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AIR FLOW CONTROL FACTORS IN PNEUMATIC TRANSPORT DEVICE

KHOLMIRZAEV FARXOD

PhD, Namangan Institute of Engineering and Technology, Namangan, Uzbekistan
Phone.: (0891) 185-5855

Abstract: The article examines the possibilities of maintaining the initial quality parameters of raw cotton and increasing productivity by improving the air flow control device in pneumatic transport.

Keywords: Cotton raw material, pneumatic transport, cotton transportation, air flow, throttle, aerodynamic resistance, fan.

Introduction. Laws and regulations for maintaining the quality of cotton and fiber, cotton processing, as well as some phenomena that occur during its transportation by pneumatic transport, cases of changing the flow parameters of pneumatic transport when transporting cotton from different distances, with different levels of humidity and pollution, devices that change the parameters of the flow ensure that the flow changes at the same rate and the established modes have been studied [1-7].

The analyzes carried out showed that there is a need to create and introduce into production such structures as a throttle with low aerodynamic resistance, which allows to change the flow parameters in the cotton pneumatic transport system at the same rate, establish a high-precision operating mode and maintain the set mode until there is a need to change it [8-12].

According to the analytical calculations carried out in the study, the selection of modes for the process of cotton transportation in pneumatic transport and the characteristics of the turbulent mode and the effect on cotton transportation in pneumatic transport equipment were studied, the simplest aerodynamic device scheme was adopted to visualize the process, and the laws of air movement were first considered (Figure 1). Figure 1 shows the place where 1- suction air pipe, 2- fan (pump), 3- drive air pipe, 4- throttle, 5- nozzle throttle can be installed.

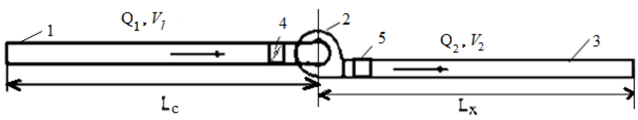

Figure 1. Aerodynamic equipment scheme

Although there are many disadvantages in the cotton industry, the most commonly used chokes are circular chokes. The main reason for this is that problems in small devices such as chokes are overshadowed by the larger economic and organizational problems that have arisen in the cotton industry. Therefore, the creation of throttle structures with low aerodynamic resistance, high automation capabilities, and the ability to change the air consumption and pressure at the same time is one of the urgent issues facing the industry.

The movement of air in the air duct occurs due to the vacuum created in the working chamber of the fan. That is, a vacuum is created in the chamber due to the fact that the fan first throws out the air in the chamber under the influence of centrifugal force with the help of its blades. Air enters this space from the fan intake and tends to fill it. The fan blades also push these air particles and throw them out. As a result, air flows in through the fan from one side and out from the other side. In short, the main factor that causes air movement is vacuum, which is static pressure with a negative sign.

A theoretical research. When the fan is closed, the full pressure in it is equal to static pressure, and the dynamic pressure is zero:

$$P_d=0,\ P_t = / P_{st} / . \qquad (1)$$

Theoretically, the absolute pressure should equal the dynamic pressure when the static pressure is zero. But, in practice, this is not the case - dynamic pressure cannot occur without static pressure. In an environment under static pressure, dynamic pressure occurs only if conditions for air movement are created, for example, if a hole is opened, a corridor is created. Therefore, it is correct to say that static pressure is primary, and dynamic pressure is its derivative. The nominal pressure that the fan can create depends on the power of the fan motor and the air consumption that it can create:

$$N = \frac{Q\,P_n}{3.6\,\eta};\ =>\ P_n = \frac{3.6\,\eta\,N}{Q}$$

If we put the found value into the full pressure equation:

$$P_{st} = \frac{3.6\,\eta\,N}{Q} - 0.811\,\rho\,Q^2/d^4, \qquad (2)$$

We determine the air velocity from the same air consumption equation:

$$\upsilon = 1.274\ Qd^2\ , \qquad (3)$$

To create an empirical equation, it is necessary to solve this system of equations:

$$\left.\begin{aligned} 4750 &= a\cdot 32 + b\cdot 3 + c \\ 900 &= a\cdot 22 + b\cdot 2 + c \\ 4750 &= a\cdot 42 + b\cdot 4 + c \end{aligned}\right\} \qquad (4)$$

