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THEORETICAL CALCULATION OF AN EFFICIENT FAN WITH A SIDE INLET IN THE SHAPE OF AN AIR TRANSPORT SYSTEM

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Abstract:

In this article, a new ovoid-shaped side inlet for a centrifugal fan in a cotton picker is proposed and its aerodynamic efficiency is theoretically substantiated. In order to maximize the efficiency of the fan, aspects related to the size and shape of the inlet surface were analyzed. A mathematical model of the ovoid shape was created and geometric parameters affecting the movement of the air flow were determined. The modeling results showed that the ovoid shape is effective in stabilizing the air flow entering the fan and reducing pressure losses.

Keywords: Ovoid, Optimization, Streamlining

1. Introduction

Centrifugal fans used in agricultural machinery, especially cotton pickers, require high efficiency. They perform the function of transporting raw materials through the air inside the equipment, and in this process, the efficiency of the fan is of great importance. The commonly used simple inlet ports increase the turbulence of the air flow and cause pressure losses, which reduces the efficiency of the fan [1].

The air transport system in cotton pickers ensures reliable transportation of the harvested cotton from the receiving chamber to the bunker through the picking devices. Based on the results of our research, we developed an updated version of the centrifugal fan for the GTP, and this design is protected by a utility model patent by the Ministry of Industry and Trade of the Republic of Uzbekistan [2]. In our previous works, we presented analytical, theoretical and experimental studies on the development of an efficient fan design for the air transport system of a cotton picker [3-6]. Based on the above, we conducted theoretical research on creating an ovoid shape for the side inlet, which would ensure maximum efficiency of the centrifugal fan of the air transport system.

2. Methods

The article uses a theoretical calculation method to determine the effect of an ovoid-shaped side inlet on the fan efficiency. The calculations analyzed the inlet velocity of the air flow, pressure losses, and geometric parameters of the inlet surface. A mathematical model of the ovoid shape was created, and the stability of the air movement and its effect on efficiency were evaluated using formulas for its surface. Based on the calculation results, the optimal inlet shape and dimensions for the fan were theoretically justified.

3. Results and Discussion

It is known that a decrease in resistance in the pipes leads to an increase in the suction speed and the amount of suction air flow. The efficiency of a centrifugal fan is directly proportional to the air consumption (efficiency) and the total pressure in the network. At the same time, the linear speed of the centrifugal fan blade and, in particular, the surface and shape of the side inlet significantly affect the efficiency of the centrifugal fan [7,8].

The inner diameter of the pipe that conveys cotton from the receiving chamber of the harvester to the fan is D=0.18 m.

The cross-sectional area of the pipe

$$F = \frac{\pi \cdot d^2}{4} = 0{,}785 \cdot 0{,}18^2 = 0{,}025\, m^2$$

The volume of air sucked through the intake chambers from one centrifugal fan (efficiency) is determined as follows:

In the experimental air transport system, the efficiency reached the indicator Q=2.2 m3/s recommended by BMKB–Agromash [9]. Thus, increasing the surface area of the inlet close to the blade surface allows increasing the efficiency. However, this efficiency was achieved at a centrifugal fan speed of 1540 rpm. At the lower point of the intake chamber, the minimum air flow velocity for the production air transport system is v0=5.0 m/s and for the improved air transport system is v0=7.1 m/s. In the production MX–2.4 cotton picker, the air flow velocity in the lower part of the intake chamber is 3.4÷5.0 m/s, which is 1.3 times less than the cotton suspension velocity [10,11].

It is known from previous analyses that in the production and modified design of centrifugal fans, 52.3% of the blade surface is used, and in the experimental design according to [12], 73.3%. In this case, the air flow velocity in the farthest intake chamber of the body increased from 5.0 m/s to 7.1 m/s. Therefore, if the side inlet of the centrifugal fan is opened to values close to the blade diameter, the efficiency of the centrifugal fan increases. Taking this into account, an improved optimal design of the side inlet of the centrifugal fan was proposed. It is presented in Figure 1 below.

