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Research Of The Influence Of The Passive Area On The Productivity Of The Screw Conveyor With A Cleaning Section Of Cotton Seeds

[1]Kh.Zh. Abdugaffarov, [2]G.B. Zaydullaeva, [3]G.O. Otakhonov, [4]Zh.D. Ulugmurodov

[1]Tashkent Institute of Textile and Light Industry, assistant professor,
[2,3]Tashkent Institute of Textile and Light Industry, master,
[4]Tashkent Institute of Textile and Light Industry, student.
Tashkent, Uzbekistan.
E-mail: zaydullayevagulbahor@mail.ru

Abstract*: The article discusses the movement of raw cotton in a screw auger, special attention is paid to the passive area on the auger, interaction with the raw cotton with a feather, which shows the efficiency of a single-support auger in comparison with a long auger where there are supports on the way.*

Keywords*: primary processing of cotton, screw auger, horizontal conveyor, Projection area, screw, Performance factor.*

INTRODUCTION

The transportation of cold-water in factories is of great importance. For this we have developed a screw conveyor for transporting seeds of a new design. The screw conveyor contains a chute 1, the lower part of which has the shape of a half-cylinder with holes 3, closed from above by a cover 2. The blades of the screw conveyor are installed with a differentiated increase in the pitch and diameter of the conveyor screw in the direction of movement of the transported material. The cover has an inlet 4 in the left part, and the groove 1 has an outlet 5 in the right part, a screw shaft 6 is installed inside the groove 1.

To remove the removed trash impurities, an inclined chute 7 is installed from the bottom of the chute. The screw conveyor operates as follows. Bulk cargo cotton seeds are fed into the chute 1 through the inlet 4 in the cover 2 and, when the screw 6 rotates, slides along the chute 1, pushed by the working surface of the rotating screw 6 to the outlet 5. The separated trash is removed using an inclined tray 7. During this movement cotton seeds constantly, weed impurities are more efficiently released, which are removed from the chute 1, due to the presence of holes 3 in it, in addition, the possibility of oscillation of the chute 1 around its axis also increases the efficiency of trash removal. The installation of the conveyor screw blades with a differentiated pitch increase makes it possible to increase the likelihood of removing weed particles from the seeds due to an increase in the area of the screening surface between the two blades. In addition, a differentiated increase in the diameter of the conveyor screw allows you to gradually increase the peripheral speed of the blades, which contributes to a more intensive loosening of the mass of transported seeds.

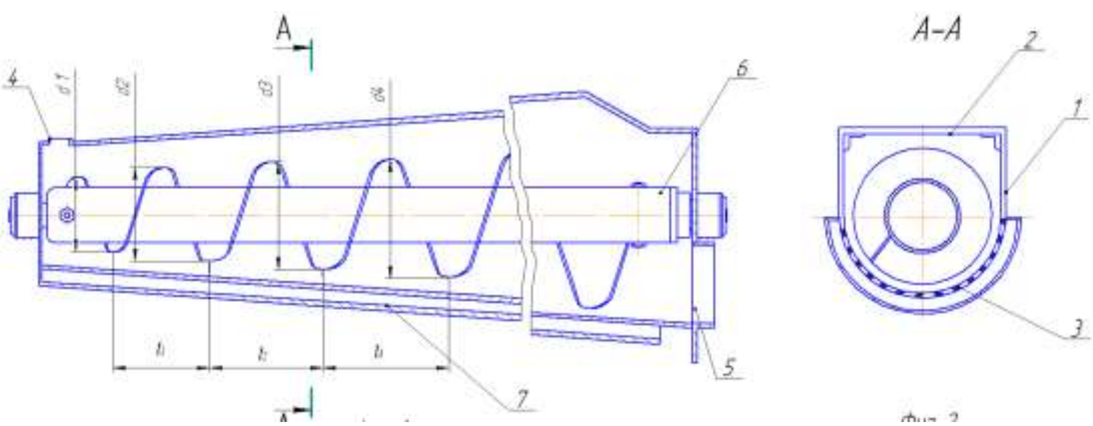

Fig. 1 New design screw conveyor

To develop a screw conveyor, and especially the design of the feathers of a new screw conveyor, we approached the main theoretical relationships for conveying screw conveyors, obtained in the study of the movement of an isolated material point and a continuous flow of bulk and small-sized materials, allow us to determine the performance of conveyors in more rigorous ways than is customary in the present time.

