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Changing the Air Parameters in the Cotton Pneumatic Transport Pipe

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Abstract

This scientific article examines the issue of changes in the density and speed of the airflow in the pipeline pneumatic conveying equipment used in ginneries, analyzes the causes of changes in the density and speed of air.

Keywords

Pneumatic Transport, Actual Pressure, Vacuum, Monomeric Pressure, Ventilator, Cotton Cleaning

1. Introduction

In order to ensure the competitiveness of ginned products in the world market, great attention is paid to maintaining the initial quality of fibre, cotton and other products. Research shows that all processes in the cotton industry have a negative impact on the initial quality indicators of the product, and the processes of air transportation of cotton are no exception.

At ginneries, raw materials are transported from the gins to the cleaning and drying shops on pneumatic equipment pipes. Its simplicity and the ability to deliver the product in any complex direction without destroying it in the specified places have led to the widespread use of air-assisted transport in the ginning industry [1] [2].

When the airflow passes through the pneumatic transport elements, its pressure decreases to a certain extent. Figure 1 shows a schematic of cotton pneumatic transport and its elements. Here I cotton mill, II production building, 1 cotton opener machine, 2 horizontal pipes, 3 pipe bending areas (shells), 4 stone catchers, 5 diffusers, 6 separators, 7 confusers, 8 throttles, 9 fans and 10 cyclone batteries. This aerodynamic equipment is designed to take cotton from the bale

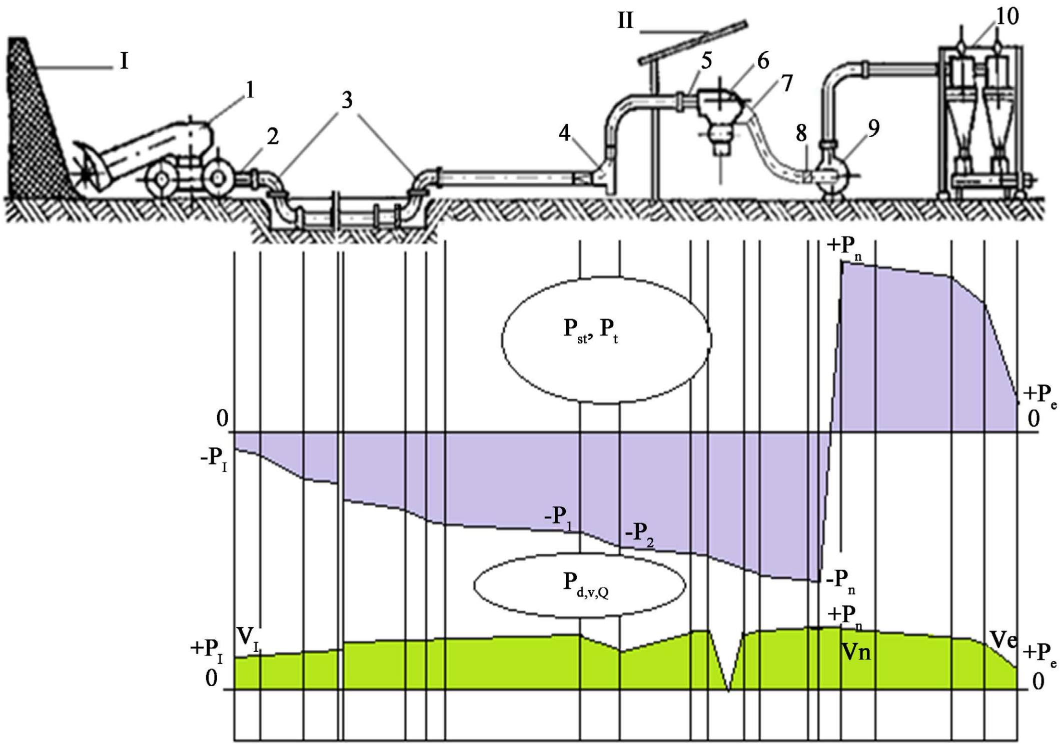

Figure 1. Scheme of cotton pneumatic transport and changes in air flow parameters in it.

and deliver it to the production work shops.

