NON-DESTRUCTIVE METHOD FOR CONTROLLING THE SURFACE DENSITY OF THIN FIBROUS MATERIALS

Shlyakhtenko Pavel
Candidate of Physical and Mathematical Sciences, Doctor of Technical Sciences, Professor Emeritus, St. Petersburg State University of Industrial Technology and Design, Russia

ABSTRACT

The optical method for controlling the surface density of thin fiber-containing materials is considered.

Examples of such materials are semi-finished products of spinning production, condenser paper, proteinaceous sausage casing, optically transparent composite materials, for example, aqueous solutions of cellulose fibers used in the paper industry, or industrial effluents of these enterprises containing optically anisotropic light-transmitting fibers, and the like. .

The method consists in the fact that the object under investigation is illuminated through the polarizer with plane polarized light, in which the plane of the light vector rotation is rotated by 45 degrees relative to the machine direction of the material being studied. By the magnitude of the measured luminous flux passing through the analyzer, the optical plane of which is 90 degrees rotated relative to the optical plane of the polarizer, the concentration of fibers in the test material is judged.

A diagram of the device according to the method under discussion is given, and its performance has been proved on samples of various fiber-containing materials.

Keywords: natural and chemical fibers; fibrous and fiber containing materials; optical anisotropy; interference of polarized light.

Introduction

In work [1] it is offered and in work [2] an optical method for controlling the surface density of such materials was described.

The method relates to non-destructive optical methods for monitoring flat light-transmitting materials containing fibers.

Examples of such materials are semi-finished products of a spinning type, condenser paper, a white-cured sausage casing, optically transparent composite materials consisting of an isotropic matrix reinforced with synthetic or natural fibers, for example, aqueous solutions of cellulose fibers used in the paper industry, or industrial effluents of these enterprises containing optically anisotropic light-transmitting fibers, and similar materials.

Closest to the proposed method is a method of controlling the physical parameters of moving flat fibrous materials [3]. The method consists in the fact that the test material is illuminated with a parallel beam of light perpendicular to its surface. Using the photodetector, the entire light flux emitted by the illuminated material in the direction of light incidence is recorded, and this flux is compared with the flux recorded by the photodetector for a reference sample of this material, and the surface density is judged by the difference in the light streams. In the device according to this method, the photodetector recorded the entire luminous flux emitted by the illuminated surface of the material under study and the standard.

Results and discussion

The aim of the proposed method [1] is to increase the accuracy of measurement. Figure 1 shows a diagram illustrating its operation.

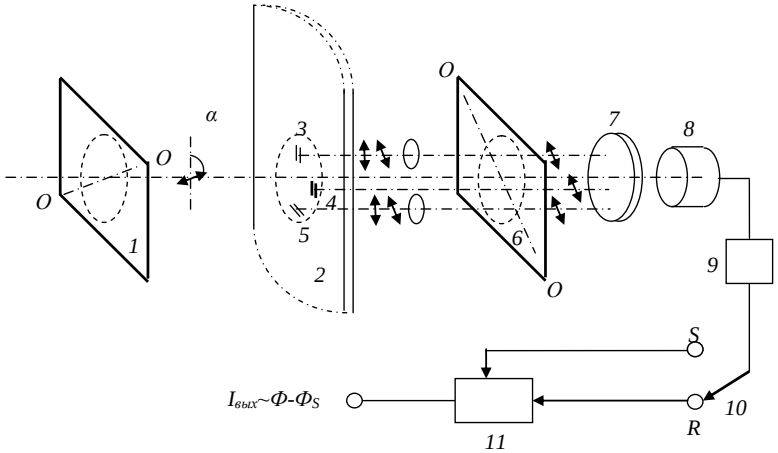

Figure 1. The device diagram explaining the method of controlling the surface density of the material

Non-polarized light is incident by a parallel beam on the polarizer *1* and illuminates the test material with light in which the electric vector ***E*** oscillates at an angle $\alpha = 45^0$ to the direction of drawing of the controlled planar light-transmitting material *2*. The material studied contains fibers mainly oriented along the machine direction (drawing direction). Figure 1 shows, for example, two types of light transmitting fibers *3, 4, 5*.

