N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES CHEMISTRY AND TECHNOLOGY
ISSN 2224-5286 **https://doi.org/10.32014/2020.2518-1491.32**
Volume 2, Number 440 (2020), 120 – 128

UDC 621.742.4
IRSTI 29.19.23

E.S. Abdrakhmanov [1], B.T. Yermagambet[2],
Zh.M. Kassenova[2], M. K. Kazankapova[2], A. Sairanbek [2]

[1] “Pavlodar State University named after S. Toraygyrov”, Pavlodar, Kazakhstan;
[2] “Institute of Coal Chemistry and Technology” LLP, Nur-Sultan, Kazakhstan.
E-mail: erai1512@mail.ru, bake.yer@mail.ru, zhanar_k_68@mail.ru, maira_1986@mail.ru, asi_48@mail.ru

INVESTIGATION OF RELIABILITY OF THE SCREW UNIT OF THE COAL-ROLL PRESS BT-3M

Abstract. In the article we propose the method of calculation of parameters of stress state and rigidity of screw blade at bending in one plane, screw-piston press of BT-3M grade for production of coal briquettes is simultaneously mixing, transporting and pressing unit. The blade is regarded as a thin axially endless helicoid shell rigidly attached to the shaft along an internal helical boundary. Considering that the presence of the blade does not affect the deformation of the constant-section shaft during bending, we examine the effect of the presence of the blade on the bending stiffness of the screw. Invention covers the problem of screw blade deformations at preset displacements at inner boundary caused by shaft bending considering that its axis has curvature.

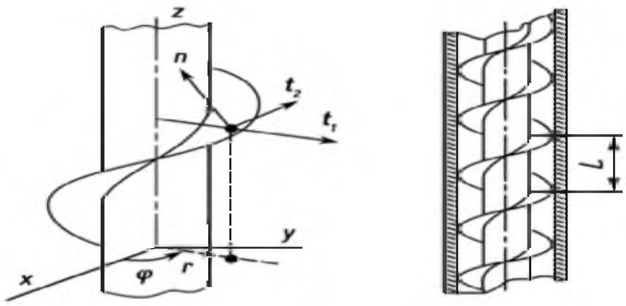
In the second stage of calculation we construct a compensating solution, which eliminates inconsistencies in differential equilibrium equations and static boundary conditions, and on the inner contour of the shell we set conditions of rigid pinching. As a result, the screw was calculated using the developed method. Blade is calculated with parameters r1 = 0.04 m, r2 = 0.1 m, r3 = 0.03 m, screw blade thickness d = 0.005 m, L = 0.2 m, total length of hollow shaft 1, 2 m. Calculations have shown that at such screw parameters and created specific pressure of material on the screw Ore = $8.5 \cdot 10^5$ Pa, the rigidity of the blade is the stiffness 11% of the tubular shaft.

Keywords: screw, press, calculation, briquette, extras, equations.

Introduction. For a number of years, the company Briquette Technologies LLC (Barnaul, Russian Federation) has been manufacturing equipment, improving and introducing it [1]. In particular, BT-type equipment is manufactured for the production of coal briquettes (figure 1).

The operation of this equipment was studied taking into account the technological parameters of its knot. The screw is at the same time a mixing, conveying and pressing knot. The screw knot (figure 2) consists of a tubular shaft and a helical tape of welded construction.

Figure 1 - Industrial screw piston press BT - 2.5-3 t/h



a) б)

Figure 2 - To the calculation of the screw knot: a) design scheme, b) auger in the trench

In this case, the screw knot experiences bending of the shaft during operation, wear of the helicoid tape and alternating loads caused by the uneven density of the mixed mass. In these cases, it can be argued that the blades and shaft of the screw will always be under high voltage.

We propose a method for calculating the parameters of the state under voltage and rigidity of a screw blade of auger during bending in one plane. We consider the blade as a thin helical shell endless in the axial direction, rigidly fastened to the shaft along the internal helical boundary (figure 2b).

Assuming that the presence of the blade does not affect the nature of the deformation of the shaft of constant cut during bending, we study the effect of the presence of the blade on the bending rigidity of the screw.

Consider the problem of the deformation of a screw blade for a given displacement on the inner boundary due to bending of the shaft, assuming that its axis has a curve $1/\rho$.

Middle surface of the helicoid shell is assigned (figure 1) to the coordinates r, ϕwhich define the orthogonal coordinate lines system on it (figure 2), with Lame parameters [6]:

$$A = 1,\ B = \sqrt{r^2 + (0{,}5L/\pi)^2},$$

where L - is the step of the helicoid.

