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HERMETICITY OF COTTON PNEUMOTRANSPORT PIPELINES, ITS INFLUENCE ON PERFORMANCE AND ENERGY CONSUMPTION

Khaydarov Khusanboy Baxtiyar o'g'li
Khamrli Ismailov[1]
Olimjon Sarimsakov Sharipjanovich[2]
Namangan Institute of Textile Industry (NamITI)[1],
Andijan State University AndSU[2]
Corresponding author: yoldashev93992020@mail.ru

Abstract: The article examines the importance of connecting pneumatic transport pipes in cotton ginning plants. The impact of air duct sealing on fan performance and energy consumption is considered.

Keywords: Pneumotransport, cross-sectional surface, pipe, cotton, fan, aerodynamic force, cyclone, cotton drum.

Introduction. It is known that the cotton growing and processing industry is important in the development of the economy of Uzbekistan. In recent years, the cotton ginning industry of our Republic has been completely renovated and modernized on the basis of the state program, and equipment with modern equipment is reaching remote areas day by day. The goal of the reforms carried out in the field in recent years is to improve the quality of the product to the level of the world market requirements, to increase the efficiency of cotton production by reducing its cost. Product quality and cost are formed at each stage of the technological process of its processing. In this case, the stage of supplying raw materials, which is considered the first link of the process, plays an important role. The supply of raw materials for cotton processing technology is carried out in cotton ginning enterprises with the help of pneumatic transport equipment. Due to the simple design of the air pipe and the lack of control and controlled parts, they cannot be changed according to the condition of the product or the production requirement. Also, to date, the use of measuring devices indicating its operating mode has not been established in pneumatic cotton transport, and the required mode is approximately set based on the experience of technical personnel servicing the equipment [1-4].

In cotton gins, cotton is delivered to the cotton mill in pneumatic transport pipes. When the mixture of air and cotton moves in the pipe, various resistance forces arise and they have a great impact on the performance of pneumatic transport and energy consumption. Also, when connecting the pipes, there are cracks between them, on the wall, holes formed due to various mechanical effects, through which a large amount of air is sucked from the outside. Such air absorption is even higher in stone hoppers and separators, and its average value is even included in the list of technical indicators of the equipment.

Air intake from the outside has a great impact on pneumatic transport performance and energy consumption. Also, due to the flow of air sucked in from the outside, the air consumption and speed from the head of the pipe to the fan increases continuously. In production measurements, it was observed that the air velocity at the head of the pipe is 15-20 m/h, and the velocity in front of the separator reaches 40-45 m/h. Such air velocities cause the speed of the transported cotton to reach 28-31 m/s and cause the cotton fiber to be blown, knotted and broken, as a result of which the defects such as shell fiber and knots in the produced fiber will increase and the quality of the fiber will decrease.

Also, on the contrary, the air consumption, speed and dynamic pressure from the fan to the mouth of the pipe are sharply reduced. This situation, of course, leads to a decrease in the range of the pneumotransport equipment, and it will not be able to transport cotton from long distances. In such cases, additional pneumatic transport equipment is connected in series to transport cotton from distant fields. As a result, the costs of transporting cotton, as well as energy consumption, increase and the cost of the manufactured product increases. In addition, air consumption in cotton transportation increases and causes a large amount of air pollution with fiber dust and the need to clean the same amount of air.

The dusty air cleaning devices used in cotton ginning enterprises cause the release of insufficiently cleaned air into the atmosphere as a result of the low efficiency of dust collection and having to clean a large amount of air mass compared to the passport indicators. This, in turn, leads to the excessive pollution of the air in the area of the cotton ginning enterprise and the objections of the residents living nearby. It was the problem that caused most of the cotton ginning enterprises to be moved to places far away from residential areas. However, this solution does not help to improve the ecological situation in the area. Because, firstly, a negative environmental situation remains for the workers in the territory of the enterprise, and secondly, the pollution of atmospheric air in one place has a negative effect on the purity of air in another place. Because atmospheric air is a whole environment that constantly moves, exchanges and mixes due to pressure and temperature changes.

