Theoretical analysis of air parameters for pneumatic transportation of products

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Abstract: *This article analyzes the problems encountered during the transportation of cotton raw materials from the fields of the primary cotton processing industry using pneumatic conveying systems. The article examines the use of ВЦ-8, ВЦ-10, and ВЦ-12 fans for transporting cotton through 400 mm diameter pipes. It also examines the factors that lead to increased energy consumption and decreased quality of cotton fiber and seeds due to the use of fans of the same power over long and short distances. To address these issues, theoretical calculations for an automatic air speed and pressure control system for the pneumatic conveying system are presented.*
Keywords: *pneumatic conveying, cotton raw materials, fan, air speed, pressure, energy efficiency, automatic control, fiber, seeds, pipe*

Introduction

Ensuring a continuous and stable flow of raw materials at primary cotton processing plants is essential for the efficiency of the technological process. Pneumatic transport systems are primarily used to deliver cleaned cotton raw materials to production facilities. These systems are characterized by high productivity and flexibility [1]. In practice, centrifugal fans of the VC-8, VC-10, and VC-12 types are used to transport cotton through 400 mm diameter pipes. The average airflow velocity during product transportation should be approximately 25-27 m/s. However, currently, fans of the same power are often used regardless of the distance between the ginning shops and the plant building. This situation leads to excessive energy consumption, especially when transporting cotton from neighboring shops, and a decrease in its quality as a result of cotton fiber and seeds striking the walls of process machines under the influence of high air pressure. Therefore, the issue of flexible and automatic control of air parameters in pneumatic transport systems is relevant.

Materials and Methods

Devices that artificially create air flow are called fans (Figure 1). The main working element of the fan is the blades mounted on a rotating shaft, which is placed inside a cylindrical shell, and when the shaft is given a rotational motion, the blades suck air particles from one side and push them out in the other. Holes are opened for air movement on the sides where air is sucked in and pushed out. If a pipe is connected to these holes, the simplest aerodynamic device is formed.

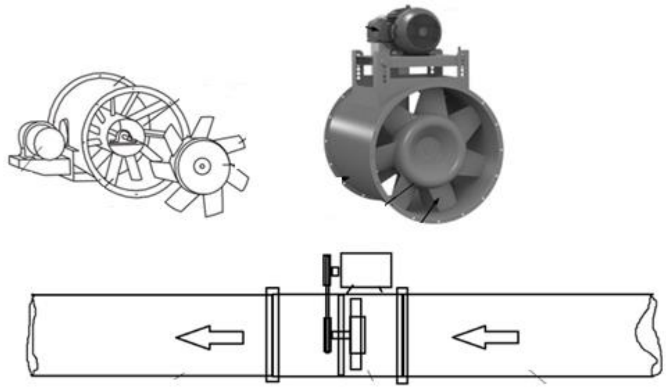

Figure 1. Fan diagram, general view and aerodynamic equipment

Figure 1 shows the simplest fan scheme and general view above, and the aerodynamic device scheme below. The fan consists of a rotating flange fixed to the shaft and blades fixed to it, as well as a cylindrical shell and an electric motor [4]. An air duct is connected to the suction and drive holes of the shell, and a corridor is formed in the middle for air movement, separated from the external environment. When the fan is operating, air flows through this corridor - the fan sucks it in from one side and expels it from the other.

The blade shaft receives movement from a motor located outside the shell, via a belt or chain transmission. Modern fans mainly use electric motors. Fans with an electric motor inside the shell are also widespread. In this case, the blade flange is mounted on the fan shaft. The air flow flows around the fan [2].

Nowadays, the types of air moving devices have increased - various designs of fans, devices such as pumps and compressors have been created, and the possibility of creating very high pressures and speeds has appeared.

Depending on the task they perform and the required air consumption and pressure, fans, pumps or compressors of various designs can be used in industry. Low and medium pressure fans are used in ventilation and aspiration systems, and high pressure fans and pumps are used in pneumatic transport systems. Compressors are used in vibration equipment and pressurized air spraying devices.

The fan in Figure 2 belongs to the centrifugal fan type. In them, the rotation of the blades causes the air to be trapped against the inner walls of the fan shell under the influence of centrifugal force, which condenses and creates a low-pressure vacuum (rare air environment) in the center of the chamber, and a compressed air environment at the edges, resulting in an air flow from the center of the chamber towards its walls [3].

