to impart colour to other materials

2.1.2
relative tinting strength
C_{rel}
percentage ratio of those mass fractions of the coloured pigment reference and test samples (m_r and m_t, respectively) that cause the particular tinting strength criterion used to have identical values for the reference and test samples

2.1.3
tinting strength criterion
parameter that describes the colouring effect of a colorant, based on its absorption

Note 1 to entry: The tinting strength criteria used in this part of ISO 18314 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 part of ISO 18314 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.

2.1.4
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 Given by ΔE^*.

2.1.5
standard shade depth
shade depth
measure of the intensity of a colour sensation, which increases with increasing chroma and decreases with increasing lightness

Note 1 to entry: Standard shade depths are values set by convention. For colourimetric purposes, the standard shade depth is defined by the shade depth parameter B = 0, which is calculated from the tristimulus value, *Y*, and the chromaticity coordinates, *x* and *y*.

2.1.6
hiding power
ability of a pigmented medium to hide the colour or the colour differences of a substrate

2.2 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

$(K/S)_r$ Kubelka-Munk value of reference sample

$(K/S)_t$ 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

$R(\lambda)^*$ reflectance of the sample

$R(\lambda)^*_{ob}$ 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

T weighted sum

x, y chromaticity coordinates

X, Y, Z tristimulus values

ΔE^* residual colour difference

ΔE^*_{ab} CIELAB colour difference

φ hue angle

φ_0 closest angle in the table below the hue angle

3 Saunderson correction

3.1 General

For colourimetric 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°) and 45° incidence, 0° observation (45°/0°). In nearly every colourimeter 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 $n = 1,5$, $r_2 = 0,596$.

3.2 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.

$$R(\lambda) = ar_0 + \frac{(1-r_0)(1-r_2)R(\lambda)^*}{1-r_2R(\lambda)^*} \quad (1)$$

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

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

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

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

$$R(\lambda)^{*} = \frac{n^2 R(\lambda)}{1 - r_0 - \bar{r}_0 + r_0\bar{r}_0 + n^2 r_2 R(\lambda)} \tag{5}$$

4 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 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):

Method 1 Measurement of the reflectance of an infinite thick (respectively hiding) layer and the reflectance $R(\lambda)^*$ of a coating of the thickness, h, on a substrate of the reflection $R(\lambda)_0^*$.

$$a(\lambda) = \frac{1}{2}\left(\frac{1}{R(\lambda)_\infty^*} + R(\lambda)_\infty^*\right) \tag{8}$$

$$b(\lambda) = a(\lambda) - R(\lambda)_\infty^* = \frac{1}{2}\left(\frac{1}{R(\lambda)_\infty^*} - R(\lambda)_\infty^*\right) \tag{9}$$

$$S(\lambda) = \frac{1}{b(\lambda)\,h}\,\mathrm{Arcoth}\,\frac{1 - a(\lambda)\left[R(\lambda)^* - R(\lambda)_0^*\right] + R(\lambda)^* R(\lambda)_0^*}{b(\lambda)\left[R(\lambda)^* - R(\lambda)_0^*\right]} \tag{10}$$

$$K(\lambda) = S(\lambda)\left[a(\lambda) - 1\right] \tag{11}$$

Method 2 This method applies two layers of equal thickness (h) on black and white substances. After the determination of the auxiliary variables $a(\lambda)$, $b(\lambda)$ according to Formulae (12) and (13), either Formula (14) or (15) may be used to calculate the scattering coefficient $S(\lambda)$. The possibility with the least experimental uncertainty should be chosen.

$$a(\lambda) = \frac{\left[1 + R(\lambda)_w^* R(\lambda)_{ow}^*\right]\left[R(\lambda)_b^* - R(\lambda)_{ob}^*\right] + \left[1 + R(\lambda)_b^* R(\lambda)_{ob}^*\right]\left[R(\lambda)_{ow}^* - R(\lambda)_w^*\right]}{2\left[R(\lambda)_b^* R(\lambda)_{ow}^* - R(\lambda)_w^* R(\lambda)_{ob}^*\right]} \tag{12}$$