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Bench-scale study of centrifugal fan parameters

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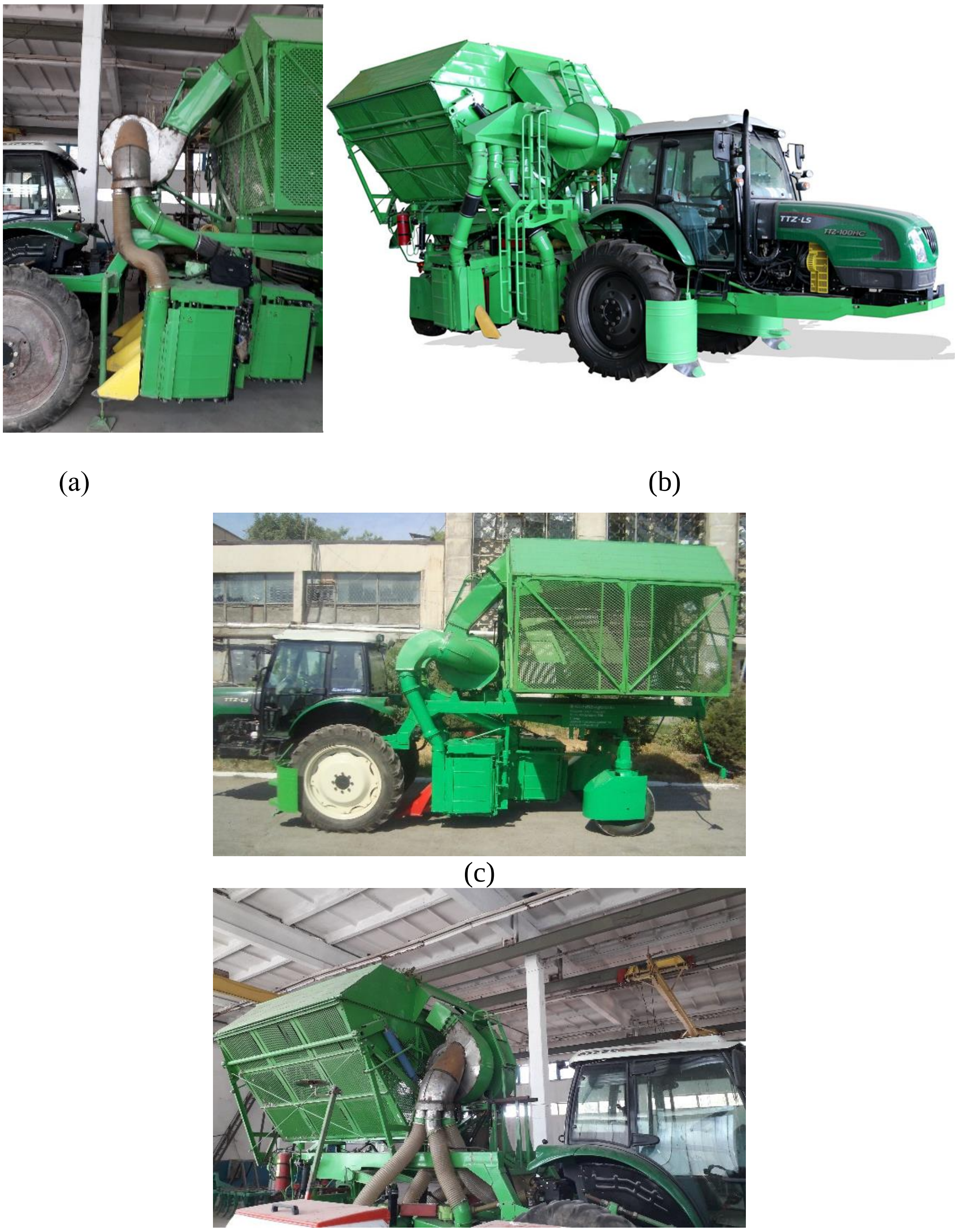
Abstract. The article is devoted to the development of a special simulation bench installation for studying the quality of the centrifugal fan used in the suction - blower pneumatic transport system of modern vertical - spindle cotton pickers. The principle of operation of a production structure of a pneumatic transport system with a lateral elliptical inlet of the fan casing is described based on a known technical solution. In order to determine the optimal location of the lateral elliptical suction channel of the fan casing, a stand was created that includes a centrifugal fan mounted on a frame and receiving movement by means of a belt drive from an electric motor. Four different positions of the ellipsoidal inlet and one central side connection of the air intake to the fan casing were tested on the bench. Based on the experiments carried out using a given amount of transported cotton, the performance of the fan was determined with the least damage to the seeds.

