Study of the Process of Cleaning Raw Cotton from Weed in Sections of Screw Conveyors

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ABSTRACT

The article presents the results of a study of the process of cleaning cotton from weeds in sections of screw conveyors. Screw conveyors have a special role in the technological process of cotton gins, they are used for the transport and distribution of cotton technological machines. Based on the analysis of the operation of screw conveyors, a device was developed for cleaning raw cotton from small weeds during transportation. A theoretical description of the process of cleaning raw cotton from impurities is proposed, according to the model proposed in the literature by A.G. Sevostyanov. An assessment of the influence of the number of sections and pins on the cleaning effect of the conveyor is given.

Keywords: raw cotton, cotton transportation, small litter, peg auger, mesh surface, dust, cleaning of raw cotton.

I. Introduction

Screw conveyors have a special role in the technological process of cotton gins, they are a highly efficient means of transporting, distributing cotton to the production lines of cleaners and the main technological machines - genie batteries [1,2].

Separately, it is worth noting that screw conveyors also perform the bulk of the work to remove waste from technological machines in the cotton gin.

Usually screw conveyors can be horizontal, vertical or inclined. Horizontal screw conveyors are mainly used in cotton gins. The advantages of screw conveyors are simplicity of design and unpretentious maintenance, relatively small overall dimensions, ease of intermediate unloading, tightness and durability [3,4].

In screw conveyors, the carrier is a screw mounted for rotation inside a closed shell. The material slides over the casing and is removed from one or more of its places. In this case, the axis of the material moves along the working surface of the rotating screw and the shell, located along the axis of the shell.

The length of the screw parts is 2-4 m. Both parts of the tubular screws are connected by a short shaft. When placing a screw conveyor auger in the shell, a gap is left between the outer edge of the screw blade and the wall of the shell. Its value is 25-32 mm in screw conveyors used in the transportation of cotton to prevent clogging of raw cotton and damage to cotton seeds. The body of the screw conveyor is made of sheet steel 3-6 mm thick. There are many examples of the use of screw conveyors in the technological process of primary processing of cotton, as indicated above, and based on their analysis, two main directions for the use of screw conveyors can be indicated:

- to transport and distribute cotton to technological machines for the purpose of cleaning;

- as a means of transporting cotton seeds and cotton gin waste.

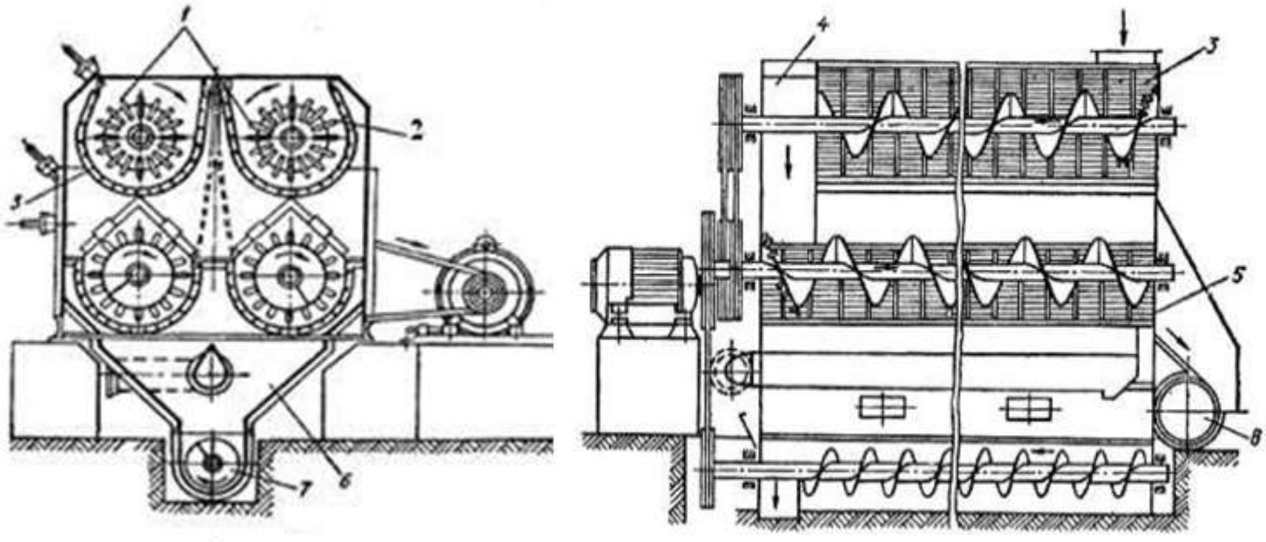
In the primary processing of cotton, it is considered one of the important links in the technological process of cleaning it from weeds, and in subsequent processes it has a high impact on the primary processing of cotton, that is, during ginning and fiber cleaning. If small impurities are not cleaned properly, they will go from passive to active and will be difficult to separate in the fiber cleaner.

