International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 05, 2020
ISSN: 1475-7192

Study of Technological Parameters of Fiber Separation Device

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Abstract--- *This article examines the strength of a device designed to separate spinning fibers from fiber waste (lint, lint) produced at a cotton gin. The study determined the resistance of the shaft to vibration as a result of periodic loading and the frequency of vibration along its axis through the critical rotational frequency.*

Keywords--- *Cotton Fiber, Fiber Out, Construction, Short Fiber, Efficiency, Device, Spinning, Fiber Separation, Needle Drum.*

I. INTRODUCTION

It is known that an average of 3-4% of cotton fiber, which is a valuable raw material for the textile industry, is added to lint or other fibrous wastes (Figure 1). This leads, firstly, to the loss of valuable fiber, and on the other hand, to a deterioration in the quality of the lint. By introducing the proposed device, it is possible to separate the spinning long fibers from the lintering process into a fluffy mixture [1].

In order to solve the task, the goal was to create a device for the separation of fiber and lint from the lintering process. As a result, the amount of fiber output in the enterprise will increase and the quality of lint will improve. The purpose of offering the device is to improve the quality of lint by separating the long fibers that are added to the lint, increasing the amount of fiber output in the enterprise and preventing long fibers from joining the lint.

a) b)

Figure 1: Fiber content: a) Lint Content, b) Fiber Content

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DOI: 10.37200/IJPR/V24I5/PR2020624
Received: 14 Apr 2020 | Revised: 22 Apr 2020 | Accepted: 12 May 2020

