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Theoretical Fundamentals of Cotton Transportation to Pnevmotransport Equipment

D.Turg'unov, O.Sarimsako.,
Fergana politechnikal institute (FerPI),
Namangan Institute of Engineering and Technology (NamIET)

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Abstract: The article examines the process of mechanical feeding of cotton. Theoretically, the importance of the horizontal feeder in the production process, the influence of the supplier on the quality of the cotton during transportation and labor productivity were applied.

Keywords: tape, drum, cotton fiber, technology, density, dirt, seed, great, pneumotransport installation, operation mode, static pressure, dynamic pressure.

I. Pendahuluan

The growth of cotton production, the development of the next technological processes - spinning, weaving, dyeing and sewing - puts before the cotton processing industry the task of increasing production capacity, increasing equipment productivity, improving product quality, reducing costs.

The performance of these tasks also depends in many respects on the operation of the air-transport device installed in the ginnery, as it is directly involved in the continuous technological process of the ginnery and is an important part of its initial and operational speed. Suction-type pneumatic transport is mainly used for transportation of cotton within the enterprise.

The advantage of this pneumatic transport equipment is that the working pipe system can be easily extended without difficulty, depending on the location of the gins, and its length can be extended by connecting additional pipes to the primary pipes. The production capacity of an air-carrying device depends on the production capacity of the ginnery (i.e., the amount of raw cotton processed per hour). For a single-battery gin, it averages 10 tons per hour.

Supply of cotton to the pneumatic machine is carried out by means of ginning machines of RP, RBX or RBA brand. These machines mechanize the process that is the most difficult and requires a great deal of physical effort in the field of ginning - breaking the cotton bale, or loading it onto trailers, or transferring it to a pneumatic conveyor pipe.

Next to the grinder is mounted a conveyor belt mounted on a wheeled base parallel to the direction of its movement. The cotton that falls on it is thrown into the pipe by the conveyor.

The creation of the ginnery made it possible to mechanize the operation of ginning cotton, one of the most difficult operations in the ginning industry. However, in recent years there has been a decline in the use of spoilers in the machine-building industry, the physical obsolescence of existing ones, the lack of spare parts for repairs, and some of its shortcomings, such as the negative impact of cotton on quality. But this is definitely a temporary phenomenon. Because progress does not go backwards. As the economic situation of the cotton industry improves, the demand for this machine will increase.

Another disadvantage of the bale is the uneven distribution of the transmitted cotton mass along the direction of movement, or in other words, the uneven transfer of the cotton. The reason for this is that as the density increases when the cotton is stored in the bale, it moves in the form of large and small balls when moved with the bale, and in this case is transferred to the tube. As a result, there are blockages in the pipe neck, in the stone, in the separator. We have studied this process in detail in our previous studies and proposed a pneumomechanical supply design that provides a uniform supply of cotton [72,73,74].

The next piece of equipment used to transport cotton to the pneumatic conveyor is the above-mentioned belt conveyor. The horizontal feeder, which ensures the smooth transmission of cotton, is based on this conveyor.

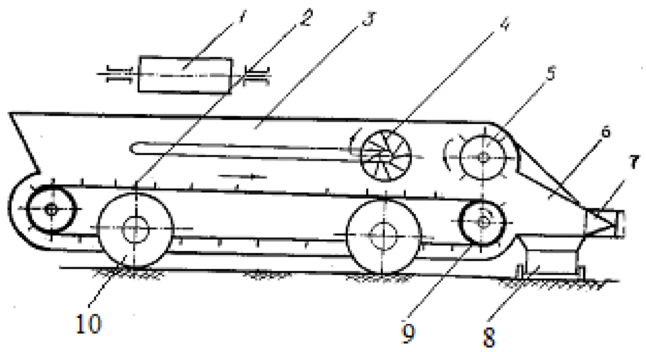

Figure-1. Horizontal supply circuit (M.G. - 1694727). 1 transmission tape; 2-horizontal tape; 3-roller; 4 leveling drum; 5-pile drum; 6-funnel; 7th pipeline; 8 collectors; 9- leading drum; 10-lead drum

The process is as follows: in a stacker, the bevel device transmits the cotton to the horizontal tape (2). Here (1,2) cotton is collected on the surface due to the difference in the speed of the tapes (2). The rotation of the roller (4) ensures that the desired height is reached on the tape surface of the cotton layer. Here the layer slowly moves in the direction of the tape towards the rotating drum (5) at a higher speed than the tape speed. At this speed, the layer plane is broken and the cotton is crushed, then the cotton falls to the receiving funnel (6). Due to the suction air from the hole of the funnel (6), the cotton passes through the air into the pipe of the conveying device (7). Heavy compounds with low volatile properties are collected in a collection drawer (8) and removed from there.