Anisotropic fibers *3, 5* are oriented along (*3*) and perpendicular (5) to the machine direction, respectively. In these fibers, incident light excites two light waves ("ordinary" ray and "extraordinary") of the same intensity, which interfere with the output of the light fiber in the general case of elliptical polarization.

Fiber *4* has a complex relief of geometry in volume, i.e., many irregular inhomogeneities on the surface and in volume. The reflections and scattering of light by these inhomogeneities lead to the fact that the light transmitted through this fiber is scattered and depolarized.

Obviously, in this case, part of the light from the fibers *3, 4,* and *5* passes through the analyzer *6*, set so that its optical plane is perpendicular to the optical plane of the polarizer *1*. At the same time, the light transmitted through the isotropic filling of the material under study is completely blocked by the analyzer *6*.

Thus, only light coming from the fiber cones located in the illuminated region of the test material, which is then collected at the receiving area of the photodetector *8*, is incident on the lens *7*.

The signal from the output of the linear photodetector at low fiber concentrations in the material, when the fibers do not obscure each other, should be proportional to the number of illuminated fibers. This signal through the amplifier *9* and the key *10* is fed to a comparison circuit *11*, where it is compared with a signal remembered by the circuit when measured on a reference sample of the test material with a known surface density (thickness, with a constant width of the material).

Measurements on the reference sample are carried out according to the above-described diagram on the same device, when instead of the material being studied, the reference sample is placed, and the key is transferred from the "*R*" position to the "*S*" position. In this case, the signal from the photodetector *8*, proportional to the number of fibers in the illuminated part of the reference sample (thickness or surface density), is fed through an amplifier *9* to the corresponding input of the comparison circuit *11*, where it is stored.

The signal from the output of the comparison circuit, proportional to the difference of the light fluxes $\Phi - \Phi_S$, indicates the deviation of the controlled parameter of the material under study from the reference value.

The proposed method is based on measuring the concentration of fibers in the material.

In the case of an increased concentration of fibers, when they shade each other, the measured difference signal is functionally related to the surface density of the material. If the type of function is known, then the desired value can be calculated. If unknown, then the form of this function can be found experimentally during control measurements on the appropriate number of samples of this material with independently measured surface density values.

Figure 2 shows the dependences of the voltage *U* at the output of amplifier 9 (Figure 1) on the surface density σ for reindeer wool comb (curve 1) and sheep wool (curve 2) at a wavelength of λ = 555 nm (comb direction in samples oriented at an angle $\alpha = 45^0$ to the optical plane of the polarizer).

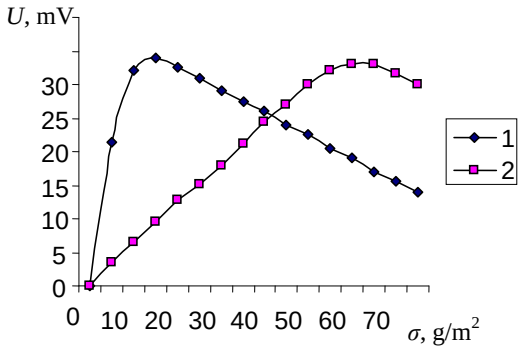

Figure 2. Experimental dependences of the measured signal on the surface density σ for reindeer wool (1) and sheep's (2)

From the course of the curves in this figure it can be seen that the appearance of the curves is the same qualitatively. In the initial section (for thin samples), the dependence is linear and increasing. After reaching a maximum, it is close to a linear dependence and decreases.

The course of the dependences in these sections can be approximated by the dependences from which the desired value of σ from the measured value of the voltage *U* can be calculated by the formulas: for reindeer wool at a low density $\sigma = 60U$, for a high density $\sigma = 660$ (0 , 18 - *U*); for sheep's wool at low

density σ = 350*U*, for high density σ = 600 (0.265 - *U*). Moreover, the dimension of the resulting density is σ [g / m^2], the dimension is *U* [V].