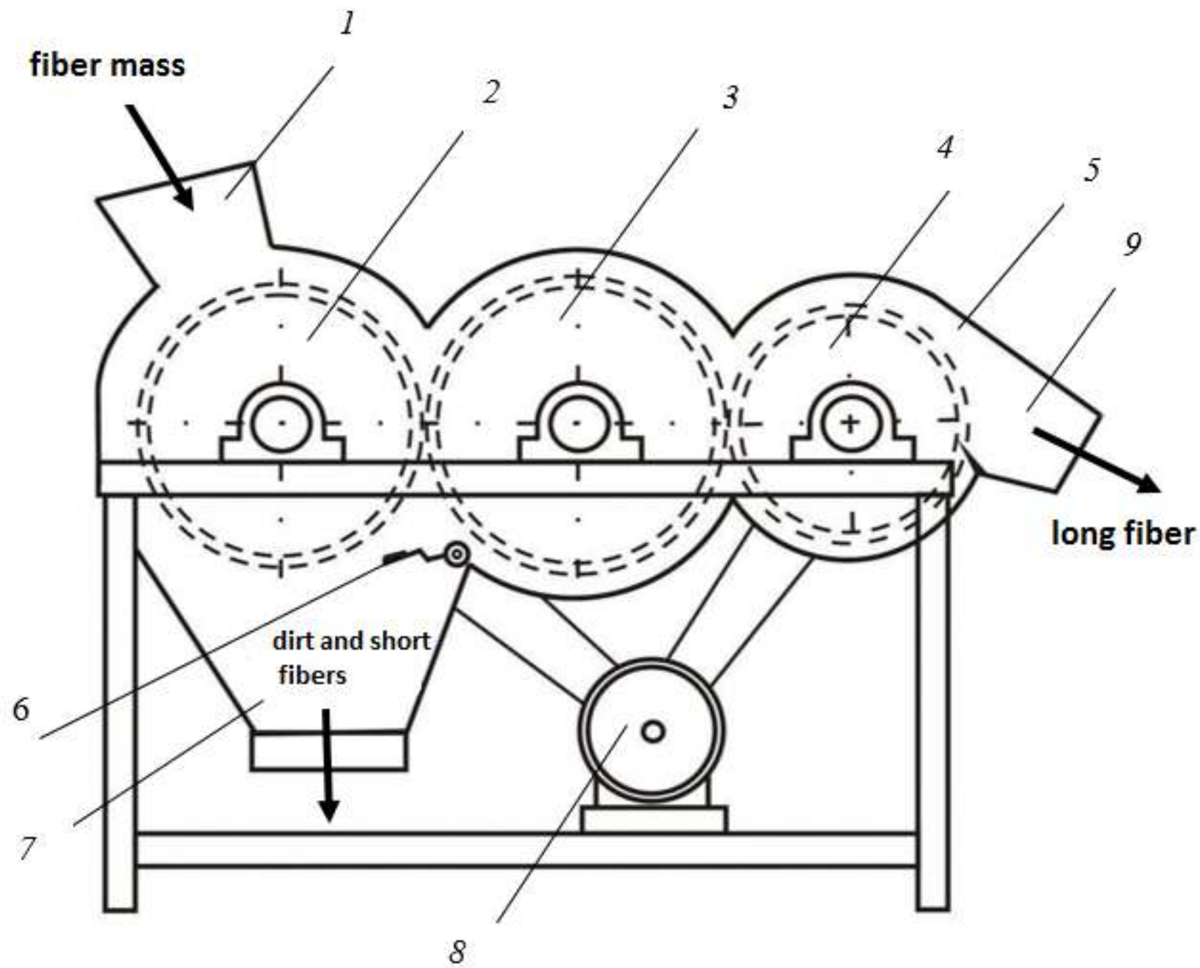

Figure 2: Schematic Diagram of a Spinning Cotton Fiber Separation Device

The proposed device consists of the following main elements: 1 inlet pipe, 2-needle receiving drum, 3-needle main drum, 4-brush drum for removing long fibers, 5-kojux, Router for 6 long fibers, mine for 7 short fibers,8-electric motor, 9-shaft for long fiber (Fig. 2).

This device works as follows: the fluffy mass from the linter comes to the needle receiving drum 2 through the inlet pipe 1, where the fibrous mass is attached to the drum for spinning and the spinning process begins and it is additionally spun using side-mounted drills (not shown in the picture). After that, the crushed fiber mass comes to the needle main drum 3 and through the oblique needles of the main drum, the long fibers in the mass are hung and removed. The remaining short fibers and other contaminants in the receiving drum 2 come down and are discharged out of mine 7 for the short fibers.

In order to increase the accuracy of hanging long fibers, a guide 6 is mounted on the lower wall of the needle main drum 3, by means of which long fibers are directed to the main drum.

The long fibers attached to the main drum 3 are removed in the next process through the brush drum 4 and for the long fibers are pulled out through the shaft 9.

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An experimental version of this device was prepared and preliminary tests were carried out to determine whether 1-2% of the long fibers were added to the lint, causing the loss of valuable raw materials. Among the properties that characterize the length of a fiber, its uniform distribution along its length is of great technological importance. Therefore, the experiments were repeated several times.

The second and most important aspect of the issue is to determine the feasibility of using this device in industry. Therefore, on the basis of the model of the device, work was carried out to determine its technological parameters. In order to justify the effective operation of the selected design of the new fiber separation device, it is first necessary to select its optimal technological parameters. Improving the efficiency and effectiveness of the process of extracting long fibers from the composition of fibrous waste (fluffy, dead) is directly related to them [2,3]. The application of mathematical methods in the planning and conduct of research allows to determine the individual effects of the interaction of several factors that characterize the combined parameters of the optimization parameters, in contrast to traditional computational methods of research. As a result, it will be possible to obtain a mathematical model of the object under study in a relatively small number of tests, which model will simultaneously serve to obtain optimal solutions.

An important issue in optimization is to identify important factors that affect the separation of long fibers from the fiber mass composition. This serves to ensure that the work is efficient by ensuring that the needle (needle) drum adheres well to the fibers. As the optimization parameters - the efficiency of the device in the separation of long fibers was selected. That is, the study of the device takes into account what percentage of the long fibers present in the fiber waste are separated by the device.