The resulting equation looks like this:

$$P = -150\ Q^2 + 900\ Q + 3550,\ (\Pi a) \qquad (5)$$

Using the same approach, we determine the relationship between power consumption and air consumption, which has a linear relationship:

$$N = 5\ Q + 6,\ (kVt) \qquad (6)$$

If we pay attention to the results, the increase in air consumption and air speed will lead to a continuous increase in dynamic pressure and fan motor power consumption, and these indicators do not have an optimal value, that is, the greater the speed or air consumption, the greater the dynamic pressure and power consumption, and vice versa. At full and static pressure, there is an optimum at small and high air consumption and speeds, and it corresponds to the value of approximately v=12 m/s (Q=3.5 m3/s) in the VTs-10 fan. According to Figures 9, 11-12, when the air velocity exceeds this value, the static and total pressure begin to decrease sharply, but the power consumption N of the motor and the dynamic pressure continue to increase relatively sharply.

Air velocity and dynamic and total pressure readings cannot be measured without inserting a special tube into the pipe. However, it is possible to determine the static pressure by opening a single hole in the air pipe and installing an external manometer, and based on its value, it is possible to estimate the air velocity, dynamic and total pressure values and analyze the process.

When the fan is working, a negative (suction) air pressure is created on the left side of the fan, and a positive (spray) air pressure on the right side of the fan and an air flow moving from right to left. The highest pressure and air consumption, as well as the speed, are generated on both sides of the fan. During our research, we have seen that part of the static pressure is used to overcome the aerodynamic resistance (more precisely, the frictional and viscous resistance forces) of the air duct. In this work, we check the pressure loss in the bends, splits, joints, expansion (diffuser), narrowing (confuser) places of the pipe, separators, separators, cyclones and throttles. Depending on the structural and technological parameters of these devices, pressure losses occur at different levels.

The static Pst and full Pt pressure characteristics are also close to each other, since the full pressure is essentially the static pressure in the absence of air movement. Only when the air is allowed to move, for example, when the fan mouth opens, does dynamic pressure occur:

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

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

According to the fundamental theory, the dynamic pressure should not change practically along the length of the pipe. Because, the law of continuity of flow:

$$\rho_1 f_1 \vartheta_1 = \rho_2 f_2 \vartheta_2 = const, \quad (7)$$

according to , if the air density is constant $\varrho = const$, the speed should not change in pipes $\vartheta = const$ with a constant cross-sectional size d=const. Then, according to the equation $P_d = 0.5\rho \cdot \vartheta^2$, the dynamic pressure should also be constant along the length of the pipe P_d=const. However, the pressure P_d in the pipes is variable. Air density changes accordingly.

If the pipe size is constant:

$$\vartheta_2 = \rho_1 \vartheta_1 / \rho_2, \quad (8)$$

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

$$PV = RT$$

according to air volume V, its pressure depends on P: its density r is inversely proportional to air volume V: V=1/ϱ. That being said:

$$\varrho = P / (RT); \quad (9)$$

On the suction side of the pneumatic transport, there is a rarefied air environment, or a low vacuum condition. The real pressure here is equal to the difference between the ambient atmospheric pressure Pat and the pressure inside the pipe (system) P_s:

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

According to him:

$$\rho = (P_{at} - P_s)/(RT); \quad (10)$$

air velocity at the pipe head $\vartheta_1 = 26\frac{m}{s}$ let it be then:

$$\vartheta_2 = \frac{\rho_1 \vartheta_1}{\rho_2} = \frac{1.165 \cdot 26}{1.07} = 28.31\ m/s.$$

We calculate the relative change of speeds:

$$k_v = \frac{\vartheta_2 - \vartheta_1}{\vartheta_1} 100 = \frac{28.31 - 26}{26} 100 = 8.885\ \%$$

Figure 2 shows the graphs based on the obtained results. According to them, the air density decreases as the manometric pressure (vacuum level) increases from the beginning of the pneumotransport pipe towards the fan. This is probably why the term "thin air" in relation to the low pressure environment appeared.