When the fan is running, inside the system, negative (suction) air pressure is created on the left side of the fan, positive air (spray) pressure is created on the right side, and airflow is moving from right to left. The highest pressure and airflow, as well as the speed, are generated on both sides of the fan. Throughout our studies, we have seen that part of the static pressure is used to overcome the aerodynamic resistance (more precisely, the friction and viscosity resistance forces) of the air duct [3] [4] [5]. In this work, we examine the bending, splitting, joining, expansion (diffuser), shrinkage (confusor) areas of the pipe, the pressure loss in the stone catchers, separators, cyclones and chokes. Depending on the design and technological parameters of these devices, different levels of pressure loss occur. **Figure 2** shows the results based on experiments conducted under production conditions in the form of a graph (diagram).

2. Theoretical Part

The reason why the plots of air velocity (ϑ), airflow (Q) and dynamic pressure (P_d) look the same is due to the fact that they are closely related:

$$P_d = 0.5 \cdot \rho \cdot \vartheta^2;\ \ \vartheta = \sqrt{\frac{2P_d}{\rho}};\ \ Q = f \cdot \vartheta; \tag{1}$$

where: p—air density, kg/m^3; f—pipe cross-sectional area, m^2.

The static P_{st} and full P_t pressure characteristics are also close to each other because the full pressure is the static pressure in the absence of the original air movement. Dynamic pressure is created only when it is possible to move the air, for example, when the fan mouth is opened:

$$P_t = P_{st} + P_d;\ P_{st} = P_t - P_d;\ P_d = P_t - P_{st};\ P_d = 0 \Rightarrow P_t = P_{st}. \tag{2}$$

Otherwise, dynamic pressure will not be generated. In addition, in pneumatic transport systems, the dynamic pressure of the fans on the passport indicators is only less than 10% of the full pressure.

According to fundamental theory, the dynamic pressure should be almost constant along the length of the pipe [6] [7] [8]. Because of the law of flow continuity:

$$\rho_1 f_1 \vartheta_1 = \rho_2 f_2 \vartheta_2 = const, \tag{3}$$

According to $p = const$, if the air density does not change, the velocity should not change in $d = const$ pipes with constant cross-sectional size $v = const$. In this case, according to the equation $P_d = 0.5\square\rho \cdot \vartheta^2$, the dynamic pressure must also be constant along the length of the pipe $P_d = const$. However, the pressure in the pipes is variable. The air density also changes accordingly. In that case, the air velocity should also change according to (3). We will try to substantiation it. (3) and:

$$\vartheta_2 = \rho_1 f_1 \vartheta_1 / (\rho_2 f_2), \tag{4}$$

If the pipe size is constant:

$$\vartheta_2 = \rho_1 \vartheta_1 / \rho_2, \tag{5}$$

The pressure in front of the fan is several times higher than the pressure at the beginning of the pipe. The Mendeleev-Clapeyron equation:

$$PV = RT$$

According to the volume of air V depends on its pressure P: its density r is inversely proportional to the volume of air V: $V = 1/p$;

According to:

$$\rho = P/(RT); \tag{6}$$

There is a sparse air environment, or low vacuum conditions, on the suction side of the pneumatic vehicle. The actual pressure here is equal to the difference between the ambient atmospheric pressure P_{at} and the pressure inside the pipe (system) P_s:

$$P_v = P_{at} - P_s.$$

According to him:

$$\rho = (P_{at} - P_s)/(RT); \tag{7}$$

At the beginning of the pipe $P_s = 0$, in that case

$$\rho = P_{at}/(RT); \tag{8}$$

Universal gas constant R = 287.06 joules/(kgK); air temperature at normal pressure T = 20˚C = 293 K; the atmospheric pressure in the region is lower than the standard atmospheric pressure P_{at} = 750 mm Hg = 101 kPa: P_{at} = 735 mm Hg

