Abstract: The design of disk digger with the possibility of cleaning work surfaces drives. The analysis and the choice of Γ-like screws. An appropriate power and kinematic calculations suggested screw disc cleaners root crop.

Key words: digging disk, auger cleaner, Γ-shaped, cleaner.

INTRODUCTION

Γ-shaped spiral augers have great future application in transport and technological systems. In particular such helix widely used to supply dry, wet, sticky, lumpy, fibrous products in agriculture, food, building, chemical and other industries and so on. But they possess additional characteristics that, depending on the inclination of the spiral can manifest themselves as functions increasing resistance to movement of the transported material to the surface of displacement, or vice versa - reducing friction material is transported to the surface displacement. In the first case, this phenomenon can be widely used in the performance of processes wiping or shredding of different materials, and the second - in the performance of processes cutting of various materials from the surface moving.

The problem of efficiency of screw conveyors are devoted to work Grigoriev A.V. Hevko B.M. [1] Rohatyn R.M. and others. But they possess additional characteristics that, depending on the inclination of the spiral can manifest themselves as functions increasing resistance to movement of the transported material to the surface of displacement, or vice versa - reducing friction material is transported to the surface displacement. In the first case, this phenomenon can be widely used in the performance of processes wiping or shredding of different materials, and the second - in the performance of processes cutting of various materials from the surface moving.

The problem of efficiency of screw conveyors are devoted to work Grigoriev A.V. Hevko B.M. [1] Rohatyn R.M. and others in which there were investigated creation and operation of screw mechanisms. The issues involved in separation processes and cutting of various materials from the working surface of the disk digger. Accordingly, under these conditions the strength necessary to overcome the resistance movement of material important impact angle of inclination μ helical spiral in its cross section (Fig. 1). Therefore the most appropriate use of spiral inclined towards the outer contour of transportation, because the normal force vector between the coil and casing \( N_1 \), acting on the load side of the coil, directed in the direction of the tangent to the casing at an...
angle γ1.

Fig. 1 - Estimated circuit for determining the effect of slope angle helical tape in cross-section of the process jamming material: a) spiral slope in the direction of transportation; b) radial spiral; c) the slope of the spiral in the opposite direction to the direction of transport.

Investigating the force parameters of forming the screw purifying elements:

The process of manufacturing the screw purifying elements is as follows:

1. Bending the shelf on a tape using the rollers.
2. Coiling the given tape with a shelf around a collet.

The process of coiling such a tape around the collet is shown in Fig. 2.

While coiling, the compression of tape fibers along the inner diameter occurs, as well as the tension of tape fibers along the outer diameter of the screw-purifying element. That is, in the shelf's zone, only the strain deformations occur, as well as in the workpiece's vertical part - the compressive deformations. Having considered the process of deformation in the hot state, the moment of tape bending in these zones can be defined.

As it is known, the radial stresses, occurring in the tape shelf, are determined by the formula [1]:

\[ \sigma_{v1} = -\beta \sigma_s \cdot \ln \frac{R}{\rho} \]

where \( \beta \) - the coefficient, which depends on the impact of the mean primary stress, equals 1.15;

\( \sigma_s \) - the liquid limit of screw clamping element material, MPa;

\( R \) - the outer bending radius, mm;

\( \rho \) - the polar coordinate of bending radius, mm.
Similarly, the radial stresses in the compression zone can be determined [2]:

$$\sigma_{r2} = -\beta \sigma_s \cdot \ln \frac{\rho}{\rho_r}.$$  

where $r$ – the inner bending radius, mm.

Tangential stresses in the tension zone:

$$\sigma_{\theta 1} = \beta \sigma_s \left( 1 - \ln \frac{R}{\rho} \right).$$  

Tangential stresses in the compression zone:

$$\sigma_{\theta 2} = -\beta \sigma_s \cdot \left( 1 + \ln \frac{\rho}{\rho_r} \right).$$

According to the computational model in Fig. 1, the radius of bending the workpiece's shelf changes from $r_1$ to $r(x)$, where

$$r(x) = r_1 + x \cdot \tan \alpha,$$

where $r_1$ – the smallest inner radius of bending the shelf, mm;

$\alpha$ - the inclination angle of the shelf, grade.