An increase in pressure in front of the fan causes a further decrease in air density here, and a decrease in it causes a slight increase in air density. In this case, the pressure decrease has a stronger effect on the density change than the pressure increase. When the pneumatic system is completely hermetic, the change in air density causes a change in the air flow rate.

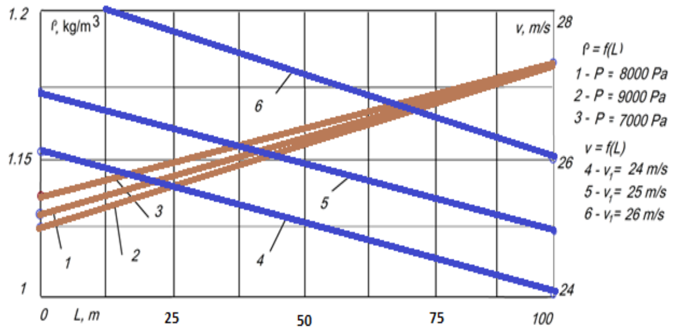

Figure 2. Variation of air density and speed along the length of the pipe

It can be seen from the results that as the pressure of the air moving through the pipe increases, its speed increases relatively. This is due to the fact that in an environment with high pressure (here, the vacuum level), the force that attracts air molecules to the vacuum source (the fan) increases, as a result, the air velocity increases, and, on the contrary, as it moves away from the fan, the pressure in the pipe decreases, as a result, the force that attracts the air towards the fan decreases, and the air velocity decreases. Also, an increase in initial speed leads to an increase in the speed difference, and a decrease in it - to a decrease. Studies show that the relative change in air density due to density changes averages 8-9%. However, experience shows that the air velocity increases dramatically from the pipe head to the fan.

Practical research. As practice shows, pneumatic transport pipes are mainly made of steel. When making a pipe, the steel sheet is rounded and the two ends are welded together. Pipes are connected to each other and long tracks are formed to convey air flow over long distances.

It can be concluded that in the design of aerodynamic and pneumatic transport equipment, it is appropriate to accept the density of air at rest in the conditions of Uzbekistan as $\rho=1.17$ kg/m³, and the density inside the suction part of the pneumatic transport equipment as equal to $\rho=1.13\div1.07$ kg/m³.

Alternatively, as seen earlier, the density of air at the mouth of the pneumatic transport pipe is close to the density of still air (ϱ = 1.17 kg/m³), while the density near the fan is lower (1.07 kg/m³). Without giving too much theory, based on the fact that the density is directly proportional to the air pressure, it can be said that the air density inside the pneumatic transport equipment increases linearly from the fan to the mouth of the air pipe, and vice versa, decreases according to the linear law from the mouth of the air pipe to the fan. A change in air density causes a change in its speed. As a result of the change in air density, its speed increases from the head of the pipe to the fan and, conversely, decreases from the fan to the head of the pipe. According to calculations, the change is 4 ÷ 9 %.

Existing choke devices consist of 2 parts: the flow resistance part, i.e. the baffle or flap (or flaps), and the control mechanism.

As a result of the analysis of the operation of the throttles, the following disadvantages were identified:

- the aerodynamic resistance of existing throttle structures in the state where they are not fully opened is high;
- it is impossible to change and maintain air parameters in the existing throttle structures;
- it is difficult to control the work of existing throttle structures and the possibilities of its automation are low.

The control device to be created should be free of these defects and easy to control.

The main disadvantage of existing pressure regulators is that they cannot provide the required pressure with high accuracy. The main reason for this is that, for example, each slot in a honeycomb arc plate provides a specific pressure, and the system cannot be adjusted to the pressure between two adjacent slots. That is, the pressure changes with a certain step. It cannot be changed in small amounts.

The following experimental device was prepared for testing throttles (Fig. 3).