It is known that in technical literature and manuals, the performance of the screw during design is recommended by the formula.

$$Q = \frac{\pi}{4}(D^2 - d^2)Sn\varphi \qquad (1)$$

where Q - productivity in units of volume; S is the pitch of the helical surface; D and d - screw and shaft diameters; n is the number of revolutions of the screw per unit of time; φ is a coefficient whose value is less than one.

MATERIAL AND METHOD

This coefficient shows how much of the transported material from the volume of one turn of the screw conveyor moves one step with each turn of the conveyor. It is this factor that is called the "filling factor". The meaning gives the impression that it shows how much of the volume of the screw conveyor is filled with material. But actually it is not. The screw conveyor can transport material while full and throughout the volume. However, its coefficient φ will not be equal to the same, but will be significantly less than it. It is more correct to call this coefficient the coefficient of productivity, or it does not show the degree of filling the volume of the conveyor with material, but the value of that part of the volume of material that moves to the end of the conveyor with each revolution of the conveyor and which determines the true productivity of the device, in contrast to the theoretical productivity, equal to

$$Q_t = \frac{\pi}{4}(D^2 - d^2)Sn \qquad (2)$$

When determining the weight of the material in the conveyor, use the formula

$$G = \frac{\pi}{4}(D^2 - d^2)L\gamma_0\varphi_{\text{н}} \qquad (3)$$

where G is the material in the conveyor; L is the length of the conveyor; γ_0 - weight per unit volume of transported material; φ_n - coefficient showing the filling of the conveyor volume with material.

It is this factor φ_n that should rightfully be called the filling factor, since it really shows which part of the conveyor volume is filled with material.

Consequently, the work of the screw conveyor must be characterized by two design factors; φ - performance factor and φ_n - filling factor, which are not equal and are in the following relationship:

$$\varphi_{\text{н}} \geq \varphi$$

If the filling factor is kept close to unity, i.e. to fully use the volume of the conveyor, then the coefficient of performance, for example, for a horizontal conveyor, will be 0.65 - 0.75. One of them increases the specific energy consumption of the conveyor, increases the abrasion and crumbling of materials. This will fully utilize the conveying capacity of the screw conveyor. If the filling factor is reduced, then the productivity factor will also fall.

When the filling factor becomes 0.25 - 0.35 (which is usually accepted), the factors will be equal, but the conveyor volume will be used only by 25 - 35%, and the possible productivity by 50%.

Unclear terminology leads to confusion of the concepts of coefficients and to a deliberate limitation of the conveyor capacity of the conveyor.

The filling factor φ_n depends on the design of the feeder or loading device feeding material into the conveyor.

The productivity factor φ depends on the properties of the transported material: the shape of particles, the coefficient of friction of the material against the surface of the conveyor and the casing, on the angle of repose and on the parameters of the conveyor, i.e. is a complex function.

$$\varphi = \Phi\,(D, S, \delta, f_1 f_2, \omega) \qquad (4)$$

The performance factor is influenced by the size of the area and the shape of the boundaries of the passive area. The greater the proportion of the working surface of the conveyor captured by it, the larger the flow section and the more intensive the transfer of material.

The principle of operation of the transporting conveyor is that the helical surface creates a condition under which the material, under the influence of gravity, is forced to continuously slide along the surface inclined to the horizon. By saying this, we mean the movement of material in a force field of gravity, for which the horizontal surface of the force field. In this case, whether the material will move, rolling off an inclined surface, is decided by the value of the angle of inclination of the platform to the equipotential surface of the force field.

