Improving quality of OE spun yarn

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Abstract. During the formation of OE yarns on high frequency spinning rotors, dynamic shocks occur which lead to variations in the yarn tension. It is well known that by increasing the spinning speed the irregularity of yarn also increases. The variation of the yarn tension reduces the quality of the product (yarn). The aim of this research work is to find method to decrease the yarn irregularity without decreasing the spinning speed. In this paper also the way of improving of the quality of OE spun yarn is discussed. The OE yarn irregularity has been decreased by changing the construction of existed OE rotor’s separator (OERS). The yarn passes through the yarn lead-funnel to the yarn lead-out tube. The variation of the yarn tension results in the change of the yarn friction on the yarn lead-out wall of the funnel. Then concentric protrusion formed at the centre on the surface of the base lead-out funnel lets the yarn contact the separator and it presses a spring disposed in a recess formed in the separator. As a result, the spring is deformed (axially) and allows the reciprocation the yarn lead-out funnel and yarn lead-out tube, whereby the vibration leading to changes in the yarn tension are absorbed.

1. Introduction

The expansion of the range of yarns - one of the products of the textile industry and the intensive increase in demand for it - has led to the improvement of equipment that carries out technological processes. There was a need to identify all the factors that affect the manufacturing processes of yarn, to analyze and find appropriate solutions. Recently, as a result of a sharp increase in the speed of the spinning machines increased productivity and quality indicators produced yarn deteriorated, i.e. irregularity of its structure and common properties level increased. An analysis of the literature shows that a wide range of research carried out to assess the performance of the mechanical properties of yarn. Also the prediction and assessment of the mechanical properties of yarn derived from various textile fibers has been studied. The relationship between fiber characteristics and yarn strength and parameters of spinning machines has been examined by the following scholars as J.W.S.Hearle, W. Oxenham, L.V.Langenhove, Demet Yilmaz, Fatma Göktepe, X.Shao, Y.Guo в Y.Wang, Y.Zeng, А.Basu, D.Rajesh, V.P.Sherbakov, G.I.Chistoborodov, . .Stolyarov. Many researchers are concerned with predicting and assessing the structure and mechanical properties of the ring and OE yarns and try to explain their mechanical properties based on the structural statement [1-5]. These studies mainly concern the relationship between the tenacity of the yarn and the fiber properties. Despite the fact that OE yarn has a lower strength than the ring yarn, this system is well known for its
performance characteristics and formation. In all of the above works, devoted to predict and assess of the mechanical properties of yarn indicators, studies, connected with the influence of the features of spinning process, has not been conducted. The purpose of this study is to develop the methods for improving mechanical properties of OE yarn, taking into account ways and features of technological processes of spinning.

2. Theoretical part

Conditionally accepting cross-section of yarn for the circle, one can determine its surface area $S_y$.

$$ S_y = \frac{\pi d_y^2}{4} \quad (1) $$

It is also possible to define values of the initial stiffness to yield point of the yarn. Absolute values of extension force under deformations $\varepsilon_y = 0.5\%$ and $1.0\%$ are used for it, and also value of stiffness to yield point $E$ in pascals is determined according to the formula:

$$ E = \frac{F}{\varepsilon_y \cdot S_y} \quad (2) $$

Absolute value of deformation is equal to $\varepsilon_y = 0.005$ and $\varepsilon_y = 0.01$. In this formula the stretching stress $F$ is measured in cN, which is defined according to the data of the tensile tester Statimat-. Thus, it is revealed that as a result of changes in the frequency of the spinning camera rotation, also initial stiffness to yield point of the yarn change (when $\varepsilon_y = 0.5\%; \varepsilon_y = 1.0\%$), that shall be taken into account when evaluating mechanical characteristics of the yarn. It is found that if under deformation $\varepsilon_y = 0.5\%$, Young's modulus of $16.10^7$ Pa is received under frequency of the spinning camera rotation $45000 \text{ min}^{-1}$, then under frequency of the spinning camera rotation $90000 \text{ min}^{-1}$ it increases up to $463.610^7$ Pa, i.e. it increases 29 times. Under deformation $\varepsilon_y = 1.0\%$ stiffness to yield point is equal to $120.310^7$ Pa. It is also found that under frequency of the spinning camera rotation $90000 \text{ min}^{-1}$ stiffness to yield point makes up $400.210^7$ Pa, that means an increase by 3.3 times. Since diameter of the yarn is changed under the influence of rotational frequency of the spinning camera, then one of the indicators of mechanical properties of yarn changes-initial stiffness to yield point. Of course, this fact shall be considered when forecasting and measuring mechanical characteristics, associated with the structure of OE spun yarn. It is this state, taken into account in the theory of elasticity of the yarn, i.e., the yarn is treated as anisotropic body. Using the curve of stretching and based on the theory of elasticity of the yarn, it is possible to predict the mechanical properties of yarn.