The outer radius of bending the workpiece:

$$R(x) = r_1 + \frac{s}{\cos \alpha} + x \cdot \tan \alpha,$$

where $s$ – the tape thickness, mm.

The value of bending moment while coiling with heating is considered as the integral sum from tangential stresses along the height of elementary elements' workpiece.

$$M = \int_{r_1}^{R(x)} \int_{r_1}^{R(x)} \rho d \rho d x + s \int_{r_1}^{R(x)} \sigma_{\theta 1} \rho d \rho,$$

where $p_1$ – the radius of neutral surface of stresses, mm;

$h$ – the height of the workpiece's vertical part, mm;

$H$ – the height of the screw element's shelf, mm;

Using formulas (3) – (6) in the equation (7) we obtain:

$$M = \int_{r_1}^{R(x)} \int_{r_1}^{R(x)} \beta \sigma_s \left( 1 - \ln \frac{\rho}{\rho_r} \right) \rho d \rho d x + s \int_{r_1}^{R(x)} \beta \sigma_s \left( 1 + \ln \frac{\rho}{R_0} \right) \rho d \rho,$$

where $R_0$ – the collet radius, mm;

Having transformed the equation (8), we obtain:

$$M = \frac{1}{2} \beta \sigma_s \left[ bH \left( \frac{K - D - b(1 + 2r_1)}{2} + b + H\tan \alpha \right) + \frac{H}{3} (H - \tan \alpha) \left( -r_1 D + b + 3r_1 K - D\tan \alpha H \right) \right]$$

$$+ 3r_1^2 \left( K - D - b(1 + r_1) \right) + r_1^3 \left( K - D - C + \ln r_1 \right) + \frac{1}{2} \left( K - C + r_1^2 \right) \tan \alpha \right] + s \left( \frac{1}{2} \left( R_0 + h \right)^2 - R_0^2 \right)$$

where the following marks are used:

$$b = \frac{s}{\cos \alpha};$$

$$K = \ln \left( \frac{r_1 + b + H\tan \alpha}{r_1} \right).$$
According to the computational model in Fig. 1, the equilibrium equation of a tape part under deformation can be written as follows:

\[
\begin{align*}
\text{sum of moments:} & \quad P \cdot l + F_{T1} \cdot R_s + F_{T2} \cdot R_0 - N \cdot R_t = M, \\
\text{sum of forces:} & \quad -P + F_{T1} \cdot \sin \gamma - N \cdot \sin \gamma + F \cdot \cos \gamma = 0; \\
\text{sum of friction forces:} & \quad F_{T1} - F_{T2} \cdot \cos \gamma + N \cdot \cos \gamma + F \cdot \sin \gamma = 0;
\end{align*}
\]

where

- \( F_{T1} \) - the friction force between the tape and the roller, H;
- \( F_{T2} \) - the friction force between the tape and the collet, H;
- \( \gamma \) - the collet's turning angle, grade;
- \( N \) - the direct force, H;
- \( F \) - the resultant force of the tape normal contact stresses;
- \( l \) - the distance between the collet centre and the clamp roller centre, mm;
- \( R_s \) - the mean radius of screw element's interaction, mm;
- \( R_0 \) - the mean radius of screw element, mm;
- \( R_t \) - the mean radius of screw element's interaction, mm;
- \( R_c \) - the mean radius of screw element, mm;

The friction forces can be developed from the dependences:

\[
F_{T1} = \mu_1 \cdot P, \\
F_{T2} = \mu_2 \cdot F,
\]

where

- \( \mu_1 \) - the coefficient of friction between the clamp roller and the tape;
- \( \mu_2 \) - the coefficient of friction between the collet and the screw element.

