

Theoretical and experimental analysis of the process of discretization of cotton fiber in OE spinning

Kamol Akhmedov^{1*}, *Saypila Matismailov*¹, *Botir Mardonov*¹, and *Alisher Yuldashev*¹

¹Tashkent Institute of Textile and Light Industry, 100100 Tashkent, Uzbekistan

Abstract. This article examines the influence of the parameters of the coating teeth of the discrete drum on the quality of the OE yarn. Based on the analysis of the conditions for retention of fibers by the covering teeth of the discrete drum, equations were obtained to determine the angle of inclination of the teeth. To determine the effect of the coating parameters of the discrete drum teeth on yarn quality, experiments were performed using the Full Factor Experiments mathematical planning method, and a regression equation was obtained for each variable. As a result, the optimal values of the discretization drum coating teeth of the OE spinning machine were determined.

1 Introduction

It is known that in order to increase the efficiency of separation of complex fibers into separate fibers and to straighten and parallel the ends of the fibers in the supplied sliver, it is recommended to increase the working speed of the discretizing drum. To do this, it is advisable to use special tooth types so that there is a correlation between the parameters of the discrete drum teeth and the fiber properties. It has been found that the distance between the discrete drum teeth and the angle of inclination of the tooth have a large effect on the processing of the fiber bundle. To better separate the fibers into individual fibers, it is necessary to increase the angle of inclination of the anterior part of the dissecting drum teeth and reduce the area of impact of the tooth tip [1, 2].

Taking into account the above, in order to improve the yarn quality performance, theoretical and experimental studies have been conducted to produce a competitive product by changing the geometric shape of the discrete drum teeth and determining the optimal value of the angle of inclination of the tooth [3].

2 Theoretical part

To increase the intensity of the discretizing drum (Fig. 1), it has been proved that increasing the number of teeth per 1 cm² surface of the discretization drum can be done by applying the multi-input wrapping method of teeth and reducing the tooth pitch (Fig. 2) [4-6].

* Corresponding author: axmedov58@mail.ru

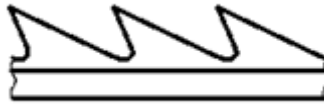


Fig. 1. Appearance of teeth wrapped around a discrete drum BD-330

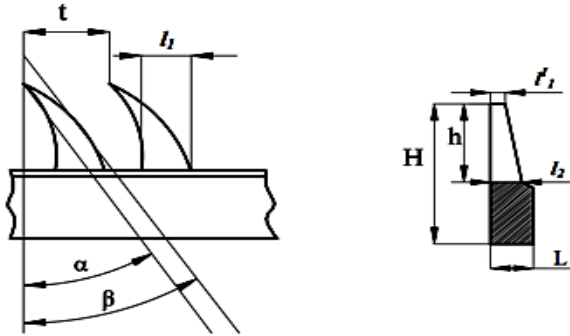


Fig. 2. A new construction tooth profile that wraps around the recommended discretion drum BD-330

In yarn formation, the flow of fiber to the continuous spinning chamber is done by discretizing drum teeth. We analyze the motion of a massive fiber whose center is at point 0 in determining the motion along the base of the tooth, which varies along the surface of the discrete drum teeth (Fig. 3).

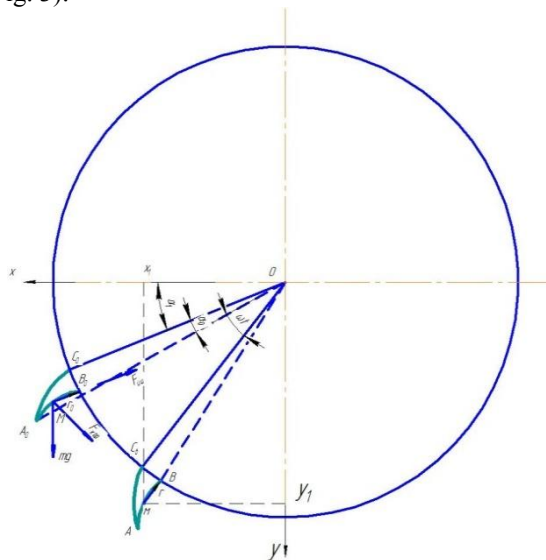


Fig. 3. Movement of fibers in discrete drum teeth.