3. Experimental

The influence of the rotational speed on the yarn structure is studied through experiment, the essence of which is to determine the deformation characteristics of the yarn, received at different speeds of the spinning rotor. The experiments were conducted on OE spinning machine BD-330, from Saurer (Schlafhorst). Yarn with linear density of 50 tex was produced from cotton under different frequencies of the rotor of $60000 \text{ min}^{-1}$, $75000 \text{ min}^{-1}$ and $90000 \text{ min}^{-1}$ (figure 1). It should be noted that the change of the rotational speed of the rotor causes yarn breaking load changes undue. With the aim to study the effects of rotor speed on yarn structure, tensile deformation curves are built.
Figure 1. Influence of the frequency of the rotor on the yarn tensile behavior

In order to identify features of the structural changes occurring by the change of the frequency of the rotor, the tensile behavior over the time is presented (figure 2).

Figure 2. One-cycle characteristics of the yarn samples, received at different speeds of the spinning rotor

The increase of the frequency of the rotor’s rotation leads to increased variation of the yarn properties, which certainly reduces the quality of the yarn. This is due to the fact that by increasing frequency of the rotor, variation on yarn tension in the cylinder increases and, therefore, tension of fibers in the torsion triangle varies. Under the influence of the variable yarn tension, the arrangement of fibers at its open end changes, and it becomes the source of the structural irregularity. To reduce its value, it is necessary to reduce the thread tension variation in the cylinder by different methods. To eliminate these deficiencies and improve the quality of manufactured textile products, when predicting and measuring the mechanical properties of OE yarn, it is necessary to take into account the factors, in particular, features of the technological processes of spinning, which affect structural changes of the yarn. The improvement of the mechanical properties of OE yarn can be achieved through the development of new structural devices and variation of operating parameters of spinning machines. One of such methods is the use of elastic elements in the yarn formation zone. Elastic yarn-lead out funnel is proposed (figure 3), fitted with a spring element, due to which yarn guide has the ability to move along its axis.
Figure 3. Yarn lead-out device

Experimental funnel was patented and installed on the OE spinning machine BD-330. When changing the frequency of the rotor from 60000 min\(^{-1}\) to 90000 min\(^{-1}\), samples of yarn with linear density of 20, 30 and 40 tex with twist factor 50 have been produced. The test results on the mechanical properties of the new yarn are given in table 1.

| №   | Yarn indicators          | Options for yarn |          |          |
|-----|--------------------------|------------------|----------|----------|
|     |                          | normal           | new      |          |
| 1   | Linear density, tex      | 20               | 40       | 20       | 40       |
| 2   | Breaking load, cN        | 237              | 492      | 237      | 516      |
| 3   | Irregularity on breaking load,% | 6,7             | 5,7      | 2,5      | 5,7      |
| 4   | Breaking elongation,%    | 5,13             | 5,92     | 6,0      | 6,25     |
| 5   | Variation on breaking elongation, % | 6,5             | 6,3      | 1,8      | 5,0      |
| 6   | Breaking tenacity, cN/tex| 12,07            | 12,56    | 12,08    | 13,1     |
|     |                          |                  |          |          |
| 7   | Variation on breaking tenacity,, % | 6,7             | 5,7      | 2,5      | 5,7      |
| 8   | Work of rupture, cN cm   | 348              | 782      | 384      | 858      |
| 9   | Variation on work of rupture,% | 12,2             | 10,1     | 4,1      | 11,3     |
| 10  | Break time, sec          | 0,31             | 0,36     | 0,36     | 0,38     |
| 11  | Mass variation on Uster, %| 14,73            | 12,58    | 15,03    | 12,4     |
|     |                          |                  |          |          |
| 12  | Thin places-50%, pcs/1000m| 35               | 1,0      | 40,0     | 1,3      |
| 13  | Thick places +50%, pcs/1000m | 66,3             | 17,5     | 85,0     | 8,8      |
| 14  | Number of neps, pcs/1000m| 421,3            | 47,5     | 586,3    | 40,0     |

