Рис.28. Статуя Свободы (Манхэттен, [8]) 1886 г.

Информация (1886) отсчитывается от белой полоски внизу по контуру круга и по часовой стрелке.

Применение 4-хэлементных форматов в бытовом искусстве безгранично. Оцифровыванные достопримечательности изобразительного искусства могут войти в каждый дом.

ИСТОЧНИКИ

1. Патраль А.В. 4-сегментный и 4-точечный форматы. Wschodnioeuropejskie Czasopismo Naukowe. 2018. № 3-1 (31). С. 52-71.

2. Патраль А.В. Устройство для индикации с наилучшей идентификацией знаков. Патент на изобретение №2460151 выдан 27 августа 2012 г.

3. Википедия. Эльсуорт Келли.

4. www.russika.ru – Л - Линейный 4-хточечный формат. Патраль А.В.

5. Википедия. Флаги государств.

6. Википедия. Достопримечательности Японии.

7. Википедия. Достопримечательности Кемерово.

8. Википедия Достопримечательности США.

METHODS AND DEVICES FOR CONTROLLING THE ANISOTROPY OF THE ANGULAR DISTRIBUTION OF FIBERS IN FIBER MATERIALS

Pavel Shlyakhtenko

Professor Emeritus, Doctor of Technical Sciences,

Saint-Petersburg State University of Industrial Technologies and Design, Russia

ABSTRACT

Optical methods and appropriate devices for monitoring the angular distribution of fibers in flat fiber materials are considered. An original method is proposed, based on the illumination of the studied fiber of the beam and the subsequent analysis of the angular pattern of backscattering. Method is suitable for the study of materials such as semi-finished spinning, paper and other similar fibrous materials. The proposed method has high sensitivity and allows you to control the angular distribution of fibers in moving fiber-containing materials during their production and at various stages of production. Two types of devices that implement the proposed method are considered.

Keywords: Polarization of Light Upon Reflection, Fiber Angular Distribution, Fiber aterials, Spinning Semi-Finished Products

Introduction

In the manufacture of yarn, nonwovens, paper and other similar materials, the fibers contained in the material are oriented mainly along the machine direction of pulling the material during its manufacture. The angular distribution of fibers relative to this direction has a significant impact on the properties of the final product, its consumer and strength properties.

Currently, to control the degree of anisotropy in the angular distribution of fibers in fibrous materials, the following methods are known and sometimes used: projection, methods using radioisotope preparations, electrophoretic, method for integrated assessment the structure of ribbons according to the magnitude of the work of discontinuity measured on samples [1].

All these methods are time consuming, require significant time costs, are designed to work on samples, and therefore, in principle, can not be applied to the current control of this parameter.

More promising are the optical control methods described in [2].

A method and device for optical control of the degree of parallelization of fibers in semi-finished spinning products was proposed in [3]. The method consists in the study of the backward scattering diagram using two identical photodetectors located in mutually perpendicular planes at identical angles to the optical axis, by rotating the sample of material around this axis.

The method of controlling the orientation and straightening of fibers in objects with low optical density is described in [4]. The method consists in analyzing the pattern of a small-angle diffraction of the He-Ne laser light transmitted through the sample of a batt-webs on the corresponding photodetector located in the focal plane of the objective. This method is not applicable in the case of materials with high values of average optical density.

The method of controlling the anisotropy of the angular distribution of fibers in the structure of a flat fibrous material is described in [5]. The method consists in that the image of the surface of the material under study is illuminated on a transparent basis with a parallel beam of light perpendicular to its surface and the distribution of the luminous flux transmitted through this image is analyzed in the corresponding Fraunhofer diffraction pattern.

All the methods discussed above are related to the measurement on specially prepared samples of the materials under study, and therefore cannot be used to monitor the fiber- containing material during its production.

A non-apparatus method for controlling the angular distribution of fibers in a fiber-containing material has been described in [2].