Taking into account the results of theoretical research and literature reviews on the new device, as well as the following factors were selected as input factors influencing the output parameters in the first one-factor experiment:

X_1 - the number of revolutions of the needle drum (n_{ab}) *circle/min*;

X_2 - the distance between the needle and the brush drum (a) *мм*;

X_3 - the angle of inclination of the guide (α) *degree*.

Based on the analysis, it was possible to create a device for the separation of long fibers [5]. The main working body of this device is the needle and brush drum zone, and the process is carried out as a result of the rotation of these drums. In addition, a switch mounted on the inlet side of the device also has a significant effect. It can ensure that the fibrous mass comes directly to the surface of the needle drum. During the operation of the device, the needle drum should be able to hold the long fibers well, as a result of choosing the optimal distance from the brush drum, it will be possible to effectively pull the fibers from the saws.

To ensure the efficient operation of the separator, the number of revolutions of the needle drum, the distance between the needle drum and the brush drum and the angle of inclination of the guide, the size of the inlet and outlet pipes, the slope of the saw, the number of brushes must be chosen. Based on practical and theoretical research, we have selected the following factors that have a significant impact on efficiency.

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The number of revolutions of the needle drum X_1. The number of revolutions of the needle drum is one of the main factors, which determines the efficiency of separating long fibers from the fibrous waste composition, the drum speed can accurately separate long fibers, and also creates a state of drum fiber mass splitting. It is convenient to separate a separate body from a self-determined crushed mass. In selecting the value of this factor, the values accepted in the fiber cleaning-separation machines were used, the value was selected in the range of 500-1500 circle/min.

The distance between the needle and the brush drum X_2. This distance also ensures that the fiber separation process is efficient. This is because the optimal distance between the two drums ensures maximum separation of the fibers adhering to the needle drum by means of brushes and transfer to the pipe. The possibility of free movement of the drums should also be taken into account when selecting this value. With this in mind, this distance was chosen in the range of 1–3 mm.

The angle of inclination of the guide X_3. The router of the fiber separation device serves to direct the incoming fiber mass from the inlet pipe from the receiving drum to the needle drum. Given that no previous studies have been conducted on structures close to this device, the slope angle was taken to be 5 Celcium to 15 C relative to the device inlet pipe wall, depending on the structure of the structure. This is because the analysis of the initial experiments showed that if the slope angle is taken to be less than 5 C, or more than 15 C, it becomes impossible to direct the flow along the desired trajectory.

Experiments were conducted using modern mathematical planning methods to determine the optimal performance of the fiber separation device [6,7]. Based on these experiments, it is necessary to select the most optimal sizes that will ensure the efficient operation of the fiber separation device.

Table 1: The Factors under Study are the Selection of Levels and Intervals of Change

Name and designation of factors		Change levels			Change interval
		-1	0	+1	
The number of revolutions of the needle drum (n_{ab}) *c/min*	X_1	300	200	500	200
Between the needle and brush drum distance (a) *mm*	X_2	1	2	3	1
The angle of inclination of the guide (α) *degree*	X_3	5	10	15	5

The process of fiber separation, which depends on many factors, has been studied using modern mathematical planning methods using exposure [8,9]. This allows you to have the optimal solution with the least cost.

It is necessary to use instruments capable of measuring with the required accuracy to conduct experimental tests. In particular, the Precision PT-2235B digital tachometer was used to measure the number of revolutions of the needle drum. In our experiments, changing the diameter of the pulleys to change the number of revolutions of the shaft was done by means of an electric motor. The distance and slope angle were determined using known methods [10].

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A fiber mixture of 30 kg was passed through the inlet pipe at the specified number of revolutions. Each test was repeated five times. It was found in the tests that the production productivity was properly selected by the number and timing of cycles accordingly. The angle of inclination of the guide was measured using a protractor. The experiments were performed in a randomized order. Prior to testing, the amount of fiber in the fiber mass longer than 16 mm is determined using an AX analyzer. After the test, the short fiber mass from the device is again checked using an analyzer to determine the amount of long fibers. As a result, the percentage of long fibers separated by the device is known, the inspection is carried out in accordance with the rules established in the laboratories of ginneries.