= 0.98 × 10^5 Ra given that the density at the pipe head is:

$$\rho_b = 0.98\times10^5/(287.06\times293) = 1.165\ \mathrm{kg/m^3};$$

If the pressure near the fan is averaged P_s = 8000 Pa, the air density there is:

$$\rho_v = (98-8)\times10^3/(287.06\times293) = 1.07\ \mathrm{kg/m^3}.$$

Let's increase the pressure in the fan by 10 kPa and decrease it by: If the pressure near the fan is averaged P_s = 9000 Pa, the air density is:

$$\rho_v = (98-9)\times10^3/(287.06\times293) = 1.058\ \mathrm{kg/m^3}.$$

If the pressure near the fan is averaged P_s = 7000 Pa, the air density is:

$$\rho_v = (98-7)\times10^3/(287.06\times293) = 1.082\ \mathrm{kg/m^3}.$$

Now, according to (5), if the air velocity at the beginning of the pipe is $\vartheta_1 = 25\ \mathrm{m/s}$, we determine the velocity near the fan:

$$\vartheta_2 = \frac{\rho_1\vartheta_1}{\rho_2} = \frac{1.165\times25}{1.07} = 27.22\ \mathrm{m/s}.$$

We calculate the relative change in velocities:

$$k_v = \frac{\vartheta_2-\vartheta_1}{\vartheta_1}\times100 = \frac{27.22-25}{25}\times100 = 8.88\%$$

Let's try to increase and decrease the speed of air by one unit: let the air velocity at the beginning of the pipe be $\vartheta_1 = 24\ \mathrm{m/s}$, in which case:

$$\vartheta_2 = \frac{\rho_1\vartheta_1}{\rho_2} = \frac{1.165\times24}{1.07} = 26.13\ \mathrm{m/s}.$$

We calculate the relative change in velocities:

$$k_v = \frac{\vartheta_2-\vartheta_1}{\vartheta_1}\times100 = \frac{26.13-24}{24}\times100 = 8.875\%$$

Let the air velocity at the beginning of the pipe be $\vartheta_1 = 26\ \mathrm{m/s}$ in which case:

$$\vartheta_2 = \frac{\rho_1\vartheta_1}{\rho_2} = \frac{1.165\times26}{1.07} = 28.31\ \mathrm{m/s}.$$

We calculate the relative change in velocities:

$$k_v = \frac{\vartheta_2-\vartheta_1}{\vartheta_1}\times100 = \frac{28.31-26}{26}\times100 = 8.885\%$$

Figure 2 shows the graphs constructed based on the results obtained. According to them, the air density decreases as the manometric pressure (vacuum level) increases from the beginning of the air transport pipe to the fan. This is probably why the term "sparse air environment" was coined for a low-pressure environment.

An increase in the pressure in front of the fan here leads to a further decrease in air density, while a decrease in it leads to a slight increase in air density. In this case, the effect of the pressure drop on the density change is stronger than

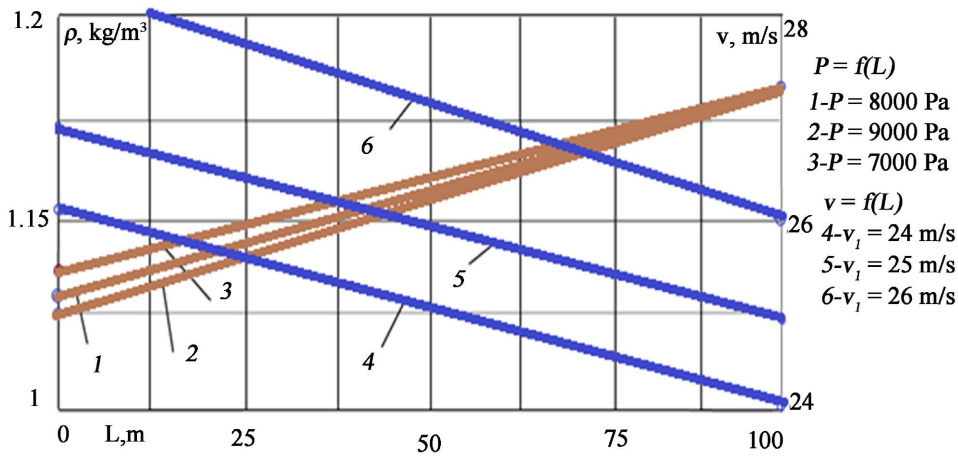

Figure 2. Variation of air density and velocity along the length of the pipe.