However, due to the relatively complex nature of this supply design and some operational shortcomings, it has not been widely introduced in the industry. Therefore, in this study, we aimed to find other backup possibilities for the smooth transmission of cotton, including the construction of bulk-breaking working elements from this perspective.

The use of a horizontal belt feeder in ginneries stemmed from the need for production. Therefore, in the first inspection, the current horizontal tape feeder was used.

In preliminary research, we theoretically analyze the process of cotton transfer using a belt conveyor in order to study the reasons for non-uniform transmission of cotton.

In a belt conveyor, for the transmission of cotton to be uniform, its throughput must be constant, and for this the height of the cotton layer on the belt must be constant. Our observations [1] showed that the cotton layer on the tape was uneven, resulting in the same amount of cotton not being transferred per unit time. We put before the study the problem of leveling the cotton layer coming at different heights.

We take the surface of the tape as the first element of the leveling process, and the surface of the leveling element as the second. As a leveling element can be used a simple fixed or working side vibrating plate or a needle or plank-pile drum rotating in the opposite direction (relative to the tape).

After analytical examination, a plank-pile drum was selected as the leveling element. It has been found that using it can reduce unevenness to a high degree. Untwisted cotton has low volatility and large bulk density.

A large airflow will be required to transport such cotton. This requires large energy consumption, high air consumption, high air and material velocity, which leads to a decrease in material quality due to seed breakage and fiber breakage. These findings raise the issue of cotton being shipped in transit, and we address this issue in the process of breaking the cotton bale. In that case, it remains a matter of normalizing the transmission of cotton to the new supplier. If a pile drum is chosen as the body for leveling the cotton layer, then along with the leveling of the cotton layers, the function of partial threshing of cotton is also provided. The pile drum is also characterized by reliability and simplicity of construction. The smoothing-grinding drum is mounted on the tape at a distance necessary for the interaction of the drum piles with the cotton to process it.

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2. Flatten a layer of cotton on the surface of the horizontal tape study the process

The cotton is mechanically transferred to the tape in balls. Uneven transfer of cotton to the tape increases the unevenness of the transfer of cotton to the pipe. This has been proven by applied research. Let's look at the possibility of transferring cotton to the tape at the same time. The cotton moves without friction, and the total amount of cotton coming in and out of the machine should be as follows:

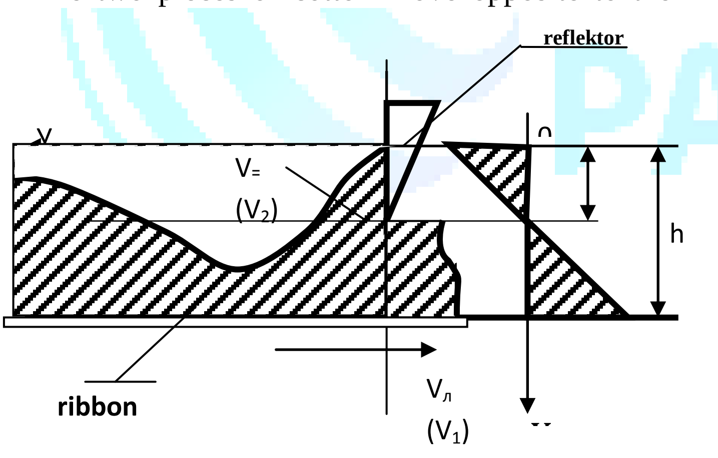
$$Q_{кир} = Q_{чик}$$

(1)

We imagine the unevenness in the case of a change in the height of the cotton layer along the longitudinal axis. We take its correction in the form of flattening the height of the layer [97, 98].

Let us consider the process of relative motion of the removable (or reversible) and passing parts of the cotton layer. Assume that the straightening body is located along the vertical x-axis (Figure 2). **Figure 2. Scheme of cotton straightening process.**

The two pieces of cotton move opposite to the x-



axis. The total height of the layer is h.