The unit vectors $\mathbf{t}_1$ and $\mathbf{t}_2$ of the coordinate lines r and the normal n to the middle surface [5] (see figure 2) are related to the unit vectors of the Cartesian coordinate system by the formulas:

$$\mathbf{t}_1 = \cos\varphi\,\mathbf{i} + \sin\varphi\,\mathbf{j}\,;$$

$$\mathbf{t}_2 = \frac{r}{B}(-\sin\varphi\,\mathbf{i} + \cos\varphi\,\mathbf{j}) + \frac{L}{2\pi B}\mathbf{k}\,; \tag{1}$$

$$\mathbf{n} = \frac{L}{2\pi B}(\sin\varphi\,\mathbf{i} - \cos\varphi\,\mathbf{j}) + \frac{r}{B}\mathbf{k}\,.$$

The next is to determine the displacements of the points of the interface line between the shell and the shaft. When the shaft bends in the YOZ plane, the movement of its points along the directions of the X, Y, Z axes is

$$\xi = 0;\quad \eta = -0{,}5\cdot\frac{z^2}{\rho};\quad \zeta = \frac{yz}{\rho}; \tag{2}$$

$$x = r_1 \cos\varphi\,;\quad y = r_1 \sin\varphi\,;\quad z = 0{,}5\,L\,\frac{\varphi}{\pi}$$

wherer_1 is the radius of the shaft, and passing using formulas (1) to the projections of displacement on the axis of the local basis of the shell, we obtain

$$u = -C\cdot\frac{\varphi^2}{2}\cdot\sin\varphi\,;\quad v = C\cdot\frac{r_1}{B_1}\cdot\left(\varphi\cdot\sin\varphi - \frac{\varphi^2}{2}\cdot\cos\varphi\right); \tag{3}$$

$$w = C \cdot \left(\frac{L}{2\pi B_1} \frac{\varphi^2}{2} \cdot \cos\varphi + \frac{2\pi r_1^2}{L B_1} \cdot \varphi \cdot \sin\varphi \right),$$

where $C = (0{,}5L/\pi)^2/\rho$; B_1 is the value of the Lame parameter of the ϕ -line at the inner boundary of the shell.

In addition to displacement (3), the values of the angle of rotation of the normal **n** or, equivalently, the unit vector $\mathbf{t}_1$ in the plane perpendicular to the boundary of the shell border must be specified. When the shell is rigidly bonded to the shaft, its unit t1 rotates with the shaft transverse cross of shaft through an angle

$$\theta = \frac{z}{\rho}\mathbf{i}.$$

It follows that the rotation angle in the plane $\mathbf{n}$, $\mathbf{t}_1$ is equal to

$$\vartheta_1 = \boldsymbol{\theta}\,\mathbf{t}_2 = \mathbf{i}\mathbf{t}_2 \frac{L\varphi}{2\pi\rho} = -\,\mathrm{C}\frac{2\pi r_1}{LB_1} \cdot \varphi \cdot \sin\varphi \qquad (4)$$

So, the kinematic boundary conditions on the inner edge of the shell are established. There is no voltage on the outer free edge.

To calculate the helicoids the equations of the general theory of shells [6], [8], [9] written in the orthogonal system of curvilinear coordinates of the surface that do not coincide with the lines of the main curvatures are used. In this case, we take into account that the curvatures of the normal cross of the helicoid passing through the r - and ϕ - lines are equal to zero, and the surface torsion is

$$\frac{1}{R_{12}} = -\frac{L}{2\pi B^2}.$$

As a result, we obtain the following system of equations:

– equation of equilibration:

$$\frac{\partial[BT_1]}{\partial r} + \frac{\partial}{\partial\varphi}\left(S - \frac{M_2}{R_{12}}\right) - \frac{r}{B}T_2 - \frac{BQ_2}{R_{12}} + Bq_1 = 0;\ \frac{\partial}{\partial r}\left[B\left(S - \frac{M_1}{R_{12}}\right)\right] + \frac{\partial T_2}{\partial\varphi} + \frac{r}{B}\left(S - \frac{M_2}{R_{12}}\right) - \frac{BQ_1}{R_{12}} + Bq_2 = 0; \qquad (5)$$

$$\frac{\partial(BQ_1)}{\partial r} + \frac{\partial Q_2}{\partial\phi} + \frac{B}{R_{12}}\left(2S - \frac{M_1 + M_2}{R_{12}}\right) + B\,q_n = 0;\ \frac{\partial(BM_1)}{\partial r} - \frac{r}{B}M_2 + \frac{\partial H}{\partial\phi} - BQ_2 = 0;$$

$$\frac{\partial(BH)}{\partial r} + \frac{r}{B} \cdot H + \frac{\partial H}{\partial\varphi} - B \cdot Q_2 = 0;$$