The resultant force of normal contact stresses is determined by the formula:

\[
F = \sigma_s \cdot s \cdot L,
\]

where

- \( \sigma_s \) - the contact normal stresses along the screw workplace's inner radius, MPa;
- \( s \) - the tape thickness, mm;
- \( L \) - the length of contact along the inner diameter, mm.

Provided the bending moment \( M \) is known, all forces, which occur while coiling, can be found after solving the equation system (7). In the given case:

\[
F = \frac{-P \cdot (\mu_1 \cdot \tan \gamma - 1)}{\mu_2 \cdot \sin \gamma + \tan \gamma \cdot (-\mu_2 \cdot \cos \gamma + \sin \gamma) + \cos \gamma}; \\
N = \frac{\mu_1 \cdot P + F \cdot (\mu_2 \cdot \cos \gamma + \sin \gamma)}{\cos \gamma}.
\]

According to the results of experimental research, the maximum bending force \( P \) by clamp roller occurs at the beginning stage of deformation, that is, when the angle \( \gamma \) equals zero. Therefore, to simplify calculations, the solution of equations system (10) will be as follows:

\[
P = F, \\
N = (\mu_1 + \mu_2) \cdot P; \\
M = \frac{l + \mu_1 \cdot (R_s - 1) + \mu_2 \cdot (R_0 - 1)}{l + \mu_1}. \\
\]

It should be noted that the friction coefficient \( \mu_2 \) between the clamp roller and the profiled tape is the given value and does not correlate directly with the value of contacting materials' friction coefficient.
coefficient. The moment applied to coining the collet depends on collets' structural peculiarities, and is generally defined as it is shown in Fig. 1, accordingly to the dependences:

\[ M_O = k_m \cdot P \cdot \left( l + \mu \cdot R_i \right) \]  

(19)

de \( k_m \) — the coefficient, which depends on the structural manufacture of the collet.

Based on the proposed above formulas, the required technological equipment can be designed. Thus, to reduce the torque of collet, and consequently to reduce the required power of coiling the screw workpiece, it is necessary to minimize friction coefficient \( \mu \), for example, using the lubricants.

The coiling of a screw element being executed in the cold state, the workpiece material is being strengthened. Consequently, the bending moment increases, which can be determined by the formula:

\[ M = \int \int \beta \left[ \sigma_{IO} \left( r_i + \frac{s}{\cos \alpha} + x \cdot \tan \alpha \right) + \frac{\rho}{R_i} \left( 2 \ln \frac{R_i}{\rho} + \ln \left( \frac{R_i + h}{\rho R_i} \right) \right) \right] \rho d\rho dx \]  

(20)

where \( \sigma_{IO} \) - extrapolated liquid limit, MPa;

\( \Pi \) - strengthening linear module, MPa.

The analytical method of solving the equation (20) is rather cumbersome, that is why the specific numerical value of bending moment should be defined by the numerical method, using appropriate software. Such method significantly reduces the calculation time.

An example of such calculation is shown in the graph in Fig. 3.

Analyzing the graph in Fig. 2 we conclude: the shelf height and its inclination angle increases, the moment of bending the screw element increases as well.

Based on the graph in Fig. 3 and formula (18), the graphs of dependence of the tape bending force on the shelf height can be drawn (Fig. 4).
Having analyzed the graphs in Figures 2 and 3, we conclude that mainly the vertical part of the workpiece deforms; and while increasing the shelf height and the inclination angle of the screw element, the bending force increases as well. As the main working surface of a screw-purifying element is a shelf, the cuts on the vertical part of the tape must be performed to reduce the bending moment of such tape.

CONCLUSIONS

As a result of investigations proved the practical feasibility of the proposed mechanism for clearing L-shaped spirals screw drives archeologists working surfaces. The proposed treatment technology manufacturing screw elements by bending the tape on shelves using dips and coiling the resulting tape with a shelf to be set.

REFERENCES