The method is based on a computer analysis of the Fraunhofer diffraction pattern calculated from a computer micro-image of the surface of the material under study with access to the numerical parameters of the controlled distribution. The method does not depend on the color and nature of the material and, unlike the hardware methods, does not contain speckles in the analyzed diffraction pattern. Experiments have shown that this method in its form is suitable for work on samples. To use it for the current control of the material, it is necessary to solve the problems associated with obtaining a variety of high-quality digital images from a moving object, their processing and averaging using the proposed algorithms in real time.

At present, there are no methods suitable for monitoring this parameter of the material in the process of its manufacture.

The development of such methods is devoted to this work.

Results and Discussion

A method allowing to assess the quality of the investigated semi-finished product using the angular diagrams of back light scattering was proposed [6] and described in [1].

Figure 1 shows a diagram of the laboratory setup, proving the basic performance of the proposed method.

Light from source 1 (W filament spiral) through a lens 2, diaphragm 3 and apertures of the rotating disk of the modulator 4 illuminates a portion of the investigated sample of material 5 perpendicular to its surface with a parallel beam.

A photomultiplier (PM) 6, oriented at an angle α to the optical axis, records the luminous flux scattered by the material in a solid angle determined by the size of the entrance pupil of the PM. The amplitude of the variable component of the flow is measured by a voltmeter 7. The device design provides the ability to set the angle α in the range of $(5–75)^0$ and the angle between the direction of material pulling and the registration plane of the backscattered light signal φ in the range of 0-2π.

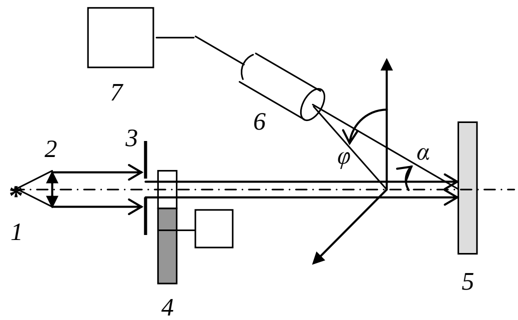

Figure 1. Block diagram of the installation

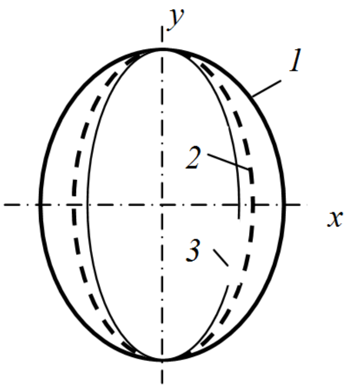

Figure. 2. Angle diagrams of backscattering normalized along the y axisfor cotton ribbons

In Figure 2 shows diagrams of reverse light scattering *U(φ)* for samples of tapes with a tactile (1), tape (2) and combed (3) machines.

As a criterion for evaluating the magnitude of the anisotropy of light scattering, the optical anisotropy coefficient *η* was introduced in [6], which is determined by the ratio

$$\eta = 1 - \chi = 1 - \frac{U_{min}}{U_{max}}, \quad (1)$$

where is the optical isotropy factor $\chi = \frac{U_{min}}{U_{max}}$ determines the degree of isotropy of the light scattering of the material under study, U_{min} is the value of the minor semi-axis of the ellipse of dispersion, U_{max} is the value of its major semi-axis.

The values of the coefficients χ, η judge the quality of the investigated semi-finished product.

A compact device was described by the method under consideration in [1] (Figure 3), consisting of two blocks: a measuring head (highlighted by a dotted line), in which light source 1 (IR LED) is located, illuminating the material under study 2 and two photodiode 3, 4, located in mutually perpendicular planes, at one angle α to the optical axis, and power supply 5, in which automatic division of signals from photodetectors 3, 4 takes place with the output of the isotropy coefficient on the digital scoreboard.