All cotton gins work in the same way, i.e. cotton with peg drums is also pulled through mesh surfaces. This process is repeated several times and the cotton is cleaned of small weeds. The cleaning efficiency of the equipment depends on the number of revolutions of the peg drums, the mesh surface and the initial quality of the cotton[5,6].

At ginneries, the process of cleaning cotton from small weeds was carried out by installing pegs at the ends of the auger and under it a grate used to transport cotton. On the basis of this design, cleaning equipment 6A-12 was created and widely introduced at all cotton ginning enterprises of the republic. Screw cleaner 6A-12M (Fig. 1) consists of two parallel sections, each of which consists of independent 1-upper and 2-lower peg screws and a 3-mesh surface.

The length of the screw in the upper part of the cleaner is 3645 mm, in the lower part 3990 mm, the total diameter of the screw is 550 mm, the pitch of the screw is 300 mm. Four splitters with a diameter of 14 mm and a length of 75 mm are installed on the peg augers, the distance between the piles is 70 mm. Wire grates with a diameter of 6 mm or a perforated mesh with dimensions of 6x50 mm are installed under the peg augers. The distance between the pins of the auger and the mesh surface is 16-18 mm, the speed of rotation of the peg auger is 7.0 m/s, the productivity of each section is 5-6 t/h.

The cotton entering the cleaning equipment is divided into two parts and equally distributed to each section, and the cotton cleaned in the peg augers located in the upper part is sent to the lower peg augers through the connecting vertical shaft, and the cotton moves in the opposite direction from the tender part. Peg augers clean cotton from small weeds with the help of shock and ripper action. The cotton moves along the length of the mesh surface. Small impurities separated in each section enter the cleaning auger and are removed from the equipment.



а) б)

Figure 1. Drawing of auger cleaner brand 6A-12M.
a) cross section, b) longitudinal section.

1-upper screws; 2 - peg; 3 mesh surface; 4-mine; 5-bunker of cleaned cotton; 6- weed bunker; 7-weed auger.

In cleaners with a peg drum and a peg auger, the cleaning process of cotton in both cleaners is compared by pulling the cotton through the mesh surface, while the working part of the pin hits the cotton and drags it through. But the different movement of the cotton in these equipments affects the cleaning process in different ways.

II.Materials and methods. Based on the analysis of the design and operation of the 6A-12M screw cleaner, it was decided to study the problem of cleaning cotton from fine litter and dust in a screw conveyor used when transporting cotton at ginneries[7]. To do this, taking into account the simplicity of the design of the ShH cotton auger and simple maintenance, relatively small overall dimensions, and the convenience of intermediate unloading, a device was developed for transporting cotton and cleaning it from small impurities (Fig. 2).

The working parts of the device were adapted to the working parts of the screw cleaner 6A-12M. The length of the peg auger in the device is 8000 mm, the total diameter of the peg auger is 550 mm, the pitch of the auger is 300 mm. The pins of the auger have a diameter of 14 mm, the length of the pins is 75 mm, the distance between the pins is 70 mm. A retinal surface 6x50 mm is installed under the peg screws. The distance between the peg screw and the mesh surface is 18-22 mm, the rotation speed of the peg screw is 160 rpm, the productivity is 10-12 t/h.

Figure 2. General view of a device for transporting and cleaning cotton from small litter at a cotton gin. 1-cotton separator (SS-15A); 2-patches; 3-conveyor for transporting and cleaning cotton from small litter; 4- mesh surface; 5 pin auger.

At a cotton gin, the process of transporting and cleaning high-quality low-moisture cotton from small weeds is carried out in the device shown in Figure 2. Cotton transported by pneumatic transport is separated from the air in the separator-1 and with a tray-2 is sent to the conveyor-3 for transporting and cleaning cotton from small litter. The peg auger cleans cotton from small weeds with the help of shock and ripper action. The cotton moves along the length of the surface of the grid-4 with a peg screw, and by rotating the peg screw-5, the cotton leaves the device.