On a general basis, we move from the natural values of the factors to the coded values. The results of the Full Factor Experiment (TOT) showed that the process under study was represented by a higher-level equation. Therefore, in order to obtain a mathematical model of secondary regression, a central non-composite experiment (CNC) was selected and implemented, which is much simpler and more convenient than other methods, as well as widely used in the study of technological processes of ginneries.

Based on the experimental results, we look for a secondary regression multivariate mathematical model. As a result of this experiment, we can obtain the following general regression model:

$$y_R = b_0 + \sum_{i=1}^{M} b_i x_i + \sum_{\substack{i=j=1 \\ j \neq 1}}^{n} b_{ij} x_i x_j + \sum_{i=1}^{M} b_{ii} x_i^2$$

Since three factors are involved in our experiment, it takes the following form:

$$y_R = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_{12} x_1 x_2 + b_{13} x_1 x_3 + b_{23} x_2 x_3 + b_{11} x_1^2 + b_{22} x_2^2 + b_{33} x_3^2$$

Regression equations were developed for each outgoing parameter and results were obtained.

According to the results, we obtain the following three-factor secondary mathematical regression equations for the resulting parameters: $y = 92 + 22{,}4x_1 + 24{,}3x_2 + 22x_3 - 58{,}2x_1^2 + 62{,}3x_2^2 - 88{,}3x_3^2$

These three-factor mathematical regression models were analyzed in the final form, i.e., taking into account the significant regression coefficients using the Student Criterion, and after the hypotheses about the adequacy of the resulting models were tested using the Fisher Criterion.

It is known that the contribution of factors to the efficiency of the separation device in the transition from the minimum value to the maximum value determines the effect of the factors. It can be seen from the obtained models that the rotation speed of the machine drum is at a medium value, the distance between the drums and the angle of inclination of the guide is at a minimum, which leads to an increase in productivity. In this case, the effect of the first factor is 98%, the change of the second factor is 92%, and the effect of the angle of inclination can lead to an increase in machine productivity up to 98%. However, it should be borne in mind that the existing limitations, i.e. the increase in productivity, lead to the efficiency of long fiber separation. The results of the numerical search method also showed that the number of drum revolutions was 480 rpm (in the first experiments), and the machine

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had the maximum productivity when the distance between the drums was 2 mm and the angle of inclination of the guide was around 10 degrees.

It is possible to observe the law of variation of the separation efficiency according to the length of the separated fibers. As shown above, in the first experiment we can see that the slope angle of the guide is not significant for its efficiency, since the separation of the longest fibers from the fine mixtures is constructively assumed. Indeed, experiments have shown that a change in the maximum value of the rotation speed allows the separation of long fibers up to 5.2%, and an increase in the angle up to 5.7%. This confirmed the conclusion of the theoretical part of the work that such an effect of factors, that is, the fiber rotates faster around the center of gravity and is oriented relative to the saw teeth.

The decrease in the efficiency of the fiber separation machine causes the geometrical parameters of the main working bodies to change according to a certain pattern. This can also be seen from the analysis of mathematical regression models. This situation can be explained by the fact that the fiber content of the fiber prevents it from gaining orientation relative to the saw teeth.

The fiber separation process in the brush drum section has been confirmed to be an important step, as it increases the fiber yield during the initial processing of the cotton. It can be seen from the regression model that the distance between the drums serves as an important factor in the separation of the fibers. At the same time, its efficiency can increase up to 6.4%.