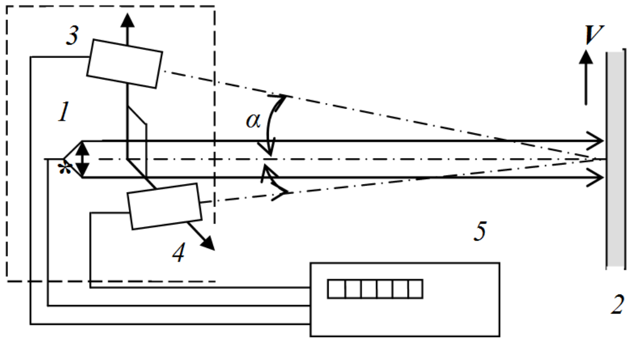

Figure 3. Scheme of the device

The device is characterized by high measurement accuracy and good noise-resistance with respect to ambient light (the third decimal point is measured steadily).

The disadvantage of this method is its relatively low sensitivity.

A method for quality control of spinning semi-finished products was proposed, which solves the problem of increasing the sensitivity of the method by illuminating the material under study with flat polarized light with a polarization plane rotating about the optical axis with a frequency ω [7].

Measurements proving the operability of the method were carried out at the laboratory installation shown in Figure 4 [8].

Presented in Figure 4, the laboratory setup differs from that shown in Figure 1 only by the fact that instead of the light modulator in Figure 1 - p. 4, interrupting the light beam with frequency ω, a polarization modulator (Figure 4- p. 3) was installed (polaroid film), rotating with the same frequency.

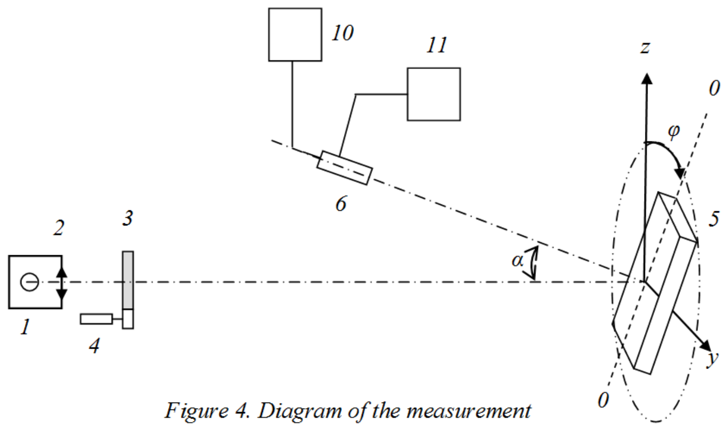

Figure 4. Diagram of the measurement

The difference of this method from that used in [6] is due to the need to separate part of the luminous flux reflected from the surface of the fibers of the material under study from the total luminous flux entering the photodetector.

The first component of the light flux is always partially plane-polarized light in such a way that it contains mainly the component of vector E, oscillating in a plane perpendicular to the plane of incidence of light on the surface of the cylindrical fiber, and therefore carries information about the orientation of this fiber in the test material.

The second non polarized component of the light flux, due to light scattered in the volume of fibers.

The intensity of the first component is proportional to the number of equally oriented fibers in the illuminated near-surface region, from which light enters the photodetector after the first reflection.

In the case of measuring the amplitude of only the variable component of the luminous flux according to the scheme of Figure 1, only the variable with a frequency 2ω of a plane-polarized component is distinguished from the total luminous flux entering the photodetector 6 [8].

In Figure 5 shows the angular diagrams $\widetilde{U}(\varphi)$ normalized to the maximum in polar coordinates, obtained from measurements according to the scheme in Figure 4 for capacitor paper with a thickness of 10 microns - cr. 1, for belkozinovoy sausage casings - cr. 2, and printer paper - cr. 3.