We assume that the motion of the layers occurs according to the law of linear coupling with respect to the x-axis. Let Uyu be the velocity of the upper layer and U_o the velocity of the lower layer.

At the leveling point we write the equation of relative displacement of cotton layers:

$$\mu \frac{\partial^2 y}{\partial x^2} = \gamma \frac{\partial^2 y}{\partial t^2} \quad (2)$$

where: (- shear modulus; (- cotton density; u - displacement; t - time.

The displacement at the leveling point is zero:

$$\mu \frac{\partial^2 y}{\partial x^2} = 0 \quad (3)$$

From this we find the law of linear displacement by two integrations:

$$y = Ax + B \quad (4)$$

We find the integration constants A and B from the initial conditions:

if $x = 0$ there $x = B + U_ю t$ is, if $x = h$ there $y = -U_o t$ is.

In that $-U_ю t = U_o t + Ah$ case, from here

$$A = -(U_ю + U_o)t \cdot \frac{1}{h} \quad (5)$$

Putting the findings, we determine the following equation of migration:

$$y = \frac{(U_o + U_ю)x}{h} t + U_ю t \quad (6)$$

Equation (2.6) of the velocity of the layers can be obtained by differentiating:

$$U = \frac{dy}{dt} = -\frac{(U_o + U_ю)x}{h} + V_2 \quad (7)$$

The main characteristic of alignment is the ability to conduct and return, which can be found as follows:

$$q = b\gamma \int_X^{X_n} U dx \quad (8)$$

Where: b is the layer width of the cotton; *x*, x_n - coordinates determining the height of the cotton layer; γ- density of cotton. Integration limits *x=0* to determine the return capability; of the layer $x_n = x_0$.

Here: x_0 is the conditional height of the rotating cotton.

We find x_0 from the condition y=0:

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$$-\frac{(U_o+U_ю)x_0}{h}+V_2=0,$$

from $$x_0=\frac{U_ю h}{U_o+U_ю} \quad (9)$$

In that case, the amount of cotton returned is equal to:

$$q_{кайт}=b\gamma\int_a^{x_0}(-(U_o+U_ю)\frac{x}{h}+U_ю)dx=\frac{0{,}5b\gamma hU_ю^2}{(U_o+U_ю)} \quad (10)$$

The throughput of the leveler is as follows:

$$q_{ут}=b\gamma\int_{x_0}^{h}\left(V_2-\frac{(U_o+U_ю)}{h}\right)dx=\frac{-0{,}5b\gamma hU_o^2}{(U_o+U_ю)}; \quad (11)$$

The minus sign indicates that the direction of cotton removal is in the opposite direction to the accepted coordinate axis. Therefore, the sign can be ignored. Accordingly, the capacity equation of the rectifier is as follows:

$$q_{ут}=\frac{0{,}5b\gamma hU_o^2}{(U_o+U_ю)} \quad (12)$$

Return capability $$q_{кайт}=\frac{0{,}5b\gamma hU_ю^2}{(U_o+U_ю)} \quad (13)$$

The results show that the capacity of the straightener depends on the speed of movement of the tape, and the ability to return depends on the linear speed of the leveling body.

The obtained dependencies allow the selection of the optimal speeds of the provider operating modes based on the required magnitudes of the transmission.

3. Kinematic calculation of horizontal supply

The technological parameters of the newly developed supplier were determined experimentally, and their value is as follows: Carrier belt velocity vl = 5.8 m / c; Plank drum linear velocity vn = 6.4 m / s; The speed of the pile drum vk = 8.6 m / s. We conduct kinematic calculations based on these indicators.

1. Determine the number of revolutions of the transmission drum when vl = 5.8 m / s. It should look like this:

$$n=\frac{30\cdot\omega}{\pi}=\frac{30}{\pi}\cdot\frac{v}{R}=\frac{30}{\pi}\cdot\frac{2v}{\alpha}=\frac{60v}{\pi d} \quad (14)$$

in that case, because d = 250 mm = 0.25

$$n\delta=\frac{60\cdot5{,}8}{3{,}14\cdot0{,}25}=443{,}3 \quad айл/мин \quad (15)$$