1. Introduction

In the known spindle cotton harvesters, pneumatic conveying systems are the simplest and the most effective ways to transport the harvested cotton from the picking device. The airflow in the pneumatic conveying channel can be created by means of a blower or a suction fan. They differ from each other in design and energy consumption [1-18]. Cotton picked from the cotton bolls is fed by spindle drums to the doffer zone of the picking device, and, owing to the reversal of spindles and brush-slat doffers, it is fed through the gap between the doffer and the side trap of the device into the receiving chamber. The receiving chamber is a parallelepiped-cylindrical pipe with a side entrance, the height of which is equal to the working length of the doffer. The doffer brushes throw the picked cotton into the receiving chamber at a certain speed. The lower part of the receiving chamber is open for air inflow and the discharge of heavy impurities entering the chamber. The fan, mounted on the machine frame by means of telescopic rigid metal short pipelines, and rigidly connected to the upper part of the receiving chamber, sucks in the airflow from this entrance and the cotton, getting the initial velocity from the doffer, falls into the receiving chamber of the apparatus and is carried away by the airflow and moves to the suction fan. In a centrifugal fan, cotton meets the impeller, which consists of blades curved in an Archimedean spiral and, moving with them, enters the tangential outlet of the fan and falls into the hopper.

At present, the Tashkent Agricultural Machinery Plant produces cotton harvesters with pneumatic transport systems (PTS), which have different position points for the pipe and centrifugal fan connection (Fig.1 a, b, c, d). In [19], it is shown that the mechanical damage to cotton seeds is influenced by the cross-sectional shape and position of the end air collector of the pneumatic transport system. A tangential pipe-fan connection, shown in Fig.2 was proposed as a rational technical solution to solve this problem. There, the cross-sectional shape of the connection has an ellipsoidal shape and one of the centers of the ellipse semi-axes is the axis of the fan blade shaft.



(a) (b)

(c)

(d)

Figure 1. Various positions of elliptical side entrance to the fan: inverted (a); equatorial (b, c); rational (d).

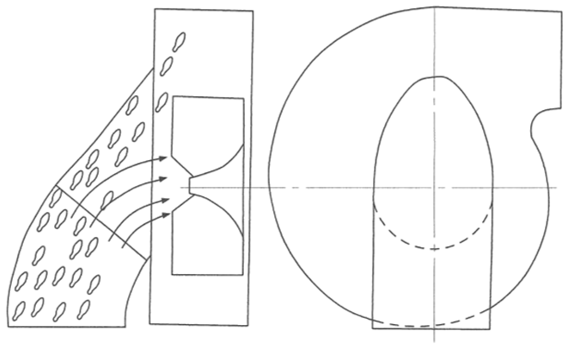


Figure 2. Technical proposal of the author's certificate No. 144939 SU for the position of the elliptical side entrance to the fan.

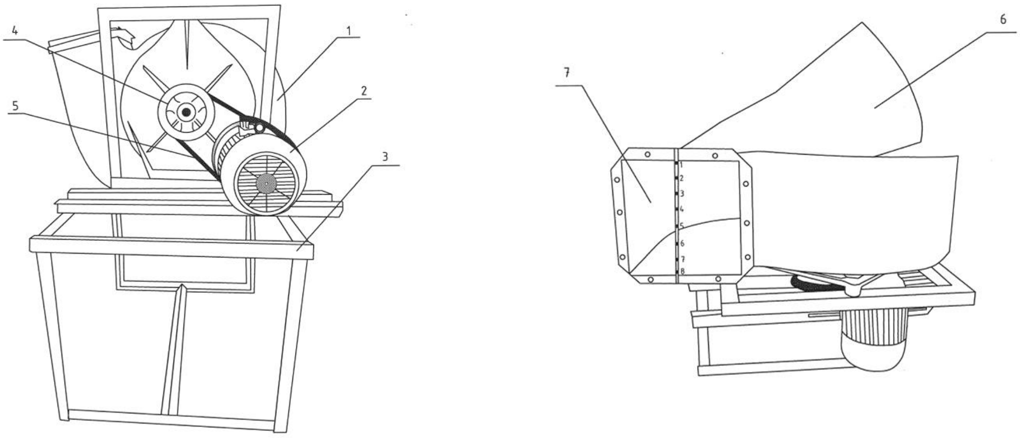
In this paper, the results of an experimental study of the methods of connecting the central air collector of the pneumatic channel to the fan are given.

