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INVESTIGATION OF DEFLECTIONS OF WINDED SCREW FLIGHTS AND AUGER BILLETS IN THE PROCESSES OF THEIR MANUFACTURE

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Summary. *Analytical dependencies to assess the rigidity of multi-profile screw flights during their manufacture by winding strip blanks with an edge on a mandrel were obtained, which made it possible to determine the profiles of turns with high rigidity and evaluate the accuracy of such blanks. The regularities of deflection of a combined auger billet with open and closed windings in various ways of its fixing in the process of cold winding of strip blanks by a rib onto mandrels have been established.*
Key words: *helical flight, auger billet, deflection.*

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Statement of the work. One of the effective technological ways to obtain the manufactured helical flighs (HF) is a single (discrete) winding of the strip on the mandrel. After winding, the obtained screw blank is removed from the mandrel. For the manufacturing of combined auger billets (AB) with winding turns the combined operation is used. In this operation the strip billet is wound on the smooth or screw support element (shaft) with simultaneous welding of the turns of the formed spiral to it. In the process of winding due to bending on the edge of the strip billet on the mandrel, there are the forces resulting in its deflection, and the value of this deflection depends on the total stiffness of the mandrel and the helical spiral. Significant deflection affects the quality of the obtained screw parts. The application of the solid shafts results in the increase of AB weight, and hence the screw operating body. Therefore, in order to provide the rationally regulated deflection, it is necessary to determine the influence of the given profile of the spiral wind on the stiffness due to bending. Combined AB can be manufactured in different technological ways and can have different cross-sectional profile of the wind. Therefore, the value of the stiffness index is also important for calculating the deflection of the combined AB in the process of machining the outer edge of its winds.

Analysis of the available investigation results. In the scientific and technical literature, the issues of HF and AB deflections in solving problems of design and optimization of technologies for their manufacturing are insufficiently covered [1-8]. In particular, in [6], based on Ritz method, the method of calculating the deflection condition of HF wind placed on the absolutely rigid mandrel is presented. In order to assess the stiffness, it is reasonable to use the technique where AB is considered as a smooth shaft, or as a lead screw with low winds [7, 8]. In the latter case, while obtaining AB with small specific height of winds (B/H<2), the calculated moment of inertia of AB cross-section is determined by formula [8]:

$$T_{calc} = 0,01(2 \div 3\frac{2R_h}{2R_H})(2R_H)^2 , \tag{1}$$

where R_H, R_h – are the radii of the inner and outer edges of helical spiral winds respectively.

This formula does not take into account the geometric parameters of the cross-sectional profile of the wind (the thickness of the outer h and inner H of its edges) and the helical spiral pitch T.

The general concept of the methodology of calculating the deflection of HF and AB in the process of their manufacture is outlined in [9, 10]. Therefore, there is the need for practical implementation of such concept.

The objective of the paper is to investigate the patterns of deflection of the combined AB with open and closed windings by different ways of its fixing in the process of cold winding of strip billets with the rib on the mandrel, to determine the analytical dependences for the estimation of stiffness of multi-profile AB in the process of their manufacturing by winding strip billets with the rib on the mandrel and on the basis of this to determine the profiles of winds with the highest stiffness.

Statement of the problem. In the process of making HF and AB by winding the strip billet with thickness H0 and width B0 on the smooth or threaded shaft (Fig. 1), there are several options for setting the shaft or support element in the chuck. Here the roller with parallel (a-d), or perpendicular position of its axis relatively to the mandrel (f, e) is used. In order to prevent loss of resistance and corrugation during winding of the strip with rib on the mandrel, it is necessary to adjust the shaped billet in the axial direction with axial force Pax = (0,7-1,1)P (for steel materials) and Pax = (0,7-1,1)P (for aluminum alloys), where P - is the bending force of the strip billet. While obtaining AB the simultaneous fixation of the shaped spiral on its inner edge to the support element is performed.