2. Transmitter drum diameter dmb = 450 mm = 0.45 m When the number of asynchronous rotations of the electric drive shaft is ndv = 960 rpm, we determine the diameter of the pulley mounted on the electric drive shaf

$$d_ш=\frac{n\delta}{nдв}\cdot d_{шб}=\frac{443{,}3}{960}\cdot0{,}45=0{,}21\ м=210\ мм \quad (16)$$

3. Determine the number of rotations of the leveling bar drum. (dn = 150mm = 0.15 m)

$$n_n=\frac{30\cdot10}{\pi}=\frac{30}{\pi}\cdot\frac{v}{R}=\frac{30}{\pi}\cdot\frac{2\cdot v}{d}=\frac{30}{3{,}14}\cdot\frac{2\cdot6{,}4}{0{,}15}=814 \quad айл/мин \quad (17)$$

in which case the diameter of the guide pulley mounted on the bar drum shaft shall be as follows.

$$d_{nn}=\frac{n_{дв}}{n_n}\cdot d_{шдв}=\frac{960}{814}\cdot0{,}21=0{,}25 \quad м=250 \quad мм \quad (18)$$

4. Determine the number of revolutions of the pile vibrating drum: (d_k=300mm=0.3m)

$$n_к=\frac{60\cdot v}{\pi\cdot d_к}=\frac{60\cdot8{,}6}{3{,}14\cdot0{,}3}=547{,}8 \quad (19)$$

Assume that the diameter of the pulley acting on this drum is $d_{shk=}$200 mm=0.2 m. Then we find the diameter of the leading pulley on the slatted drum, which moves to the vibrating drum:

$$d_{nem}=\frac{n_к}{n_{nem}}d_{шк}=\frac{547{,}8}{814}\cdot0{,}2=0{,}134м=134 \quad (20)$$

Thus, the results obtained are as follows:
a) the number of revolutions of the electric drive shaft $n_{дв}$ = 96 rpm; The diameter of the leading pulley in it is $d_{шдв}$ = 210 mm
b) the number of revolutions of the transmission drum: $n_б$ = 443.3 rpm; The diameter of the leading pulley in it: $d_{шб}$ = 450 mm; The linear velocity of the

conveyor belt is $v_л$ = 5.8 m / s; Number of planar leveling drum rotations: n_n=814 rpm; Its linear velocity v_n= 6.4 m / s; The diameter of the leading pulley in it $d_{шn}$ = 250 mm; The diameter of the pulley moving to the pulley of the gear drum is $d_{n.em}$=134mm.
c) the number of revolutions of the pile vibrating drum: $n_к$ = 547.8 rpm; Its linear velocity

$v_к$ = 8.6 m / s; The diameter of the leading pulley in it d $d_{шк}$=200 mm.

4. To study the effect of the horizontal feeder on productivity and quality of cotton

The performance of a tape device depends on the width of the tape, its coefficient of application per unit area, the linear velocity of the tape, and the moisture and density of the layer of material moving in it.

The supplier we are projecting is located at the head of the primary processing technological chain of cotton, and its performance determines the performance of the entire technological chain.

It is therefore important to calculate the performance of a new supplier. Based on the above, the supplier's cotton transfer productivity equation can be expressed as follows:

$$У=к\cdot v_л\cdot B\cdot h\cdot \gamma \quad (21)$$

Where: $v_л$–tape speed, m/s; B – tape width, m; h is the height of the cotton layer, m; k_x-tape surface utilization factor; (γ-cotton layer density, kg/s^3. According to the available data, the tape velocity $v_л$=5.8 m/s; tape width B=0.4 m; the density of the cotton layer (γ=40-60 kg/m^3. However, this figure (γ) decreases 1.5-2 times during mechanical exposure to cotton.

So far, studies have shown that the coefficient of utilization of the tape surface is around

k = 0.3-0.5.

The height of the passing cotton layer depends on the distance between the outer circumference of the leveling drum and the tape.

This distance is equal to h = 150 mm.

However, it is reduced due to the bonding force between the wings mounted on the surface of the tape and the cotton layer slatted drum slats.

Depending on the results of applied research, we assume that this height is h=0,1m. We get the density of the cotton layer (γ=30 kg/m^3, and the coefficient of utilization of the tape surface as k=0,45.