In the technological process of processing low-grade high-moisture cotton, the process of transportation and cleaning from small weeds is carried out in the device shown in figure 3.

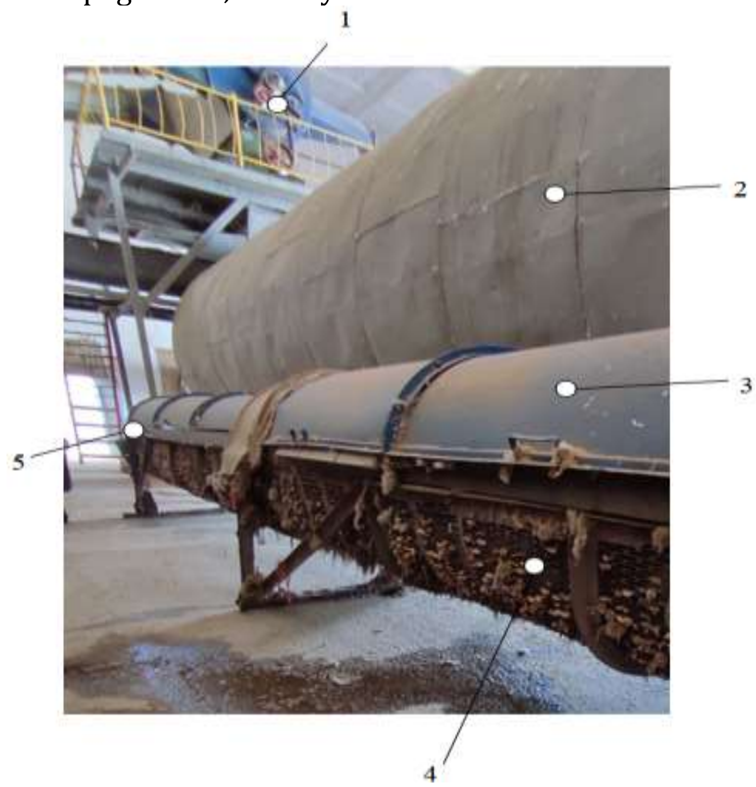


Figure 3. General view of a device for transporting and cleaning cotton from small litter and dust after a drying drum at a cotton gin.
1-cotton separator; 2-dryer drum (2SB-10); 3-devices for transporting and cleaning cotton from small litter and dust; 4- mesh surface; 5-outgoing part of peeled cotton.

In the device, low-grade high-moisture cotton transported by pneumatic transport is separated from the air in the cotton separator-1 and the dryer drum-2 is supplied. In the dryer drum, cotton is dried to a moisture content of 8-9% and fed to devices for transporting and cleaning cotton from fine litter and dust-3. The peg auger loosens the cotton, cleans it along the length of the mesh surface 4 and removes the cleaned cotton from the device through the outlet 5.

It is known that as a result of the impact on raw cotton of working bodies (drums with pegs, knives, saws, etc.), its size increases and separate lumps of cotton appear, its density changes. Let us consider the movement of raw cotton entering the peg screw conveyor with a constant flow rate Q.

First, we simulate the movement of individual cotton balls and the process of separation from the composition of the cotton ball under the influence of the pins of the screw conveyor. The model of this process is presented in the works of Sevostyanov A.G. [8-11]

Let us denote by k the number of pins in each section of the screw conveyor. We investigate the process of separating weed impurities from raw cotton in one complete revolution of the screw conveyor.

If we denote ω by and h_0 the speed of rotation and the step of the conveyor, then the time spent by the cotton raw material in the sections of the conveyor will be equal to $T = h / v_k$, where $v_k = \omega\sqrt{r^2 + h^2}$ the absolute speed of the flow of the cotton raw material, is the r -radius of the screw conveyor, $h = h_0 / 2\pi$.

We assume that in the stationary state of the process in all sections of the screw conveyor per unit of time the same amount of raw cotton arrives. As a result of the separation of impurities in the first section of the screw conveyor in the time interval from t=0 to t=T, the relative change in the mass of raw cotton in the section according to [8] is calculated by the formula:

$$\frac{dm}{m} = \frac{d\rho}{\rho(1+a)}$$

(1)

Here: a - coefficient of proportionality, determined on the basis of experiments.