When the screw rotates, centrifugal force will also act on the material. Then, to determine the boundaries of the passive region, it will be necessary to consider the angle of inclination to the equipotential surface of the complex field of forces,

The shape and size of the passive area when the conveyor operates in a given force field shows the nature of the influence of various parameters on productivity, including the effect of the conveyor rotation speed.

The dependence of the productivity factor on the size of the passive area can be expressed by the following equation:

$$\varphi = r\,(1 - \frac{f}{F}) \qquad (5)$$

where f is the area occupied by the passive area on the surface of one turn of the conveyor; F - full working surface of one turn of the conveyor; r - correction factor.

When calculating the area ratio $(\frac{f}{F})$, it is possible to take not the true values of the areas, but their projections onto the *xoy* plane of the orthogonal section of the conveyor.

The projection area f can be determined on the basis of the previously found equations of the boundaries of the region relatively simply, and the projection of the working surface of the entire loop can be taken equal to $F = \frac{\pi D^2}{4}$ D - the outer diameter of the conveyor.

In this case, dependence (5) can be rewritten as follows:

$$\varphi = k\left(1 - \frac{4f}{\pi D^2}\right) \qquad (6)$$

Formula (6) does not take into account the effect of the shaft due to the smallness of its cross-section in comparison with the area f. If its comparative value is significant, then it is necessary to add to the passive region λ a part of the shaft surface for which the slope angle is equal to the friction angle λ0 or less, so this shaft surface also participates in the transfer of the transported material into the lagging cavity, in creating a circular movement of the material.

The size of this surface will be expressed

$$F_e = \pi d_e S \frac{\lambda_0}{360^0} \qquad (7)$$

where d_e -is the shaft diameter.
In fig. 1 shows a graph of dependence $\varphi = f(\omega_0)$ for a horizontal screw. The solid curve $f(\omega_0)$ is drawn along the points obtained by experiment.

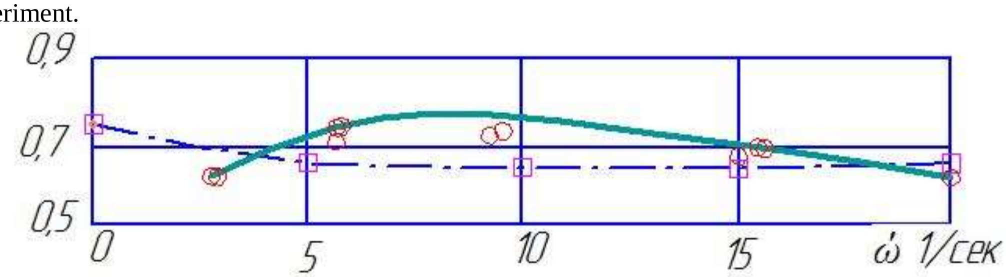

Fig. 1. Graph of the change in the coefficient of performance of the horizontal conveyor when changing ω = 0 ÷ 20 1 / sec.

RESULTS

The curve has a negative curvature and fits into a narrow band of values φ = 0.62 ÷ 0.75 when the angular velocity changes from ω_0 = 2.5 to ω_0 = 2.5 (1 / sec). When the speed is changed by 8 times, the productivity ratio changes only by 19%. This happens because the angular velocity of rotation has little effect on the size of the passive region, affecting more on the change in its shape.

The curve drawn along the points enclosed in rectangles is calculated by the formula

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$$\cos\lambda_0 = \frac{2}{\sqrt{1+\left(\frac{\omega^2}{g}\right)^2\rho^2 - 2\frac{\omega_0^2}{g}\cos\xi\cos\alpha}}\left(\frac{\sin\xi}{\sqrt{1+\left(\frac{S}{2\pi\rho}\right)^2}} + \frac{\cos\xi\sin\alpha}{\sqrt{1+\left(\frac{2\pi\rho}{S}\right)^2}}\right) \quad (8)$$

The area f was determined with a planimeter.