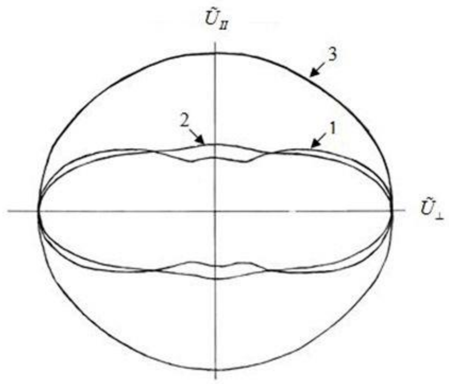

Figure 5. Angle charts of reverse light scattering for a condenser paper (1), a sausage casing (2), a printer paper (3)

In Figure 6 - similar diagrams $\widetilde{U}(\varphi)$ for a tape of non-transparent carbon monofilaments - cr. 1, capacitor paper - cr. 2 and the viscose ribbon from the second transition of the belt machine - cr. 3 [14].

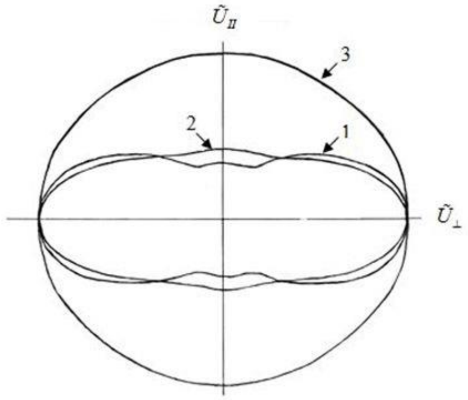

Figure 5. Angle diagrams reverse light scattering for condenser paper (1), sausage casing (2), printer paper (3)

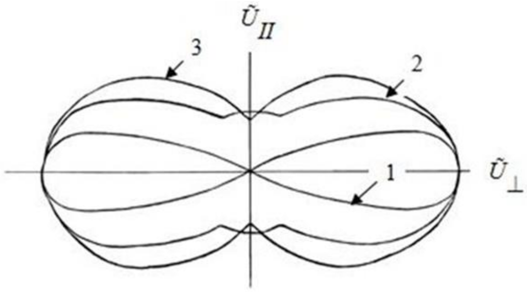

Figure 6. Angle charts of reverse light scattering for a tape of carbon fibers (1), a capacitor paper (2), a viscose tape from the second transition of a tape machine (3)

When constructing the angular diagrams, the symmetrization of the experimental data with respect to the machine direction of drawing of the samples under study was made (axis of ordinates in Figures 5, 6). This was due to the natural assumption that the deviations in the angular arrangement of the fibers to the right and left relative to the machine direction of pulling the material during its manufacture are equiprobable. To this end, when constructing the desired dependence $\widetilde{U}(\varphi)$, experimental values were measured, measured at four values of these angles φ, - φ, $\varphi + \pi$ and - $(\varphi + \pi)$ for all angles φ, except for values$\varphi = 0$, $\varphi = \pi / 2$, $\varphi = \pi$, $\varphi = 3\pi / 2$, for which averaging is carried out over two values of the variable components of the light fluxes, measured at the specified values of the angle φ and angles $\varphi + \pi$.

In Figure 7 shows a possible diagram of the device controlling the material under investigation by the method under discussion using two measured current parameters of the angular backscattering diagram $\widetilde{U}_{II}$ и $\widetilde{U}_{\perp}$. Their comparison of data in Figure 5 and Figure 6 that in all cases (except for kr.3 - Figure 6), the measured angular diagrams $\widetilde{U}$ (φ) are very different from the elliptic ones that were observed (Figure 2) in studies using the method [9].

This difference indicates a significantly higher accuracy of the proposed method.

This conclusion is supported by the presence of a “fine structure” in dependencies $\widetilde{U}$ (φ) for capacitor paper (Figure 5 - cr. 1 and Figure 6 - cr. 2), which, within the framework of measurement error, practically do not differ and consist of two components: an inverted figure-eight and a part of a circle, which we explain by the well-known composition of capacitor paper, in which, besides short (~ 2 mm) fibers, there is also an isotropic filling of ground powdered cellulose. Scattering from it "clogs" the course of dependence $\widetilde{U}$ (φ) for fibers in the central region.