– geometric ratio:

$$\varepsilon_1 = \frac{\partial u}{\partial r};\ \varepsilon_2 = \frac{\partial v}{B\partial\varphi} + \frac{ru}{B^2};\ \gamma_{12} = \frac{\partial u}{B\partial\varphi} + B\frac{\partial}{\partial r}\left(\frac{v}{B}\right) - \frac{2\omega}{R_{12}};$$

$$\theta_1 = -\frac{v}{R_{12}} - \frac{\partial w}{\partial r};\ \theta_2 = -\frac{u}{R_{12}} - \frac{\partial w}{B\,\partial\varphi};\ \Omega_n = \frac{1}{2B}\left[\frac{\partial(Bv)}{\partial r} - \frac{\partial u}{\partial\varphi}\right];\ \boldsymbol{\nu}_1 = \frac{\partial\theta_1}{\partial r} - \frac{\Omega_n}{R_{12}}; \qquad (6)$$

$$v_2 = \frac{\partial\theta_2}{B\partial\varphi} + \frac{r\theta_1}{B^2} + \frac{\Omega_n}{R_{12}};\ \eta = \frac{\partial\theta_1}{B\partial\varphi} - \frac{r\theta_2}{B^2} + \frac{\varepsilon_2}{R_{12}};$$

– ratio of elasticity:

$$T_1 = \frac{Eh}{1-\nu^2}(\varepsilon_1 + \nu\varepsilon_2) \quad (1 \leftrightarrow 2); \quad S = \frac{Eh}{2(1+\nu)}\varphi_{12};$$

$$M_1 = D(\chi_1 + \nu\chi_2) \quad (1 \leftrightarrow 2); H = D(1-\nu)\,\eta. \tag{7}$$

We write the static boundary conditions on the external contour of the helicoid in the form [8]

$$T_1^* = T_1 - \frac{H}{R_{12}} = 0; \quad T_{12} = S - \frac{M_1}{R_{12}} = 0; \quad Q_1^* = Q_1 + \frac{\partial H}{B\partial\varphi} = 0; \quad M_1 = 0. \tag{8}$$

In this screw bending problem, the distributed loads q_1, q_2, q_n are absent, all blade turns are in the same stressed state, so internal forces and deformations are periodic coordinate functions. Displacements u, v, w and rotation angles ϑ_1, ϑ_2, Ω_n have no periodicity property.

The blade is calculated in two stages.

First, we set an approximate law for changing the movements of the blade points assuming that its radial sections passing through the horns t_1, n (figure 2) do not deform. It is assumed that kinematic boundary conditions (3) and (4) are satisfied.

In the second stage of calculation we build a compensating solution, which eliminates inconsistencies in differential equations of equilibrium (5) and static boundary conditions (8), and on the inner contour of the shell we set conditions of rigid pinching.

Thus, all components of stress-strain state are represented as sums $f = f^{(1)} + f^{(2)}$, where $f^{(1)}$ - components of approximate solution satisfying kinematic boundary conditions of shell with shaft, and $f^{(2)}$ - components of compensating solution.

In the first solution, the movement functions according to the conditions (5) have the form:

$$u = -C\frac{\varphi^2}{2}\sin\varphi; \quad v = C\frac{r_1}{B_1}\left(\varphi\sin\varphi - \frac{\varphi^2}{2}\cos\varphi\right); w = C\cdot\left(\frac{L}{2\pi B_1}\frac{\varphi^2}{2}\cdot\cos\varphi + \frac{2\pi r_1^2}{L B_1}\cdot\varphi\cdot\sin\varphi\right). \tag{9}$$

Using ratios (6), we find membrane deformation components

$$\varepsilon_1^{(1)} = 0; \varepsilon_2^{(1)} = C\cdot\frac{r}{B^2}\cdot\sin\varphi; \quad \gamma_{12}^{(1)} = 0 \tag{10}$$

and parameters for changing the curvature and torsion of the middle surface $\chi_1^{(1)} = 0$;

$$\chi_2^{(1)} = -C\cdot\frac{2\pi}{LB}\cdot\left(1+\frac{r^2}{B^2}\right)\cdot\cos\varphi; \quad \tau^{(1)} = -C\cdot\frac{Lr}{\pi B^4}\cdot\sin\varphi. \tag{11}$$

using elastic ratios (7) we determine internal forces and moments $T_1^{(1)} = \nu\cdot T_2^{(1)}$;

$$M_2^{(1)} = -D\cdot C\cdot\frac{2\pi}{L\cdot B}\cdot\left(1+\frac{r^2}{B^2}\right)\cdot\cos\varphi; \tag{12}$$

$$H^{(1)} = -D\cdot C\cdot(1-\nu)\cdot\frac{L\cdot r}{\pi\cdot B^2}\cdot\sin\varphi;$$

from the fourth and fifth equations of equilibrium of moments from (5), we get transverse forces

$$Q_1^{(1)} = \frac{D\cdot C\cdot r}{B^5}\cdot\left(\frac{4\pi r^2}{L} - \frac{L}{2\pi}\right)\cdot\cos\varphi; \tag{13}$$

$$Q_2^{(1)} = \frac{D \cdot C}{B^2} \cdot \left[\frac{2\pi}{L}\left(1 + \frac{r^2}{B^2}\right) + (1-\nu) \cdot \frac{L}{\pi B^2}\left(\frac{2r^2}{B_2} - 1\right)\right] \cdot \sin\varphi \ .$$