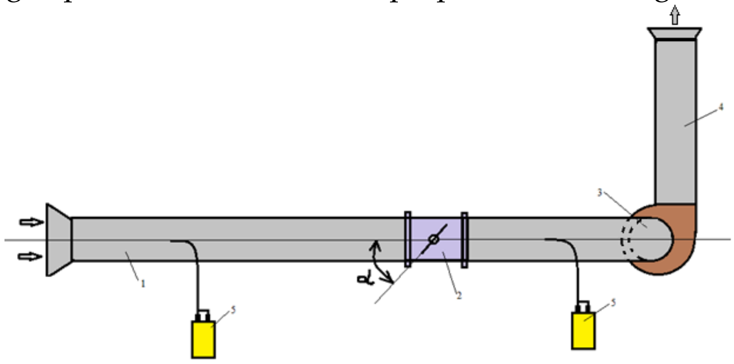

Figure 3. Scheme of the experimental device. 1-inlet pipe; 2 - throttle; 3- fan; 4- outlet pipe; 5-electronic micromanometer with pitot tube.

After the necessary measurements were taken, throttle 2 was replaced with the next type of throttle and measurements were taken and the results were entered into the appropriate tables. The aerodynamic drag coefficient was determined and tabulated using the following equation:

$$\lambda = \Delta P \frac{2L}{\rho} \frac{d}{\vartheta^2}$$

The measurements started from the initial position of the throttle 2 blades - it is parallel to the vertical axis, i.e., the pipe section is turned 20 degrees relative to the position, and it was carried out for every 10 degrees.

It should be noted that there is a certain level of resistance even when the throttle blades are fully open. This resistance depends on the projection of the horizontal valve in the vertical plane. Therefore, the amount of this projection and, accordingly, the resistance coefficient also increases as the number of cells increases.

All dorsals should have a uniform result when the wings are fully closed. However, despite the same conditions, in multi-blade throttles, the pressure is relatively low when the blades are fully closed. This happens because the number of blades increases, and the number of gaps between them increases. Therefore, even when the fins are fully closed, a certain amount of air passes between the fins, and this situation causes a slight decrease in the total pressure. However, since this air flow meter is below the sensitivity limit, its readings cannot be determined. This situation occurs due to the inability of multi-leaf chokes to fully ensure the hermeticity of pneumatic transport equipment. However, when the shutters are fully closed, pneumatic transport equipment does not enter the operating mode. Therefore, it is not of great practical importance that the throttle cannot provide complete hermeticity in the closed state. However, the greater the number of parts, the lower the reliability of the mechanical system. From this point of view, it is desirable for any system, including air flow control mechanisms, to have as few working elements as possible.

Another positive aspect of the large number of blades is that they can change the air flow relatively steadily. Especially in the case of intermediate cases of blades, that is, when the deviation angle α is greater than zero and less than 90 degrees, multi-blade throttles show less aerodynamic resistance.

According to the above analysis, it can be concluded that the most effective throttle for pneumotransport systems are 2- and 3-bar constructions. Accordingly, for practical use in cotton pneumatic transport, we recommend a 2-piece throttle for high-pressure (6-8 thousand Ra) systems, and a 3-piece choke for lower (4-6 thousand Ra) pressure systems. A 3-bar throttle has less aerodynamic drag in working conditions than a 2-bar throttle. However, the construction of the 3-blade choke is relatively complicated and the strength is relatively low.

Summary. In conclusion, for further research, 2- and 3-blade rectangular cross-section throttles were selected, and by generalizing it with the screw adjustment mechanism selected in previous studies, we developed throttle designs with 2- and 3-blade, screw fixing, which are reliable and stable, allowing to control the air flow in a uniform manner. released The developed equations for determining its parameters were processed in the Maple 2020 program and the values of the output parameters were determined at different values of the input factors, and the corresponding values of the throttle aerodynamic resistance and the radius of influence of the pneumatic transport equipment were determined. As a result, it turned out that the following parameters have the lowest throttle aerodynamic resistance and the highest radius of influence of pneumatic transport equipment: number of throttle blades: 2; inlet pipe narrowing angle: $\alpha=30$ degrees; outlet pipe expansion angle, $\beta=15$ degrees.