The latter conclusion is completely correlated with the conclusion made in the independent spectrographic studies described for these types of capacitor paper in [1].

The type of dependence (cr. 3 in Figure 3) for a carbon monofilament tape within the framework of the error of the method coincided with the dependence obtained in the installation of Figure 1 for the same sample tape according to the method [8].

This is not surprising, since in this case, a single reflected signal is fed to the photodetector from the sample when it is reflected only from near-surface fibers (the fibers completely absorb light, and further penetration of light into the depth of the material is completely excluded).

Table 1 shows the comparative results of the calculation of the coefficient of optical isotropy χ and anisotropy η by formula (1), and by formula (2) in studies of the proposed method.

$$\eta_{\sim} = 1 - \chi_{\sim} = 1 - \frac{\tilde{U}_{II}}{\tilde{U}_{\perp}} \quad (2)$$

Table 1.

COMPARATIVE DATA.

Material	χ	η	$\chi_{\sim}$	$\eta_{\sim}$
Printer paper	0,99	0,01	0,89	0,11
Calendered capacitor paper	0,86	0,14	0,31	0,69
Matte Condenser Paper	0,87	0,13	0,29	0,71
Belkozinovy cove	0,75	0,25	0,38	0,62
Carbon tape	~0	~1	~ 0	~1
Viscose tape (2 transfer belt machine)	0,76	0,24	0,24	0,76

From the data presented in the Table 1, it is clear that the range of measurements of the reduced coefficients for all the light transmitting materials studied according to the proposed method has significantly expanded. If for the isotropy coefficient χ according to the method [6], it was measured within 0.99 - 0.76 = 0.25, then according to the proposed method of measuring the coefficient $\chi_{\sim}$, this range for the same materials has significantly expanded (0.89 - 0.24 = 0.65). This is easily explained by the fact that in this method only the variable component of the signal from the photodetectors directly related to the orientation of the fibers is recorded, and the constant diffuse non polarized component of the signal that is registered in the method [8] is cut off from registration.

For a carbon tape consisting of hard, rectilinear fibers with a small angular spread from the machine direction, the controlled value of the U_{II} and $\widetilde{U}_{II}$ signal turned out to be less than the measurement error, which indicates that there is no visible advantage of one of the methods when measuring on such light-absorbing fibrous materials.

In Figure 7 shows a possible diagram of the device controlling the material under investigation by the method under discussion using two measured current parameters of the angular backscattering diagram $\widetilde{U}_{II}$ и $\widetilde{U}_{\perp}$ [9].

The light from the white LED 1 in a parallel beam passes through the polarizer 2, rotating with a frequency ω from the engine 3, and illuminates a portion of the material under study 4 perpendicular to its surface. The light scattered by the material in the opposite direction is recorded by the same photodetectors 5 and 6. In this case, the photodetector 5 is located in the plane passing through the optical axis and the drawing speed of the material under study V, and the photodetector 6 is in the perpendicular plane.

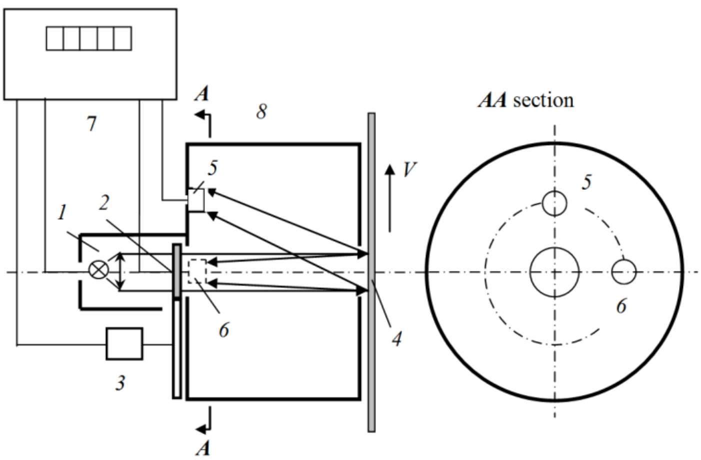

Figure 7. Diagram of the device according to the method [13]

Variable voltages from the photodetectors 5 and 6 are fed to the recording unit 7. The photodetectors are protected from external illumination by a conductive screen 8.