Using the equation of motion of the fibers, we obtain the following equation.

Using the sine theorem, the following equation was derived:

$\frac{L}{\sin \beta} = \frac{R}{\sin \varphi_0}$ in this $\sin \beta = \frac{L}{R} \cdot \sin \varphi_0$ or $\beta = \arcsin \left[\frac{L}{R} \sin \varphi_0 \right]$ at time $t > 0$. If the angle $\beta > 0$ then it β_0 is as follows:

$$\beta_0 = \beta - \alpha_0 - \alpha_1 - \omega \cdot t$$

In Fig. 5 analyzed for torsion angle values at $\beta_1 = 64^\circ$; $\beta_2 = 68^\circ$; $\beta_3 = 72^\circ$ graphs on the variation of the angular velocity of the fiber movement and the tilt angles are given.

The parameters affecting the cotton fiber of the newly recommended discrete drum teeth were analyzed (Fig. 6).

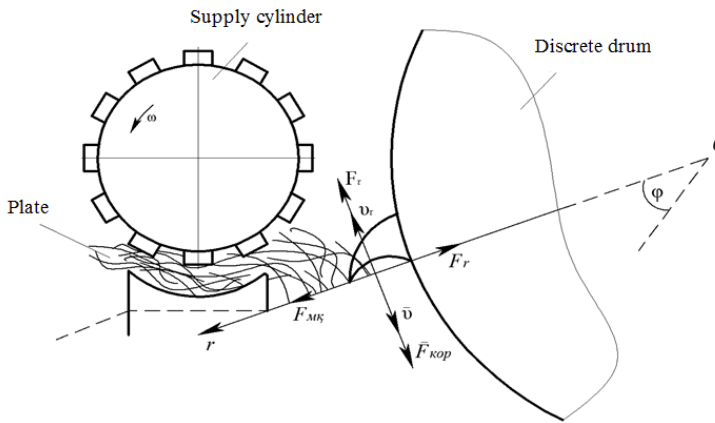


Fig. 6. BD-330 OE spinning machine supply zone diagram

If the rotational speed of the discrete drum is too high, the placement of the fibers in the transverse direction can affect the structure and quality of the yarn. Therefore, the rotational frequency of the discrete drum of the above OE spinning machine from 600 to 10000 rpm values of the rotation frequency corresponding to the angle of inclination of the coating tooth was analyzed.

3 Materials and Methods

The aerodynamic drag forces acting on the fibers along the test and radius-vector were determined as follows.

$$\vec{F}_r = \frac{1}{2} \cdot f_r \cdot S_r \cdot \rho \cdot \vartheta_r^2 \tag{2}$$

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

The velocities of the fibers at the base of the discrete drum coating tooth along the shear and radius-vector were calculated (Table 1 and Fig. 7).

$$\vartheta_r = \frac{dr}{dt} = \dot{r} \tag{3}$$

$$\vartheta_\tau = r \cdot \frac{d\varphi}{dt} = r \cdot \dot{\varphi}$$

Table 1. Values of variable parameters in determining the trajectory of fiber motion.

Trajectory	v (min ⁻¹)	\mathcal{G}_1 (m/s)	β (degree)
1	6500	0.543	64
2	6500	0.416	64
3	6500	0.231	64
4	7000	0.543	68
5	7000	0.416	68
6	7000	0.231	68
7	7500	0.543	72
8	7500	0.416	72
9	7500	0.231	72

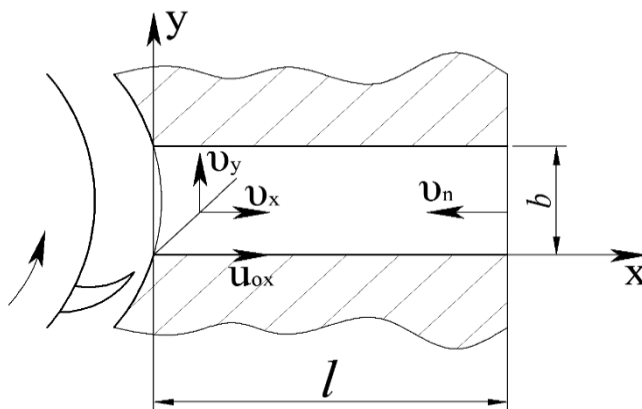


Fig. 7. Schematic diagram of small impurities and fibers in the channel for separating small particles and dust