The quantitative differences in the course of curves 1 and 2 in Fig. 2 are associated with differences in the color and diameter (d) of the fibers (for the studied reindeer core fibers d = 0.3 mm, for the fibers in the sheep's comb d ~ 0.01 mm).

To control the surface density of the proteinaceous sausage casing at the Belkozin plant (Luga), according to the considered method, an operating device was assembled, a block diagram of which is shown in Figure 3.

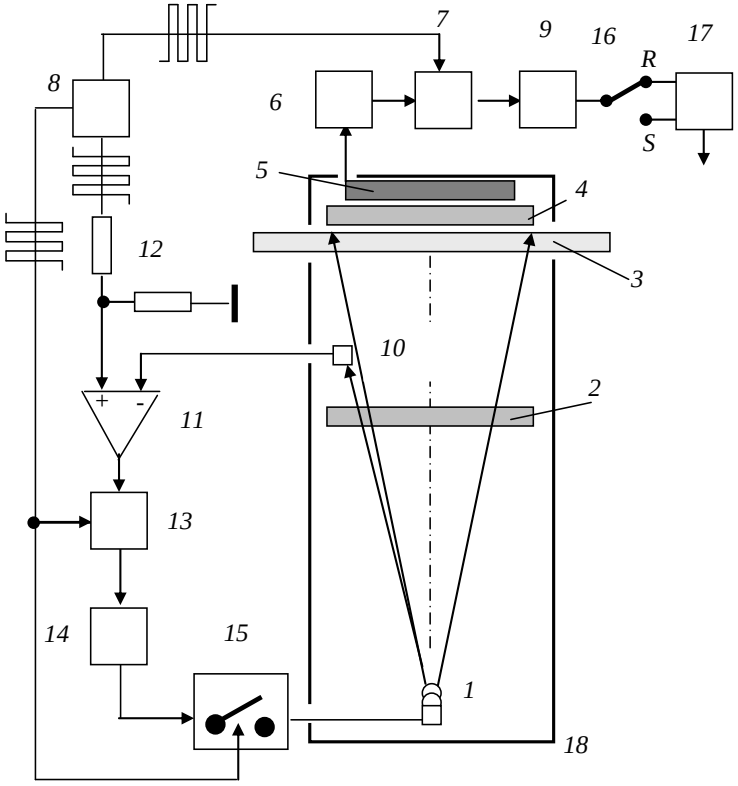

Figure 3. Block diagram of the device

A light emitting diode *1* was used as a light source, emitting light whose wavelength lies in the region of 567 nm, the light from which is transmitted through polaroid *2*, the optical plane of which is oriented at an angle of 45^0 to the direction of drawing of the material under study. The light emitted by the test material *3* through analyzer 4 crossed with the polarizer *2* (polaroid film) enters the photodetector *5*, which consists of solar photodiode batteries connected in parallel and installed parallel to the surface of the test material 3 immediately after the analyzer *4*.

The signal from the photodetector *5* is fed to the amplifier 6, passes through a phase detector *7*, connected to the reference frequency generator *8* and the amplifier *9*. A part of the light from the source *1* goes to the photodiode receiver *10*. The signal from the photodetector *10* then goes to one of their inputs an amplifier *11*, to the second input of which a signal comes from a voltage divider *12* connected to a reference frequency generator *8*.

From the output of amplifier *11*, the signal is supplied to a phase detector *13* connected to *8*, an integrator *14*, and a chopper *15* controlled by a generator *8*. The amplifier *9* is connected to a key *16*, which can be connected either to the measuring input of the comparison circuit *17* ("R") , or to the reference input ("S").

The device operates as follows. The variable component of the signal from the photodetector *5*, passing through the amplifier *6*, enters the phase detector *7*, the reference signal of which is generated by the reference frequency generator *8*. The amplified and detected signal from the photodetector 5 then goes to the constant voltage amplifier *9*, the output voltage of which characterizes the surface density of the investigated fiber - sheet material *3*.