In the use of pneumatic transport, in many cases, due to the indifference of the company's workers and the wear, erosion, perforation, cracking, deformation of the pipes, it is impossible to ensure the hermeticity of the system when the pneumatic transport pipes are connected to each other and long routes are formed and air is sucked into the pipe from outside, resulting in very large pressure losses. According to the information of "Cotton Industry Scientific Center", it is impossible to eliminate air absorption from the outside in the pipes and its amount corresponds to the value of 1-3% for every 10 m of the pipe [5,6]. In this case, a lower value of this value corresponds to new pipes, and a higher level to old ones.

It is possible to assess the degree of air intake from outside the pipe. If we accept this feature as a technological indicator, it should depend on certain indicators in the system. In the technical literature, this property is explained by the term "hermeticity", but there are no attempts to evaluate it as an indicator. Therefore, we try to evaluate this feature as a technological indicator.

Method.

This characteristic should be determined by the amount of air flow that has entered and added to the main air flow in aerodynamic systems. We call this characteristic "hermeticity coefficient".

Based on the above considerations and a logical approach, we adopt the following equation to evaluate the aerodynamic system hermeticity:

$K_g = \frac{Q_q}{Q_v}$ (1),

Here Q_v is the air consumption in front of the fan, m^3/h; Q_q- air consumption at the pipe head, m^3/h.

If we pay attention to the equation, $Q_v \neq 0$, that is, the equation is valid when the fan is working, more precisely, when the air consumption in front of the fan is not zero. Also, if $Q_v \rightarrow Q_q$, or the air consumption at the mouth of the pipe approaches the air consumption in front of the fan, $K_g \rightarrow 1$, or the hermetic coefficient approaches 1, because the air intake from the outside decreases. $Q_v = Q_q \Rightarrow K_g = 1$, or if Q_q- the air consumption at the head of the pipe is equal to Q_v– the air consumption in front of the fan, then no air is sucked from the outside and the hermetic coefficient is equal to 1. This is the most ideal state for the pneumotransport system $K_g = 1$.

The worst case is when $Q_v \neq 0$, $Q_q = 0$. That is, the fan is working, but there is no air flow at the head of the pipe. In this case, $K_g = 0$. However, such a situation can occur only when there is some kind of obstruction inside the pipe, and the air is sucked only through the cracks and holes in the pipe. $Q_v \neq 0$, $Q_q \neq 0$ when the aerodynamic system, including the pneumotransport system, is in normal working condition, when there is air suction in the fan, there is also air flow in the pipe mouth. However, in the case that $Q_v \neq 0$, we can see that $Q_q \rightarrow 0 \Rightarrow K_g \rightarrow 0$, that is, in any case where the fan is operating normally, if the air consumption at the head of the pipe is close to zero, the coefficient of hermeticity will also be close to zero. It can be concluded that the coefficient of hermeticity is $0 < K_g < 1$and its high values are considered as "good" and low values as "bad".

Knowing the negative consequences of air intake from the outside, we try to eliminate it and study the consequences of this event through practical research.

We carried out our research at the scientific laboratory of technology of preliminary processing of natural fibers of the Namangan Institute of Engineering and Technology and at the private enterprise "Ven-kon air engineering" of the city of Namangan. Scientific research was carried out on a high-pressure centrifugal fan. This fan driver has 4kW 3000Rpm blades and is connected to a duct system that can be extended up to 26m in length. Each pipe is 1.25 m long and equal to the width of the steel sheet from which the pipe is made.

Initially, 21 pipes were connected by means of 20 clamps, and a 26 m long pneumotransport track was formed (Fig. 1). Such fastening of pipes reflects the fastening of pneumatic transport lines in cotton ginning enterprises. In enterprises, stationary (immovable) parts of pipes are fixed using mutual welding or bolt-nuts. Movable parts are interconnected by wearing each other, attaching with a clip, and wrapping with fabric.

Figure 1. Experimental pneumatic transport equipment.