According to studies [9], the efficiency of cotton cleaning is proportional to the path of movement of raw cotton along the helical conveyor line,

$$\varepsilon = \frac{d\rho}{\rho} = -bkv_k dt$$

where is the b - coefficient of proportionality, the number of pegs in each section.

Taking into account equality (1), we obtain:

$$(1+a)\frac{dm}{m} = -bv_k kdt$$

Let us consider the case when the values *a, b* are the same for all sections of the screw conveyor and do not depend on time.

Solution of equation (1) with the condition m=m0 at t=0

$$m = m_0 \exp(-\lambda_0 v_k t)$$

(2)

here, $\lambda_0 = \frac{bk}{1+a}$

The efficiency of cleaning cotton - raw on the first section of the screw conveyor:

$$\varepsilon_1 = \frac{m_0 - m}{m_0} = [1 - \exp(-\lambda_0 v_k t)]$$

(4)

The movement of raw cotton in the first section of the screw conveyor ends at the moment $t = t_1 = h_0 / v_k$, and according to equation (2) at this moment, the relative mass of raw cotton m_1 / m_0 and the cleaning efficiency after separation of weeds are:

$$\frac{m_1}{m_0} = \exp(-\lambda_0 h_0)$$

(6)

$$\varepsilon_{01} = \frac{m_0 - m_1}{m_0} = \left[1 - \exp(-\lambda_0 h_0)\right]$$

(7)

The amount of weed impurities released, taking into account (6) and (7), is equal to:

$$\Delta m_1 = m_0 - m_1 = m_0 \varepsilon_{01}$$

The movement of raw cotton in the second section of the screw conveyor and the change in the mass of raw cotton in time $t \geq t_1$ will be obtained by integrating equation (1) by the condition $m(t_1) = m_1$.

Then the purification efficiency and the change in mass over time are determined by the following formulas:

$$\varepsilon_2 = \exp(-\lambda_0 h_0)\{1 - \exp(-\lambda_0 v_k (t - t_1)]\}$$

(8)

$$m = m_1 - m_0 \varepsilon_2 (t)$$

(9)

The mass of impurities separated from the second section of the screw conveyor at the time $t = 2t_1$ according to (8) and (9) will be equal to:

$$\Delta m_2 = m_1 - m(2t_1) = m_1 - m_1 + m_0 \exp(-\lambda_0 h_0)[1-$$
$$= m_0 \exp(-\lambda_0 h_0)[1 - \exp(-\lambda_0 h_0)] = m_0 \exp(-\lambda_0 h_0$$

The mass of raw cotton at $t \geq 2t_1$ entering the third section of the screw is calculated by the formula:

$$m = m_2 - m_0 \varepsilon_3 (t)$$

(10)

Here, the cleaning efficiency will be equal to:

$$\varepsilon_3 = \exp(-2\lambda_0 h_v)\{1-\exp[-\lambda_0 v_k(t-2t_1)\}$$ (11)

The amount of weed impurities separated from the third section of the conveyor at the moment of time $t = 3t_1$ according to expressions (10) and (11) will be equal to:

$$\Delta m_2 = m_2 - m(3t_1) = m_2 - m_2 + m_0\exp(-2\lambda_0 h_0)[1-\exp(-\lambda_0 h_0)] = m_0\exp(-2\lambda_0 h_0)\varepsilon_{01}$$

Continuing this process, we establish patterns of change in the mass of raw cotton and the cleaning efficiency of the n-th section of the screw conveyor:

$$m = m_{n-1} - m_0\varepsilon_n(t) = m_0\exp[-\lambda_0 h_0(n-1)] - m_0\varepsilon_n(t)$$

$$(n-1)t_1 < t < nt_1$$

$$\varepsilon_n = \exp[-(n-1)\lambda_0 h_0][1-\exp\{-\lambda_0 v_k[t-(n-1)t_1]\}]$$

