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I TECHNICAL SCIENCES: COTTON, TEXTILE AND LIGHT INDUSTRY

IMPROVING THE SEPARATOR DESIGN TO PREVENT COTTON FIBER LOSS

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Abstract: This scientific study addresses the problem of fiber loss in the cotton ginning industry, examining the scientific and practical basis for the structural improvement of the working chamber of the cotton air separator. The key innovation is the introduction of specialized trapezoidal guide vanes into the separator's inlet, which serve to minimize the mechanical contact between the cotton flow and the grid surfaces. The results of theoretical modeling and experimental analysis under industrial conditions confirmed the high efficiency of the proposed design. The implementation of the guide vanes significantly reduced the fiber loss coefficient: for I-II grades, from 0.70 kg/h to 0.28 kg/h (60 % reduction), and for lower-grade cotton (III-V), from 3.78 kg/h to 2.42 g/h. Comparative calculations indicated that the enterprise saves a total of 4,495.5 kg of cotton fiber over one year of operation. The monetary equivalent of this saved raw material is over 73 million Sum, ensuring a rapid payback for the equipment modernization costs.

Keywords: Separator, cotton fiber, loss, trapezoid, guide vane, design, efficiency, mechanical damage, economic benefit.

Introduction. The cotton fiber processing industry is one of the crucial sectors of Uzbekistan's economy, and its production efficiency directly depends on preserving the quality indicators of the cotton raw material. During the initial processing of raw cotton at ginning factories, especially during pneumatic transport and air separation stages, mechanical damage and loss of fiber represent a serious challenge. These losses not only result in a quantitative decrease in fiber but also lead to a decline in its quality parameters, ultimately causing significant damage to the national economy.

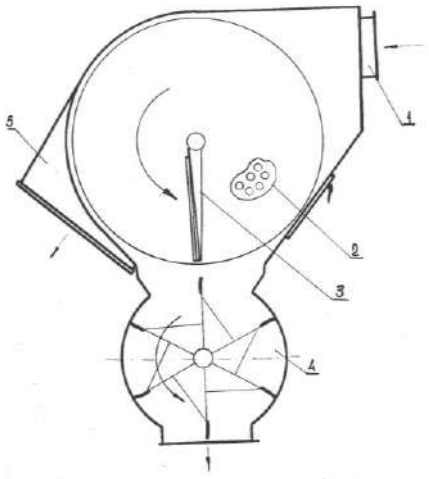

Figure 1. "SS-15" separator

1-inlet pipe; 2-mesh surface; 3-thruster; 4-vacuum valve; 5-suction short pipe.

Conventional air separators used in the cotton industry exert a strong mechanical impact on the cotton fiber due to their high operating speed. The movement and impact of cotton against the grid surfaces within the working chamber lead to partial separation, crushing, and subsequent loss of the fiber. Analysis of the current technological processes indicates that fiber loss coefficients in separators vary significantly by grade, ranging from 0.7 kg/h to 3.78 kg/h. The highest levels of loss are observed when processing III, IV, and V grade raw cotton.

One of the primary objectives facing the modern cotton ginning industry is to minimize fiber loss by improving the design of technological equipment. Scientific research suggests that this problem can be addressed by optimizing the mechanical movement of the cotton and reducing its contact time with the working surfaces [68, 69, 70].

The objective of this study is to develop the scientific and practical basis for preventing cotton fiber loss by installing new, trapezoidal guide vanes in the working chamber of the cotton air separator and to evaluate its economic efficiency. The study provides a detailed comparative analysis of the influence of the improved design on fiber loss indicators compared to the existing separator.

MATERIALS AND METHODS.

2.1. Improved Separator Design

The main object of the study is the improved design of the cotton air separator. The novelty of the project is defined by the introduction of elements with a specific geometry—the trapezoidal guide vanes—inserted into the separation chamber within the side wall of the input pipe.

Design Solution: Trapezoidal guide vanes were installed in the working chamber of the separator along the direction of the air flow. The purpose of these vanes is to reduce the movement and subsequent mechanical impact of the raw cotton towards the grid surface of the chamber during the processing cycle.