The parts of the pipe in the area where the cotton is transferred are simpler - they are inserted into each other, and the slits are closed with the cotton itself. Therefore, the absorption of air from the outside is stronger in these parts, because cotton is a porous product, and its air permeability is very high.

We drilled pitot tubes in 3 places of the pneumotransport pipeline route. Hole 1 was drilled at a distance of 0.20 m from the fan throat, hole 2 at 6.70 meters and hole 3 at a distance of 25.5 meters. The device was connected to a 380 V current source through an inverter device, and the current and voltage changes were monitored. The velocity, static and dynamic pressures of the sucked air in the pipe were measured using special measuring devices: anemometer and micromanometer. A stationary electronic micromanometer was installed at a distance of 0.2 m in front of the fan, and it was possible to regularly monitor the aerodynamic parameters in the system. The parameters at the following points were measured by a portable pitot tube micromanometer, and the air velocity at the head of the tube was measured by an electronic anemometer. The experiments were carried out as follows: after the equipment was connected to the power source and the system began to work normally, first, the full pressure in the condition that the fan mouth was completely closed from the inlet pipe, and then, starting from the closest point, the static and dynamic pressures in the pipe were measured. Depending on the diameter of the pipe, the air flow speed and consumption were calculated and included in the appropriate tables:

Dynamic pressure:

$$P_d = 0.5\rho v^2, \qquad (1)$$

Airspeed:

$$v=\sqrt{\frac{2P_d}{\rho}}, \qquad (2)$$

air consumption:

$$Q = v \cdot f, \qquad (3)$$

Here, p = 1.2 – air density, kg/m^3; $f = 0.25\,\pi \cdot d^2$–pipe cross-sectional area, m^2; d = 0.14 – pipe diameter, m.

Results. The obtained results are presented in tables 1 and 2.

Results of aerodynamic measurements **Table 1**

№	Fan status			Electric power (A)	Tension (B)	Power kW		Frequency Gs	Static pres-sure (P)	Dynamic pres-sure (P)	Speed m/h	Air consumption m^3/h
	Pipes are clamped by a clamp (bandak).											
1	Fan duct in closed position (0.20 m)			3	380	1,7		50	5350			
2	Pipe length 26 meters	Hole 1	0,20 metre	9,8	380	5,54		50	3380	1880	56	7,84
		Hole 1	0,20 metre	9,8	380	5,54		50	2270	1500	50	7
		Hole 3	25,50 metre	9,8	380	5,54		50	520	710	34	4,76

According to Table 1, the pressure obtained with the fan inlet pipe mouth closed is 5350 P, which gives full pressure. When the fan inlet pipe is connected to a 26 m long track, a static pressure of 3380 P and a dynamic pressure of 1880 P occurs at a distance of 0.20 m.

Air velocity is 56 m/h and air consumption is 7.84 m^3/h. Along the pipeline route, the air pressure and velocity decrease, and at a distance of 26 m, the static pressure was 520 P, the dynamic pressure was 710 P, the air velocity was 34 m/h, the air consumption was 4.76 m^3/h, and the current in the fan driver was 9.8 A.

If calculated based on the indicators in the table, for the first case, according to the current dimensions:

$K_g=\frac{Q_q}{Q_v}$=4,76/7,84= 0,57

In subsequent experiments, the holes opened and identified in the pipes were closed with thick tape. The slits in the places of connection of the pipes were covered with a soft film in three layers under the clamp (bandak), taped on both edges and gypsum was fixed with the help of the bandak (clamp) (Fig. 2).

Figure2.Experimental device

Then, the pneumotransport was started and the aerodynamic measurements were repeated in the previous order and sequence. The results obtained in the experiment were included in Table 2.