As it can be seen from the table above, the elastic yarn guide (funnel) smoothes the fluctuations of the yarn tension in the cylinder and decreases the variation of both linear density and breaking load. Samples of yarn with linear density 20 tex have equal breaking load (237 cN) under both options, but the variation of the breaking load is different.

Variation of the breaking load of the new yarn produced with proposed mechanism is 2.7 times lower (2.5%) than the variation of normal yarn (6.7%). Variation of the breaking extension of the new yarn (1.8%) accordingly is 3.6 times lower than the variation of the normal yarn (6.5%). Along with this, variation on Uster of the new yarn with linear density of 20 tex (15.03%) exceeds the variation of the normal yarn (14.73%) by 2%, which is likely related to the amount of neps. If new yarn has 586.3 neps in one kilometer length, the normal yarn contains 421.3 neps, which is lower by 39.2%. It should be noted that this does not constitute structural variation and neps can be removed during the winding process. To analyze the performance of the yarn with linear density of 40 tex, it is possible to notice that the new yarn has similar variation of breaking load (5.7%) and it exceeds the breaking load of the normal yarn (492 cN) against (516 cN) by 5%. Mass variation on Uster, number of thick places and
neps is less in comparison with normal yarn. With a view to assess stress strain state of yarn samples, it is necessary to compare stress-strain curves, obtained through tensile tests (figure 4)

Figure 4. Stress-strain curves, 1) Normal yarn with linear density 40 tex; 2) New yarn with linear density 20 Tex

In order to achieve greater efficiency, it is necessary to choose suitable spring element, depending on the range of the linear density of the yarns, and to continue the current research work.

4. Results
It can be seen that the normal yarn with linear density 40 tex has pre-breaking curves, very much scattered (see figure 4, a, 1), and the new yarn has non-scattered pre-breaking curves. It shows that the new yarn has very uniform stiffness to yield point (see figure 4, and 2). So apparently in the countries of the European Union, as usual, stiffness on the yield point is estimated at 0.5% and 1.0% of yarn extension. Taking into account the results of these experiments for the evaluation of the mechanical characteristics of the yarn, it is necessary to introduce an additional test for the determination of the variation of its stiffness on the yield point.

The curves of the yarn tensile tests with linear density 20 tex, which are quite compact, but the breaking points of the normal yarn are dispelled noticeably that shows variation on its breaking load (see figure 4, b, 1). Breaking points of the new yarn are concentrated (see figure 4, b, 2), which is the criterion for uniformity on rupture. In both cases, evident advantage of the spring element is the production of yarns with better quality characteristics.
5. Discussion

As the figures show, the increase of the frequency of the rotor, leads to decrease of the yarn deformation. Yarn, produced under frequency of the rotor of 60000 min$^{-1}$, has the highest value of deformation, and yarn, produced at the frequency of the rotor of 90000 min$^{-1}$, has the lowest deformation. This is due to the structural change, i.e. changing of the fibers location in the yarn, which occurs under different linear speeds of the rotor. By increased frequency of the rotor the centrifugal force increases and, consequently, the value of the force increases, dipping fiber in the singeing plate. This contributes to more dense arrangement of fibers in fiber ribbon, and hence, yarn density increases. As a result, the friction between the fibers increases, which leads to increase a number of fibers, and resistance to stretching. Thus, with the change of the frequency of the rotor, structural transformation of the yarn occurs, i.e. the fibres are denser. Besides changes of fibers location density, their tension (straightening) increases in the torsion triangle and they enter in the yarn body more elongated, and therefore yarn has less breaking elongation. Thus, the dependence of the mechanical deformation characteristics and in particular, the yarn deformation characteristics, than the frequency of the rotor has been determined, and it is found that with increased frequency of the rotor, the resistance to stretching increases and the deformation decreases, i.e. the tensile deformed state of the yarn changes.

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