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COMBINED HIGHLY STRETCHABLE YARN USING HIGHLY STRETCHABLE POLYURETHANE FIBRE

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The technology for manufacturing combined highly stretchable yarn by pneumomechanical spinning is examined. Regression models were obtained for Dorlastan V850 elastomeric fibre with 4.4 tex linear density. Examples of the dependence of the breaking load of the highly stretchable yarn on the twist and stretching value of the elastomeric component are reported.

Improvement of the consumer properties of textile materials by using elastic fibres is heightening the interest in elastomeric fibres. The elastomeric fibre, natural or chemical, with elongation at break of more than 100%, can be shrunk to a length close to the initial length, and the elasticity of the fibre is ensured by its chemical composition. Light industry has three kinds of elastomeric fibres: rubber (spun and cut) based on natural rubber; synthetic obtained from man-made rubber, and polyurethane. Polyurethane fibres have many important advantages over rubber fibres. They have higher strength (by 2-3 times), higher elasticity (by 2-3 times), higher abrasion resistance, much higher resistance to repeated deformations (by 10-20 times).

Processing of pure polyurethane fibres in weaving is not possible on existing looms, so that elastic fibres with a coating — combined fibres — are used (Fig. 1) [1]. External materials with elastic fibres do not differ from cotton, wool, or blended yarns containing polyester or nylon fibres, but they have high stretchability. Yarns made of natural or chemical fibres obtained on ring, spinning-twisting, or pneumomechanical spinning machines.

A process for manufacturing combined highly stretchable yarn on a pneumomechanical spinning machine was developed in the Department of Spinning of Natural and Chemical Fibres at Vitebsk Technological University. An experimental bench based on a PPM-120-A pneumomechanical spinning machine was prepared for studying production of this yarn. The possibility of obtaining combined highly stretchable yarn by feeding complex highly stretchable fibre into the working zone of the spinning chamber is a feature of the bench (Fig. 2). Elastomeric polyurethane fibre 1 is fed through channel 2 in the spinning chamber rotor into the working zone of chamber 3. The fibre stream 4 is fed into the spinning chamber from separating device 8, where the combined yarn is spun. With exit device 6, combined yarn 5 goes out of the spinning chamber and a pack of combined highly stretchable yarn 7 is formed [2]. The process of spinning the combined yarn in the spinning chamber is combined with twisting of the pneumomechanical yarn (Fig. 3). The fibre ribbon formed from the discrete fibre stream is removed from the spinning chamber channel at the takeoff point. After passing the takeoff point along the spinning chamber groove once, the fibre ribbon obtains one complete twist, and one turn around the elastomeric core is formed.

The number of twists of the pneumomechanical yarn around its own axis is thus equal to the number of turns around the elastomeric core in combined highly stretchable yarn made by the pneumomechanical method [3]. The number of twists of the pneumomechanical yarn is determined by the ratio of the angular velocity of the takeoff point to the rate of removing the yarn from the spinning chamber.

Inclusion of an elastic constituent in the finished yarn is usually from 2 to 10% as a function of the application of the fabric or knit in which the yarn will be used. In some cases, for example, in swim suits and active leisure clothing, the content of the elastomeric component can attain 20-25%. Inclusion of an elastomeric fibre consists of replacing the standard yarn with a combined highly stretchable yarn, and the percentage content of the elastomeric fibre in the combined yarn is

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Fig. 1. Highly stretchable combined yarn from the pneumomechanical spinning method.

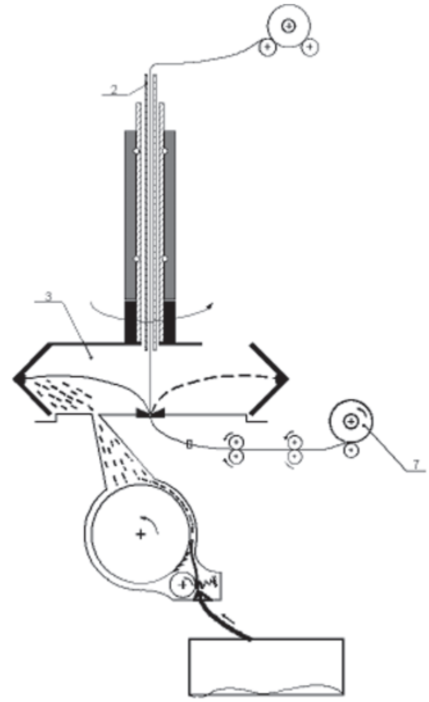

Fig. 2. Diagram of the manufacturing process for highly stretchable combined yarn by pneumomechanical spinning: 1) elastomeric polyurethane fibre; 2) channel in spinning chamber rotor; 3) spinning chamber; 4) discrete fibre stream; 5) combined yarn; 6) takeoff device; 7) combined highly stretchable yarn pack; 8) separating device.

determined by the linear densities of the pneumomechanical yarn and the elastomeric fibre and by preliminary stretching of the elastomeric fibre.