The results of aerodynamic measurements   Table 2

№	Fan status			Electric power (A)	Tension (B)	Power kW	Frequency Gs	Static pres-sure (P)	Dynamic pres-sure (P)	Speed m/h	Air consumption m^3/h
Pipes are hermetically sealed											
1	Fan duct in closed position (0.20 m)			3	380	1,7	50	5350			
2	Pipe length 26 meters	Hole 1	0,20 metre	7,9	380	4,47	50	3510	1950	57	7,98
		Hole 1	0,20 metre	7,9	380	4,47	50	2900	1880	56	7,84
		Hole 3	25,50 metre	7,9	380	4,47	50	1200	1680	53	7,42

If you look at the data in the table, the pressure obtained with the mouth of the fan inlet pipe closed is 5350 P, which gives the full pressure. When the fan inlet pipe is connected to a 26 m long hermetic track, a static pressure of 3510 P and a dynamic pressure of 1950 P occurs at a distance of 0.20 m. Air velocity is 57 m/h and air consumption is 7.98 m^3/h. Along the pipeline route, the air pressure and velocity decrease, and at a distance of 26 m, the static pressure is 1200 P, the dynamic pressure is 1680 P, the air velocity is 53 m/s, the air consumption is 7.42 m^3/h, and the current in the fan driver is 7.9 A.

We find the coefficient of hermeticity from (1), according to the actual dimensions:

$К_g = \frac{Q_q}{Q_v}$ = 7,42/7,98 = 0,93

This is much higher than the indicator in the 1st option, that is, compared to the previous one, the intake of air from the outside into the system is sharply reduced, and the hermetic coefficient is close to 1. But why is the air tightness coefficient not equal to 1 if there is no air intake from the outside?

If the amount of air flow passing through the fan and entering the pipe was the same, the coefficient of hermeticity would be equal to 1. The experimental device was carefully inspected before the research and all cracks and holes were tightly sealed. If so, Where did the air absorbed from the outside and equal to

"$Q_m = Q_v - Q_q$ = 0,56 m^3/h" come from?

The answer to this question can be as follows. First, when aerodynamic devices, including pipes, are connected to each other, no matter what methods and tools are used, there may be cracks and holes that are difficult to determine at the connection points. For example, if we assume that the most densest connection is welding, depending on the quality of the welds, there may be cracks of various small sizes. In connection with other methods, due to reasons such as the air permeability of the connecting material, the contact surfaces are not compatible with each other, there may be conditions for more air to pass. Because the pressure value inside the pipe is very high, and the fluidity of air is high.

Secondly, air consumption means the volume of air flowing in a unit of time. In our example, the volume of air passing through the fan and entering the system is different, and this difference is manifested when the volume of air in front of the fan is large, and the volume of air entering the pipe is small. If we pay attention to the numbers, the total air pressure at the beginning of the pipe is 2880 P, and in front of the fan this figure is 5460 P. Air is a deformable gas. Therefore, pressure forces deform air molecules. In our example, there is a negative pressure - vacuum condition inside the pipe, and it has a lower value at the beginning of the pipe and a larger value in front of the fan. Here, an isothermal process can be observed. Because here the temperature does not change. The pressure is negative in the suction part of the pipe, that is, in the form of a low level of vacuum, and according to the Boyle-Marriott law, when the temperature is constant, the gas volume V is linearly related to the pressure P. That is, the mass of the gas entering the pipe does not change, but under the influence of the vacuum, the gas stretches, more precisely, becomes rarefied, its density decreases [7,8]:

$$T = const \Rightarrow V = f(P) \qquad (4)$$

Or, according to the law of conservation of mass for a constant medium:

$$\rho_1 \cdot v_1 \cdot s_1 = \rho_2 \cdot v_2 \cdot s_2 = const, \qquad (5)$$

From this, if we consider that the speed $\vartheta = \frac{l}{t}$,

$$\rho_1 \cdot \frac{l_1}{t} \cdot s_1 = \rho_2 \cdot \frac{l_2}{t} \cdot s_2 \qquad (6)$$

Given that the product of the distance l and the pipe cross-sectional area s gives the volume, that is, $l \cdot s = V \Rightarrow$

$$\rho_1 \cdot V_1 = \rho_2 \cdot V_2 \qquad (7)$$

Here, the volume V belongs to the pipe, ρ to the gas, while the diameter of the pipe remains unchanged, the gas expands due to the length of the pipe, and the volume occupied by a unit amount of gas increases, that is

$l_1 < l_2 => V_1 < V_2$

Since the air in front of the fan expands under the influence of high pressure, the volume of the pipe occupied by the unit air here is large, and at the head of the pipe is low. Accordingly, it can be said that here, respectively, are the length and volume of the pipe occupied by a unit amount (for example, 1 kg) of gas. here, l_1, $l_2$and V_1, V_2, respectively, are the length and volume of the pipe occupied by a unit amount (for example, 1 kg) of gas, in practice, the air consumption in front of the fan is increasing due to the increase in volume or decrease in density, not the air mass.