By substituting the forces found into the first three equilibrium equations (5), we find surface loads

$$q_1^{(1)} = \frac{EhC}{1-\nu^2}\left[(1+\nu) \cdot \frac{r^2}{B^4} - \frac{\nu}{B^2}\right] \cdot \sin\varphi \ ;$$

$$q_2^{(1)} = -\frac{EhC}{1-\nu^2} \cdot \frac{r}{B^2} \cdot \cos\varphi \ ; \tag{14}$$

$$q_3^{(1)} = -\frac{DCL}{2\pi B^2}\left[16r^2 + (3\nu - 1)\left(\frac{L}{2\pi}\right)^2\right] \cdot \cos\varphi \ ;$$

In the expressions for loads $q_1^{(1)}$ and $q_2^{(1)}$ and omitted the components having order $(h/B)^2$.

As can be seen from the dependencies (12), forces exist on the outer contour of the blade

$$T_1^{*(1)} = \frac{\nu \cdot EhC}{1-\nu^2} \cdot \frac{r_2}{B_2^2} \cdot \sin\varphi \ ; \quad T_{12}^{(1)} = -\frac{\nu \cdot DC}{B_2^2} \cdot \left(1 + \frac{r_2^2}{B_2^2}\right) \cdot \cos\varphi \ ; \tag{15}$$

$$Q_1^{*(1)} = \frac{DCr_2}{B_2^5} \cdot \left[\frac{4\pi r_2^2}{L} - (3-2\nu) \cdot \frac{L}{2\pi}\right] \cdot \cos\varphi \ ; M_1^{(1)} = -\nu D C \cdot \frac{2\pi}{L B_2} \cdot \left(1 + \frac{r_2^2}{B_2^2}\right) \cdot \cos\varphi \ ,$$

Where r_2 – is the outer radius of the blade; B_2 - is the value of the Lame parameter at this radius.

Thus, the inconsistencies in equilibrium equations generated by approximate solutions are established.

Let 's look at the problem of finding a solution that compensates for mischief. This solution must satisfy equations (5) - (7) at loads

$$q_1^{(2)} = -q_1^{(1)} \ ; \ q_2^{(2)} = -q_2^{(1)}; \ q_n^{(2)} = -q_n^{(1)} \ , \tag{16}$$

boundary conditions of the specified rigid fixation on the inner contour

$$u^{(2)} = v^{(2)} = w^{(2)} = \vartheta_1^{(2)} = 0, \tag{17}$$

and conditions of specified loading on external circuit free in relation to displacements

$$T_1^{*(2)} = -T_1^{*(1)}; \ T_{12}^{(2)} = -T_{12}^{(1)}; \ Q_1^{*(2)} = -Q_1^{*(1)} \ ; \ M_1^{(2)} = -M_1^{(1)} . \tag{18}$$

The formulated task allows for the separation of variables. This procedure differs from the same procedure in the related task of calculating *rotation shells*.

Accepting that functions

$$u^{(2)}, \ \varepsilon_1^{(2)}, \ \varepsilon_2^{(2)}, \ T_1^{(2)}, \ T_2^{(2)}, \ \vartheta_1^{(2)}, \kappa^{(2)}, H^{(2)}, Q_2^{(2)}$$

change along helical lines r = const by the law of the sinus, i.e.

$$f^{(2)} = \tilde{f}(r) \cdot \sin\varphi \ , \tag{19}$$

Where $f^{(2)}$ – is any of the functions listed.

Each of functions

$$v^{(2)},\ \gamma_{12}^{(2)},\ \Omega_n^{(2)},\ S^{(2)},\ w^{(2)},\vartheta_1^{(2)},\kappa_1^{(2)},\kappa_2^{(2)},M_1^{(2)},M_2^{(2)},Q_1^{(2)}$$

imagine in the form

$$g^{(2)}=\widetilde{g}\cdot\cos\varphi\ . \tag{20}$$

Unlike the shells of rotation in the helicoid, normal forces and bending moments are functions of different parity. The same can be said of shear forces and torques. As a result of substitution of expressions (19), (20) in equations (5) - (7) and separation of angular coordinate ϕ functions, we obtain a system of ordinary differential equations, which can be represented as

$$\frac{d}{dr}Y=FY+GZ+g\,;\ Z=MY, \tag{21}$$

where

$$Y=\left\{\widetilde{u},\ \widetilde{v},\ \widetilde{w},\ \widetilde{\vartheta}_1,\ B\left(\widetilde{T}_1-\frac{\widetilde{H}}{R_{12}}\right),\ B\left(\widetilde{S}-\frac{M_1}{R_{12}}\right),\ B\left(\widetilde{Q}_1+\frac{\widetilde{H}}{B}\right),\ B\widetilde{M}_1\right\}.$$

