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INNOVATIVE SEPARATOR DESIGN FOR ENHANCING FIBER RETENTION IN PNEUMATIC TRANSPORT SYSTEMS

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Abstract. This research focuses on minimizing cotton fiber loss by optimizing the structural design of the cotton-air separator. The proposed modification involves the integration of specialized trapezoidal guide vanes within the working chamber. This innovation reduces the contact area between the raw cotton and the screen surfaces by approximately 40%, thereby significantly mitigating mechanical damage to the fibers. Experimental data indicate a substantial reduction in the fiber loss coefficient: from 0.70 kg/h to 0.28 kg/h for high-grade cotton (I-II) and from 3.78 kg/h to 2.42 kg/h for lower grades (III-V). Economic analysis confirms an annual fiber saving of 4,495.5 kg, resulting in an estimated benefit exceeding 73 million UZS. With a rapid payback period of 3-4 months, this technical solution offers high efficiency for the cotton ginning industry.

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

Introduction. The cotton fiber processing industry is one of the important sectors of the economy of Uzbekistan, and production efficiency directly depends on maintaining the quality indicators of cotton raw materials. Mechanical damage and loss of fiber during the primary processing of raw materials in cotton ginning plants, especially during the stages of cotton transportation and air separation, is a serious problem. These losses lead not only to a quantitative decrease in fiber, but also to a decrease in its quality parameters, which ultimately causes significant damage to the national economy [1-3]. Traditional air separators used in the cotton industry, due to their high-speed operation, have a strong mechanical effect on cotton fiber. The movement and impact of cotton on the mesh surface in the working chamber leads to partial separation, crushing and, as a result, loss of fiber. Analysis of existing technological processes shows that the fiber loss coefficients during cotton processing through separators vary significantly depending on the grade and range from 0.7 kg/h to 3.78 kg/h. In particular, these losses are observed at the highest level when processing cotton raw materials of grades III, IV and V [4-5]. One of the main tasks facing the modern cotton ginning industry is to minimize fiber loss by improving the design of technological equipment. Scientific studies show that this problem can be solved by optimizing the mechanical movement of cotton and reducing the time of contact with working surfaces [6-7].

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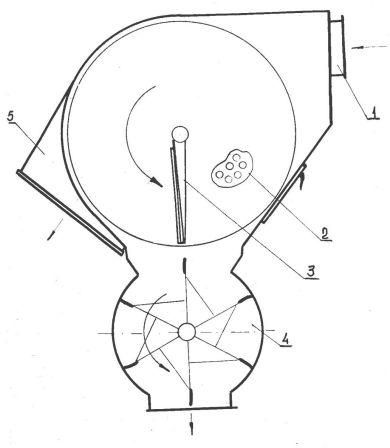

Figure 1. "SS-15" separator

1-inlet pipe; 2-mesh surface; 3-squeeze; 4-vacuum valve;

5-short suction pipe.

The purpose of this study is to develop scientific and practical foundations for preventing fiber loss by installing new, trapezoidal-shaped deflectors in the working chamber of a cotton air separator and to assess its economic efficiency. The study provides a detailed comparative analysis of the effect of the improved design on fiber loss indicators compared to the current separator [8].

Materials and methods. The main object of the study is the improved design of a cotton air separator. The novelty of the project is determined by the introduction of elements with a special geometry into the side wall of the separator inlet pipe and into the working chamber [9].

Constructive solution: Trapezoidal deflectors were installed in the working chamber of the separator along the direction of the air flow. The purpose of these guides is to reduce the movement of the chamber towards the mesh surface during the processing of cotton raw materials and the resulting mechanical shocks.

In-depth analysis of the constructive solution: The trapezoidal shape of the guides gently receives the incoming flow, increasing the efficiency of cotton capture, while the wider base serves to direct the cotton away from the mesh surface and towards the vacuum valve. Through this mechanism, the area of contact of the fiber with the mesh surfaces is reduced by up to 40% compared to the traditional design.

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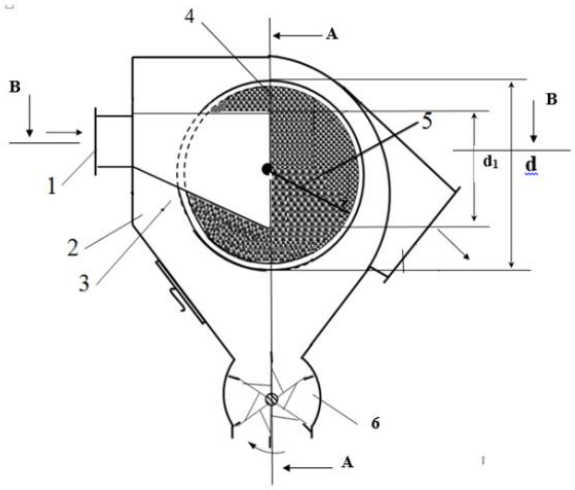

Figure 2. Scheme of a separator with a guide (patent No. FAP 01879)

1-inlet pipe; 2-working chamber; 3-trapezoidal guide;

4- mesh surface; 5- strainer; 6- air suction pipe; 7- vacuum valve.

The movement of cotton in the working chamber was modeled based on Newton's second law and hydrodynamic resistance forces [9]. These theoretical calculations helped to predict the influence of such important factors as cotton flow density and air velocity on fiber loss. The results of theoretical modeling predicted that the lowest loss was observed in a certain range of trapezoidal angle α.