The analysis of tables 1, 2 shows that the results of the measurements obtained when the fan throttle is closed are the same, but Air flow, speed, static and dynamic pressure values at the points up to the pipe head in the case of pneumatic transport pipelines connected in a simple way, without sealing materials, are much lower than the values obtained in the hermetically connected pipeline pipeline. Correspondingly, we can see that the system has a small hermetic coefficient and the fan driver uses less current (4.47 kW instead of 5.54).

Graphs of changes in air speed, dynamic and static pressures, and current in the pneumotransport route when the pipes are connected through a duct and hermetically are given in Figures 3, 4, 5, 6, respectively.

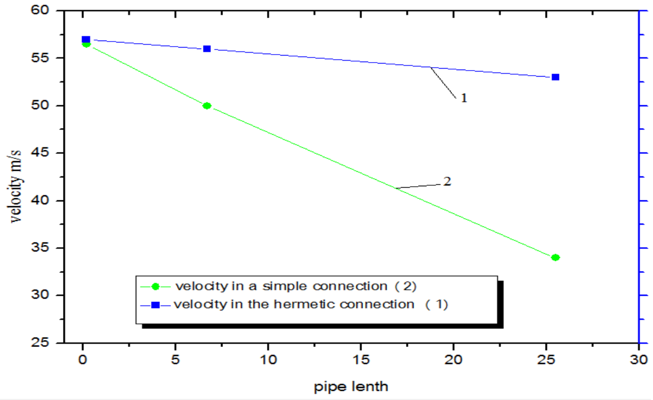

Figure 3. Variation of air velocities in the pipe along the length of the pipe when the pipes are connected through a duct and hermetically

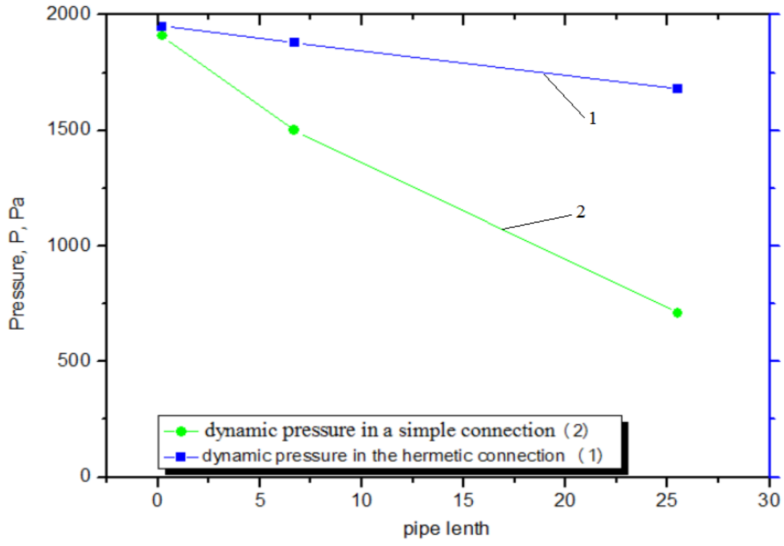

Figure 4. Variation of dynamic pressures in the pipe along the pipe when the pipes are connected through a duct and hermetically