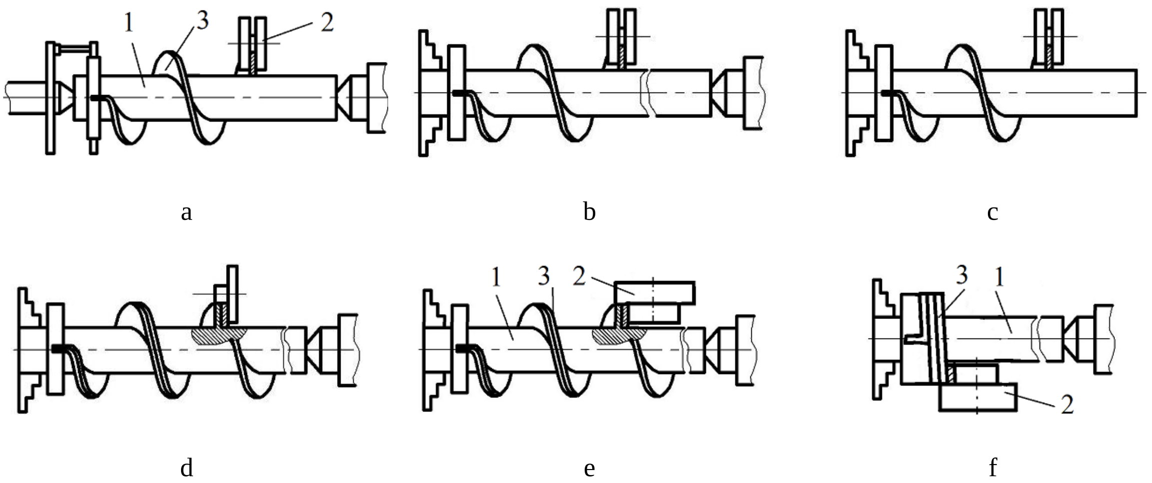


Figure 1. Types of fixings of the mandrel or support element of the spiral in the process of manufacturing HF and AB on the lathes: 1 – mandrel, 2 – roller, 3 – screw spiral of HF or AB

Results of the investigation. The potential energy of elastic deformation of one wind of the helical spiral is determined by the integral [11]:

$$U = 0,5\int_{R_H}^{R_h}\int_{0}^{2\pi}\frac{EH_c}{1-\mu^2}((\varepsilon_r+\varepsilon_\varphi)^2+2(1-\mu)(0,25\gamma_{r\varphi}-\varepsilon_r\varepsilon_\varphi))\times$$
$$\times\sqrt{r^2+C^2}d\varphi d\gamma+0,5\int_{R_H}^{Rh}\int_{0}^{2\pi}D[(\chi_r+\chi_\varphi)+2(1-\mu)\cdot(\chi_{r\varphi}^2-\chi_r\chi_\varphi))\sqrt{r^2+C^2}d\varphi dr, \tag{2}$$

where r,φ – are polar coordinates; E – is Young's modulus; $1/\rho$ – is curvature of HF wind axis; ρ – is Poisson's ratio of the material; Hc – is wind thickness; C – is the step parameter of the helical HF line; $C = T/2\pi$; D – is cylindrical stiffness: $D = \dfrac{E_z H_c^3}{12(1-\mu^2)}$; $\varepsilon_r, \varepsilon_\varphi, \chi_{r\varphi}$ – are components of membrane deformation; $\chi_r, \chi_\varphi, \chi_{r\varphi}$ – are parameters of curvature change and torsion of the middle surface.

$$\varepsilon_r = 0; \quad \varepsilon_\varphi = \frac{C^2 r}{\rho\sqrt{r^2+C^2}}\sin\varphi; \quad \gamma_{r\varphi} = 0; \quad \chi_r = 0;$$

$$\chi_\varphi = -\frac{C}{\rho\sqrt{r^2+C^2}}\left(1+\frac{r^2}{(r^2+C^2)}\right)\cos\varphi; \qquad \chi_{r\varphi} = \frac{-C^3 r}{\rho(r^2+C^2)^2}\sin\varphi. \tag{3}$$

After substituting expressions (3) in (2)

$$\begin{aligned} U = 0{,}5\int_{R_H}^{R_h}\int_0^{2\pi}\frac{EH_c}{1-\mu^2}\left(\frac{C^2 r\sin\varphi}{\rho(r^2+C^2)}\right)\sqrt{r^2+C^2}\,d\varphi dr + 0{,}5\int_{R_H}^{R_h}\int_0^{2\pi} D \times \\ \times\left(-\frac{C}{\rho\sqrt{r^2+C^2}}\left(1+\frac{r^2}{r^2+C^2}\right)\cos\varphi^2 + 2(1-\mu)\left(-\frac{C^3 r\sin\varphi}{\rho(r^2+C^2)}\sin\varphi\right)^2\right)\sqrt{r^2+C^2}\,d\varphi dr. \end{aligned} \tag{4}$$

Bending stiffness of one SB wind is

$$j = 2U/\theta^2, \tag{5}$$

where $\theta = T/\rho$ – is the mutual angle of rotation of the sections placed at the distance of one step of the winding.