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CONTENTS

PRIMARY PROCESSING OF COTTON, TEXTILE AND LIGHT INDUSTRY

Korabayev Sh. From street traffic to space: innovations in autonomous vehicles	**3**
Egamov N. Investigation of vertical forced vibration in the longitudinal - vertical plane of a binder that softens the crush between cotton rows	**10**
Khamraeva S., Kadirova D., Davlatov B. Determination of alternative technological factors for the production of functional fabric with a complex structure	**15**
Khamraeva S., Kadirova D., Daminov A. Designing fabrics for a given stretchability	**21**
Kuliyev T., Rozmetov R., Tuychiev T., Sharipov Kh. The effect of the angle of heat agent supply to the drying - cleaning equipment on cotton quality and cleaning efficiency of the equipment	**28**
Abdujabbarov M., Alieva D., Karimov R. Determination of the influence of the length of the tested yarn samples on their mechanical characteristics	**35**
Jurayeva M., Nabidjonova N. Research on physical and mechanical properties of fabric selected for special clothing of preschool children	**41**
Yangiboev R., Allakulov B., Gulmirzayeva S. Studying the alternative technological factors of the loom in the production of textiles based on basalt yarn	**45**
Ganikhanov Kh., Mavlyanov A., Abdusamatov A., Mirzaumidov A. Analysis of the maintechnologicalparameters of the condenser	**55**
Mavlyanov A., Mirzaumidov A. The scientific basis of the lightened shaft	**60**
Elmanov A., Mirzaumidov A. Modeling of laser processingof thin-walled steel gears	**69**
Nurillaeva Kh., Mirzaumidov A. Cotton cleaner with multifaceted grates	**77**
Ganikhanov Kh., Mavlyanov A., Abdusamatov A., Mirzaumidov A. The equation of motion of cotton fiber in the condenser	**83**
Khuramova Kh., Xoshimxojaev M. Progressive method of cotton regeneration	**89**

Abdukarimova M., Lutfullaev R., Usmanova N., Mahsudov Sh. Evaluation of aestheticity of women's dress models based on deep learning models	**94**

GROWING, STORAGE, PROCESSING AND AGRICULTURAL PRODUCTS AND FOOD TECHNOLOGIES

Zufarov O., Isroilova Sh., Yulchiev A., Serkayev K. Theoretical aspects of obtaining oxidation-stable vegetable oils	**101**
Toshboyeva S., Dadamirzaev M. Filling sauces for canned fish and their layer kinetics	**110**
Atamirzaeva S., Saribaeva D., Kayumova A. Prospects for the use of rose hips in food technology	**115**
Turgunpolatova Sh. Study of the quality of fruit pastela products	**121**
Sultanov S. Analysis of experiments on the process of deodorization of vegetable oil using floating nozzles	**126**
Adashev B. Physical-chemical analysis of oil taken from seeds of safflower	**132**
Ismailov M. Influence of surface layer thickness on hydraulic resistance of the device	**137**
Khurmamatov A., Boyturayev S., Shomansurov F. Detailed analysis of the physicochemical characteristics of distillate fractions	**142**
Madaminova Z., Khamdamov A., Xudayberdiyev A. Preparing peach seed for oil extraction and improving oil extraction through pressing	**154**
Aripova K. Methods of concentration of fruit juices and their analysis	**162**
Djuraev Kh., Urinov Sh. Theoretical and experimental study of the crack formation device in the shell of apricot kernels	**168**

CHEMICAL TECHNOLOGIES

Urinboeva M., Abdikamalova A., Ergashev O., Eshmetov I., Ismadiyarov A. Study of the composition and main characteristics of petroleum oils and their emulsions	**175**
Tursunqulov J., Kutlimurotova N. Application of 1-(2-hydroxy-1-naphtoazo)-2-naphthol-4-sulfo acid in amperometric determination of scandium ion	**182**
Kucharov A.	**191**