When light is reflected from the surface of dielectric fibers, the light is always partially polarized so that the plane of oscillations of the light vector (E) mainly oscillates in a plane perpendicular to the plane of incidence of light on the fiber. The plane-polarized component of the intensity of scattered radiation in accordance with the law of Malus is modulated with a frequency of 2ω [7]. In block 7, the amplitude values of the variable voltages from the photodetectors are measured and averaged over a time Δt equal to a given number N of periods T

$$\Delta t = NT = N\pi/\omega \qquad (3)$$

and using the average values of the amplitudes $\widetilde{U}_{II}$ (from the photodetector 5) and $\widetilde{U}_{\perp}$ (from the photodetector 6), the coefficient of optical anisotropy is calculated by the formula (2). This coefficient value is displayed on a digital display panel of block 7, which is used to judge the quality of the material under study.

In figure. 8 shows a possible diagram of a device connected to a computer allowing, in the current mode, to display the angular pattern of light scattering from a moving test fibrous material [9].

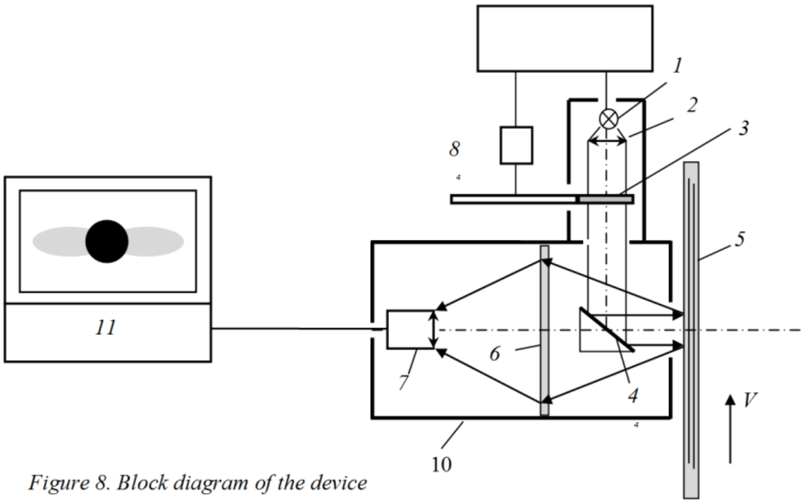

Figure 8. Block diagram of the device

The light from the white LED 1 through the lens 2 and the polarizer 3 by a parallel beam at an angle of 450 is reflected from the metal mirror and illuminates a portion of the material under study 5. The light scattered in the opposite direction falls on the isotropic diffusing light-transmitting screen 6, the image from which is recorded on the web -camera 7. The polarizer 3 rotates from the engine 8, powered from the source 9. The device is placed in a light-protective conductive screen 10. The webcam 7 displays the image on the screen 6 on the PC 11 display. The PC analyzes by blunt it webcam image according to the following algorithm (Figure 9):

1.On the image a ring of radii R_1 and R_2 is set, the center of which coincides with the center of the image;

2.On the ring at an angle φ allocated sector Δφ area ΔS;

3.At the frequency 2ω, the amplitude of the variable total luminous flux emitted by the surface ΔS is measured;

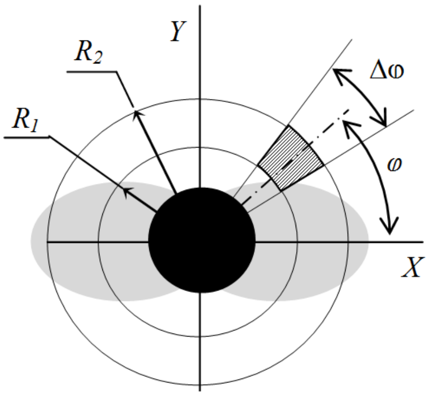

Figure 9. Scheme explaining the method of constructing an angular diagram.