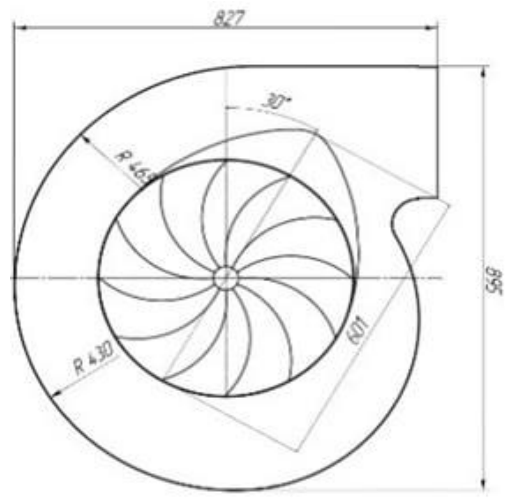


Figure 1. Centrifugal fan with an ovoid-shaped side inlet [2], [13].

For this case, we calculate the coefficient K:

$$K = \frac{S}{S_r} = \frac{0.19586}{0.19625} = 0,998 \quad \text{or } 99,8\ \%$$

The results of measuring the air flow velocity in the receiving chambers of the MX-2.4 cotton picker are presented in Table 1.

Table 1. Airflow velocities in the intake chambers of the improved air transport system [11].

Air velocity measurement points in the receiving chamber	Air flow speed, m/s							
	At the end of the camera				On camera head			
Improved air transport system	20,3	22,7	23,1	21,8	11,5	13,5	10,6	9,6

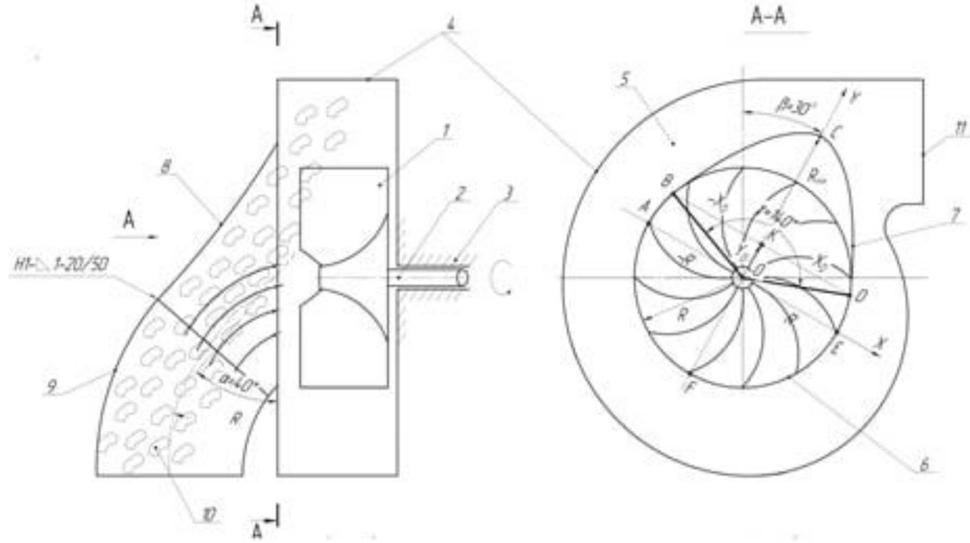
The air volume (performance) is determined as follows:

$$Q'_{total} = 0,025(20,3 + 22,7 + 23,1 + 21,8) = 2,2\ м^3/s$$

It can be seen that the performance of the improved centrifugal fan design [9] was in line with the recommendations given in the literature. In order to maximize the use of the centrifugal fan area, the surface of the side inlet should be as shown in Figure 1. In this case, the useful surface of the suction centrifugal fan is almost completely used.

We have seen above that the efficiency of the centrifugal fan with an ovoid-shaped side inlet of the improved air transport system is Q=2.2 m^3/s. In this section, the mathematical expression of the ovoid-shaped side inlet is constructed.