A vector of basic variables (order 8), $Z=\{\widetilde{\kappa}_1,\ \widetilde{\tau}\}$ - a vector of complementary variables (order 2); F, G, M – are coefficient matrices.

$$F=\begin{pmatrix}
-\frac{\nu\kappa}{B^2} & \frac{\nu}{B} & 0 & 0 & \frac{1-\nu^2}{EhB} & 0 & 0 & 0\\
-\frac{1}{B} & \frac{r}{B^2} & \frac{2}{R_{12}} & 0 & 0 & \frac{2(1+\nu)}{EhB} & 0 & \frac{2(1+\nu)}{EhBR_{12}}\\
0 & -\frac{1}{R_{12}} & 0 & -1 & 0 & 0 & 0 & 0\\
-\frac{(1-2\nu)}{BR_{12}} & \frac{(1-\nu)r}{B^2R_{12}} & -\frac{\nu}{B^2}+\frac{1-\nu}{R_{12}^2} & -\frac{\nu r}{B^2} & 0 & \frac{2(1+\nu)}{EhBR_{12}} & 0 & \frac{1}{BD}\\
\frac{Ehr^2}{B^3} & -\frac{Ehr}{B^2} & 0 & 0 & \frac{\nu r}{B^2} & \frac{1}{B} & 0 & \frac{(1-2\nu)}{BR_{12}}\\
-\frac{Ehr}{B^2} & \frac{Eh}{B} & 0 & 0 & -\frac{\nu}{B} & -\frac{r}{B^2} & \frac{1}{R_{12}} & -\frac{(1-\nu)\cdot r}{B^2R_{12}}\\
0 & 0 & 0 & 0 & 0 & -\frac{2}{R_{12}} & 0 & \frac{\nu}{B^2}-\frac{1-\nu}{R_{12}^2}\\
0 & 0 & 0 & 0 & 0 & 0 & 1 & \frac{\nu\cdot r}{B^2}
\end{pmatrix}$$

$$G^{\mathrm{T}}=\begin{pmatrix}
0 & 0 & 0 & 0 & -\frac{2D\left(1-\nu^2\right)}{R_{12}} & \frac{D\left(1-\nu^2\right)\cdot r}{BR_{12}} & D\left(1-\nu^2\right)\left(\frac{B}{R_{12}^2}+\frac{1}{B}\right) & \frac{D(1-\nu)\cdot r}{B}\\
\frac{(1-\nu)h^2}{12R_{12}} & 0 & 0 & 0 & \frac{(3+\nu)(1-\nu)rD}{BR_{12}} & -\frac{D\left(1-\nu^2\right)}{R_{12}} & -\frac{2(1-\nu)rD}{B^2} & -2D(1-\nu)
\end{pmatrix}$$

$$M=\begin{pmatrix}
-\frac{2}{BR_{12}} & \frac{r}{B^2R_{12}} & \frac{1}{R_{12}^2}+\frac{1}{B^2} & \frac{r}{B^2} & 0 & 0 & 0 & 0\\
\frac{2r}{B^2R_{12}} & -\frac{1}{BR_{12}} & -\frac{r}{B^2} & -\frac{1}{B} & 0 & 0 & 0 & 0
\end{pmatrix}.$$

The edge problem for the system of equations is solved numerically by the method of orthogonal Godunov run. With known blade deformations, its effect on screw bending stiffness can be determined by Lagrange 's theorem. For this purpose we calculate deformation energy of one blade turn [5]

$$U=\frac{1}{2}\int_{r_1}^{r_2}\int_{0}^{2\pi}\left\{\begin{array}{l}\frac{Eh}{1-\nu^2}\left[(\varepsilon_1+\varepsilon_2)^2+2(1-\nu)\left(\frac{\gamma_{12}^2}{4}-\varepsilon_1\varepsilon_2\right)\right]+\\ +\quad D\left[(\kappa_1+\kappa_2)^2+2(1-\nu)\left(\tau^2-\kappa_1\cdot\kappa_2\right)\right]\end{array}\right\}B\,d\varphi\,dr \qquad (22)$$

Each deformation component in expression (22) defines the superposition of two solutions, for example: $\varepsilon_2=\varepsilon_2^{(1)}+\varepsilon_2^{(2)}$ etc. In so much as the deformations are proportional to either sin or cos, in you (22) it is necessary to calculate only a one-dimensional integral by the pen r, in which the deformations are replaced by their amplitude functions.

