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About the Change in Air Pressure in the Pipeline during the Pneumatic Transportation of Cotton

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Abstract

The article is devoted to the study of the issues of determining the patterns of changes in air pressure along the length of a pneumatic transmission pipeline for raw cotton at different flow parameters and different pipeline diameters. Theoretical studies have proved the reduction of static and total pressure along the line of pneumatic cotton transportation. The dependence of the pressure change on the diameter of the transport line and the aerodynamic drag of the pipeline is obtained. The results obtained are recommended for use in the design of raw cotton pneumatic transport systems.

Keywords

Pneumatic Conveying, Pipeline, Raw Cotton, Air Pressure, A Fan

1. Parameters of the Air Flow in the Cotton Pneumatic Transport Pipeline

Pneumatic conveying installation, is primarily the aerodynamic unit, which pumps air from one place to another [1] [2]. The difference is that pneumatic conveying installation serves the material, which captures the moving air and throws it at the destination. If judged on the merits, the air is also a material substance that has mass and volume, to transfer which requires no less effort and energy. Thus, any object or substance being in contact with the air, especially moving air, will be under force action. If the walls of the duct the air has the static pressure, seeking to destroy the wall and the force of friction of air particles on the surface of the wall, seeking to carry the wall along with in the direction of movement, and if a particle or body in certain shapes and sizes—the forces of inertia and friction, which also tend to carry them in the direction of movement. However, the nature of the interaction of the air with other bodies (particles in particular) is so complex that the theoretical description of this process with all ending phenomena and effects is impossible. For this, all the known theoretical background is carried out with certain assumptions and the confluence of empirical approaches based on experimental data [3] [4] [5].

Studies have also established the pressure drop along the length of the pipeline. Connecting or removing 1 m of a pipeline or pneumatic system elements, a stone trap, separator, or knee is accompanied by a decrease or increase in pressure at the neck of the pipeline. Often this is due to the pressure losses in pipelines [5] [6]. To establish regularities of change of pressure along the length of pipe material in the first place it is necessary to study the process of emergence pressure.

Any aerodynamic setup contains at least 3 components, it is a fan, the incoming and outgoing pipelines. In any design fan pressure, it creates an impeller (or wheel) which, for a focused air flow, is mounted inside a casing having inlet and outlet windows which are connected respectively to the input and exhaust pipes. During the rotation of the impeller (or the wheels cut the surrounding layers of air from the input window and throw them to the side of the output window. Moreover, the input window formed sparse, and output-rich (dense) environment.

The discharged medium is a vacuum, which attracts nearby particles, *i.e.*, particles of air and creates a corridor for the movement, forming a stream that is part of the fan. Similarly, the repulsive force of the compacted environment so forms a flow, only the exhaust. Fan binds these threads into one, *i.e.*, during operation, the fan sucks air flow or Aero mixture on one side and outputs it to the other side. According to this, the dices of the incoming and outgoing flow are the same. Rate of discharge (also called compaction), in fact, is the indicator measured in units of force (or mass) per unit volume (this is the unit of density). However, to date no science of such a measure as an indicator of low (or compaction), there is no means of measurement. But, there is the concept of pressure, which is measured by the magnitude of the force per unit area.

This, the power that is in the field of vacuum pulling pipe wall to the center of the stream, and in the field of sealing pressure on pipe wall from the inside. And this power can be measured instrumental and attributing its importance to the area of action of this force determines the pressure value. In pipelines, the forces acting on the pipe wall perpendicular to cause static pressure P_{ct}, the forces acting along the pipeline—dynamic $P_{д}$. Total pressure $P_{п}$ is the algebraic sum of the absolute values of $P_{д}$ the dynamic and static $P_{ст}$ pressure [6] [7]:

$$P_{ст} = \rho g h, \quad (1)$$

$$P_{д} = 0.5\rho v^2, \quad (2)$$

$$P_{п} = /P_{ст}/ + /P_{д}/, \quad (3)$$

where ρ—is the density (kg/m^3), υ—speed (m/s) of flow; g—gravitational acceleration, m/s^2; h—height piezometric pressure, which is equal to the height of air column or liquid, giving a pressure to the P_{CT} on the contact surface equal to 1 m^2.

2. Change of Flow Indicators for the Transport Line and Its Description

It is known that the dynamic pressure depends on density and air velocity, in the absence of vacuum (or exhaust) gas through the wall of the pipe (or pipe joints), *i.e.* the constancy of the speed of air, it does not change along the entire length of the pipeline and its possible to define the flow-rate measurement. And static pressure, assuming the density of known value that depends only on the height of the column of air, which is not determined instrumentally. This pressure is estimated a direct measurement at the beginning (the mouth) and the end (of the fan) of the pipeline. Judging by the formula, the static pressure depends on the height of the column of gas, which by its weight presses on the support surface, and this in turn is the distance that starts from the point where the pressure is minimum (or zero) value and continues to the point of contact pressure force with a supporting surface where it has maximum value. At a constant cross-section and resistance to duct static pressure from the mouth of the duct to the fan varies in a linear relationship.

