

Selection Of Optoelectronic Methods For Controlling Moisture And Whiteness (Bleaching) Quality Of Textile Materials, As Well As Justifying Their Use

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Abstract

Moisture control of textile materials is carried out at all stages of technological processes in the textile industry. The most accurate technical means of humidity control and measurement are optoelectronic devices operating in the infrared range. Optoelectronic devices operating in the infrared range are optical converters, which are based on the principle of infrared rays falling on the material being tested for moisture and returning from it.

Keywords: Fabric, whiteness, instrumental, spectral, Optoelectronic, Correlation.

Introduction

Nowadays, the quality of textile materials is considered to be their degree of whiteness or bleaching. The degree of whiteness of fabrics is determined on the basis of instrumental and spectral methods, and it is a very complex issue in the field of color measurement.

The optoelectronic gloss measuring device (OEY) is designed to remove the gloss of cotton fabrics (Fig.1). It is measured when light rays fall on the painted surface of the fabric at an angle of $45^\circ/45^\circ$. The goal is to quantitatively evaluate the perception of the specified coating and other surfaces, the spectrum of vision by the human eye.

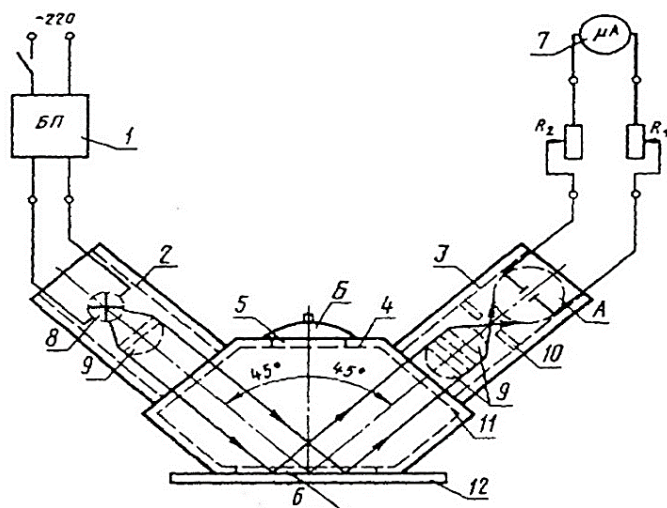


Fig.1. Scheme of bleaching measuring optoelectronic device

The structure of the optoelectronic gloss measuring instrument (OEY)

- light-emitting source;
- lens;
- the flow of parallel rays falling on the surface under examination directing and receiving lenses;
- diaphragms that receive rays.

The angle between the perpendicular to the inspected surface and the stream of falling parallel rays is: $20^\circ \pm 0.1^\circ$, $60^\circ \pm 0.1^\circ$ or $85^\circ \pm 0.1^\circ$ (Table 1).

The difference between the angle of refraction of the incident beam and the receiver should not exceed $\pm 0.1^\circ$. The surface width of the tested plate should be around 10mm to get the average value of the wear. The angular size of the receiving aperture is measured from the receiving lens.

For a light receiving device, the spectral coefficient of the correction of the light filter is determined by the following formula:

$$\tau(\lambda) = k \frac{V(\lambda)S_c(\lambda)}{s(\lambda)S_s(\lambda)}, \quad (1)$$

Here: k-calibration (comparative) constant, $V(\lambda)$ -illumination effect, $S_c(\lambda)$ -relative energy distribution spectrum, $s(\lambda)$ - relative detection spectrum of the photocell, $S_s(\lambda)$ - real source power distribution spectrum.

Table 1 The aperture of the receiver and the relative dimensions and angles of the image

Parameter	1) on the measurement plane			Perpendicular to the measuring plane		
	σ^2 corner	$2 \tan \sigma/2$	Relative size	σ^2 corner	$2 \tan \sigma/2$	Relative size
Image source aperture	$0,75^\circ \pm 10,1^\circ$	$0,0131 \pm 0,0018$	$0,171 \pm 0,023$	$2,5^\circ \pm 0,1^\circ$	$0,0436 \pm 0,0018$	$0,568 \pm 0,023$
20° aperture of the measuring device at an angle	$1,80^\circ \pm 0,05^\circ$	$0,0314 \pm 0,0009$	$0,409 \pm 0,012$	$3,6^\circ \pm 0,1^\circ$	$0,0629 \pm 0,0018$	$0,819 \pm 0,023$
60° aperture of the measuring device at an angle	$4,4^\circ \pm 0,1^\circ$	$0,0768 \pm 0,0018$	$1,000 \pm 0,023$	$11,7^\circ \pm 0,2^\circ$	$0,2049 \pm 0,0035$	$2,668 \pm 0,046$
85° aperture of the measuring device at an angle	$4,0^\circ \pm 0,3^\circ$	$0,0698 \pm 0,0052$	$0,909 \pm 0,068$	$6,0^\circ \pm 0,3^\circ$	$0,1048 \pm 0,0052$	$1,365 \pm 0,068$

Methods.