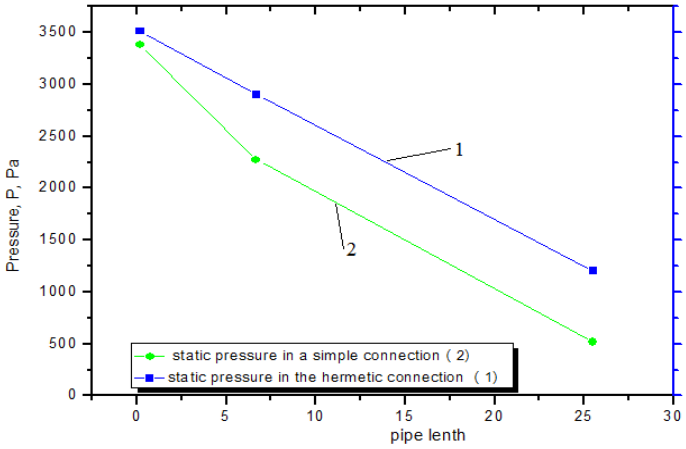

Figure 5. Variation of the static pressure in the pipe along the pipe when the pipes are connected through a band and hermetically

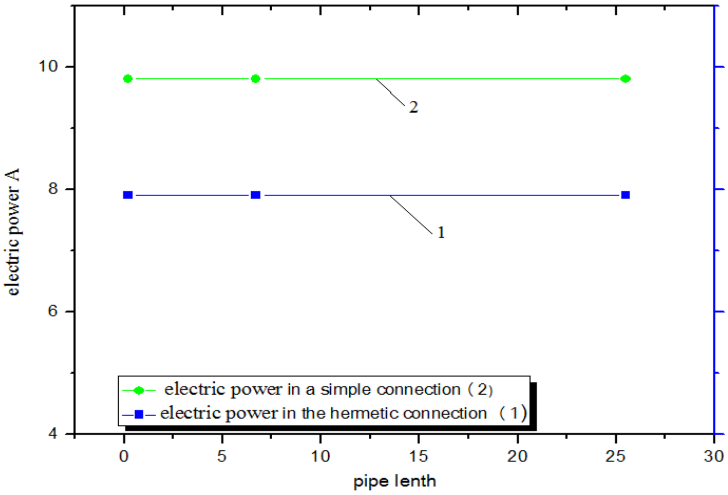

Figure 6. Variation of the current strength depending on the length of the pipe when pipes are connected through a band and hermetically.

According to the results, the velocity of the air flow in the pipe at a distance of 30 meters from 57 to 34 m/h, or 40%, the dynamic pressure from 1880 P to 710 P or 62%, the static pressure from 3380 to 520 P, or 85% is decreasing in the hermetically connected state. When the pipes are hermetically connected, the velocity decreases from 57 to 53 m/h, or 7%, the dynamic pressure from 1950 P to 1680 P, or 9.2%, and the static pressure from 3510 to 1200 P, or 66%. In this case, the consumed electric power decreased from 9.8 amperes to 7.9 amperes, or 9.2%, and the power decreased from 3.7 kW to 3.0 kW, or 18.9%.

According to these results, it can be concluded that it is important to ensure the hermeticity of its elements in aerodynamic systems. Ensuring hermeticity in pipelines and pneumatic transport elements provides a relatively large air consumption and pressure at the mouth of the pipe at the same nominal pressure and energy consumption [5-9]. This, in turn, makes it possible to transport cotton over long distances under the same conditions, or to transport cotton with less air and energy consumption while reducing the frequency of the current transmitted to the electric motor and, depending on this, the consumption of electricity and air, without changing the transportation distance [10-15]. Also, the installation of a stationary micromanometer in front of the fan allows the operator to monitor the changes in the air parameters in the system and to identify and eliminate possible negative situations in advance.

Conclusions. In pneumatic transport systems, it is important to ensure that air is not sucked into the system from the outside. Accordingly, in the analysis of the operation of pneumatic transport systems, it is appropriate to include the coefficient of hermeticity of the system. Based on its physical meaning and essence, the coefficient of hermeticity of aerodynamic equipment can be determined by the ratio of the amount of air consumption after a certain element to the amount of air consumption before it and this coefficient varies between zero and 1 ($0<K_g<1$), and its increase leads to a decrease in hermeticity, and a decrease - to its increase.

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