the pressure increase. When the pneumosystem is completely hermetic, a change in air density also leads to a change in air flow rate. The results show that as the pressure of the air moving along the pipe increases, its velocity increases relatively. This is because in an environment where the pressure (here the vacuum level) is high, the force that draws air molecules to the vacuum source (fan) increases, resulting in an increase in air velocity and, conversely, a decrease in pressure in the pipe decreases. Also, an increase in the initial speed leads to an increase in the speed difference, and a decrease—to a decrease. Studies have shown that the relative change in air density due to the change in density is on average 8% - 9%. However, experience shows that the air velocity increases significantly from the beginning of the pipe to the fan.

Practice shows that pneumatic pipes are mainly made of steel. When making a pipe, the steel tin is rounded and the two ends are welded together. To deliver airflow over long distances, pipes are connected to each other to form long trails.

The pipes are welded together and fastened using screw connectors (bolt-nuts). There are also temporary (temporary) ways to connect the pipes. In this case, one side of the pipe is prepared as a conical end, and when extending the pipe, the first pipe end is inserted into the larger side of the second. Regardless of the type of connection, it is difficult to maintain the tightness of the connection. There are several reasons for this:

1) Poor quality of welding in the joint. As a result, holes of different sizes remain at the joints.

2) Pipes erode when operated for a long time, the wall becomes thinner and especially the turning points become perforated.

3) As a result of improper operation (due to impact of hard, pointed objects, crushing under the influence of heavy objects, bending), holes and cracks are formed in the pipe, as well as the shape of the pipe is distorted, leaving open spaces when connected to each other.

4) When connecting pipes with screw connectors, the joints are left open due to drying, breakage, spillage of sealing material (usually rubber is used).

5) When connecting pipes temporarily, cracks remain at the joints as a result of incompatibility of their shapes and sizes.

As a result of long-term observations, the Cotton Research Center found that even during normal operation of pneumatic transport equipment, air absorption is observed along the length of the pipe and 3% of air is absorbed from every 10 meters of the pipe made. If the amount of air absorption determined by the measurement is greater, the tightness of the pipe and the aerodynamic elements installed between it and the connection points shall be checked and any holes and cracks found shall be closed. However, recent measurements show that the amount of air sucked along the length of the pipes at ginneries in the country is several times higher than the allowable amount. Enterprises do not pay attention to the excess air and energy consumption in the transportation of cotton due to the obsolescence of aerodynamic systems, lack of repairs and maintenance, and other organizational problems [9] [10] [11] [12].

The pneumatic transport process occurs due to the airflow that occurs due to the thinning of the air pressure inside the closed system (in suction air transport) or condensation (in the drive or blower pneumatic transport). Although scientific studies to date have reported changes in air density in air transport, the extent to which it has been studied has not been studied. We have tried to clarify this issue in this case.

3. Conclusions

1) It can be concluded that in the design of aerodynamic and air transport equipment in the conditions of Uzbekistan it is expedient to assume that the density of air at rest is $r = 1.17$ kg/m^3, the density inside the suction part of air transport equipment is $r = 1.13 \div 1.07$ kg/m^3.

2) Experiments have shown that the air density in the neck of the transport pipe is close to the stationary air density ($r = 1.17$ kg/m^3), while the density near the fan decreases to 1.07 kg/m^3. Moreover, the air density inside the transport pipe increases linearly from the fan to the neck of the duct and vice versa decreases in accordance with the linear pattern from the beginning of the duct to the fan.

3) A change in the density of air with a constant cross-section of the pipe causes a change in its velocity. As a result of the change in air density, its velocity increases from the pipe head to the fan and, conversely, decreases from the fan to the pipe head. The estimated change is 4% to 9%.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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