The curve has a weak positive curvature, within the limits ω0 = 5 ÷ 20 1 / sec, it is almost horizontal and completely fits into the strip of curves; the first has a negative, the second has a positive curvature. Both curves show a comparatively small dependence of the productivity factor on the number of revolutions when changing the last 25 - 200 per minute.

Formula (6) expresses well the dependence of the productivity factor on the passive area.

For a horizontal conveyor, the area of the passive region can be determined in a simplified form by the equation.

$$f = \left(\frac{S}{4\pi\cos\lambda}\right)^2 (\sin 2\lambda_0 - 2\lambda_0 \cos 2\lambda_0) \quad (9)$$

The calculation formula for a horizontal conveyor is especially simple.

According to equation (4), the area of the passive region at cos λ_0 = 0.3 will be f = 0.186S^2.

The accepted value of cos λ_0 corresponds to the material with which the experiments were carried out. This refers to cotton seeds with a moisture content of 5 - 8%. Comparison of the values of the coefficients calculated by the formula (6) with the obtained experience shows that at cos λ_0 = 0.3, the best agreement of the results is provided at the value of the correction factor r = 0.87.

Thus, for cotton seeds, one can take, for example, r = 0.87 and cos λ_0 = 0.3. The value of the coefficient of performance under these conditions cannot be more than 0.87.

Substituting expression (5) in formula (6) and taking into account that r = 0.87, we go for a horizontal conveyor.

$$\varphi = 0{,}87\left[1 - 0{,}237\left(\frac{S}{D}\right)^2\right] \quad (10)$$

or, with a rounding factor,

$$\varphi = 0{,}9\left[1 - 0{,}24\left(\frac{S}{D}\right)^2\right] \quad (11)$$

Calculation by formula (11) gives the following values for a horizontal conveyor (Table 8).

Table 8.

Параметры	$\frac{S}{D}$				
	0,75	0,80	1,00	1,075	1,20
$\varphi_{выч}$	0,75	0,73	0,65	0,62	0,55

Formulas (10) and (11) are valid when the passive area is entirely placed on the surface of the screw, i.e. given that

$$\frac{D}{2} \geq \rho_{max} \quad (12)$$

Calculation of p_{max} by the formula

$$\rho_{max} = \frac{\frac{S}{2\pi}}{\left(\frac{\cos\lambda_0}{\cos\zeta}\right) + tg^2\zeta}\left(\pm\frac{\cos\lambda_0}{\cos\zeta}\sqrt{1-\left(\left(\frac{\cos\lambda_0}{\cos\zeta}\right)^2 - tg^2\zeta\right)\pm tg^2\zeta}\right) \quad (13)$$

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for a horizontal conveyor at cosλ0 = 0.3, ξ = 0 gives pmax = 0.506 S.

Therefore, formulas (10) and (11) are valid in the limit

$$\frac{D}{2} \geq 0{,}506S;\ \frac{S}{D} \leq 1. \qquad (14)$$

When the passive area does not fit entirely on the screw surface, its boundary remains open; the area of the passive area for substituting its formula (8) by constructing the boundary in the form of a circle with a radius

$$r = \frac{1}{2}\, p_{\text{мах}} \qquad (15)$$

For an inclined screw, the projection of the area of the passive area can be calculated with acceptable accuracy by formula (12), where pmax is determined by equality (8).

The calculation results for the screw S = 100 mm, D = 94 mm at ξ = 0.400 and the experimental data are given in Table 1.

Table 1.