To compensate for temperature instability and temporary departure of the parameters of the emitter *1*, the emitter is powered as follows. The signal from the photodetector *10* (using a solar battery of the same type as in the photodetector *5*), which characterizes the radiation power, is compared with the reference signal and amplified by a differential amplifier *11*. The reference signal is obtained by attenuating the signal of the reference frequency generator 8 in the voltage divider *12*. From the output of the amplifier *11*, the signal enters the phase detector *13*, then is integrated

into *14* and through the chopper *15*, controlled by the generator *8*, is supplied to the emitter *1*.

The electrical circuit of amplifiers operating on a variable signal component, in combination with phase detection, provides the necessary protection and independence of readings from extraneous illumination and intrinsic noise of highly sensitive amplifiers.

At the output of the comparison circuit *17*, the signal measured on the test material is compared with the signal received and stored earlier in the measurements when the key *16* is in position "S", and instead of the test material, a reference sample of the same material known surface density. The mismatch signal from the output of the circuit *17* can be used to adjust in the circuit automatically adjust the surface density to the standard.

The photosensitive part of the circuit, together with the emitter, is placed in a light-shielding casing *18* to protect photodetectors from irregular constant flashes that change the recombination ability of pn junctions, which is important when their power is sufficient.

Figure 4 shows the experimental dependence of the measured signal at the output of amplifier *9* on the surface density of the protein-sausage sausage casing, measured by an independent method in a factory laboratory by weighing on an analytical balance.

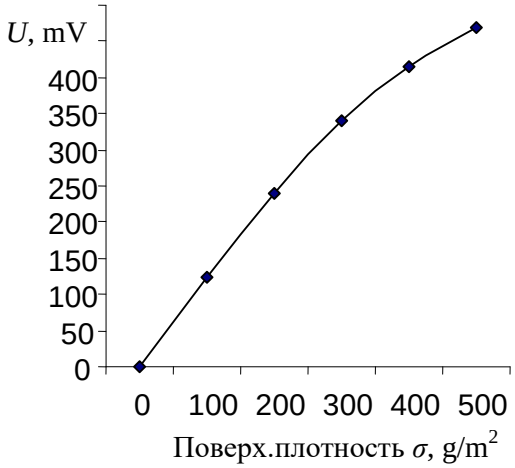

Figure 4. Experimental dependence *U (σ)* for a sausage casing

The measurements were carried out according to the method under consideration, both on individual samples and on samples obtained by adequately superimposing (combining machine directions) the samples on top of each other.

It can be seen that in the entire range of shells manufactured by the «Bel-kozin» factory, whose surface density varies up to 300 g / m2 for various diameters, this dependence is linear.

Measurements showed that measurements of surface density in this range are confidently recorded at the level of 5% (P = 0.9) of the standard, which fully satisfied the needs of the factory.

The measurements performed on the prototype [3], which were carried out on the same device, but without a polarizer *2* and analyzer *4*, gave an error in measuring the surface density, significantly exceeding the required tolerances for controlling the protein shell in the required interval. In measurements, the dependence of the signal on surface density was extremely irregular. For some samples of the sausage casing, the deviation sign at the output of circuit *17* was positive, for other samples of the same surface density it was negative, especially when measuring the surface density of up to 200 g / m^2 , which made the measurements by the prototype method completely unsuitable in the most interesting factory range.

References

1. Patent RF № 2024011 G 01 N 21/86 Sposob kontrolia poverhnostnoi plotnosti slabopogloshaycshih voloknosodergaschih materialov / Shlyakhtenko P.G.,Zinoviev A.V., Gilikova R.P. Opubl. 30.11.94., Бюл. № 22.

2. Pavel Shlyakhtenko Opticheskie methodi kontrolia parametrov voloknosodergiaschih materialov. Kontrol strukturi tekstilnih materialov: LAP LAMBERT Academic Publishing GmbH & Co. KG. – 2012. – 347 s.

3. Patent RF № 1483344 G01 N 21/86. Ustroistvo dlia kontrolia fizicheskih paramerrov dviguchihsia ploskih voloknistih svetopropuskayshih materialov / Shlyakhtenko P.G.,Surikov O.M., Truevtsev N.N. I dr. Opubl. 30.05.89, Bul. № 20.