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STUDY OF THE PROCESS OF FIBER RECOVERY FROM CUTTINGS

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Abstract: The article is devoted to the regeneration of fibers from garment waste, i.e. from cuttings and flaps, which are secondary raw materials. The influence of the cylinder diameters of the feeder of the fiber recovery machine and their rotation frequency on the properties of the recovered fiber, that is, the fiber yield, the residual fiber content and the degree of fiber shortening, has been studied. The output parameters are the amount of waste to be separated, the proportion of unreported and scraps of thread, as well as the shortening of the fiber length. Experiments on the matrix of a rotatable central compositional experiment were carried out and the corresponding regression equations were obtained. As a result of their solution, the best options were found. As a result of the experiments, the values of the factors providing the best indicators of the properties of the fiber were determined, and, accordingly, the possibility of obtaining a high-quality reconstituted fiber was proved. The properties of yarn obtained using reduced fibers as a component in a mixture have been studied.
Keywords: waste, sewing trim, secondary raw materials, disconnection, recovered fiber, pinching machine, supplying cylinder, regression equation, optimization, matrix, factor.

INTRODUCTION

One of the promising areas of development of the textile industry of the country is the saving of raw materials, processing of textile waste, production of high-quality recovered fiber, production of yarn, fabrics, knitwear [1-17].

Rational use of textile waste allows to save primary raw material resources, expand the range of products, reduce product costs and waste, create resource-efficient and waste-free technology in production [1-4, 10,11].

The properties and degree of fineness of regenerated fibers obtained from sewing sheets depend mainly on the operation of spinning machines, in particular, on the process of splitting into fibers [1,2].

The solution to the problems of increasing production efficiency and improving product quality is often achieved by optimizing technological processes [3-8].

The main purpose of the study is to determine the parameters of the effective operation of the device for the supply of pinching machine in the production of regenerated fiber, separating the secondary raw material - fiber into fibers.By determining the optimal values of the diameters of the supply cylinders of the spinning machine and their rotational frequency, it is possible to obtain a quality restored fiber. The selection of the optimum performance parameters of the supply device ensures high efficiency of fiber separation into fibers, reduces the separation of untreated fiber particles into waste and maintains the staple length and toughness of the fiber.

By obtaining high-quality regenerated fibers and adding a certain amount of them to the mixture, it is possible to reduce its cost without reducing the physical and mechanical properties of the yarn.

It is known that the factors influencing technological processes can be quantitative and qualitative. Quantitative factors are determined by numbers and their level is continuously changed [7, 8]. In spinning, these factors include speed, splitting, strength, elongation, and linear density of the fiber. Qualitative factors are the variety of equipment, the variability of cotton sorting, the type of fiber, etc., which are found by exact numbers in accordance with the factor change levels. Mathematical models are usually used to express the effect of factors. When choosing a model, first passive experiments are conducted and a modeling plan is selected. Active experiments in spinning are carried out under production conditions in accordance with the rules, and the number of tests has to be limited.

When spinning, as well as practical tests should not exceed 12-16 [9]. It should be noted that due to the need to re-evaluate the results, it is possible to increase the number of tests when the tests are repeated.

Experimental planning methods are the most advanced mathematical methods used in the study of technological processes, because the process is achieved efficiently and economically, changing the factors in the study interval and obtaining a mathematical model of the studied process [5,6]. With the help of experimental planning, all factors are changed at the same time and their interactions are also evaluated.

THEORETICAL RESEARCH

Experimental studies were conducted using the D-Vox Optimization Plan to optimize the preparation parameters of the fiber separation machine. The levels and intervals of factor change are given in Table 1.

TABLE 1

Change levels of factors

Factors	Levels of Change				
	-1,414	-1	0	1	1,414
X_1 -is the diameter of the first cylinder, mm	62,9	65,0	70,0	75,0	77,0
X_2 - is the diameter of the second cylinder, mm	55,7	57,0	60,0	63,0	64,2

The following were selected as optimization parameters: $Y1$ - amount of waste, g;
$Y2$ - percentage of unprocessed yarn and particles,%; $Y3$ is the reduction in fiber length,%.
The planning matrix and experimental results are presented in Table 2.