,

In this case, the amount of impurities separated at time $t = nt_1$, is equal to:

$$\Delta m_n = m_0\exp[(n-1)\lambda_0 h_0]\varepsilon_{01}$$

The total mass of weed impurities separated from the screw conveyor during the movement of raw cotton in stationary mode on the screw conveyor is equal to:

$$M = \sum_{i=1}^{n}\Delta m_i = m_0\sum_{i=1}^{h} e^{-(i-1)\lambda_0 h_0}(1-e^{-\lambda_0 h_0}) = m_0(1-e^{-\lambda_0 h_0})\left[1+e^{-\lambda_0 h_0}+e^{-2\lambda_0 h_0}+\ldots+e^{-(n-1)\lambda_0 h_0}\right] =$$

$$= m_0(1-e^{-\lambda_0 h_0})\left[\frac{1-e^{-n\lambda_0 h_0}}{1-e^{-\lambda_0 h_0}}\right] = m_0(1-e^{-n\lambda_0 h_0})$$

(12)

If we denote by β (in percent) the mass of impurities of raw cotton entering the screw conveyor, then the amount of impurities on the conveyor will be equal to $\beta \cdot m_0 \cdot 10^{-2}$.

Then, taking into account in formula (12) $M = \beta \cdot m_0 \cdot 10^{-2}$, we obtain:

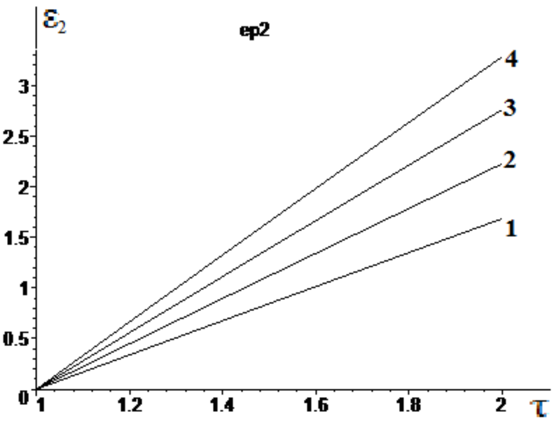
$$m_0(1-e^{-n\lambda_0 h_0}) = 0.01\beta m_0)$$

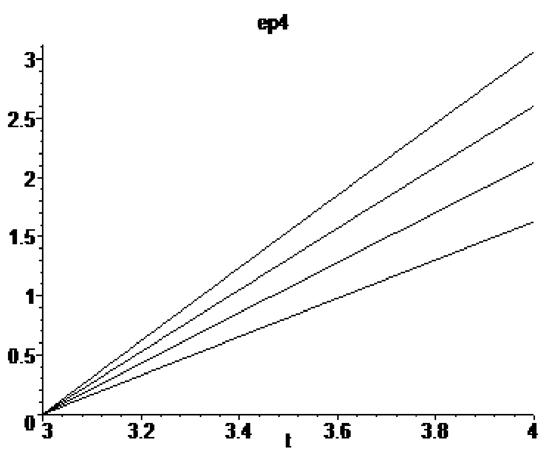
From this equation, it is possible to determine the number of sections of the screw conveyor to isolate the total mass of weed impurities $0.01\beta m_0$ in the composition of the initial mass of raw cotton.

$$n = E\left[\frac{1}{\lambda_0 h_0}\ln\frac{1}{1-0.01\beta}\right]$$ (13)

Here - Здесь $E(Z)$ - Z defines the integer part of the value.

On fig. Figure 4 shows the dependence of the cleaning efficiency when choosing the number of sections 6, 8, 10, and 12 of the screw conveyor on the dimensionless time $\tau = v_k t / h_0$ at $\lambda = 0.012$. Based on the analysis of the curves, the following conclusion can be drawn: with the selected technological indicators, the dependence of the cleaning efficiency on time is linear and practically the same in all sections of the screw conveyor, which indicates a uniform distribution of the emitted trash along the length of the screw conveyor.