Imagine that the origin of P0L is located at point 0 at the fan (not shown) (**Figure 1**). The 0L axis is the length of the pipeline, and 0P is the static or total pressure. According to the figure, the static and total pressure at point 0, *i.e.*, near the fan has a maximum value equal to P_n and decreases linearly in the direction of elongation. And the dynamic pressure R_d does not change, where, V air velocity, m/s. For the case of a linear pressure change, the line equation can be described as:

$$\left(P-P_{н}\right)/\left(P_{b}-P_{н}\right)=\left(L-L_{0}\right)/\left(L_{b}-L_{0}\right), \quad (4)$$

where, P_H is the initial or nominal pressure (*i.e.*, pressure of the fan, which is equal to the certified value of the pressure generated by the fan) Pa; P_b – the final pressure, or pressure at the mouth of the pipeline, Pa; L_0 and L_b, respectively, the initial and final length of pipeline, m. Imagine that the count down starts right at the fan and take $L = L_0 = 0$, then the mouth of the pipe $L = L_b$. If, given these conditions, to solve the equation for R, we get:

$$P=\left(P_{b}L+P_{н}\left(L_{b}-L\right)\right)/L_{b}, \quad (5)$$

Check: If $L = 0$, $P = P_H$; and when $L = L_b$, $P = P_b$. Hence, the equation correctly describes the law of variation of pressure along the transport line.

On the other hand, at the mouth of the pipeline pressure decreases to a pressure value of $P_к$ is required to overcome the resistance of the pipeline:

$$P_{к}=0.5\rho\upsilon^{2}\lambda L_{b}/d, \quad (6)$$

where, λ is the drag coefficient. Accordingly, the pressure at the mouth of the pipeline will be equal to:

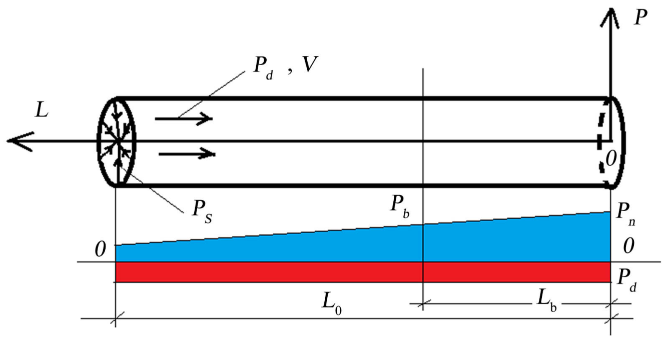

Figure 1. Scheme of air pressure change along the material transportation line.

$$P_б = P_н - 0.5\rho\upsilon^2\lambda L_б/d. \quad (7)$$

If the equation describes the relative static pressure, the pressure at any point on pneumotrack will be equal to:

$$P_{ст} = P_{нс} - 0.5\rho\upsilon^2\lambda L/d, \quad (8)$$

Here $P_{нс}$ is the nominal static pressure, Pa. And total pressure $P_п$ according to (2), (3) and (8):

$$P_п = P_{нп} - 0.5\rho\upsilon^2(\lambda L/d - 1), \quad (9)$$

Here, $P_{нп}$—full rated pressure of the passport is also the index fan, Pa.

3. Analysis of Changes in Air Pressure Depending on the Flow Parameters

From Equations (8) and (9) it is seen that the air pressure in any section of the pipeline depends on the nominal pressure fan negative pressure expended in overcoming the resistance of pipe material, which in turn is the length of the pipeline is directly proportionate to and from the diameter of the pipeline is in inversely proportional. The analysis of dependencies at different flow settings:

Internal diameter of the pipeline is equal to d = 0.315; 0.355; 0.4 m, the air density ρ = 1.2 kg/m^3. The resistance coefficient for clean air for rough pipes is often determined by the formula of Shiferson [8]:

$$\lambda = 0.111(a/d)^{0.25}, \quad (10)$$

Here a, coefficient of roughness of the pipe, which for the new pipes is equal to a = 0.133; used for pipes a = 0.044.

Analysis of Equation (9), conducted on a computer with different flow parameters is presented in **Figure 2**.

Photos 1, 2 and 3, full line pressure, 4, 5 and 6 lines of static pressure and dynamic pressure line 7. At the same time, 1 and 4 - 400 mm pipe, 2 and 5 - 355 mm pipe, 3 and 6 - 315 mm pipe.