Measuring the whiteness of materials by reflectometric method.

Reflectometric measurement of surface whiteness of materials has been widespread since the 1960s and is still used today.

This method is based on the principle of reflection of electromagnetic waves from the uneven surface of materials. It can determine the whiteness of the smoothest surfaces. If the ratio of the uneven height of the material to the electromagnetic wavelength is less than one, this material is considered to have the smoothest surface. Theories of propagation of electromagnetic waves from highly smooth surfaces are divided into two types: a) theory of scalar wave propagation b) theory of vector wave propagation. These theories are based on Kirchhoff's approximate solutions or the method of small excitation of the electromagnetic diffraction problem.

The theory of scalar wave return takes into account the static properties of surfaces. The theory of vector wave return, in addition to the above, also takes into account the nature of propagation of electromagnetic rays (currents).

Constraints corresponding to the real conditions of measurement, the conclusions of the scalar theory are appropriate, physical models of absorbing surfaces, and geometric relations are also appropriate.

Mathematical expressions of the boundary conditions are still being determined, in the xy-coordinate system (Fig. 2) as follows:

$$V = 1; \quad \frac{\sigma}{\lambda} \ll 1; \quad \frac{T}{\lambda} \ll 1; \quad kR \ll 1;$$

$$kT \left(\frac{L}{R_{1,2}} \right) \cos^2 \psi \ll 1; \frac{L}{R_{1,2}} \ll 1; \quad (2)$$

if $k \gg 2\pi/T$, after $k\sigma \sin \psi \ll 1$, agar $k \ll 2\pi/T$ kase

$$\frac{2\pi\sigma}{T} \ll 1. \sigma \sqrt{k^2(k \sin \psi + 2\pi/T)^2} \gg 1 \quad (3)$$

Here: λ -propagating wavelength; T -correlation interval; $k=2\pi/T$ - number of knots; ψ -is the angle of incidence of rays, θ -is the angle of return of rays.

R - surface curvature radius; R_1, R_2 - are the distances from the surface to the source of light propagation and to the point of observation, respectively. $\Delta\omega_r$ - is the expansion angle. L is the size of the illuminated area;

The mutual location of the observation points, the wave reception angle α_0 , and the boundary conditions of the illuminated area are as follows

$$\sigma: \left(\frac{T}{\lambda} \right)^4 (2L^2/R_2^2) \left(\frac{\alpha_0}{2} \right)^2 \leq 3 \cdot 10^{-4} \quad (4)$$

The unevenness of the examined surfaces does not affect the absorption of waves. Perhaps it causes the flow of light rays to spread over the surface.

$$\frac{F_D}{F_0} = 1 - \frac{F_3}{F_0} = 1 - 1 \exp \left\{ - \left(\frac{4\pi\sigma \cos \varphi}{\lambda^2} \right)^2 \right\} \approx (4\pi\sigma \cos \varphi / \lambda)^2. \quad (5)$$

Here: F_D - is the diffusion return of the flow of light rays in the hemispherical space; F_3 -return of the flow of light rays in the right direction;

F_0 - is the total return of the flow of light rays in the hemispherical space;

This relationship has been confirmed in experiments. The angular distribution of refracted (returned) waves depends on the height of the surface roughness, i.e. the correlation function of the non-textel height:

$$f_{ic} = \frac{8\pi^4 \sigma^2}{\lambda^4 \cos \theta \cos \psi} \int_0^\infty J_0(v_{xy}\tau) C(\tau) \tau d\tau; \quad (6)$$

$$v_{xy} = \frac{2\pi}{\lambda} (\sin \theta - \sin \psi).$$

Here: $J_0(v_{xy}\tau)$ - is the Bessel function of the zeroth order; $C(\tau)$ - is a normalized correlation function.

Usually, the distribution function of the light flux is $F(\theta, \psi)$, θ -return $\Delta\omega_r$ -by angle: $F(\theta, \psi) = F_n V(\psi) f_{ic}(\theta, \psi) \cos \theta \Delta\omega_r / \pi$.

Here: F_n is the incident light flux; $V(\psi)$ - is the coefficient of absolute return by the angle of ψ -reflection.

