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ВЛИЯНИЯ ГЕОМЕТРИЧЕСКИХ ПАРАМЕТРОВ ГАРНИТУРЫ ДИСКРЕТИЗИРУЮЩЕГО БАРАБАНЧИКА ПНЕВМОМЕХАНИЧЕСКОЙ ПРЯДИЛЬНОЙ МАШИНЫ НА ПОДАЧУ ВОЛОКОН В ЗОНУ ПРЯДЕНИЯ

INFLUENCE OF GEOMETRICAL PARAMETERS OF THE DISCRETE DRUM HEADSET OF A PNEUMOMECHANICAL SPINNING MACHINE ON THE FEED OF FIBERS INTO THE SPINNING ZONE

Ж.К. ЮЛДАШЕВ[1], Ш.А. КОРАБАЕВ[1,2], С.Ш. ТАШПУЛАТОВ[1,3], Х.Т. БОБОЖАНОВ[1], Ж.З. СОЛОХИДДИНОВ[1], Д.С. ТАШПУЛАТОВ[1,3]

J.K. YULDASHEV[1], SH.A. KORABAYEV[1,2],S.SH. TASHPULATOV[1,3], H.T.BOBOJANOV[1], J.Z. SOLOXIDDINOV[1], D.S. TASHPULATOV[1,3]

([1]Наманганский государственный технический университет, Республика Узбекистан, [2]Ташкентский институт текстильной и легкой промышленности, Республика Узбекистан, [3]Джизакский политехнический институт, Республика Узбекистан)

([1]Namangan State Technical University, Uzbekistan, Republic of Uzbekistan, [2]Tashkent Institute of Textile and Light Industry,Republic of Uzbekistan, [3]Jizzakh Polytechnic Institute, Republic of Uzbekistan)

E-mail: ssht61@mail.ru

В данной статье представлен теоретический анализ воздействия зубьев пилы на волокна дискретизирующего барабанчика пневмопрядильной машины. Отмечается, что при слишком высокой скорости вращения дискретизирующего барабанчика волокна могут располагаться в поперечном направлении и ухудшать структуру пряжи. Поэтому в ходе исследования частота вращения, соответствующая углу наклона зуба пилы, анализировалась из частоты вращения дискретного барабана пневмопрядильной машины 6000-11000 мин$^{-1}$. При анализе перемещение волокон по зубьям определяется высотой зубьев пилы, в случае $h_{1.I}$=1,6 мм; $h_{1.II}$=1,8 мм; $h_{1.III}$=2мм и $h_{2.I}$=1,2мм; $h_{2.II}$=1,4 мм; $h_{2.III}$=1,6 мм учитывались скорости внешних сил, действующих на волокна. При линейной скорости раскрывающего валика v=35 м/с и высоте зубьев $h_{1.II}$=1,8 мм и $h_{2.II}$=1,4 мм волокна, захваченные зубьями, непрерывно передаются в рабочую камеру.

This article presents a theoretical analysis of the effect of saw teeth on the fibers of an opening roller of a rotor spinning machine. It is noted that when the rotation speed of the opening roller is too high, the fibers can be located in the transverse direction and deteriorate the structure of the spun yarn. Therefore, during the research, the rotation frequency corresponding to the angle of inclination of the saw tooth was analyzed from

6000-11000 min^{-1} rotation frequency of the opening roller of the rotor spinning machine. During the analysis, the movement of the fibers based on the teeth is determined by the height of the saw teeth in the case of $h_{1.I}$=1.6mm; $h_{1.II}$=1.8mm; $h_{1.III}$=2mm and $h_{2.I}$=1.2mm; $h_{2.II}$=1.4mm; $h_{2.III}$=1.6 mm, the velocities due to external forces acting on the fibers were considered. When the linear speed of the opening roller is v=35 m/s and the heights of the teeth are $h_{1.II}$=1.8mm and $h_{2.II}$=1.4mm, the fibers caught by the teeth are continuously transferred to the working chamber.

Ключевые слова: дискретизирующий барабанчик, пневмомеханическое прядение, дискретность волокон, высота зубьев пилы, скорость дискретизирующего барабанчика.

Keywords: opening roller, rotor spinning machine, opening the fiber, height of saw teeth, opening roller speed.

One of the yarn's most important physical and mechanical properties is its strength. This indicator is one of the decisive factors in determining the stability of the spinning process, and the assortment and quality of finished products. The low strength of the manufactured yarn is a process characteristic of rotor spinning [1, 2], and this situation is explained by the fact that fibers are not equally involved in the structure of the yarn during yarn formation.