ξ	$p_{\text{мах}}$	$f^{\,см}$	$\varphi_{выч}$	$\varphi_{эксп}$	ξ	$p_{\text{мах}}$	$f^{\,см}$	$\varphi_{выч}$	$\varphi_{эксп}$
0	0,506	18,5	0,637	0,61	20^0	3,63	38,0	0,418	0,42
10^0	1,21	28,4	0,515	0,53	25^0	1,19	41,0	0,356	0,34
15^0	3,82	32,0	0,470	-	30^0	0,72	45,5	0,300	0,26
$17^0 31$`	-	35,0	0,434	0,45	40^0	0,387	57,5	0,150	-

The numbers in column f were obtained by measuring the area with a planimeter on the drawing of the boundaries of the passive area, since, starting from the line ξ = 100, the passive area is not placed on the conveyor and therefore has an open boundary and cannot be calculated by formula (6). In other words, condition (14) is not satisfied from the row ξ = 100.

Starting from the angle ξ ≥ 17030`, the curve closes the active area inside itself. The productivity coefficient is calculated by the formula (5) at r = 0.87. To evaluate the accuracy of calculating the productivity factor by the proposed method, which consists in determining the area of the passive area f and drawing it in the form of a circle with a radius according to formula (10) on the surface of the conveyor of a given diameter, we show Fig. 2. Here is a graph of the dependence φ = F (ξ), where the experimental data are plotted with thin lines, at various angular speeds of the screw.

The dotted line with a dot shows the curve calculated by formula (10). The graph shows that the proposed method captures the nature of the dependence and the relationship of this coefficient with the passive region.

The calculated curve runs in the middle of the strip occupied by the experimental points and gives accurate values for the productivity factor at ω_0 = 2.5 1 / sec and ω_0 = 20 1 / sec. For ω_0 = 2.5 ÷ 28 (1 / s), the calculated value is obtained with an error (0.05 ÷ 0.08). The true value of φ is in the range $\varphi = \varphi_{выч} \pm (0{,}05 \div 0{,}08)$ when the rotation speed changes from ω_0 = 2.6 to 28 1 / sec and the angle of inclination is from ξ = 00 ÷ 400.

The graph (Fig. 2) combines the experimental points obtained at various crumb moisture contents from 51 to 53.4%. As can be seen from the graph, the character of the bending curve is the same for all cases.

Noteworthy is the high value of the productivity factor (0.6 - 0.7) for a horizontal conveyor, while in the calculations it is usually taken half the value, of the order of 0.25 - 0.33, which is indicated by reference books. Meanwhile, the experiment with dry sand, carried out for control, again confirms the value ω0 = 0.7 ÷ 0.6 for horizontal conveyors. In fig. 3 shows a graph of the dependence $\varphi = f\,(\omega_0, \xi)$ during the transportation of dry sand, for which the experimental points were obtained on two conveyors. It can be seen from the graph that for a horizontal conveyor, the productivity coefficient is within the limits φ = 0.6 ÷ 0.65 with a pitch to diameter ratio equal to 1.075, and φ = 0.76 - for a ratio $\frac{S}{D} = 0{,}75$, with numbers conveyor revolutions from 50 to 150 per minute. And even with an angle of inclination of 220 30`, the coefficient of performance is still high, of the order of 0.34 - 0.40.

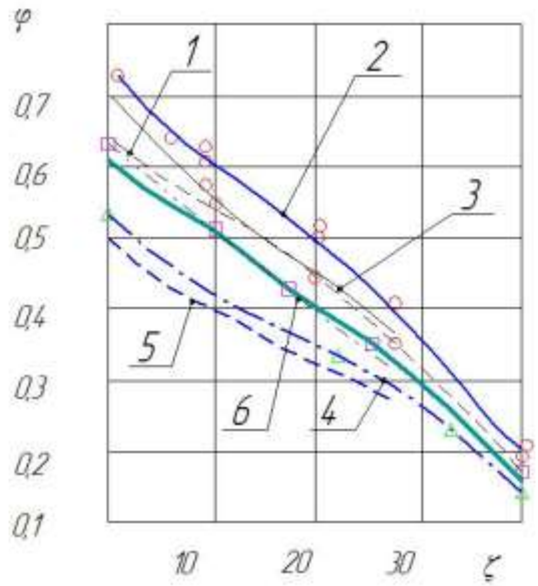

Fig. 2. Graphs of the change in the productivity factor of the inclined conveyor at ω = 5.6 ÷ 28 1 / s and material moisture *W* = 51÷53,4% 1) ω=10, *W=53,4%; 2) ω=5÷10%*, *W=51÷52%*; 3) ω=15; 4) ω=28; 5) ω=28, *W=53,4%; 6)* ω=15, *W=53,4%*