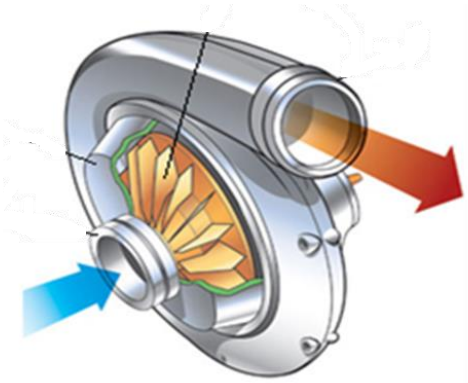

Figure 2. Centrifugal fan diagram

A hole cut into the chamber wall allows this flow to escape. At the same time, a hole cut in the middle of the chamber from the side allows air to enter the vacuum environment from the outside. Thus, the fan sucks in air from the side and throws it out through the hole located along the edge of the blade, resulting in a directed flow of air. Both the sucked-in air flow and the sprayed air flow can be directed in any direction and delivered to the required distance using pipes. There are many designs of centrifugal fans [4]. In particular, there are simple straight-bladed and curved-bladed, disc-shaped, cylindrical and flat, as well as types with a complex chamber configuration, with blades bent in the direction of rotation and against it. Depending on the shape, design, material, and dimensions of the blade and shell, their power, nominal pressure, and air consumption, as well as their scope and application, vary.

Figure 3. Centrifugal fan blade with a straight blade and a disc

Figure 4. Centrifugal fan blade with curved blades

Figure 5. Centrifugal fans with cylindrical chambers

In industry, longitudinal fans are also widely used. They have a relatively simple structure, they suck air along the axis of the fan blade and expel it back in the same direction. These fans can create a large air flow, but cannot create high pressure. Centrifugal fans can create a large air flow and relatively high pressure [2].

In the pneumatic transport system, the product moves inside the pipe using air flow. Since cotton raw material is a fibrous, light and bulky material, it is necessary to ensure a certain minimum air velocity for its transportation. According to the results of experience and practice, the average air velocity for transporting cotton is 25-27 m/s.

Relationship between air flow and pipe cross-section

The cross-sectional area for a pipe with a diameter of D=0.4 m is:

$$F = \frac{\pi D^2}{4} = \frac{3.14 \cdot (0.4)^2}{4} = 0.126 \text{ m}^2 \quad (1)$$

Air consumption is determined as follows:

$$Q = F \cdot v \quad (2)$$

If we take v=26 m/s:

$$Q = 0.126 \cdot 26 = 3.28 \text{ m}^3/\text{s} \quad (3)$$

Determining pressure losses in the process

The total pressure losses in a pneumatic conveying system depend on the length of the pipe, bends, inlet and outlet resistances, and product resistance, and are determined by the following expression:

$$\Delta P = \lambda \frac{L}{D} \frac{\rho v^2}{2} + \sum \zeta \frac{\rho v^2}{2} \quad (4)$$

here:

- λ-coefficient of friction,
- L-pipe length,
- ρ-air density,
- ζ-local resistance coefficients.

With increasing distance, pressure losses increase sharply, while at short distances these losses are relatively small.

Results and Discussion

The analysis showed that while the use of high-power fans of the ВЦ-12 type is justified for transporting cotton from long distances, for short distances ВЦ-8 or ВЦ-10 fans are sufficient [1]. However, in practice, the use of fans of the same power leads to the following negative situations:
excessive electricity consumption (up to 15-25%);
excessive air velocity in the pipe;
strong impact of cotton fiber and seed on metal walls;
breakage of fibers and damage to the seed.
To eliminate these problems, it is necessary to develop a system that automatically controls the air speed and pressure in the pneumatic transport system.
This system involves controlling the number of fan revolutions using a frequency converter based on distance, pipe resistance and real load.
As a result of automatic control:
the air speed is maintained in the optimal range of 25-27 m/s;
energy consumption is reduced;
the quality indicators of cotton raw materials are maintained.
Conclusion
Theoretical studies have shown that the introduction of an automatic control system for air parameters in the transportation of cotton raw materials by pneumatic transport is technologically and economically effective. The proposed system allows reducing energy consumption, optimizing equipment operation, and maintaining the quality of cotton fiber and seed. It is advisable to widely implement this approach in primary cotton processing enterprises.

References

1. А.Бурханов, “Совершенствование рабочих элементов пневмотранспортной системы с целью сохранения природных свойств семян перерабатываемого хлопка”, диссертация к.т.н. Ташкент 1987-159 с.
2. Х.Т.Ахмедходжаев Исследование транспортирования хлопка-сырца в металлополимерных трубопроводах и их влияние на качество волокна и семян. // Диссертация канд. техн. наук, Ташкент, 1980. –186 с.
3. Х.Т.Ахмедходжаев, М.А.Алиев О повреждаемости семян при пневмотранспортиравании хлопка-сырца. // Ж. Хлопковая промышленность, 1977.№2, С. 10-11.
4. M.O.Mutalov Paxta pnevmotransporti material o‘tkazuvchi quvur parametrlarini nazariy va amaliy asoslari. Dissertatsiya. Texnika fanlari bo‘yicha falsafa doktori (PhD). 2023-yil.