The most elastic fibers participating in the yarn structure are initially involved in the strength of the yarn produced by the ring spinning machine, and after the breaking of these fibers, it leads to the redistribution of tension in the remaining fibers and new breaks in the more elastic fibers [3, 4].

In some scientific studies, it was shown that the relative tensile strength of the yarn obtained by the rotor spinning method is 25-30% lower than the tensile strength of the yarn produced by the ring spinning machine. The strength of rotor-spun yarns is reduced as a result of the accumulation of fibers that do not have the same tension around the core fibers. The relationship between the number of curved and loop-like fibers and their strength in the yarn structure of rotor spinning method was studied [5, 6, 7].

It is stated that the relative breaking strength depends on the grouped fibers [8]. One of the reasons for the low relative breaking strength of the rotor yarn is explained by the low fiber density in the yarn. Such a situation means that the fiber friction force involved in the rotor yarn strength is less than the fiber friction force in the ring-spun yarn[9, 10].

The shape of the sliver fiber tuft in the chamber of rotor spinning machines is similar to the arc shape of the fiber tuft of ring spinning machines. They differ from each other only quantitatively [11], because the ratio of thickness and width of the spindle in ring spinning machines is 1/80.

The process of twisting fiber tufts in rotor spinning has several features. The most characteristic of them, as mentioned above, is the lack of forces on the surface of the spinning chamber of the fibers in the yarn to have sufficient strength with the fiber tufts, in the rotor spinning method, the twisting triangle is not formed due to the lack of support points of the fiber tufts. Since individual opened fibers are involved in the twisting process in the process of yarn formation in the rotor spinning method, their strength is low. The number of actual twists of the yarn obtained by the rotor spinning method is observed to decrease mainly due to the lack of a reference point, and the low friction force between the chamber wall and the fibers [12, 13]. In addition, during twisting, the fiber bundles can slide on the chamber wall under the influence of centrifugal forces, because the fibers in the belt are connected to the collecting surface only by frictional forces, which also directly affects the number of turns.

Some other factors affect the stable operation of the rotor spinning process and

the quality indicators of the produced yarn. It is also studied the process of discretization and the effect of this process on the physical and mechanical properties of the produced yarn[14, 15, 16]. According to the results of the conducted research, it was found that imperfections in the supply of raw materials in the spinning unit of BD-200 rotor spinning machines harm the quality indicators of the yarn, mainly its breaking strength, coefficient of variation, and degree of contamination. In the process of opening, the level of fiber damage increases as a result of the parallelization of fibers in the flow of opened fibers and the interaction of the fibers with the teeth of the opening roller. At the same time, the average length of the fibers decreases, which undoubtedly harms the breaking strength of the yarn, however, it is possible to reduce the degree of fiber damage (shortening) by choosing the right raw materials and adjusting the parameters of the machine. Based on the conducted research, it was determined that fiber breakage occurs mainly in fibers with a length of 34 mm and above. By improving the structure of the supplied semi-finished product (sliver), it is possible to reduce the speed of damage to the fibers, increase the strength, and reduce the level of breakage.

It should be noted that preparation for the opening process is important for the production of high-quality yarn. In recent years, scientists have been conducting many studies on improving the quality of produced yarn [17…21].

Rotor spinning machines are equipped by leading machine-building companies with opening rollers with different garnitures, depending on the type of processed raw materials, the optimal profile of the garniture and the geometry of the teeth are selected. Diamond and nickel plating are optimal in terms of the absence of tangles in the product and good separation of fibers in the sliver. When the frequency of rotation of opening roller teeth is from 6000-8000 min^{-1} to 11000 min^{-1}, the opening flow of continuous fibers is separated into individual, unconnected fibers, simultaneously cleaning them from impurities and defects. The essence of opening consists of dividing the provided product into separate fibers, moving them between each other, and sorting them according to their length (see Fig. 1).

Opening roller performance is affected by: feed rate, roller rotation speed, product linear density, and air velocity in the confusor. If these are not at the standard level, the fibers in the sliver are not opened, and many knots are formed, fiber complexes are formed from them, and this hurts the quality of the spun yarn.