In experiments conducted in industrial conditions, two different separator conditions were compared: (1) control group (standard separator without guides) and (2) experimental group (separator with the proposed guide). The experiments were conducted at three different moisture contents and different levels of contamination of cotton, and for each experiment, the lost mass of fiber (g) in special collectors after processing was accurately measured [10-11].

To determine the difference in loss, the annual operating time of the enterprise and the distribution of cotton were taken into account. The total annual operating time of the separator was taken as 5882 hours.

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

● Operating time (T1) for grades III, IV, V cotton: T1=(17.0%+19.81%)/100% 5882 = 2165 hours.

Table 1

Qualitative and quantitative distribution of cotton varieties (According to the annual plan)

Cotton grade	Overall distribution (%)	Annual operating time (hours)	Average pollution level (%)

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Grades I and II	62.8	3693	2.0 - 3.5
Grades III, IV, V	36.81	2165	4.0 - 7.0

Research Results and Analysis. The research results showed the improved design's fiber loss efficiency compared to the current separator as follows:

Table 2

Effect of Separator Design on Fiber Loss (Annualized)

Variety group	**Indicator**	**Current option (h_s)**	**Proposed option (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 loss, kg**	**10768.8**	**6273.3**	4495.5

1. Efficiency for grades I and II cotton: The loss coefficient was reduced from 0.70 kg/h to 0.28 kg/h, which means that 1551.1 kg of high-quality fiber was saved per year.

2. Efficiency for grades III, IV and V cotton: The loss coefficient was reduced from 3.78 kg/h to 2.42 kg/h, and the largest amount of fiber was saved per year - 2944.4 kg.

3. Overall result: The improved design allows saving a total of 4495.5 kg (about 4.5 tons) of cotton fiber per year.

The results obtained prove that the introduction of trapezoidal guides is technically and economically highly effective.

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The installation of guides regulates the cotton flow and dramatically reduces the mechanical impact of cotton on the mesh surfaces. The observation of high efficiency in low-grade cottons (III, IV, V) (2944.4 kg saved) indicates that even the high flow of impurities contained in these grades is quickly directed to the outlet by the diverters, which prevents secondary fiber loss caused by impurities.

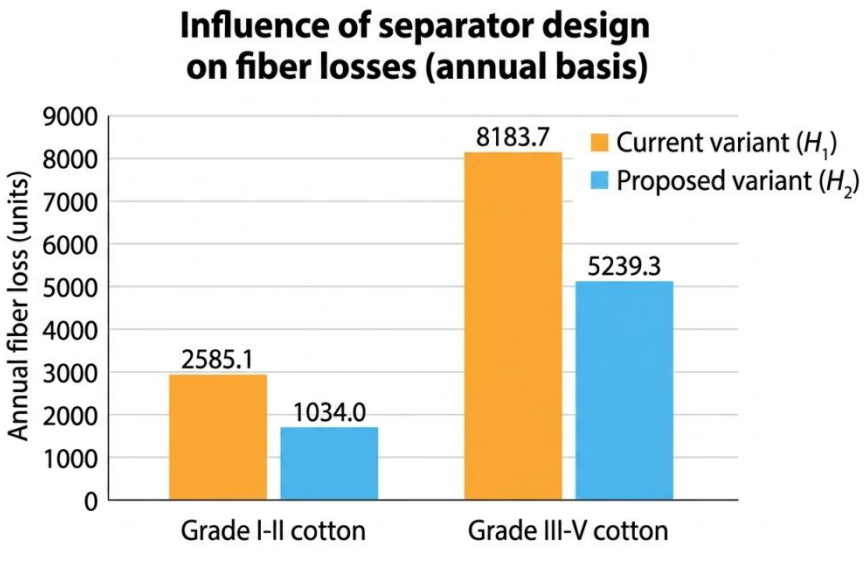

Figure 4. Graph of the effect of the separator design on fiber loss

The economic efficiency of the design was determined by expressing the amount of saved fiber in monetary terms. The average prices from the dissertation data (≈ 18,153 soums/kg for grades I and II, ≈ 15,301 soums/kg for grades III-V) were taken as a basis.

Table 3

Economic benefit saved from fiber loss

Variety group	Fiber retained (kg)	Average price (sum/kg)	Economic profit (sum)
Grades I and II	1551.1	≈ 18,153	28,157,476
Grades III, IV, V	2944.4	≈ 15,301	45,051,720
Jami	**4495.5**	**-**	73,209,196

With low investment costs for installing trapezoidal guides in the separator, the net economic benefit of more than 73 million soums per year allows to cover this investment in a

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very short period of time (approximately 3-4 months). This ensures high profitability of the proposed solution.

Conclusion. This study confirmed that high scientific and practical results were achieved by introducing trapezoidal guides into the working chamber of the separator. The guides effectively reduced the movement of cotton raw materials on the mesh surface, which became the main solution for preventing mechanical damage to cotton fibers.

As a result of the study, the enterprise was able to save a total of 4495.5 kg of cotton fiber during the year, the total economic value of which is about 73,209,196 soums. The improved separator design serves as a highly effective and economically viable solution for preventing fiber loss in the cotton ginning industry.

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