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TECHNOLOGY FOR PRODUCTION OF COMBINED CONDUCTIVE YARN OF HIGH LINEAR DENSITY FOR CARPETS

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Twist from 95 to 107 tw./m and microwire tension of 20 to 26 cN must be used for manufacturing combined conductive yarn. The decrease in the resistivity of the yarn and the strength level allows preventing accumulation of static electricity on the surface of carpets.

Production of combined conducting fibres and yarn is one of the most developed classes of modern manufacture of chemical materials. The necessity of developing these materials was due to the new requirements imposed on many branches of technology and the drawbacks inherent in traditional conductive materials — metals and their alloys. Shielding and antistatic textile materials of any form, protective clothing with high specific conductivity for personnel working with high-frequency currents, and many other items can be manufactured from conductive fibres.

The Department of Spinning of Natural and Chemical Fibres at Vitebsk Technological University developed new technology for manufacturing fleecy conductive yarn on an updated K-176-2 doubler-twister in conditions of Vitebsk Carpets Co. Feed units (feed frames) for feeding copper microwires were also installed on the machine.

A copper microwire and part-wool yarn from three feed packs goes into the output pair of the twisting frame under fixed tension. Then the copper microwire and yarn, bending around the tension rod, directly enter the twisting zone. The slubbed yarn with the copper microwire is twisted in the twisting zone, and then the finished combined conductive yarn is wound in a cylindrical pack.

The total linear density of the combined conductive yarn is determined with the equation

$$T_{ccy} = T_y \cdot 3 + T_{cw}, \qquad (1)$$

where T_{ccy} is the linear density of the combined conductive yarn, tex; T_y is the linear density of isolated yarn (165 tex); T_{cw} is the linear density of the copper wire (18 tex).

The physicomechanical and electrophysical properties of combined conductive yarn with a linear density of 520 tex are reported in Table 1.

Since fabrication of conductive yarn has been little studied, we conducted an experiment to determine the degree of the effect of the process parameters of operation of the K-1762 doubler-twister on the qualitative characteristics of the yarn. The factors and intervals of their variation are reported in Table 2. The intervals of variation of the factors were selected in accordance with the specifications of the equipment and the results of preliminary experiments.

We selected the breaking load P_l, cN; elongation at break P_e, %; coefficient of variation for the breaking load CVP_l, %; coefficient of variation for the elongation at break CVP_e, %; coefficient of variation for the linear density CVP_T, %, as the optimization criteria.

The planned experiment was conducted in the production conditions of Vitebsk Carpets Co. The range of limitations was selected in accordance with the technical description of manufacturing of fleecy conductive yarn.

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TABLE 1. Physicomechanical Properties of Combined 520 tex Conductive Yarn

Characteristics	Numerical value
Absolute breaking load, cN	2204.3
Coefficient of variation for breaking load, %	6.6
Elongation at break, %	12.6
Coefficient of variation for elongation at break, %	15.5

TABLE 2. Table of Intervals and Levels of Variation of Factors

Parameter	Factor	Level of variation of factor			Interval of variation of factor
		-1	0	1	
Twist, tw./m	*X*1	80	100	120	20
Tension of copper microwire, cN	*X*2	10	20	30	10

TABLE 3. Surface Resistivity of Investigated Yarn

Yarn	R_{mea}, Ω
Blended twisted 500 tex	$3.42 \cdot 10^{11}$
Combined conductive 520 tex	$4.1 \cdot 10^{2}$

*Average value.

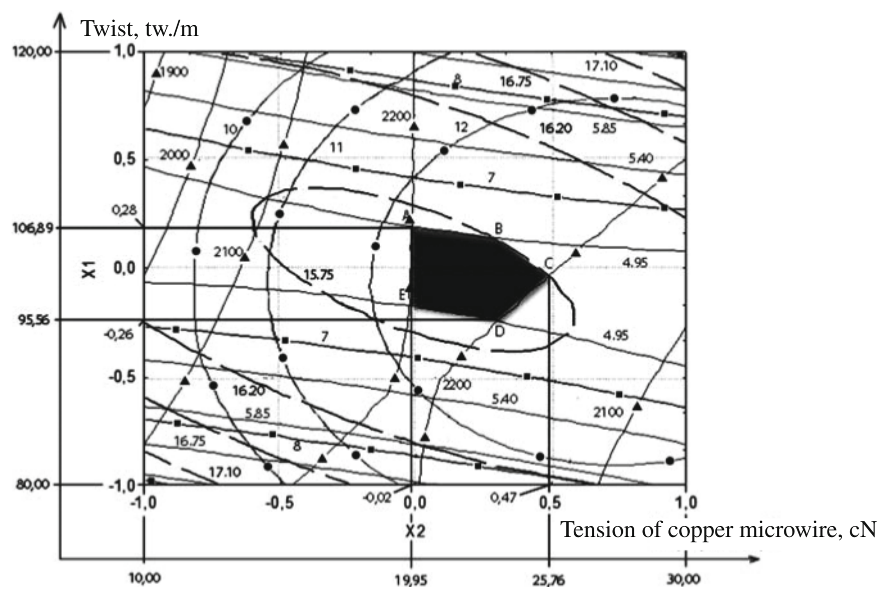

Fig. 1. Combined lines of equal levels for quality indexes of combined conductive yarn with 520 tex linear density: ▲ — minimum breaking load of 2200 cN; ● — minimum elongation at break of 12%; ■ — maximum coefficient of variation for breaking load of 15.75%; ---- — maximum coefficient of variation for linear density of 4.95%.