Bending stiffness of the blade is found by formula $K = \frac{2U}{\theta^2}$, where $\theta = \frac{L}{\rho}$

- Mutual rotation angle of shaft sections spaced apart by screw L pitch.

When calculating the screw as a bending rod, the rigidity of the blade (23) is added to the stiffness of the shaft *EI/L*. Figure 3 shows the dependence of the bending stiffness of the blade *K/(Eh)* 3 on the pitch L, *mm*.

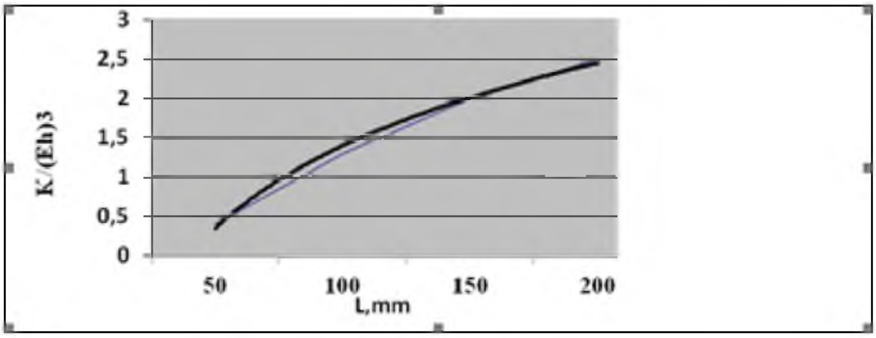


Figure 3 - Graphic dependence of bending stiffness of blade K/(Eh) 3 on pitch L, mm of screw line

Conclusion. According to the developed method, the screw of the auger press BT-3M for the production of coal briquettes was calculated. Calculation of the blade with r_1=0,04м parameters of m, r_1=0,04 м, r_2=0,1 м, r_3=0,03 м, thickness of the screw piston δ=0.005 blade of m, L=0.2 m, total length of a hollow shaft 1, 2 m is executed.

Calculations have shown that at such screw parameters and created specific pressure of material on the screw Ore = $8{,}5\cdot10^5$ Pa, the rigidity of the blade is the stiffness 11% of the tubular shaft. Reliability by capacity criterion P = 0.667, which is structurally insufficient.

In order to increase reliability, one-piece version of the screw with the developed casting technology can be offered.

Е.С. Абдрахманов[1], Б.Т. Ермагамбет[2],
Ж.М. Касенова[2], М.К. Казанкапова[2], А. Сайранбек[2]

[1] «С. Торайгыров атындағы Павлодар мемлекеттік университеті», Павлодар, Қазақстан;
[2] «Көмір химиясы және технология институты» ЖШС, Нұр-Сұлтан, Қазақстан