The following figure 2 shows a diagram of a centrifugal fan with an ovoid side inlet. The surface area of the side inlet of the centrifugal fan shown in this diagram is S0=0.19586 m2. The centrifugal fan consists of a blade 1, a blade shaft 2, a support 3 and a spiral body 4, a side wall 5, a circular part of the inlet 6, a parabolic part 7, a supply pipe 8, an air collector 9 and an outlet 11. The diameter of the side inlet is equal to the blade diameter and its longitudinal axis is inclined at an angle of β=30° to the vertical axis of the centrifugal fan. The guide pipe 8 is fixed to the centrifugal fan body 4 at an angle of α=40º using a welded joint.



1–blade, 2–main shaft, 3–base, 4–spiral body, 5–side wall (wall),

6–circular part of the window, 7–parabolic part of the window, 8–pipe leading to the centrifugal fan, 9–air collector, 10–cotton, 11–exit window

Figure 2. Schematic of the ovoid side inlet of a centrifugal fan [2], [13].

As a result of the relatively high (more than 18÷22 m/s) velocity of the air flow generated by the suction aerodynamic force at the center of the blade, the transported cotton (60÷100 times heavier than air) is compacted by inertia. Since the cotton at the inlet to the centrifugal fan is less than the critical velocity (35 m/s) as a result of the increase in the side wall, the negative mechanical effect of the centrifugal fan on the cotton seeds is theoretically minimal. The equations of a circle and a parabola were used to construct an ovoid shape for the side inlet of the centrifugal fan. Each value in the equations and their range of change are related to the radius of the blade. Special attention is paid to the preservation of the ovoid shape with a change in radius and the validity of the mathematical model at any radius.

The ordinates of the ovoid shape shown in Figure 2 are expressed using formulas (1)–(3) [2,14]:

parabola BCD:

$$y_{BCD} = R + y_0 - 1{,}8 \cdot 10^{-5} x^2; x \in (-x_0; x_0); \quad (1)$$

partial circle ABDE

$$y_{ABDE} = \sqrt{R^2 - x^2}; x \in (-R; -x_0) \cup (x_0; R); \quad (2)$$

semicircle AEF

$$y_{AEF} = \sqrt{R^2 - x^2}; x \in [-R; R] \quad (3)$$

where R is the blade diameter, mm;

x– abscissa axis (transverse axis) of the ovoid, mm;

y_{o-} initial/internal coordinate of the smooth transition from a semicircle to a parabola, mm;

The radius of the centrifugal fan blade is R=250 mm (unified centrifugal fan blade No. 5).

where $\angle$BOD=140°

OK=y_o=R·cos70°=250·cos70°=85,5 mm;

KD=x_o=R·sin70°=250· sin70°=235 mm.

Figure 3 below shows the expression for this ovoid shape constructed in MS Excel using expressions (1)–(3).

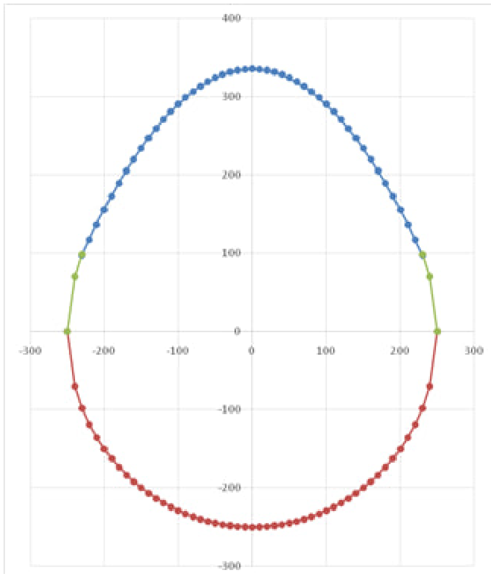


Figure 3. MS Excel view of an ovoid side entrance window [79,80].

As can be seen from Figure 3, it is possible to construct an ovoid shape of the centrifugal fan side inlet through expressions (1)–(3), which indicates that the chosen mathematical model is correct.

4. Conclusion

a. It was proved that the ovoid shape of the side inlet of the centrifugal fan of the air transport system of the cotton picker is the most optimal. In this case, there is a possibility of maximum use of the suction power of the fan blade.

b. The mathematical model of this ovoid shape was constructed using the equations of the parabola and circle. When the constructed model was entered into the MS Excel program, it was confirmed that it represents the ovoid shape. This indicates that the mathematical model is constructed correctly.

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