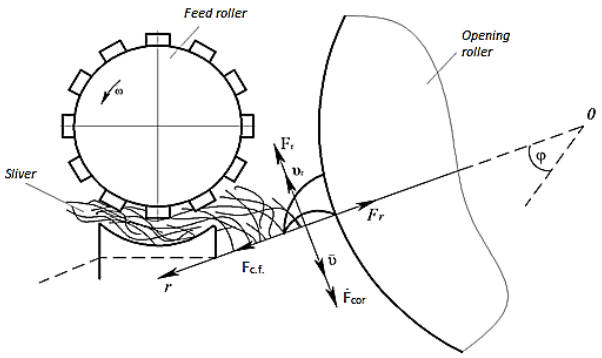

Fig.1

In the process of discretization, the parameters affecting the fibers of the recommended saw tooth set are analyzed. In addition to the correctly selected garniture, it is important to correctly select the frequency of rotation of the opening roller. As a result of the increase in the frequency of rotation, the discretization of fibers is improved, and the separation of fibers from the set and their transmission is improved, but at the same time, the number of damaged fibers may also increase. When the speed of the opening roller is too high, the fibers can be located in the transverse direction and deteriorate the structure of the spun yarn. Therefore, from 6000-11000 min^{-1} of the opening roller of the rotor spinning machine mentioned above, the rotation frequency corresponding to the angle of inclination of the saw tooth was analyzed. The opening roller is affected by the following forces during the separation of fibers from the product; Aerodynamic resistance force along the radius vector ($\vec{F}_r$), aerodynamic resistance force acting along the effort ($\vec{F}_\tau$), centrifugal force ($\vec{F}_{c.f.}$), Coriolis force ($\vec{F}_{cor}$), effort and radius-

vector direction resistance coefficient (f_r) and (f_τ), fiber flow surfaces (S_r) and (S_τ), air resistance (ρ), test speed (ϑ_τ), radius-vector speed (ϑ_r), air speed along the test (ϑ).

The above-mentioned parameters, which are formed during the separation of the product into fibers, were analyzed. The effort on the fibers based on the tooth and the aerodynamic resistance forces acting on the fibers on the radius vector were determined as follows.

$$\vec{F}_r = \frac{1}{2} f_r S_r \rho \vartheta_r{}^2, \quad (1)$$

$$\vec{F}_\tau = \frac{1}{2} f_\tau S_\tau \rho (\vartheta + \vartheta_\tau)^2. \quad (2)$$

The saw tooth-based velocities of discrete fibers along the effort and radius vector were calculated.

$$\vartheta_r = \frac{dr}{dt} = \dot{r}\vartheta_\tau = r\frac{d\phi}{dt} = r\dot{\phi}. \quad (3)$$

Pole radius and pole angles were introduced as a function of time in the study of the motion flow of discrete fibers.

$$m\ddot{r} + F_{c.f.} = \pm F_r$$

$$mr\ddot{\phi} + F_{cor} = F_\tau \quad (4)$$

here the centrifugal and Coriolis forces $\vec{F}_{c.f.} = mh\dot{\phi}^2$ and $\vec{F}_{cor} = -2m\dot{h}\dot{\phi}$ were determined as a result of the movement of fibers along the arc on the tooth base.

$$\ddot{r} + r\dot{\phi}^2 = \pm a\dot{r}^2,$$

$$r\ddot{\phi} - 2\dot{r}\dot{\phi} = \pm(\vartheta - r\dot{\phi})^2. \quad (5)$$

Values at φ=0 were determined using the initial condition, that is, in the process of separating the product into fibers.

$$(h)_{\phi=0} = h_0; (\vartheta_r)_{\phi=0} = \pm\vartheta_{r0}; (\vartheta_\tau)_{\phi=0} = \vartheta_{\tau 0}.$$

Using the initial conditions, the rotation frequency of the opening roller of the rotor spinning machine recommended for determining the overall movement speed of fibers is n_1=6500min^{-1}; n_2=7000min^{-1}; at values of n_3=7500min^{-1}, the height of the teeth is $h_{1.I}$=1.6 mm; $h_{1.II}$=1.8 mm; $h_{1.III}$=2 mm and $h_{2.I}$=1.2 mm; $h_{2.II}$=1.4 mm; At the values of $h_{2.III}$=1.6 mm and the linear velocities of the fibers corresponding to the values v_1=30 m/s, v_2=35 m/s, v_3=40 m/s, the fiber velocities are as follows

If $h > h_0$ then

$$\vartheta = 0.1rve^{-5.09(h-h_0)}/h_0\alpha^{0.75}.$$

If $h < h_0$, then $\vartheta = 0.1rv$ is determined. Here, v is the rotation frequency, h_1 and h_2 are the lengths of the saw teeth, and h_0 is the starting distance of the saw teeth. By relating the external forces acting on the fibers to the parameters of the recommended opening roller, the velocities of the fibers were analyzed.