In the finished article, the relative elongation of the elastomeric fibre is usually within the limits of 5%. In the combined highly stretchable yarn spun by the pneumomechanical method, the elastomeric fibre can be stretched to the length where the coils in the pneumomechanical yarn are straightened. For this reason, selecting the working segment of the elastomeric yarn on its tensile force (P) — relative elongation (ε) curve is an important moment in planning the characteristics of a combined highly stretchable yarn (Fig. 4). The tensile curves of polyurethane elastomeric fibres have a pronounced nonlinear character [4], and the slope of the curves changes when the deformation increases. The required force of elastic recovery of the combined yarn, which is a function of the type and application of the article containing the yarn, is a determining factor in selecting preliminary stretching of an elastomeric fibre.

The preliminary stretching coefficient of the elastomeric component in pneumomechanical spinning of combined highly stretchable yarn is given by the ratio of the rate of removal of the combined yarn 5 from the spinning chamber to the feed rate of the elastomeric fibre 1 into spinning chamber 3 (see Fig. 2):

$$K = \frac{\upsilon_r}{\upsilon_f} \cdot 100.$$

In designing the properties of combined yarn with computer technology, different regression models whose coefficients can be found with the method of least squares can be used. The regression models for Dorlastan V850 elastomeric fibre with a linear density of 4.4 tex are reported in Table 1.

TABLE 1. Regression Models for Dorlastan V850 Elastomeric Fibre

Type of curve	Regression model	Determinacy coefficient
Linear	$P = 0.133\varepsilon - 16.1$	$R^2 = 0.8815$
Exponential	$P = 1.8633e^{0.0071\varepsilon}$	$R^2 = 0.9721$
Power	$P = 0.0008\varepsilon^{1.7656}$	$R^2 = 0.9833$
2nd Degree polynomial	$P = 0.0004\varepsilon^2 - 0.0941\varepsilon + 10.4$	$R^2 = 0.9814$
3rd Degree polynomial	$P = 2{\cdot}10^{-06}\varepsilon^3 - 0.001\varepsilon^2 + 0.2795\varepsilon - 16.2$	$R^2 = 0.9994$
4th Degree polynomial	$P = 4{\cdot}10^{-09}\varepsilon^4 - 3{\cdot}10^{-06}\varepsilon^3 + 0.0008\varepsilon^2 - 0.0258\varepsilon - 2{\cdot}10^{-10}$	$R^2 = 1$

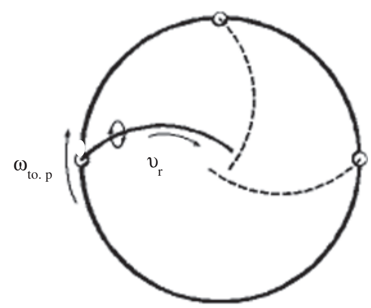

Fig. 3. Diagram of spinning of highly stretchable combined yarn in a pneumomechanical spinning chamber: $\omega_{to.p}$ — angular velocity of takeoff point; υ_r — rate of removal of yarn from spinning chamber.

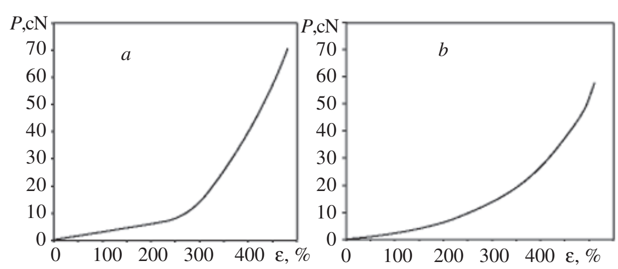

Fig. 4. Tensile force (*P*)—relative elongation (ε) for Dorlastan V 500 yarn with 4.5 tex linear density (a) and 4.4 tex Dorlastan V 850 yarn (b).

The determinacy coefficient can be used to assess the adequacy of the model. Its being equal to one means that the calculated values of the regression curve are in agreement with the experimental values. Defining the required force of elastic recovery of the combined yarn and using the regression model for a given brand of elastomeric fibre, we can determine the necessary preliminary stretching of the elastomeric fibre in spinning combined yarn:

$$K = \varepsilon_{calc}.$$

By varying such parameters as the composition, linear density, and twist of pneumomechanical yarn and the linear density and preliminary tension of the elastomeric fibre, it is thus possible to obtain a wide assortment of combined highly stretchable yarns for different applications.

The breaking load of the combined highly stretchable pneumomechanical yarn as a function of the preliminary stretching of the elastomeric fibre and twist of the pneumomechanical yarn with a linear density of 50 tex and linear density of the elastomeric fibre of 16 tex is shown in Fig. 5.

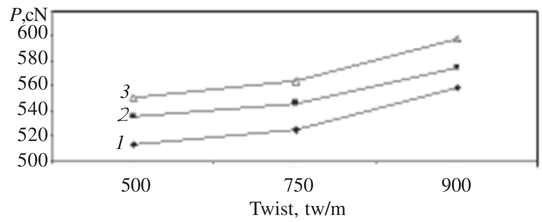

Fig. 5. Breaking load as a function of twist and preliminary stretching of elastomeric component (in cN): 1) 1.5; 2) 3; 3) 4.5.

An assortment of combined highly stretchable pneumomechanical yarns is currently being developed in the Department and used in further processing in different textile industry manufacturing processes. The combined highly stretchable pneumomechanical yarn is distinguished by elevated bulking, low twist, and low irregularity. The production technology is distinguished by the comparatively low cost due to combining spinning of the pneumomechanical yarn with braiding of the elastomeric core.

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