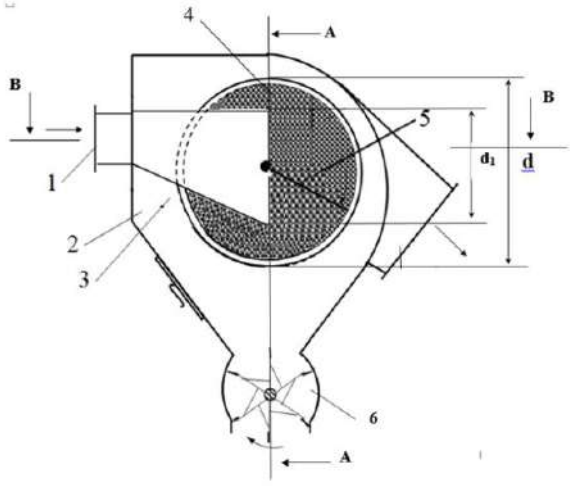

Figure 2. Scheme of a separator with a guideway (patent №FAP 01879)
1-inlet pipe; 2-working chamber; 3-trapezoidal guideway; 4- mesh surface; 5-damper; 6- air suction pipe; 7- vacuum valve.

In-Depth Analysis of the Design: The trapezoidal shape of the guide vanes is crucial; their pointed end gently receives the incoming flow, enhancing the efficiency of capturing the cotton, while the wider base directs the cotton away from the grid surface and straight towards the vacuum valve (outlet). This mechanism reduces the contact area of the fiber with the grid surfaces by up to \$40\ %\$ compared to the conventional design.

2.2. Theoretical and Experimental Methodology

The motion of cotton in the working chamber was studied theoretically based on Newton's second law and hydrodynamic resistance forces [68]. These theoretical calculations, relying on the principles outlined in [68], helped predetermine the influence of key factors like cotton flow density (kg/m^3) and air velocity m/s) on fiber loss. The theoretical modeling suggested that the minimum loss occurs when the trapezoid angle is within the range of 25° ± 3°.

Experimental Validation: Experiments were conducted under industrial conditions, comparing two states of the separator: (1) the control group (standard separator without vanes) and (2) the experimental group (separator with the proposed guide vanes). The trials were carried out with various cotton moisture levels and degrees of contamination. For each trial, the mass of lost fiber (g), collected by specialized collectors after processing, was accurately measured.

2.3. Methods for Calculating Fiber Loss

To assess the efficiency, the difference in fiber loss was calculated based on the factory's annual operating time and cotton grade distribution. The total annual operating time of the separator was taken as 5882 hours.

●Operating time for Grades I and II cotton (T): T = (48.4% + 14.4%)/100% times 5882 = 3693 hours.

●Operating time for Grades III, IV, and V cotton (T_1): T_1 = (17.0% + 19.81%)/100% 5882 = 2165 hours.

Table 1. Quantitative Distribution and Quality Characteristics of Cotton Grades (Based on Annual Plan)

Cotton Grade Group	Total Distribution (%)	Annual Operating Time (hours)	Average Contamination Level (%)
Grades I and II	62.8	3693	2.0 - 3.5
Grades III, IV, V	36.81	2165	4.0 - 7.0

RESULTS.

The results of the experimental and computational studies clearly indicate the efficiency of the improved separator design (trapezoidal guide vanes) in terms of reducing fiber loss:

Table 2. Impact of Separator Design on Fiber Loss (Annual Basis)

Grade Group	Indicator	Current Variant (H_s)	Proposed Variant (H_n)	Difference in Loss (kg)
Grades I and II	Loss Coefficient (kg/h)	0.70	0.28	-
	Annual Loss (H_{s1}, H_{n1}), kg	H_{s1} = 2585.1	H_{n1} = 1034.0	1551.1
Grades III, IV, V	Loss Coefficient (kg/h)	3.78	2.42	-
	Annual Loss (H_{s2}, H_{n2}), kg	H_{s2} = 8183.7	H_{n2} = 5239.3	2944.4
TOTAL	**Total Annual Loss, kg**	**10768.8**	**6273.3**	4495.5

Interpretation of Results:

1. *Efficiency for Grades I and II:* The fiber loss coefficient was reduced from 0.70 kg/h to 0.28 kg/h, indicating an annual saving of 1551.1 kg of high-quality fiber.
2. *Efficiency for Grades III, IV, V:* For lower grades, the loss coefficient decreased from 3.78 kg/h to 2.42 kg/h, resulting in the largest saving of 2944.4 kg of fiber per year.
3. *Overall Result:* The implementation of the improved separator design enables the enterprise to save a total of 4495.5kg (approximately 4.5 tons) of cotton fiber annually.