The range of rational values ABCDE was obtained (Fig. 1). In analyzing it, note that for production of combined conductive yarn of a given quality, it is necessary to use *X*1 (twist) from 95 to 107 tw./m and *X*2 (copper microwire tension) from 20 to 26 cN from the range of limitations.

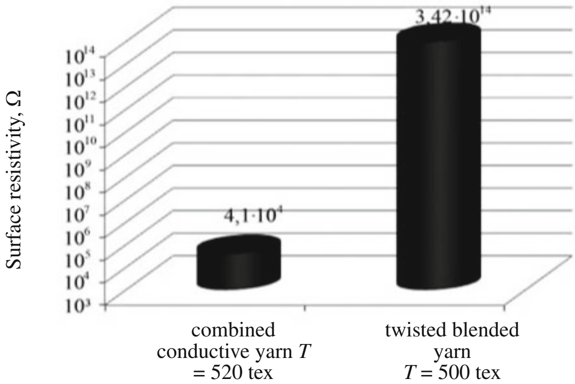

Fig. 2.

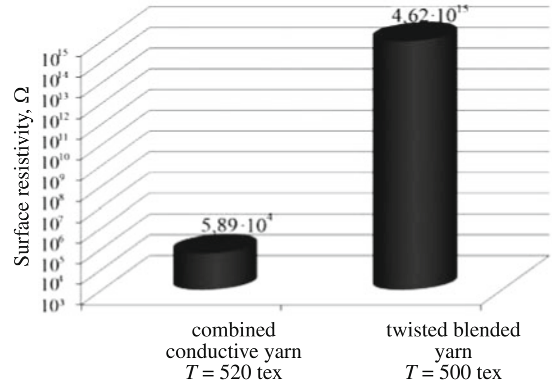

Fig. 3.

Fig. 2. Comparison of surface resistivity of blended twisted yarn T = 500 tex and combined conductive yarn T = 520 tex with a length of 1 cm.

Fig. 3. Comparison of the surface resistivity of blended twisted yarn T = 500 tex and combined conductive yarn T = 520 tex.

The surface resistivity of 520 tex combined conductive yarn T and blended twisted yarn (polyacrylonitrile, polycaproamide, wool) T = 500 tex was determined on a IESN-2 instrument according to GOST 19806-74 at the VSTU Certification Laboratory base. The results of the determination are reported in Table 3.

The resistivity of yarn 1 cm long (R_{1cm}, Ω) was calculated with the equation

$$R_{1\text{cm}} = R_{\text{mea}} n_1 n_2, \tag{2}$$

where R_{mea} is the arithmetic mean of the results of the measurements, Ω; n_1 is the number of contact groups in the sensor; n_2 is the number of fibre loops in the sensor.

The values of the surface resistivity of the blended twisted yarn T = 500 tex and the combined conductive yarn T = 520 tex 1 cm long are compared in Fig. 2.

The surface resistivity of the yarn (R_{res}, Ω) was calculated with the equation

$$R_{res} = \frac{0.01 \cdot R_{1\text{cm}}}{l} \cdot \sqrt{\frac{T}{\rho}}, \tag{3}$$

where l is the length of the yarn, equal to the distance between electrodes (1 cm); T is the nominal linear density of the yarn, tex; ρ is the average density of the combined yarn, g/m^3.

The average density of the combined yarn was calculated with the equation

$$\rho_{\text{ccy}} = \frac{\sum_{i=1}^{n} \rho_i \cdot x_i}{n}, \tag{4}$$

where ρ_{ccy} is the average density of the combined conductive yarn (1.54 g/m^3); ρ_p is the average density of the combined yarn (1.2 g/m^3); ρ_1 is the density of the copper microwire (8.9 g/m^3); ρ_2 is the density of polyacrylonitrile fibres (1.17 g/m^3)*;* ρ_3 is the density of the polycaproamide fibres (1.14 g/m^3); ρ_4 is the density of wool fibre (1.3 g/m^3); x_1 is the per-unit inclusion of polycaproamide fibres; x_4 is the per-unit inclusion of wool fibre; n is the number of components in the combined yarn.

It was found that incorporation of copper microwire in the structure of the combined yarn decreased the resistance by 10 orders of magnitude (from 10^{14} to 10^4 Ω) in comparison to the blended yarn T = 500 tex, and the surface resistivity by 11 orders of magnitude (from 10^{15} to 10^4 Ω).

Using fluffy conductive yarn in carpets improves the electrophysical characteristics of the carpets: decreases their surface resistivity and strength, preventing possible accumulation of static electricity on the surface of the articles in this way.

Incorporation of the combined conductive yarn in carpets will significantly expand the assortment and make it possible to use new carpet items in furnishing aircraft and fabricate floor coverings for railways.

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