Based on the results, we calculate the cotton transmission efficiency of the supplier. $У=к\cdot v_л\cdot B\cdot h\cdot \gamma=0,45\cdot 5,8\cdot 0,4\cdot 0,1\cdot 30=3,132$t/h.
or since 1 kg/s=3600kg/h=3.6 t/h, $У=3,132\cdot 36=11.28$ t/h.

The efficiency of the technological process in ginneries varies around 8-12 t/h. The result obtained by calculation falls into this range, and it can be said that the new supplier can be successfully applied in the existing ginneries.

As a result of research on the process of transporting cotton on an air-transport device, it was found that the quality of cotton transported in it is deteriorating.

Quality degradation occurs mainly due to the shocks received by the seed as it hits its walls while moving inside the pipe. when the speed of cotton with a moisture content of 9.2% and a contamination of 1.2% in the air-carrying device is V = 24-26 h/t, 1.2-1.4% of the seed breaks. As a result, cotton fiber defects will increase by 0.3-0.4%. When transporting cotton from cotton bales located at a distance from the shops, it is necessary to extend the radius of action of the air-carrying device. This increases the likelihood of the above seed breakage and the formation of various defects in the fiber.

The main reason for this is the uneven transfer of cotton from the gins to the pipe. The pile milling machine of the RBX brand spinning machine cuts the cotton and feeds it to the tape. The cotton is transferred to the tube in the form of unevenly distributed pieces on the tape. This situation results in uneven placement and movement of the cotton inside the pipe. Uneven movement not only impairs the quality of the cotton in the pipe, but also prevents all the machines in the technological process from working smoothly. This situation has a negative impact on their effectiveness.

Often, as a result of uneven transmission, there are cases of clogging of the cotton in the working bodies of processing machines. This in turn causes the machines to stop for a certain period of time. In addition, due to the clogging of the cotton, the machine working bodies quickly fail.

Figure 2.3 shows the dependence of seed breakage on the air flow rate as a result of uneven transport of cotton in an air-carrying device on the basis of graphs using cotton of different humidity.

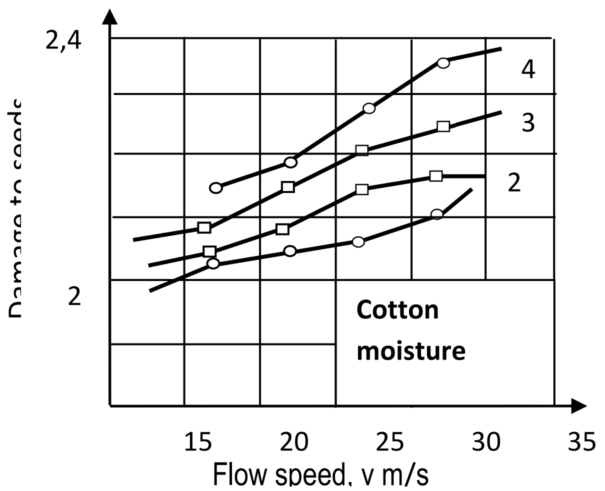

Figure 2.3. The effect of changes in cotton flow rate on seed damage at different humidity

In addition, 5-6 kW of electricity will be used to transport 1 ton of cotton to a distance of 60-80 meters. Given that often 2-3 air-carrying devices are connected in series, it is not difficult to imagine how high the energy consumption is.

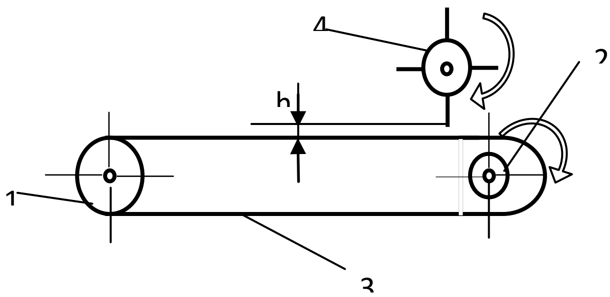

Figure 2.4. A device that transmits cotton evenly to an air-carrying tube.

1,2 rotating drums; 4 pile drum is the distance between the h-moving belt and the pile drum. The main goal of our work is to eliminate the above-mentioned shortcomings of the air-carrying device, air to choose a convenient mode of operation of the device, reduce energy consumption, transfer cotton to a flat pipe and improve the process of separating it from the air. According to the results obtained, during the transportation of cotton by air, a certain amount of seed breakage, a decrease in fiber quality was observed. In order to eliminate these shortcomings, a number of theoretical and practical experiments were conducted [164÷166,206].