2. Research method

The design of the existing less energy-consuming pneumatic transport system of modern cotton pickers is described and a simulation bench installation is developed, including a centrifugal fan with a changed location of the side inlet channel of its body. The stand allows you to simulate real processes in the pneumatic transport system of a cotton picker. In accordance with the requirement of GOST 21820-76, the stand determined the quality of cotton seeds transported from the harvester to the bunker of the machine. The experimental results were processed by methods of mathematical statistics. On the basis of bench tests and static processing of their results, an improved fan design has been determined, which provides the required performance with minimal damage to cotton seeds. An improved fan design was developed based on bench-scale tests and static processing, which provides high productivity and minimal damage to cotton seeds.

3. Results and discussion

To conduct research on the task at hand, a test bench installation was developed, a schematic representation of which is shown in Fig.3 (a, b).

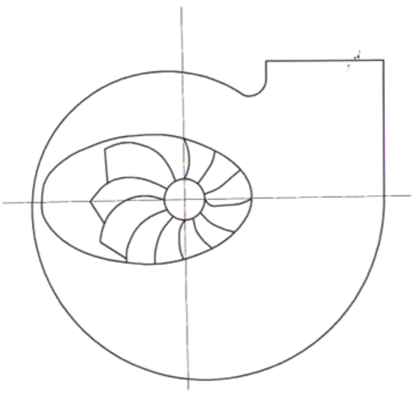


a) b)

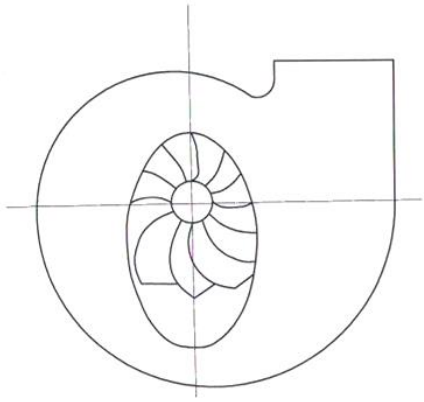
Figure 3. Schematic representation of the bench
a) side view; b) top view

The bench installation (Fig.3 (a, b)) consists of a centrifugal fan 1 used in vertical-spindle cotton harvesters, an electric motor 2, a frame base 3, a pulley 4, a belt 5, an air inflow collector 6, and a tangential outlet 7 in the fan casing. In comparative experiments, the fan rotor speed was taken equal to n= 1300 rpm.

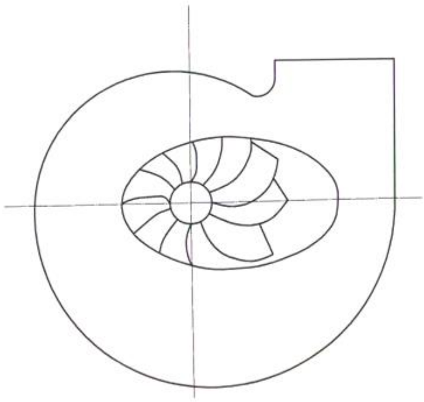
The experiments were conducted with five options of the end connection of the air collector to the fan casing, shown in Fig.4 (a, b, c, d, e).



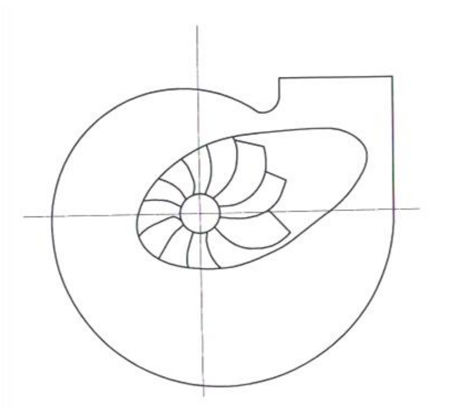
a)



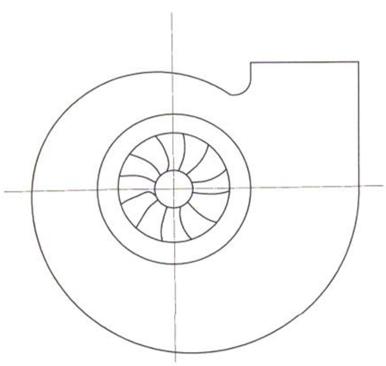
c)



b)



d)



e)

Figure 4. Options for connecting the central air collectors to the fan housing.