TABLE 2
Planning matrix and experimental results

Experiments №	Factors		Optimization parameter		
	X_1	X_2	Y_1	Y_2	Y_3
1	+	+	38,6	36,0	9,0
2	-	-	32,4	35,4	6,8
3	+	-	26,0	32,8	7,2
4	-	0	25,2	35,2	7,3
5	-1,414	0	31,8	35,7	11,4
6	1,414	-1,414	25,2	35,7	8,1
7	0	1,414	24,0	34,2	6,7
8	0	0	43,0	38,2	8,3
9	0	0	27,3	36,1	7,3
10	0	0	28,0	35,9	7,6
11	0	0	28,4	34,4	7,8
12	0	0	27,5	35,0	7,4
13	0	0	27,0	34,9	7,5

To solve the problem, the calculation and optimization parameters of the regression multivariate model (RKOM) were performed using the computer's MATHCAD program. The MATHCAD program was also used to determine the performance of the regression equation.

Y=b0+b1·x1+b2·x2+…+bn·xn+b ·x 2+b22·x22+…bnn·xn2+b12·x1·x2+b13· x1· x3+… (1)
11 1

here: b0 – free step; b1, b2, ... bn … bnn …. – coefficients.

As a result of statistical processing of the experimental results on a computer program MATHCAD obtained regression multivariate mathematical model in the following forms with a probability of 95% reliability of the adequacy of the parameters:

$$Y_1=27,64–0,492X_1+5,834X_2+1,75\,X_1\,X_2+0,317\,X_1^2+2,818X_2^2 \quad (2)$$
$$Y_2=35,26–0,348\,X_1+1,097X_2+0,745\,X_1\,X_2–0,174\,X_1^2+2,201X_2^2 \quad (3)$$
$$Y_3=7,52–0,428\,X_1+0,545\,X_2+0,575\,X_1\,X_2+0,853\,X_1^2+0,273\,X_2^2 \quad (4)$$

Since the issue is multidimensional, the optimization problem is to determine the diameters of the first and second cylinders (X1 and X2) so that Y1 is the amount of waste released, Y2 is the percentage of poorly spun yarn and particles, and Y3 is the minimum percentage of fiber shrinkage. should be. To solve the problem, we use the target function (D) of the generalized optimization criteria and the complex efficiency indicator (F).

In the calculation it should be taken into account that the optimization parameters have different meanings relative to each other. Significance of an indicator means the importance of a quantitative characteristic of that indicator, among other indicators. The quantitative value of a property is usually determined using one of three different expert, correlation, and evaluation methods. Significance coefficients should be defined in such a way that their sum n is equal to the number of optimization parameters.

Thus, in the presence of many optimization criteria, the task of optimization is to determine the maximum values of the target function (D) and the efficiency complex indicator (F). According to the expert assessment, the significance of the optimization parameters (Si) S1 = 0.58; S2 = 1.5; S3 = 1.0.

The following generalized target function was obtained and the results for the experiments performed after the calculation on the computer

Are given in Table 3.

TABLE 3
Target function values

Number of experiments	1	2	3	4	5	6	7	8	9	10	11
D (scrap)	0,562	0,656	0,734	0,678	0,535	0,670	0,717	0,486	0,650	0,649	0,630

Analyzing the values in the table, we can say that the target function was

D = 0.734 (X1 = +1, X2 = -1) in Experiment 3 and D = 0.717 in Experiment 7. (X1 = 0, X2 = -1,414) have the largest values.

Thus, when finding the optimal values of the diameters of the cylinders that provide the separation of fragments into fibers in the flow system, the coded values of the target function on the experimental data are 0 <X1 <1,414; - 1,414 <X2 <-1, and the natural values are:

diameter of the first cylinder – D1 = 70 mm <X1 <78 mm,

the diameter of the second cylinder is D2 = 55.7 mm <X2 <57 mm. In this case, the best experimental result of the optimization parameter is Y1exp. = 25.2 g, Y2exp. = 32.8%, Y3exp. = 7.2% ga teng.

It is then necessary to continue to determine the optimal (next stage of optimization) by combining all the specific (Y1 – Y2) indicators in a single efficiency complex indicator (F) using the complex efficiency indicator (F), thereby transforming the multidimensional problem into a single criterion. In this direction, the combination of optimization parameters Y1 – Y2 is carried out by the following formula:

F(X)=C1·F2+ C2· F2+ C3·F3 (5)

Here: C1, C2, C3 - respectively Y1– Y3 the importance of optimization parameters; $F_i = \frac{Yi - Yi\ max}{Yi\ max - Yi\ min}$

(6)

Equation (3.6) is divided into equations (3.2) - (3.7) by taking the corresponding maximum and minimum values of mathematical models and optimization parameters from Table 1, Y1 – Y3, and placing them in equation (3.8) with a one-criterion complex quality index. The optimization parameters are then determined using the Neldera-Mida simplex method of the optimization function (3.5) at selected values (Table 4) with a certain limit and significance. Calculations are completed when the complex quality indicator has a maximum value.