In theoretical studies, the equation of motion of a piece of cotton on the tape under the influence of aerodynamic and gravitational forces was constructed, and on this basis its trajectory was determined.

The trajectory also showed the cotton hitting its walls as it moved inside the pipe. The technical solution designed to eliminate the above-mentioned shortcoming is based on the installation of a reverse slatted drum on the tape on it (Figure 2.4). This device mainly consists of 1 and 2 rotating drums and a moving belt on them. A series of experiments were performed to determine the distance h between the tape and the pile drum.

The plank drum flattens a layer of cotton that moves unevenly over the tape. This ensures that the cotton is transmitted evenly, moving inside the pipe without hitting the walls. In this case, it is necessary to determine the speed of the bar drum relative to the movement of the tape and to accurately determine the distance between them. By varying the distance between them at a certain rotational speed of the tape and the lathe drum, it is possible to ensure different operating efficiencies of the cotton transmission.

A bunker was mounted on the tape to verify that the process of transferring the cotton to the air-carrying device depended on its performance. During the work, cotton is loaded into the bunker and transferred to the tape with the required productivity. A special scale mounted on the end of the tape records the height of the cotton layer for its different speeds and it is adjusted for a given productivity.

As a result, results were obtained showing that the height of the cotton layer depends on the transmission efficiency of the tape at different speeds. Based on these results, we will be able to transfer the cotton to the air-carrying device at the required speed at the specified speed of the tape. Based on the results obtained, the positioning height of the leveling drum, which is mounted on the supply tape, is determined. The next task will be to determine the leveling drum speed. This is because if its speed is not chosen correctly, there is a possibility
that the cotton will get stuck between the tape and the bar drum.

Based on the results, it was determined that the speed of the leveling drum should be 1,5 times the speed of the tape. After carrying out the process of uniform transfer of cotton, the degree of fracture of the seed was determined by changing the air flow rate and hitting the pipe walls at different humidity. On this basis, the graph in Figure 2,11 was constructed.

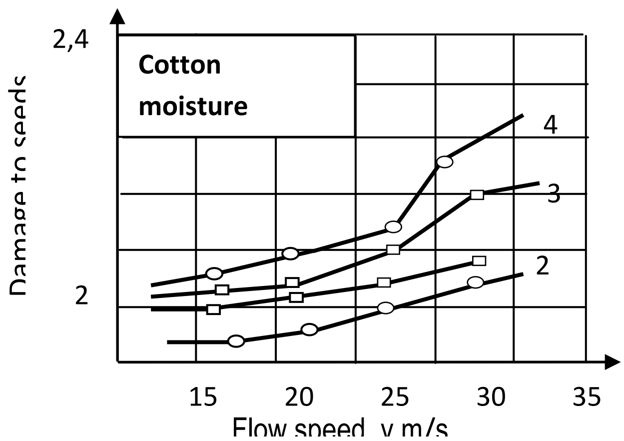

Figure 2.5. Influence of cotton flow rate on seed damage under conditions of smooth transmission at different humidity.

Comparing the graph in Figure 2.4 with the graph in Figure 2.5, we conclude that:

For example, in cotton transported at an air flow rate of 25–30 m / s with a moisture content of 8.2%, seed damage is 1.2–1.6% for an existing air-carrying device (Figure 2.4) and after the installation of a new supplier (Figure 2.5) is 0.4–0.8%. It can be seen that when a carrier device using a new element air is used, the seed damage is reduced by 2-3 times.

Thus, as a result of improving the process of transferring cotton to the air-carrying device, it prevents the formation of various defects in the fiber structure, while reducing seed breakage by ensuring its smooth movement inside the pipe. At the same time, the machines installed in the technological process of the ginnery will ensure the smooth operation. This increases the productivity of the machines and ensures that the processes performed on them are smooth.

5. To study the effect of tape speed on cotton transmission productivity

The process of smooth transfer of cotton using a feeder is influenced by the following parameters of the feeder: the speed of the tape, the speeds of the leveling and grinding drum, as well as the distances between the leveling drum and the tape.

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By varying the distance between the drum and the tape, it is possible to ensure different efficiencies of cotton transfer at certain speeds of rotation.

At a given production capacity, a bunker feeder was installed under the horizontal feeder to select the tape speed at different sizes of drum and belt distances.