ИССЛЕДОВАНИЕ НАДЕЖНОСТИ ШНЕКОВОГО УЗЛА УГЛЕБРИКЕТНОГО ПРЕССА БТ-3М

Аннотация. Мақалада бір жазықтықта иілу кезінде шнектің бұрандалық алағының кернеулі күйі мен қаттылыгының параметрлерін, бірмезгілде араластырып,тасымалдайтын және нығыздаушы түйін болып табылатын көмір брикеттерін өндіру үшін БТ-3М маркалы шнек-поршенді престің параметрлерін есептеу әдісін ұсынамыз. Iшкі бұрандалы шекара бойынша білікпен қатты бекітілген қалақты, осьтік бағытта жіңішке шексіз геликоид қабық ретінде қарастырамыз. Қалақтың болуы иілу кезінде тұрақты қима білігінің деформациясының сипатына әсер етпейді деп есептейміз, қалақтың бар болуын шнектің иілу қаттылығына әсері зерттелді. Осінің $1/\rho$ қисықтығы бар деп есептей отырып, біліктің майысуымен байланысты ішкі шекарада берілген орын ауыстырулар кезінде бұрандалы қалақтың деформациясы туралы тапсырма қаралды. Бұл ретте шнек торабы жұмыс істеген кезде біліктің майысуын, геликоид таспасының тозуын және аралас массаның біркелкі емес тығыздығымен туындататын белгісіздік жүктемелерді сынайды. Әрине, бұл жағдайларда шнектің қалақтары мен білігі әрдайым жоғары кернеумен болады деп айтуға болады. Қарастырылып отырған тапсырмада иілу шнектің бөлінген жүктемелер q_1, q_2, q_n жоқ, жауырынның барлық орамдары бірдей кернеулі күйде, сондықтан ішкі күш пен деформациялар ϕ координатаның периодтық функциялары болып табылады. Жылжыту U, V, w және бұрылу бұрыштарында ϑ_1, ϑ_2, Ω_n, мерзімділік қасиет жоқ. Екінші кезеңде дифференциалдық теңдеулерінде және статикалық шекаралық жағдайларда таңғыштарды жоятын компенсациялық шешім құралды, сонымен қатар қабықтың ішкі контурында қатты қысымның шарттарын қойылды. Нәтижесінде әзірленген әдістеме бойынша шнекті есептеу жүргізілді. r_1=0,04 м, r_2=0,1 м, r_3=0,03 м м параметрлер арқылы қалақты есептеу орындалды, шнекті қалақтың қалыңдығы δ=0,005 м, L=0,2 м, қуыс біліктің жалпы ұзындығы 1, 2 м. Есептеу нәтижесінде, шнектің белгіленген параметрлерінде және кен шнектерінде материалда пайда болатын меншікті қысым $P_{уд}$=8,5•10^5Па, қалақтың қаттылығы құбырлы біліктің қаттылығының 11% құрайтынын көрсетті. Ең алдымен, қалақ нүктелерінің жылжу өзгерісінің жақын заңын белгілейміз, бұл оның t_1 , n орталары арқылы өтетін радиалды қималары деформацияланбауын көрсетеді (сурет 2).Бұл ретте кинематикалық шекаралық жағдайлар (3) және (4) қанағаттандырылады. Есептеудің екінші кезеңде дифференциалдық теңдеулерінде тепе-теңдік (5) және статикалық шекаралық жағдайларда (8) таңғышты жоятын компенсациялық шешім түземіз, сонымен қатар қабықтың ішкі контурында қатты қысым шарттарын қоямыз. Сонымен, кернеулі-деформацияланған күйдің барлық компоненттерін $f = f^{(1)} + f^{(2)}$ қосындылары түрінде елестетеміз , мұнда $f^{(1)}$ – қабықшаның білікпен жанасуының кинематикалық шекаралық шарттарын қанағаттандыратын, жақындатылған шешімнің компоненттері, ал $f^{(2)}$ – компенсациялық шешімнің компоненттері.

Түйін сөздер: шнек, пресс, есептеу, брикет, қалақ, теңдеу.

Е.С. Абдрахманов[1], Б.Т. Ермағамбет[2],
Ж.М. Касенова[2], М.К. Казанкапова[2], А.Сайранбек[2]

[1] «Павлодарский государственный университет им. С. Торайгырова», Павлодар, Казахстан;
[2]ТОО « Институт химии угля и технологии», Нур-Султан, Казахстан

ИССЛЕДОВАНИЕ НАДЕЖНОСТИ ШНЕКОВОГО УЗЛА УГЛЕБРИКЕТНОГО ПРЕССА БТ-3М

Аннотация. В статье предлагается метод расчета параметров напряженного состояния и жесткости винтовой лопасти шнека при изгибе в одной плоскости, шнекопоршневого пресса марки БТ-3М для производства угольных брикетов являющего одновременно смешивающим, транспортирующим и прессующим узлом. Лопасть рассматриваем как тонкую бесконечную в осевом направлении геликоидную оболочку, жестко скрепленную с валом по внутренней винтовой границе. Считая, что наличие лопасти не влияет на характер деформаций вала постоянного сечения при изгибе, исследуем влияние наличия лопасти на изгибную жесткость шнека. Рассмотрена задача о деформациях винтовой лопасти при заданных перемещениях на внутренней границе, обусловленных изгибом вала, считая, что его ось имеет кривизну

При этом шнековый узел испытывает при работе изгиб вала, износ геликоидной ленты и знакопеременные нагрузки, вызываемые неравномерной плотностью смешиваемой массы. Естественно, в рассмотренных этих случаях, можно утверждать, что лопасти и вал шнека всегда будет находиться под высоким напряжением. В рассматриваемой задаче изгиба шнека распределенные нагрузки q_1, q_2, q_n отсутствуют, все витки лопатки находятся в одинаковом напряженном состоянии, поэтому внутренние усилия и деформации являются периодическими функциями координаты. Перемещения *u, v, w* и углы поворота, свойством периодичности не обладает. Во втором этапе расчета строим компенсирующее решение, которое устраняет невязки в дифференциальных уравнениях равновесия и статических граничных условиях, причем на внутреннем контуре оболочки ставим условия жесткого защемления. В результате по разработанной методике проведены расчеты шнека. Выполнен расчет лопасти с параметрами r_1=0,04 м, r_2=0,1 м, r_3=0,03 м, толщина шнековой лопасти δ=0,005 м, L=0,2 м, общая длина полого вала 1, 2м. Расчеты показали, что при таких параметрах