Development of coal enrichment and gas extraction technology for the use of construction materials industrial enterprises	
Abdulkhaev T., Mukhammadjonov M., Mirzarakhimova F. Isotherm of benzene adsorption and differential heat of adsorption on AgZSM-5 zeolite	**198**
Vladimir L., Eshbaeva U., M.Ergashev Innovative environmental packaging for separating storage of two components, allowing to extend the lifetime without preservatives	**204**
Kodirov O., Ergashev O. Energetics of adsorption of water molecules to aerosol	**212**
Yusupov K., Erkabaev F., Ergashev D., Rakhimov U., Numonov M. Synthesis of melamine-formaldehyde resins modified with n-butanol	**219**
Ergashev O., Abdikamalova A., Bakhronov Kh., Askarova D., Xudoyberdiyev N., Mekhmonkhonov M., Xolikov K. Thermodynamics of Congo red dye adsorption processes on mineral and carbon adsorbents	**228**
Ergashev O., Maxmudov I. Water vapor adsorption isotherm in zeolites regenerated by microwave thermoxidation method	**235**
Jumaeva D., Zaripbaev K., Maxmudov F. The elements and oxide content of the chemical composition of the feldspar	**242**
MECHANICS AND ENGINEERING	
Khudoyberdiev U., Izzatillaev J. Analysis of research on small wind energy devices	**249**
Atajonova S. Mathematical model of system analysis of technological processes in the form of key principles for effective decision-making	**258**
Kuchkarbayev R. Mathematical modeling of heat transfer through single-layer and multi-layer cylindrical walls in buildings and structures	**264**
Atambaev D. Difference in the length of individual yarn composition of twisted mixed yarn and comparative analysis of single-thread elongation deformations	**269**
Abdullayev S. Modeling the functionalities of an automated system for managing movement in the air	**276**
Turakulov A. Describing computational domains in applications for solving three-dimensional problems of technological processes	**285**
Mamaxonov A.	

Mathematical model of machine aggregate of tillage equipment process	**293**
Khudayberdiyev A.	**304**
Technical and economic aspects of processing pyrolysis distillate into motor fuel	
Abdurahmonov J.	**311**
Research results on the selection of the mesh surface of a lint-cleaning device	
Vohidov M.	
Development of a program for determining eccentricity by analyzing the magnetic field in the air gap of an asynchronous motor	**319**
Utaev S., Turaev A.	
Analysis of methods and prospects for application of optical methods for control of working surfaces of cylinder liners of internal combustion engines	**327**
Boltabayev B.	
Determination of seed damage in the pneumatic transport system by conducting experiments	**335**
Azizov Sh., Usmanov O.	**339**
Simulation of equation of motion of the new construction gin machine	
Sharibaev N., Homidov K.	
Theoretical analysis of the coefficient of friction induced by the pressure force of a vertical rope acting from above and below	**347**
Aliyev B., Shamshitdinov M.	**356**
Improvement of the linter machine and development of its working scheme	
Mukhametshina E.	**362**
Analysis of cotton flow behavior in different pneumatic pipes	
Yangiboev R., Allakulov B.	**369**
Obtaining and analyzing correlational mathematical models of the sizing process	
Mirzakarimov M.	**379**
Efficient separation of fibers from saw teeth in the newly designed gin machine	
Azambayev M.	**387**
Measures to improve the quality of fluff	
Abdullayev R.	**392**
Scientific innovative development of cotton gining	
Kholmirzaev F.	**397**
Air flow control factors in pneumatic transport device	
Sharibaev N., Makhmudov A.	
Separation of cotton from airflow in pneumatic transport systems of the cotton industry	**404**
Sharibaev N., Mirzabaev B.	

Effect of steam temperature on yarn moisture regulation in textile industry	**410**
Sultanov S., Salomova M., Mamatkulov O. Increasing the useful surface of the mesh surface	**415**
Muhammedova M. Kinematics of the foot in a healthy person's foot and ankle injury	**421**
ADVANCED PEDAGOGICAL TECHNOLOGIES IN EDUCATION	
Abdullayev H. Algorithm for creating structured diagrams of automatic control systems	**429**
Kodirov D., Ikromjonova N. On delayed technological objects and their characteristics	**437**
Uzokov F. Graphing circles, parabolas, and hyperbolas using second-order linear equations in excel	**444**
ECONOMICAL SCIENCES	
Zulfikarova D. Issues of developing women's entrepreneurship	**449**
Ergashev U., Djurabaev O. Methods for assessing the effectiveness of waste recycling business activities in the environmental sector	**455**