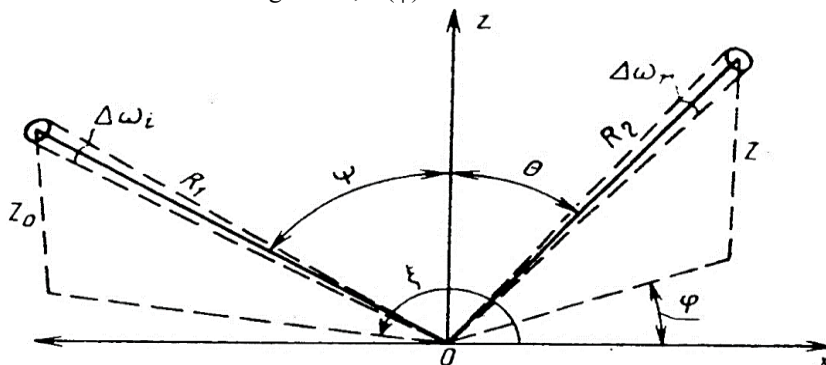


Fig.2. Scheme of light falling and returning to a high smooth surface

In order to use the equations of scholastic theory, it is necessary to know the uneven height correlation function in addition to the uneven height distribution law. The density spectrum of the correlation function is expressed by Fourier transforms as follows:

$$W(v_{xy}) = \frac{1}{2\pi\sigma^2} \int_0^\infty J_0(v_{xy}\tau) C(\tau) \tau d\tau \quad (7)$$

Experiments and results.

Static analysis of extremely smooth surfaces

In order to test the theoretical connections and compare the results, σ and T -reflectometric methods were compared with other methods in terms of physical meaning.

Modern methods and tools for researching ultra-smooth surfaces are presented in the work: multibeam interferometer, Twyman-Green interferometer, multibeam interferometer Fizeau microscope, equichromatic beam multibeam microscope, multibeam scanner Fizeau interferometry, ellipsometer, electron stereomicroscope, standard polar microscope. In determining the statistical parameters of surface roughness, the above-mentioned measuring tools are considered universal.

State of the instruments for measuring the whiteness of ultra-smooth surfaces

Currently, various reflectometric methods for determining σ and T are known.

They determine the parameters of the reflected rays using theoretical formulas. They can be divided into the following classifications according to measurement schemes:

1. Determination of σ , the flux of reflected rays by the ratio of fluxes returned in the general hemispherical space: $F_a/F_0: F_a/F_0 = \exp [-(4\pi\sigma\cos\theta/\lambda)^2]$.

2. Determination of σ by the ratio of the flux of reflected rays to the flux returned from the examined surface: $F_{a2}/F_{a1} = \exp [-(4\pi\sigma/\lambda)^2(\cos^2\theta_2 - \cos^2\theta_1)]$.

Determination of σ , the ratio of the flux of reflected rays to the flux returned from the examined surface, by means of two different wavelengths.

$$\frac{F_{32}}{F_{31}} = \exp [-(4\pi\sigma\cos\theta)^2 \left(\frac{1}{\lambda_2^2} - \frac{1}{\lambda_1^2} \right)].$$

3. Determining σ , the ratio of the diffusion current to the return flows in the general hemispherical space: F_{π}/F_0 [10, 28]: $F_{\pi}/F_0 = 1 - \exp [-(4\pi\sigma/\lambda)^2] \approx (4\pi\sigma/\lambda)^2$.

4. Determination of σ and T by the return of the beam flow at different angles: $F_{\pi}/F_0 = \exp [-(4\pi\sigma/\lambda)^2] + \{1 - \exp [-(4\pi\sigma/\lambda)^2]\} [1 - \exp [-(4\pi\sigma\alpha/\lambda)^2]]$, where α — $\Delta\omega_r$ — is the corresponding semi-flat angle.

5. Determination of σ , the ratio of the flux of reflected rays to the flux returned from the surface of the examined sample depending on different angles:

$$\frac{F(\theta)}{F'(\theta)} = (\sigma/\sigma_0)^2$$

6. Determining σ , the flow of reflected rays, taking into account the return of the T-diffusion wave in relation to the flow returned from the surface of the sample under investigation: $\frac{F_3}{F'_3} = \exp [-(\frac{4\pi\sigma\cos\theta}{\lambda})^2]$; $\frac{F_D}{F'_D} = f(\sigma, T)$.

Determining the density spectral function based on the light scattering indicator.

7. Determination of the correlation function according to the ray propagation indicator.

8. Determination of σ and T of two different current ratios by return angles

$F(\theta_1)/F_a$ и $F(\theta_2)/F(\theta)_1$.

Conclusions.

- The second and third methods are not sensitive enough when measuring the roughness of very smooth surfaces;
- In order to use the fifth, sixth and seventh methods, it is necessary to have a tested sample that is compared with the tested sample;
- The first and fourth methods cannot be used on the same platforms. The fourth method is used in the USA and at the State Optical Institute. In this method, only one parameter of roughness (unevenness) can be determined;
- determination of the density spectrum of the correlation function by the reflectometric method has many advantages compared to conventional methods. It does not require a lot of work and time.

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