Table 2: Influence of the Values of Selected Factors on the Basis of the Results of Theoretical Studies on the Efficiency of Fiber Separation

n, c/m	*a, mm*	*α, degre*	v_{wr}, *м/sec*	*Y, %*
300	2,0	5	0,16	83
400	1,5	10	0,21	92
500	1,0	10	0,26	96
600	1,5	15	0,31	91
700	3,0	20	0,37	86

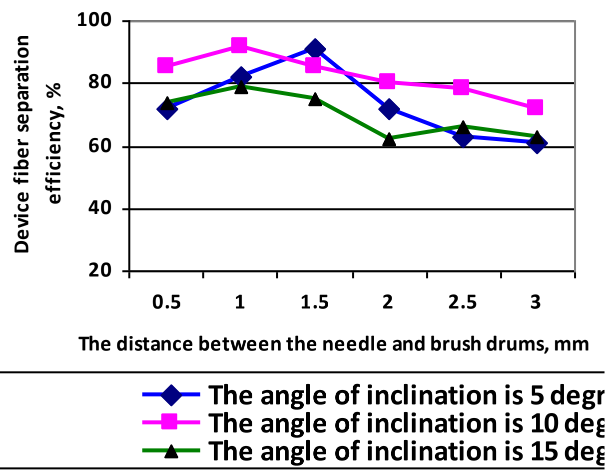

Figure 3: Graph of the Distance between the Drums at different Slope Angles as a Function of the Separation Efficiency of the Device

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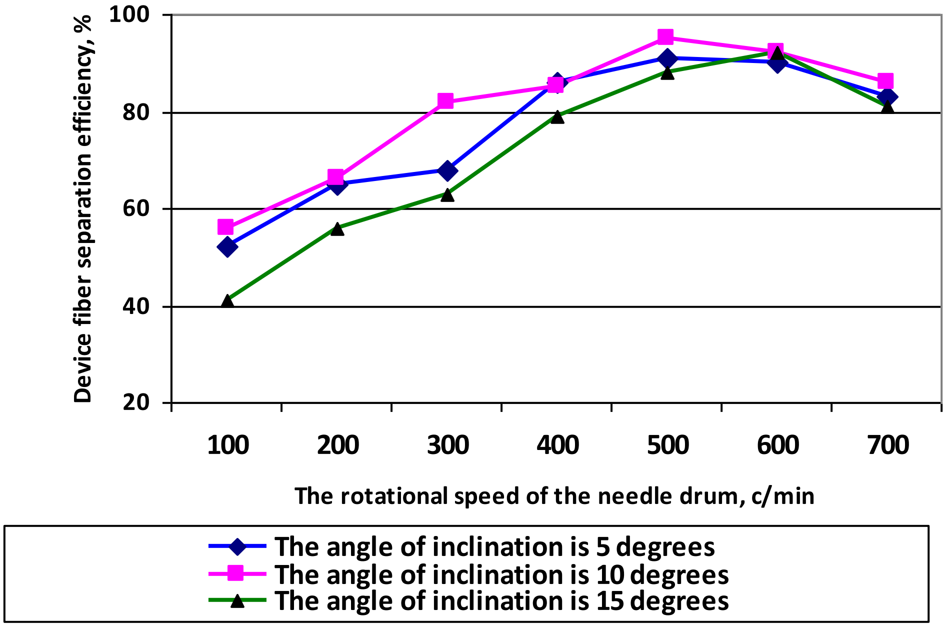

Figure 4: Graph of Dependence of Needle Drum Rotation Speed on Device Separation Efficiency at Different Slope Angles

II. Conclusion

From the above analysis of the effect of factors on each outgoing parameter, it can be seen that in determining the optimal values of the factors, multifaceted mutually exclusive aspects must be taken into account. For this purpose we found it necessary to use the following mathematical apparatus of optimization.

As a comparison, analysis of the extremum of the output parameters and a compromise solution that meets all requirements, the following optimal values of factors influencing the performance of the fiber separation device were determined: Number of revolutions of the needle drum - 480 rpm; The distance between the needle and brush drum - 1 mm; The angle of inclination of the guide is 10 degrees.

Based on the results of the above studies, the results on fiber separation efficiency are presented in Table 2 and the graphs in Figures 3-4 by substituting the required factor values from the regression equations in order to compare the theoretical conclusions.

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