TABLE 4
Data evaluation table

Number	Name	Optimization parameter		
		Y_1	Y_2	Y_3
1	The best	24,0	30,0	6,0
2	Average	32,0	35,0	9,0
3	The lowest	40,0	40,0	12,0

The solution of the general problem of optimization of selection parameters in the simplex method [6] is within the following limits, ie

24 <U1 <40 g; 30 <U2 <40%; 6.0 <U3 <12%.
The optimal values of the diameters of cylinders X1 and X2 are given in Table 5.

Optimal values of cylinder diameters X1 and X2

TABLE 5

Number	Name	Optimal parameters				
		X_1	X_2	Y_1	Y_2	Y_3
1	scrap	+1,0	- 1,0	22,69	33,09	6,55
2	scrap	+1,414	-1,414	21,05	21,05	6,05

Complex performance demonstration management good results optimization parameter X1 = 1,414; X2 = -1,414 is obtained and their diameter is prepared for the following natural values.
X1 - diameter of the first cylinder – D1 = 77 mm,
X2- is the diameter of the second cylinder – D2 = 55.7 mm
Thus, the optimal parameters of the cylinder diameters obtained by the crown method, which perform the function of the optimization method based on the complex properties, were determined.
The absolute and relative error in relation to the values of the optimization parameters obtained in the experimental and large methods are given in Table 6

TABLE 6
Optimization parameter values

Number	Name	Optimization parameter		
		Y_1	Y_2	Y_3
1	Experimental	23,20	32,80	7,20
2	Accounting	22,36	33,31	7,44
3	Abs. Error	0,74	-0,51	- 0,22
4	Comp. Error	3,2 %	1,6 %	3,14 %

The analysis of Table 6 shows that the relative error between the experimental and calculated results is not large, ie with 95% reliability Y1 – Y3 (3.2) - (3.4) mathematical models adequately represent the process of splitting fragments into fibers and are used to determine the optimal diameters of cylinders.

Multi-factor optimization, based on the results of production experience on a pinching machine to separate the particles into fibers, allows to determine the optimal diameters of the cylinders of the supply device.

The next step in optimization is to determine the rotational frequency of the supply device, which ensures high efficiency of fiber separation into fibers, reduces the separation of unbroken fiber particles into waste, and maintains the staple length and toughness of the fiber.

It is known that the value of the change in the coefficient of loss of fiber toughness is significantly affected by the composition of the mixture from which the yarn and fabric are produced. In addition, the addition of chemical fibers to the mixture allows to increase the coefficient of loss of fiber toughness, but makes it difficult to add the obtained recovered fibers to the mixture.

Preliminary studies have shown that the efficiency of splitting strands into fibers depends on the density of the fabric, the type of weave, the type of fiber and the yarn used.

EXPERIMENTAL RESEARCH

Experiments on the processing of sewing knitting needles on the first pinching machine of SHANDONG SHUNXING MACHINERY of EUROAZIA ALLIANCE TEX LLC were carried out [11] and the obtained results are given in Table 7.

Based on the results of the experiment, the quality indicators of the recovered fiber from the cuttings, the efficiency of fiber separation, the amount of fluff output and the amount of waste were determined.

Based on the results of the experiment, the experimental parameters were approximated and a third-order mathematical model was obtained, which shows that the staple length, shear strength, fiber separation efficiency of the recovered fibers depend on the rotational frequency of the first supply cylinder.