Assuming that there is a constant cross-section of the channel for the separation of small particles and dust from the fibers, a coordinate system was chosen in which the *OX* axis corresponds to the wall of the dust removal channel.

$$\begin{aligned}
 m \cdot \frac{d\mathcal{G}_y}{dt} &= \pm \frac{1}{2} \cdot C_y \cdot S \cdot \rho \cdot \mathcal{G}_y^2 \\
 m \cdot \frac{d\mathcal{G}_x}{dt} &= -\frac{1}{2} \cdot C_x \cdot S \cdot \rho \cdot (\mathcal{G}_x + \mathcal{G}_n)^2
 \end{aligned}
 \tag{4}$$

Equation (4) represents the differential equations of motion along the channel of separation of fine particles and dust from fibers.

Here the fibers are the flowing surfaces (*S*), the coefficients of resistance C_x and C_y , the air density (ρ), the mass of the fibers (m).

$$\begin{aligned}
 y &= \frac{\mathcal{G}_t^2}{g} \cdot \ln \left[\frac{g}{\mathcal{G}_t^2} (t - t_0) + \frac{1}{k \mathcal{G}_{y0}} \right] \cdot k \mathcal{G}_{y0} \\
 x &= -\mathcal{G}_n t + \frac{\mathcal{G}_t^2}{g} \cdot \ln \left[\frac{g}{\mathcal{G}_t^2} t + \frac{1}{u_{0x} + \mathcal{G}_n} \right] \cdot k \mathcal{G}_{y0}
 \end{aligned}
 \tag{5}$$

Equations (5) show the movement of fibers along the separation channel of fine impurities and dust.

The equation of the total trajectory of the fibers along the channel was calculated:

$$l = \frac{g_t^2}{g} \cdot \ln \left[\ln \frac{u_{0x} + g_t}{g_n} - \frac{u_{0x}}{u_{0x} + g_n} \right] \cdot k \cdot g_{y0} \quad (6)$$

In order to separate fine impurities and dust from the fibers from the (6) equation of motion, the following condition must be met.

Thus, in the separation of fine impurities and dust from the fibers, the distance traveled by the fibers in the channel is determined by the value of the velocity component, as well as the magnitude and direction of the air flow velocity.

4 Results and Discussion

As the rotational frequency increases, the velocity of the fibers along the trajectory and the conditions of movement in the duct during fiber dust separation change with the direction of fiber movement and the reverse direction of air flow, the rotational frequency leads to changes in particulate matter and dust mass and quality composition (Fig. 8).

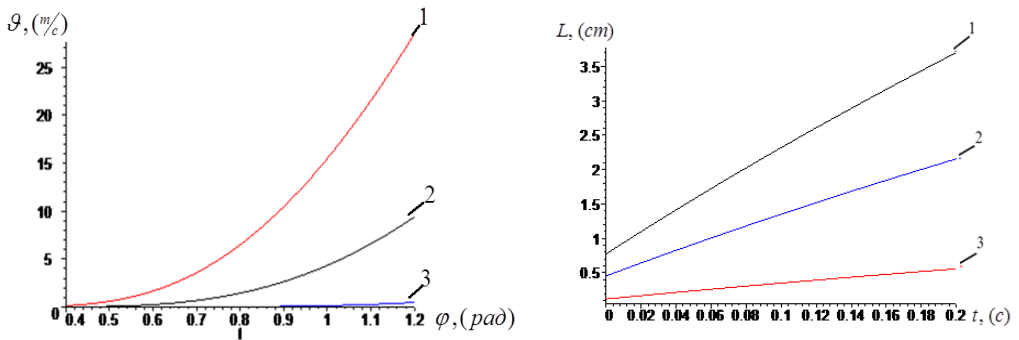


Fig. 8. Analysis of $\beta_1 = 64^\circ$; $\beta_2 = 68^\circ$; $\beta_3 = 72^\circ$ at different values of coating tooth deflection angles and different values of linear velocities depending on the time of movement under the tooth

The motion of the fibers under the influence of external forces was studied, and the angular velocity and deflection angles in it were calculated and graphs were given. Based on the analysis of the conditions of fiber retention with the discrete drum coating teeth, the equations for determining the angle of inclination of the teeth were obtained.