4.For the set time *Δt*, the amplitude value is averaged, which is memorized;

5.The operation is repeated for all values of the angle φ with a set step in the range of $0 - 360^0$;

6.The display shows the angular scattering diagram normalized to the maximum value;

7.An additional part of the program, the algorithm of which depends on the type of material being studied, displays on the display the numerical values of the parameters by which its quality is judged. This is the anisotropy coefficient (3) or the area bounded by the angular light scattering diagram.

Obviously, the polarization method under discussion is applicable to the current control of the material under study during its production. Measurements in such conditions can only increase the measurement accuracy by averaging the allowable local inhomogeneities of the actual angular distribution of the fibers in a material moving relative to the light beam.

Conclusion

In conclusion, it can be concluded that the proposed method is promising when creating devices for monitoring the function of the angular distribution of fibers in any, both light-transmitting and non-transparent flat materials, regardless of the nature and optical properties of the fibers contained in them.

References

1. Shlyakhtenko P. G. Nerazrushaychie metodi opticheskogo kontrolia strukturnih parametrov volokno-sodergaschih materialov, SPb.: SPGUTD, 2010. – 258 s.

2. Pavel Shlyakhtenko. Diffraktsioni control tekstilnih materialov. Apparatnie i bezapparatnie

metodi: LAP LAMBERT Academic Publishing GmbH & Co. KG. – 2016. – 239 c.

3. Iakovlev V.V. Issledovanie opticheskogo metoda opredelenia stepeni parallelizatsii volokon// Izv. vuzov. TTP - 1967.- №1.- C. 56-64.

4. Kornuhina T. A., Borzunov I. G. Opredelenie orientatsii I raspriamlennocti volokon metodom rasseiania izluhenia // Izv. vuzov. TTP - 1976,- №1- C. 25-28; №3- C. 19-22.

5. Patent RF № 2463578, MPK8 G 01 N 21/00; G 01 N33/34; G 01 N33/36 / Sposob kontrolia anizotropii uglovogo raspredelenia volokon v structure ploskogo voloknistogo materiala / P. G. Shlyakhtenko, V. P. Nefedov, Yu. N. Vetrova, A. E.Rudin, P. A. Suharev. Opubl. 10.10.2012. Bul. № 28.

6. P. G. Shlyakhtenko, N. N. Truevtsev, Yu. N. Vetrova. Optiheski metod izmerenia koeffitsienta raspriamlenosti volokon v voloknistih lentah // Izvestia vuzov TTP. – 1987. – № 4. – C. 9–10.

7. Patent RF № 2437078 МПК G01N 21/21 Sposob kontrolia optiheskoi anizotropii svetorasseiania ploskih voloknistih maqterialov / P. G. Shlyakhtenko, N.N. Truevtsev, Rudin A. E., Miheeva E. I. Opubl. 20.12.2011. Bul. № 35.

8. P. G. Shlyakhtenko, Yu. N. Vetrova, A. E. Rudin, and Ya. I. Zolotova Optical method of monitoring the angular distribution of fibers in flat fiber-containing materials // Journal of Optical Technology, Vol. 78, Iss. 6, pp. 389–392 (2011).

9. Shlyakhtenko P. G. Ustroistva dlia kontrolia strukturnih parametrov voloknistih materialov po uglovoi diagramme obratnogo svetorasseiania // «Evraziiskoe Nauhcnoe Obiedinenie». Sovremennie kontsepsii nauchnih issledovanii. XXIV Megdunarodnaia nauchnaia konferentsia. • № 2 (24), 2017, C. 46-49.