The obtained values (see Fig. 2-5) indicate the movement of the fibers based on the teeth, the height of the saw teeth, in the case of $h_{1.I}$=1.6mm; $h_{1.II}$=1.8mm; $h_{1.III}$=2mm and $h_{2.I}$=1.2mm; $h_{2.II}$=1.4mm; $h_{2.III}$=1.6 mm, the speed due to external forces acting on the fibers was considered.

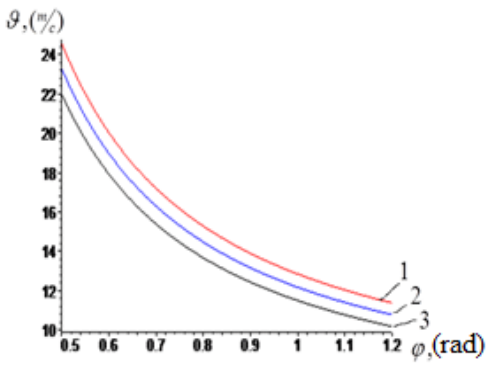

Fig.2

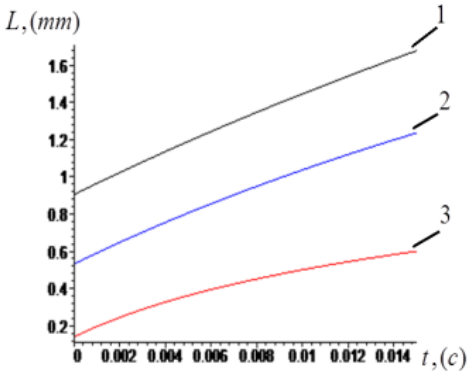

Fig.3

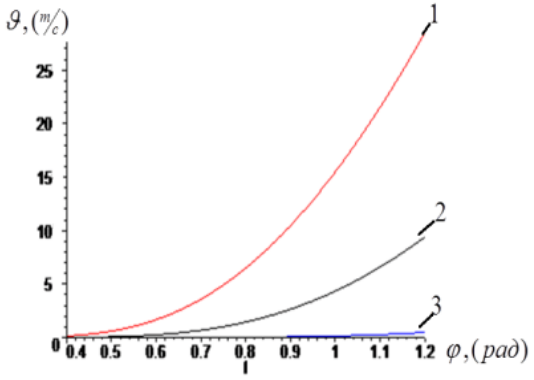

Fig.4

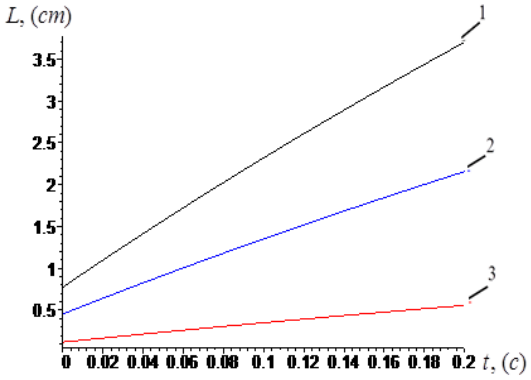

Fig.5

During the discretization process, when analyzing the parameters affecting the fibers of the recommended saw tooth garniture, it was found that in addition to the correctly selected garniture, the correct selection of the rotation frequency of the opening roller is considered important. As a result of the increase in rotation frequency, the discretization of fibers is improved, and the separation of fibers from the set and their transfer are improved. Still, at the same time, it was found that the number of damaged fibers may also increase. When the rotation speed of the opening roller is too high, the fibers may be located in the transverse direction and deteriorate the structure of the spun yarn.

In conclusion, based on the analysis of the conditions of fiber retention with the opening roller garniture teeth, the height of the garniture saw teeth, at values $h_{1.I}$=1.6mm; $h_{1.II}$=1.8mm; $h_{1.III}$=2mm and $h_{2.I}$=1.2mm; $h_{2.II}$=1.4mm; $h_{2.III}$=1.6 mm, at the distance from the process of separating the product into fibers to the working chamber, the twist angle is φ=0-1.2 rad, when the linear speed of the opening roller is v_2=35 m/s and the height of the teeth is h_1 =1.8mm and h_2=1.4mm ensure continuous transmission of the fibers caught by the teeth to the working chamber. Also, it is determined that the parameters of the saw tooth are of great importance in providing uniform and continuous fibers.

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