The equations of the change in the speed of the discrete drum, the force of gravity relative to the surface of the front ends of the tooth and the coefficient of friction of the centrifugal force, the mass of fibers held by the teeth were obtained [7].

An analytical expression of the law of motion of the fiber on the surface of the discrete drum teeth is given. As a result of the analysis of fiber tension and velocity from them, it was found that the tensile strength and velocity of the fiber increase with the increase of the discretizing zone [8, 9].

The laws of fiber velocities, discrete drum teeth torsion angle, number of revolutions and time dependence are expressed in the form of graphs.

At the Department of "Spinning Technology" of the Tashkent Institute of Textile and Light Industry in the laboratory studied the effect of tooth pitch and the angle of inclination

of the front edge of the tooth, as well as parameters of rotational frequency of the discrete drum on the quality of OE yarn Ne 24 and stability of the spinning process.

Type 5, 1st grade, good grade, Bukhara-6 selection cotton fiber was used in the production of yarn. The Full Factor Experiments-23 method of mathematical planning was used in the calculations [8].

The following indicators were accepted as undesirable factors.

x_1 - disreting drum rotation frequency, min^{-1} ;

x_2 – disreting drum tooth pitch, mm;

x_3 - teeth front edge slope angle, grad.

In constructing regression equations, the coded values of the factors were coded in the range (-1) to (+1) for each independent variable. When the minimum value of the independent variable is given as "-1", and the maximum value in the range "+1", the corresponding coded values of the factors of the natural level are obtained.

The degree of variability of the factors is given in Table 1 and Table 2 in the experimental plan.

Table 1. Level of variability of factors

Factors	Factors level			Variation intervals
	-	0	+	
x_1 - disreting drum rotation frequency, min^{-1}	6500	7000	7500	500
x_2 – disreting drum tooth pitch, mm	2,5	3,5	4,5	1,0
x_3 - teeth front edge slope angle, grad	64	68	72	4

Optimization parameters:

y1 - tensile strength of the yarn, cm/tex

y2 - CV in breaking strength, %

y3 - yarn appearance defects, km

Regression equations were constructed for each optimization parameter.

Evaluation of the values of the coefficients of regression equations is carried out by the Student's criterion, the assessment of the adequacy (suitability) of the equation is carried out by the Fisher criterion [8, 9].

Table 2. Experimental plan and results (on the specific tensile strength of the yarn)

	Factors			Experiments						
	X_1	X_2	X_3	y_{i1}	y_{i2}	y_{i3}	\bar{y}_u	S_u^2	\hat{y}_u	$R_0(\%)$
1	-	-	-	11.4	10.6	11.3	11.1	0.57	11.815	0.69
2	+	-	-	10.6	9.8	10.8	10.4	0.68	11.086	0.40
3	-	+	-	11.02	10.85	11.01	10.96	0.48	11.432	0.25
4	+	+	-	11.8	10.7	11.10	11.5	0.43	11.043	0.93
5	-	-	+	11.9	11.2	11.1	11.4	0.46	12.21	0.93
6	+	-	+	10.6	10.7	10.1	10.8	0.62	10.96	0.25
7	-	+	+	11.9	11.4	11.8	11.7	0.37	11.42	0.40
8	+	+	+	11.7	12.01	11.84	11.85	0.40	10.93	0.69

Evaluation of the quality of the raw product and yarn is tested on modern laboratory equipment (Table 3).

Table 3. Table summarizing the results of experiments

#	Coding the value of factors							Optimization parameters				Continuous variance
	x ₁	x ₂	x ₃	x ₁ ·x ₂	x ₁ ·x ₃	x ₂ ·x ₃	x ₁ ·x ₂ ·x ₃	y1 - tensile strength of the yarn, cm/tex	y2 - CV in breaking strength, %	y3 - yarn appearance defects, km	Average value	
								\bar{Y}_1	\bar{Y}_2	\bar{Y}_3	\bar{Y}	
1	-	-	-	+	+	+	-	11.1	9.4	141	53.8	5699.3
2	+	-	-	-	-	+	+	10.4	9.7	153	57.7	6811.7
3	-	+	+	-	+	-	+	10.96	9.5	130	50.2	4782.2
4	+	+	-	+	-	-	-	11.5	9.1	124	48.2	43106.7
5	-	-	+	+	-	-	+	11.4	9.3	128	49.6	4615
6	+	-	+	-	+	-	-	10.8	9.6	146	55.5	6147.7
7	-	+	+	-	-	+	-	11.7	8.8	116	45.5	6294.8
8	+	+	+	+	+	+	+	11.85	8.6	120	46.8	4075