TABLE 7
Quality indicators of fiber recovered from cuttings

№	Rotation of the supply cylinder frequency, min-1		Quality indicators of regenerated fiber		Fiber separation efficiency,%	The amount of down,%			Amount of waste,%
	The first cylinder	the second cylinder	L SF, мм	Breaking force, sN		1 drum	2 drum	Exit	
1	0,35	0,44	23,0	1,52	37,1	16,2	20,2	8,2	26,0
2	0,40	0,54	23,2	1,83	37,0	16,4	20,0	7,9	26,3
3	0,45	0,59	24,2	1,92	37,2	15,9	18,1	8,0	26,4
4	0,48	0,60	24,2	2,20	38,2	29,0	23,3	19,1	32,0
5	0,54	0,66	21,3	1,77	35,3	24,0	22,0	20,0	44,1
6	0,58	0,75	24,3	1,50	36,8	28,8	22,2	18,9	33,3
7	0,61	0,75	22,7	1,41	36,0	34,6	24,4	24,0	43,1
8	0,64	0,80	23,1	1,79	36,5	25,2	25,0	21,2	25,6
9	0,67	0,85	24,1	1,51	37,9	29,1	22,4	18,5	31,0

Dependence of the staple length (Ln) of the fiber on the rotational frequency (n) of the first supply cylinder.

LSF= − 40,3256+397,63n-806,47n2+532,006n3 (7)

The dependence of the breaking strength (R) of the fiber on the rotational frequency (n) of the first supply cylinder.

P= −23,76+155,782n−307,75n2+196,869n3 (8)

The dependence of the rotation frequency (n) of the first supply cylinder on the fiber separation efficiency (E.exp.).

Эexp= −32,9+448,227n−920,44n2+623,581n3 (9)

Based on the obtained models and experimental results (Table 1), experimental and computational curves of the above connections were constructed (Figure 1).

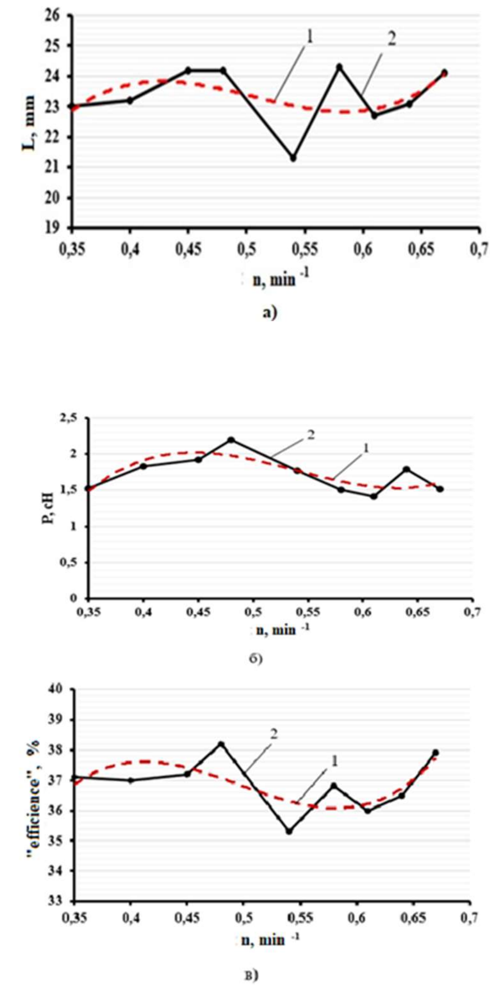
Analysis of the obtained results showed that the best physical and mechanical properties of the recovered fibers were obtained in the following experiments on the efficiency of fiber separation and toughness coefficient:

Experiment № 4; n1 = 0,48 min -1; n2 = 0,60 min -1:

staple length - LSF = 24,2 мм

breaking force - P = 2,2 cH

fiber separation efficiency - Cexp = 38,2%.



1- calculation curve, 2- experimental values.

FIGURE 1. Staple length of fibers recovered from the cuttings a), tensile strength b) and fiber separation efficiency c) Graph of dependence on the frequency of rotation of the supply cylinder.

The results of the research showed that the movement of cuts at low speeds in the supply zone of the spinning machine and careful processing in a technological mode with a small rotational frequency of the spinning drum ensures a satisfactory separation of sewing pieces into quality fibers.

CONCLUSION

The optimal values of the parameters of the machine for the separation of cotton fiber sewing knitwear into fibers were determined on the basis of mathematical planning of experiments. Experiments were carried out to obtain regenerated fiber from sewing sheets, the optimal values of the rotational frequency of the supply cylinders of the twisting machine were determined, the best physical and mechanical properties of the regenerated fibers were , 48 min -1; the quality of the recovered fiber is obtained when the diameter of the second supply cylinder d2 = 55.7 mm and the rotational frequency n2 = 0.60 min-1.

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