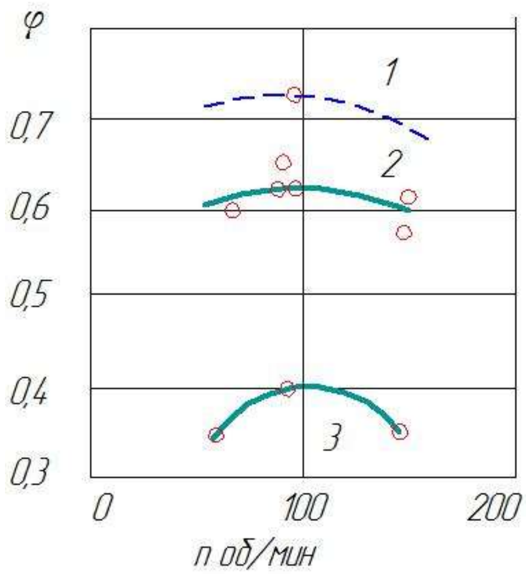

Fig. 3. The graph of the change in the coefficient of performance for dry sand at n *=0 ÷ 200 об/мин:*
1 – шнек D = 100 мм, S = 75 мм, ξ = 0⁰: 2-шнек D = 92 мм, S = 99 мм, S = 99 мм, ξ = 22⁰30`

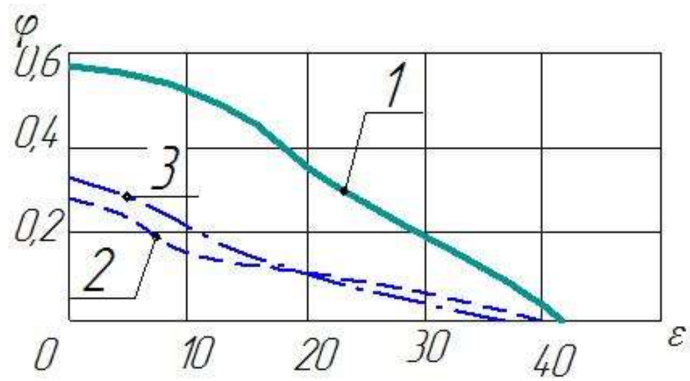

Fig. 4. Influence of intermediate supports on the productivity factor of conveyors:1 - without intermediate bearing, n = 60 rpm. screw length L = 2 m; 2 - with an intermediate bearing, a = 90 rpm, L = 4 m.

CONCLUSION

The discrepancy in the value of the coefficient obtained in this work, with that indicated in the reference literature, can be explained by the following reason.

Reference literature, giving the values of the coefficient φ = 0.25 ÷ 0.33 means screws with intermediate shaft bearings in the middle of the screw length. The presence of such a bearing causes a break in the continuity of the screw surface and creates a significant resistance to the movement of the material by the body of the bearing itself. At the same time, the productivity of the auger is almost halved. This position is well confirmed by experiments.

Conveyor parameters: : D = 200 мм, S = 150 мм, $\xi = 0 \div 40^0$, angle $\lambda_0 = 36^0$. It can be seen from the graph (Fig. 4) that with the removal of the intermediate bearing, the productivity factor increased from 0.3 to 0.57, those. almost doubled.

From this follows a practical conclusion: the cost of metal for screw bearings, which makes our design effective. And this proves that the design of our auger with one support is effective.

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