At the calculated yield, the bunker was filled with cotton and transferred to the tape. This creates a layer of cotton on the surface of the tape. Its height varies in proportion to the speed of the tape and the transmission efficiency of the cotton.

When cotton is delivered using a bunker feeder with a production capacity of 6-12 t/h, the layer height at different speeds of the belt is determined using a special scale installed at the end of the belt and adjusted to the given productivity. The results are presented in Table 1.

TABLE 1. THE HEIGHT OF THE COTTON LAYER IN THE TAPE DEPENDS ON ITS TRANSMISSION EFFICIENCY AT DIFFERENT SPEEDS

	Trans mission capacity t/h	Layer height h, mm at different velocities of the tape				
		V л=1 м/с	**V л=3 м/с**	**V л=5 м/с**	**V л=7 м/с**	**V л=9 м/с**
	4	89	29	1 9	18	1 7
	6	13 3	44	2 7	19	1 7
	8	17 8	59	3 5	25	1 8
	10	22 2	74	4 4	32	2 5
	12	26 6	89	5 3	38	3 0

The results of the study show the effect of tape speed on the height of the cotton layer. The analysis of the obtained results gives the following conclusions:

a) The speed of the tape feeder significantly affects the height of the cotton layer. For example, at a speed of 3 m / s of tape, at a yield of 10 t / h, the height of the layer is 0.074 m, at a speed of 7 m / s, at the same productivity the height decreases by 0.032 m.

b) As the productivity increases, the layer height decreases. For example, when the productivity is 4 t / h, the layer height is 29 mm, and if the productivity is 10 t/h (tape speed 3 t/h) the layer height is 74 mm (at a speed of 7 t/h).

Based on the results obtained, it is possible to determine the height of the placement on the leveling drum supply tape. Subsequent research is expected to determine the tape speed, which will ensure production productivity, taking into account a certain height.

Investigation of the leveling process of the cotton layer

The aim of the study was to investigate whether the smoothing drum speed $V_т$ depends on the tape speed $V_л$. This requires ensuring the reliability of the equipment. The condition for reliable operation is the complete removal of the excess cotton layer by means of a leveling drum and the elimination of cotton stagnation between the tape and the leveling drum.

The research was conducted as follows. After checking the spacing, dimensions, and condition of the working elements, the supply was started and the voltage magnitudes of the transformer providing the desired linear speed of the tape were determined. Once the desired results were obtained, the tape was stopped and a flat piece of cotton was loaded on top of it. In this case, the height of the cotton layer was made greater than the distance between the tape and the leveling drum.

The speed of the leveling drum was controlled from zero using an autotransformer electric motor. The formation of the brake or the removal of the excess layer was detected by visual observation of the process occurring between the leveling drum and the tape. By varying the speed of the smoothing drum, a minimum magnitude of the drum speed was found, which eliminates the complete removal of the excess cotton layer and the braking of the transmitted cotton. In order to avoid errors in

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the results, checks are carried out 3 times, separately for each speed magnitude given to the tape.

5.CONCLUSIONS

Based on the results of theoretical and practical work, a comprehensive analysis of scientific research on the transmission of cotton to the air carrier, we draw the following conclusions:
1. The theoretical basis of the process of transfer of cotton to the air carrier has been created.

2. When moving the raw material to the starting part of the air-carrying device pipe at different initial speeds, the trajectories of the distance of the cotton to the pipe and inside the pipe were determined. In this case, it was theoretically proved that the cotton moves with jumps at the beginning of the pipe and gradually moves in a straight line.

3. Based on the theory of motion of cotton at the head of the pipe, the equation of the effect of the speed of transfer of cotton on the air pressure used to accelerate it was found. It was found that the higher the initial velocity, the lower the energy consumption required to accelerate the cotton.

4. The theory of transmission of raw materials that ensure the smooth movement of cotton in the pipeline has been developed. It has been scientifically proven that the leveling drum must work together with the horizontal tape to transfer the raw material in one plane.

5. Taking into account the technological conditions, experimental copies of vertical and horizontal supply devices that provide a smooth transfer of raw materials to the starting part of the air-carrying device pipeline were prepared and studied.

6. Theoretical and experimental composition of the horizontal support working bodies, the distances between them, the directions and speeds of movement were found.

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