The model has a second-order polynomial shape:

$$y = b_0 + \sum_{i=1}^N b_i x_i + \sum_{ij=1}^N b_{ij} x_i x_j + \sum_{i=1}^N b_{ii} x_i^2 \tag{7}$$

where, b₀, b_i, b_{ij} - the estimates of the model coefficients; N - number of experiments; and, x_i, x_j- are factors.

After subtracting the insignificant coefficients, the regression equations look like this:

$$y_1 = 11,26 + 0,157x_1 - 0,448x_2 - 0,2x_3 + 0,35 x_1 \cdot x_3 - 0,2 x_2 \cdot x_3 \tag{8}$$

$$y_2 = 9,21 - 0,117x_1 + 0,383x_2 - 0,325 x_1 \cdot x_3 + 0,1 x_2 \cdot x_3 \tag{9}$$

$$y_3 = 132,88 - 5,5x_1 + 8,33x_2 + 8,25x_1 \cdot x_2 - 8,25 x_1 \cdot x_3 + 8,5 x_2 \cdot x_3 \tag{10}$$

To evaluate the adequacy of equations (8-10), the calculated values y_1 , y_2 , y_3 were determined (Table 3). The adequacy of the equations (8-10) was evaluated using the F-ratio (Fisher's criterion) [9]:

$$F = s_{agi}^2 / s_{yi}^2,$$

Where, s_{agi}^2 -equality variance is calculated according to Equation (11)

The exact values of the y_f values calculated as the adequacy variance are a measure of the deviation from y_f .

5 Conclusions

Thus, from the compatibility of Equations 8-10, it can be concluded that:

- the tensile strength of the yarn increases with increasing rotational frequency of the discretizing drum and decreasing the pitch of the tooth. Increasing the angle of inclination of the tooth is advisable when the tooth pitch is not large.

- the CV in the breaking force decreases with increasing discretizing drum rotation frequency, decreasing tooth pitch and increasing the front edge slope angle;

- the total amount of appearance defects decreases with increasing discretizing drum rotation frequency and increases sharply with increasing tooth pitch, increasing the front edge slope angle reduces the number of yarn imperfection, but their amount increases sharply with increasing tooth pitch.

Using the obtained regression dependencies, the following optimization task was constructed: minimizing the amount of appearance defects as a result of high limits of specific breaking strength and low limits of CV in breaking strength. Option 8 is suitable for this optimization task. The rotational frequency of the discrete drum is 7000 rpm, the pitch of the tooth is 2.5 mm, and the angle of inclination of the front edge of the teeth is 68°.

Proper selection of the parameters of the sampling drum increases the stability of the OE spinning process. Yarn breaks decreased from 38 to 26 breaks per 1,000 chambers.

References

1. V. E. Ribin, *Fiber* **17**(13), 17 (2005)
2. S. N. Khripunov, *Fiber* **9**, 11 (2000)
3. A. Pirmatov, *Fiber technology*, 149 ("Ijod Print" Press, Tashkent, 2020)
4. YU. V. Pavlov, *Technology of cotton fiber*, 521 (Ivanovo Press, Moscow, 2000)
5. F. M. Plekhanov, *Theory of fibering*, 298 (Nauka Press, Moscow, 2000)
6. A. R. Horrocks, S. Anand, *Handbook of technical textiles*, 576 (The Bolton Institute Press, UK, 2000)
7. T. R. Rashidov, SH. SHoziyotov, Q. B. Mo'minov, *Theoretical Mechanics* 290-295 (1990)
8. M. M. Varkovetskiy, *Light Industry*, 72-73 (1982)
9. A. G. Sevostyanov, *Light Industry* **12**, 165-167 (2007)