The results show that the dynamic pressure under the condition of complete tightness of the system has a constant value along the line of current. And static and total pressure linearly decreases from the point of disturbance, *i.e.*, from the

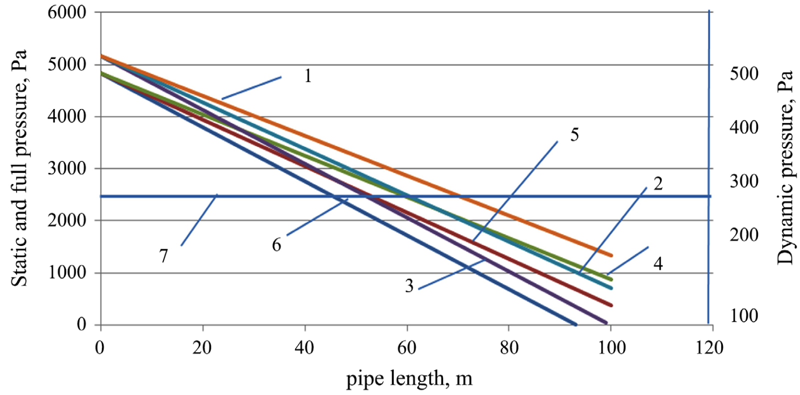

Figure 2. Distribution of statically and dynamic pressure along the line of the pipe.

fan to the extremities of pneumotrack. The figure shows that at smaller diameters the decrease in pressure is more intense. This shows high resistance of pipes of a smaller size relatively large. For example, if pipe diameter 315 mm static and dynamic pressure approaches zero at a distance of 95 to 100 m. Important this time graphics of pressure when the diameter of 355 mm (2-line) and 400 mm (4-line) intersect and the values are very close to each other. This shows that replacement of the pipeline diameter 400 mm pipeline diameter 355 mm to large losses of pressure and power will not. According to this, the pipe diameter is 355 mm can successfully replace the pipes of 400 mm diameter.

4. Analysis of Changes in the Resistance Coefficient of the Inner Surface of the Pipeline from Its Diameter and Flow Rate

Indeed, many studies report an increase in the resistance of the pipeline with decreasing diameter of the pipeline. However, Blasius [1] found that for hydraulically smooth tubes the increase in air velocity at a constant diameter of the pipe reduces the resistance of the pipeline. They have the inversely proportional dependence of drag coefficient on Reynolds number:

$$\lambda = 0.3164/Re^{0.25}\ , \tag{11}$$

In turn, the Reynolds number is defined as the product of duct diameter and air velocity:

$$Re = \rho d \upsilon/\mu\ .$$

Here μ, the coefficient of dynamic viscosity of air (1.85×10^{-5} Pa·s). The results of the analysis of (13) are presented in **Figure 3**.

In **Figure 3**, λ_b is the Blasius drag coefficient (plot 1—for pipeline diameter d = 400 mm; 2—for pipeline diameter d = 355 mm; 3—for pipeline diameter d = 315 mm); λ_e is the experimental drag coefficient (4—for pipeline diameter d = 400 mm; 5—for pipeline diameter d = 355 mm; 6—for pipeline diameter d = 315 mm). If you pay attention to the results of the analysis, you can see that a decrease in the diameter of the pipe leads to an increase in resistance, and an increase in flow velocity to a decrease. In addition, the experimental results under odds on Shiferson,

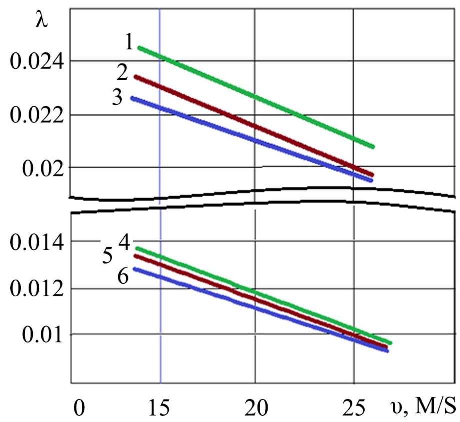

Figure 3. The dependence of the aerodynamic drag from air velocity and duct diameter.

more of the coefficients for the Blasius. In this case, the experimental drag coefficient λ_e are determined according to the equation:

$$\lambda = \left(0.5\rho\upsilon^2 + P_{\text{н}} - P_{\text{п}}\right)d \Big/ \left(0.5L\rho\upsilon^2\right), \tag{12}$$

the substitution of actual values of pressure of air at the mouth of the pipeline (RP) and the fan pneumatic conveying installation (P_{H}).

From the results of the analysis, it can be concluded that, indeed, an increase in the resistance of tubing with smaller diameters can be compensated by an increase in the flow rate [9]. This shows the possibility of successful use of pipes with a diameter of 355 and 315 mm in pressure pneumatic conveying plants for raw cotton. In addition, this will make it possible to reduce the energy intensity, material consumption of aerodynamic processes, and pneumatic transportation of raw cotton, including [10] [11] [12] [13].

5. Conclusions

1) Theoretical studies have shown and proved the reduction in static and full pressure on the line of transportation.

2) The dependence of pressure change on the transport line diameter and aerodynamic resistance of the pipeline.

3) The obtained results are recommended to apply when designing pneumatic conveying systems for raw cotton.

Conflicts of Interest

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

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