шнека и создаваемом удельном давлении материала на шнек $P_{уд}$=8,5•10^5 Па , жесткость лопасти составляет 11% жесткости трубчатого вала. Сначала задаем приближенный закон изменения перемещений точек лопасти в предположении, что ее радиальные сечения, проходящие через орты $\mathbf{t}_1$, $\mathbf{n}$ (рис. 2), не деформируются. При этом предполагается, что удовлетворяются кинематические граничные условия (3) и (4).Во втором этапе расчета строим компенсирующее решение, которое устраняет невязки в дифференциальных уравнениях равновесия (5) и статических граничных условиях (8), причем на внутреннем контуре оболочки ставим условия жесткого защемления. Итак, все компоненты напряженно-деформированного состояния представим в виде сумм $f = f^{(1)} + f^{(2)}$, где $f^{(1)}$ – компоненты приближенного решения, удовлетворяющего кинематическим граничным условиям сопряжения оболочки с валом, а $f^{(2)}$ – компоненты компенсирующего решения.

Ключевые слова: шнек, пресс, расчет, брикет, лопасти, уравнения.

Information about the authors:

Abdrakhmanov Ermagambet Seisenbekovich - Candidate of technical sciences, Professor "Pavlodar State University of S. Toraygyrov", Pavlodar, Kazakhstan, e-mail: erai1512@mail.ru, https://orcid.org/0000-0001-9726-1642;

Yermagambet Bolat Toleukhanuly– Doctor of Chemical Science, Professor, Director of LLP "Institute of Coal Chemistry and Technology", Nur-Sultan, Kazakhstan, e-mail:bake.yer@mail.ru; https://orcid.org/0000-0003-1556-9526;

Kassenova Zhanar Muratbekovna – Master of Chemical Sciences and Technology, Deputy Director of LLP "Institute of Coal Chemistry and Technology", Nur-Sultan, Kazakhstan, e-mail: zhanar_k_68@mail.ru;https://orcid.org/0000-0002-9497-7319;

Kazankapova Maira Kuttybaevna - PhD in Philosophy, LLP "Institute of Coal Chemistry and Technology", Nur-Sultan, Kazakhstan, e-mail: maira_1986@mail.ru; https://orcid.org/0000-0001-9016-3062;

Sairanbek Asiya – Master of Chemical Sciences and Technology, Junior researcher of LLP "Institute of Coal Chemistry and Technology", Nur-Sultan, Kazakhstan, e-mail: asi_48@mail.ru, https://orcid.org//0000-0001-7763-2450

REFERENCES

[1] Nikishanin M.S., ZagrutdinovR.Sh., Senachin P.K. (2016) Briquetting of local fuels and waste for energy supply systems in rural areas [Briketirovaniye mestnykh topliv i otkhodov dlya sistem energoobespecheniya v sel'skoy mestnosti] 1:88-95 (in Russ.).

[2] Sabyrov T., Abdrakhmanov E. S. (2004) Calculation and study of the hydro-mechanical and hydrodynamic characteristics of the mixing apparatus with mixers. Part I [Raschet i issledovaniye gidromekhanicheskikh i gidrodinamicheskikh kharakteristik smeshivayushchego apparata meshalkami. ch. I] 1:49 – 58 (in Russ.).

[3] Sabyrov T., Abdrakhmanov E.S (2005) Calculation and study of the hydro-mechanical and hydrodynamic characteristics of the mixing apparatus with stirrers. Part II [Raschet i issledovaniye gidromekhanicheskikh i gidrodinamicheskikh kharakteristik smeshivayushchego apparata meshalkami. ch. II] 3:98-110 (in Russ.).

[4] Vodnev V. T., Naumovich A. F., Naumovich N. F. (1984) Mathematical Dictionary of Higher Education. Vysh. School, Minsk. ISBN: 978-00-1296937-0

[5] Ilyin V. A., Poznyak E. G. (2002) Fundamentals of mathematical analysis. Part II. Science, Moscow. ISBN: 5-9221-0131-5

[6] Goldenweiser A. L. (1976) The theory of elastically thin shells. Science, Moscow.

[7] Novozhilov V. V., Chernykh K. F., Mikhailovsky E. I. (1991) Linear theory of thin shells. Polytechnic , Leningrad. ISBN: 5-7325-0127-4

[8] Alexandrov A.V., Potapov V.D. (1990) Fundamentals of the theory of elasticity and plasticity. High school, Moscow. ISBN: 5-06-000053-2

[9] Bauman V.A., Klushantsev B.V., Martynov V.D. (1981) Mechanical equipment of building materials and products enterprises. Engineering, Moscow.

[10]Gorsky A.I. (1978) Calculation of machines and mechanisms of automatic foundry production lines. Engineering, Moscow.

[11]Kuznetsova V.I., Barzilovich E.Yu. (1990) Reliability and efficiency in technology. Volume 8, Engineering, Moscow.

[12]Vygodsky M.I. (2002) Handbook of Higher Mathematics. Science, Moscow. ISBN: 5-271-03651-0