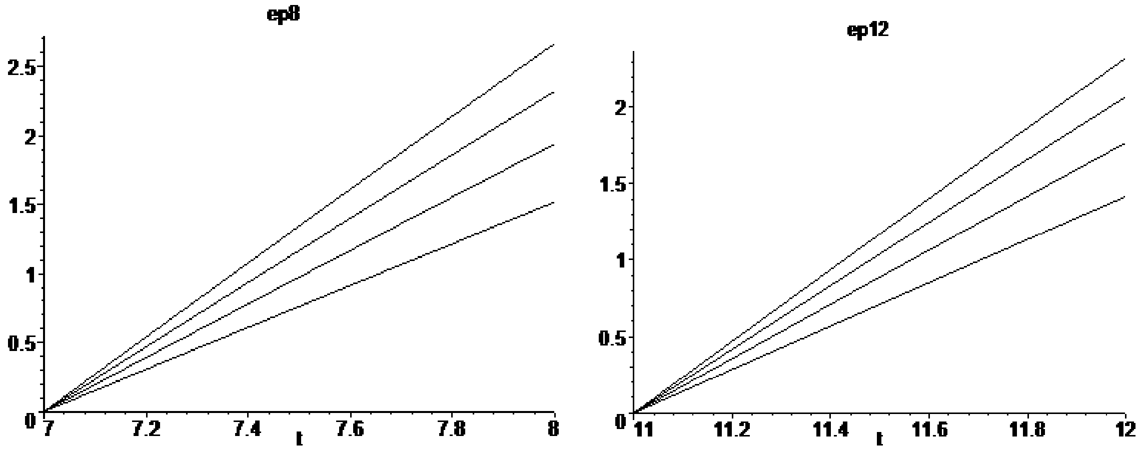


Figure 4. Graphs of the dependence of the efficiency of cleaning sections of screw conveyors on the dimensionless time $\tau = v_k t / h_0$ for different numbers of pins $1-k=6$, $2-k=8$, $3-k=10$, $4-k=12$.

According to the well-known formula (13), it is possible to determine the number of sections of the screw conveyor and the number of pins in each section, which ensure the implementation of the cleaning of raw cotton from impurities with a fractional weight β (percentage) in the original raw cotton entering the conveyor. Tables 1 and 2 show the results of calculating the number of conveyor sections and the number of pins required for cleaning from impurities with a fractional mass β in the original raw material at two values of the dimensionless experimental coefficient λ. An analysis of the data presented in the tables indicates the possibility of choosing the number of pins for a given number of conveyor sections, or vice versa, with a known number of pins, to choose the number of sections for the implementation of raw cotton cleaning with a known initial impurities in raw cotton. The growth of the experimental dimensionless coefficient β, associated with the rational choice of the shape of the mesh surface, or the value of the speed of rotation of the conveyor, makes it possible to clean raw cotton using a small number of conveyor sections or the number of pins. So, for example, if you lie and $\beta = 15\%$, i.e. consider, that the original raw material contains weed impurities by mass, $0.15m_0$, then to clean cotton in a conveyor with four sections $\lambda = 0.01$, when you should choose the number of pins equal to four, if a conveyor with two sections is used, then the number of pins should be chosen equal to 8 or 10 то. When $\lambda = 0.02$ cleaning, choose two sections with four pegs, or one section with eight pegs.

Table1. The number of sections and the number of pins that ensure the implementation of the cleaning of raw cotton from the initial fractional mass of impurities β for the value of the dimensionless experimental coefficient $\lambda = 0.01$

k/β	2	4	6	8	10	12	14
10%	5	3	2	1	1	1	1
15%	8	4	3	2	2	1	1
20%	11	6	4	3	2	2	2

25%	14	7	4	4	3	2	2
30%	18	9	6	5	4	3	2

Table 2. The number of sections and the number of pins that ensure the implementation of the cleaning of raw cotton from the initial fractional mass of impurities β for the value of the dimensionless experimental coefficient $\lambda = 0.02$

k / β	2	4	6	8	10	12	14
10%	3	1	1	1	1	1	1
15%	4	2	1	1	1	1	1
20%	6	3	2	1	1	1	1
25%	7	4	2	2	2	1	1
30%	9	4	3	2	2	2	1

Conclusions. Based on the analysis of the work of small litter cleaners, a device was developed for cleaning raw cotton from small weed impurities during transportation.

1) A theoretical description of the process of cleaning raw cotton from weed impurities is proposed, according to the model proposed in the work of A.G. Sevostyanov. An assessment of the influence of the number of sections and pins on the cleaning effect of the conveyor is given.

2) The dependence of the cleaning efficiency on time in all sections of the conveyor is linear, and the mass of weed impurities released is evenly distributed along the length of the screw conveyor.

3) The possibility of choosing the number of pins for a given number of sections of the conveyor or, conversely, with a known number of pins, to choose the number of sections for the implementation of the cleaning of raw cotton with a known initial amount of impurities in cotton has been established.

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