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The air flow rate was measured at the tangential outlet of the fan casing, which has a square section of an area of F = 0.078 m^2. To determine the average velocity of the outflow air, measurements were taken at 8 points of the outlet section, see Fig. 3 (b).

The average value of air flow velocity was determined by the following expression

$$V_{cp} = \frac{V_1 + ...V_8}{8}, \quad m/s$$

The airflow rate at a given average velocity was determined as $Q_b=F\cdot V_{sr}=0{,}078\cdot V_{sr}$ [m^3/s]. An amount of 100 g of cotton was supplied to determine the effect of the elliptical inlet position of the air collector on cotton seed damage when passing through a centrifugal fan. The experiments were carried out in triplicate. Damage to cotton seed was determined in laboratory conditions using sulfidic acid. The experimental results are presented in the table.

Table 1. Effect of the position of the end inlet of air collector relative to the fan on airflow productivity and cotton seed damage

Indices	Fan according to scheme (a)	Fan according to scheme (b)	Fan according to scheme (c)	Fan according to scheme (d)	Fan according to scheme (e)
Air flow productivity, Q, m^3/s	1.77	1.91	2.04	1.71	1.56
Cotton seed damage, *n*, %	0.4	0.6	0.4	0.2	1.2

Analysis of the data given in the table shows that when the end air collector is connected to the fan casing according to schemes a), b) and c), the air flow rate increases from 1.77 m^3/s to 2.04 m^3/s and the seed damage is within 0,4 ... 0, 6. This is due to the fact that the path of rotating air flow along the fan casing spiral is shortened and this leads to a decrease in pressure loss. The increase in seed damage for the scheme (b) is due to the fact that when the air flow enters the inlet pipe, strong turbulence occurs. For the scheme (d), the decrease in the air flow rate is due to the fact that the elliptical section is increased and brought to the boundary of the inlet pipe. The decrease in cotton seed damage is explained by an increase in cotton volume passing the fan blade without contact with it. In [20] it was noted that the effective use of the impeller largely depends on the inlet device designed to direct airflow to the impeller inlet. In this regard, in the fan design of scheme (e), a central inlet collector in the form of a truncated cone was selected. Experiments have shown that in this option the air flow rate is reduced to Q = 1.56 m^3/s. Damage to cotton seeds is 1.2%. Besides, there is observed an intense negative phenomenon of raw cotton winding on the fan blade, schematically shown in Fig.5.

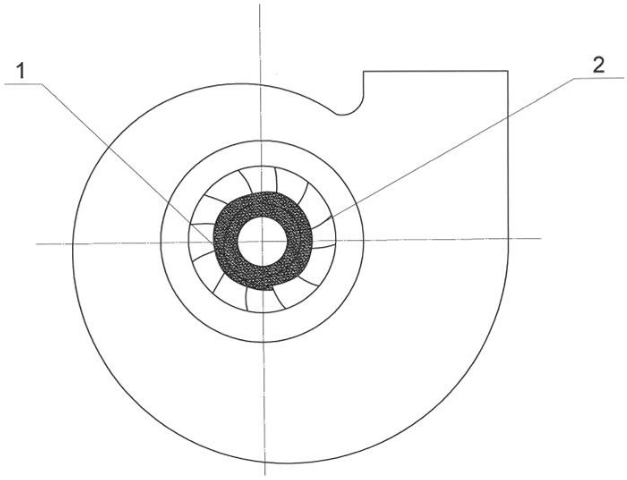

Figure 5. Raw cotton winding on fan blades: - wound cotton, 2 - fan blade.

4. Conclusion

1. On the basis of the analysis of the existing suction - injection principle of the pneumatic transport system of the vertical - spindle cotton harvesting machine, a special simulation stand was created, including an industrial design centrifugal fan and its drive mechanism.
2. Bench tests have shown that different locations to the side ellipsoidal inlet of the air collector channel relative to the fan axis lead to changes in the air flow rate from 1.77 m3 / s to 2.04 m3 / s and cotton seed damage from 0.2 to 1.2%. In this case, the best performance of the fan was obtained in options "c" and "d". The latter was used in the development of an experimental industrial model of the MX-2.4 machine.

Bench-scale tests showed that the position of the inlet end air collector relative to the fan led to a change in the air flow rate from 1.77 m^3/s to 2.04 m^3/s, and the cotton seed damage increased from 0.2 to 1.2%. At that, the most rational options for connecting the pneumatic transport pipe to the fan are the options shown in Fig. 4, c and d.

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