Discussion.

The results demonstrate that introducing trapezoidal guide vanes into the separator design is scientifically justified and highly effective, both technically and economically.

4.1. Analysis of Technical Results

The technical success lies in the ability of the guide vanes to effectively regulate the cotton flow, thereby drastically reducing the mechanical impact of the cotton stream on the grid surfaces. This reduction directly mitigates fiber breakage and adherence to the surface.

The particularly high efficiency observed in the low-grade cotton group (III, IV, V, with 2944.4 kg saved) is explained by the fact that these grades contain a higher percentage of fine and coarse trash. The guide vanes not only protect the fiber but also quickly redirect the trash-laden cotton masses toward the outlet, reducing the likelihood of trash-related clogs and secondary fiber loss at the grid surface.

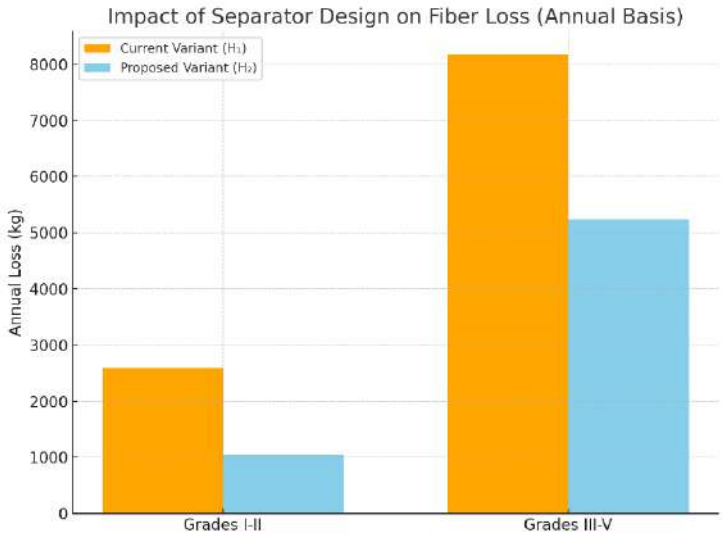

Figure 3. Graph of Impact of Separator Design on Fiber Loss

Yellow column — Annual fiber loss in the current option (H_1)

Blue column — Loss in the proposed new option (H_2)

4.2. Economic Efficiency Assessment

The economic value of the proposed design was determined by calculating the saved fiber's monetary equivalent. The average prices used for the calculation were derived from the dissertation data (approximately 18,153 Sum/kg for Grades I-II and 15,301 Sum/kg for Grades III-V).

Comparative Economic Analysis: The economic benefit achieved annually (approx 73 million Sum) is achieved despite the relatively low investment cost associated with installing the trapezoidal guide vanes (primarily material and installation costs). This significant annual return ensures a very rapid payback period (estimated at 3-4 months), confirming the high profitability and strong justification for industrial implementation of this solution.

Table 3. Economic Benefit from Preventing Fiber Loss

Grade Group	Saved Fiber (kg)	Average Price (Sum/kg)	Economic Benefit (Sum)
Grades I and II	1551.1	approx 18,153	28,157,476
Grades III, IV, V	2944.4	approx 15,301	45,051,720
TOTAL	**4495.5**	-	73,209,196

Conclusion.

This study confirms the achievement of high scientific and practical results by introducing trapezoidal guide vanes into the working chamber of the separator. The

vanes successfully reduced the movement of raw cotton towards the grid surface, serving as a primary technical solution to prevent mechanical damage to the cotton fibers.

The research found that the enterprise saves a total of 4,495.5 kg of cotton fiber per year, with an economic value of approximately 73,209,196 Sum. The improved separator design provides a highly effective and economically justifiable solution for preventing fiber loss in the cotton ginning industry. Further research may focus on studying the wear rate and mechanical properties of the separator elements under prolonged use.

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