The value of the potential energy of elastic deformation of one wind depends on the law of change of its cross section thickness. For trapezoidal profile (Fig. 2)

$$h_r = h + \frac{H-h}{R_h - R_H}(R_h - r), \tag{6}$$

The value H and h depends on the method of SB manufacturing. For winded SB [5]:

$$h_r = H_0\frac{\sqrt[4]{R_h R_H}}{\sqrt{r}} \tag{7}$$

where H_0 is the thickness of the strip from which is obtained.

To simplify the calculations, the cross-sectional profile of SB wind can be considered as trapezoidal, where

$$h = H_0\sqrt[4]{R_h R_H}/\sqrt{R_h};\; H = H_0\sqrt[4]{R_h R_H}/\sqrt{R_H} \tag{8}$$

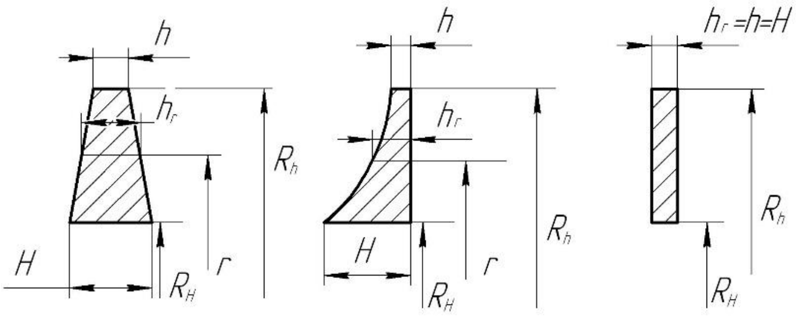
In the case of the application of SB, obtained by the method of strips rolling, the law of change of the wind thickness depends on the profile scheme. Trapezoidal and hyperbolic profiles are economical. The law of the change of wind thickness for hyperbolic profile is as follows

$$h_r = \frac{(r_2 - r_1)H}{r_2 - r_1 + (\frac{H}{h} - 1)(r_2 - r_1)} \tag{9}$$

For wide-wind SB with constant thickness by wind height

$$h_r = h = H \tag{10}$$

Based on the determination of the value of the potential energy of elastic deformation of one wind for B/H>20, taking into account the law of change of the thickness of its cross section, the following dependences are determined for the calculation of one wind stiffness.



a *b* *c*

Figure 2. Scheme of cross-sectional profiles of SB and AB winds

Bending stiffness of one wind of SB of trapezoidal profile in cross section (Fig. 2 a)

$$j = \frac{E}{4\pi^2(1-\mu^2)} \int_{R_H}^{R_h}\int_0^{2\pi} [\frac{(h\cdot(R_h - R_H) + (H-h)(R_h - r))r^2\cdot c^2 \sin^2\varphi}{\sqrt{r^2+c^2}(R_h - R_H)} + \frac{(h(R_h - R_H) + (H-h)(R_h - r))^3}{12(R_h - R_H)^3} \times$$
$$\times \left((\frac{\cos^2\varphi}{\sqrt{r^2+c^2}}(1+\frac{r^2}{\sqrt{r^2+c^2}})^2 + 2(1-\mu)\frac{c^4 r^2 \sin^2\varphi}{(r^2+c^2)^3\sqrt{r^2+c^2}} \right)]d\varphi dr, \tag{11}$$

where $c = T/2\pi$; T is SB wind pitch; D is cylindrical stiffness: $D = \frac{E_z H_c^3}{12(1-\mu^2)}$; r, φ are polar coordinates; E – is Young's modulus; μ is Poisson's ratio; H i h are the thickness of the outer and inner edges of SB wind, respectively. The values H and h depend on the method of SB manufacturing.

The value of the stiffness of one SB wind with hyperbolic profile of its cross section (Fig. 2 b) is

$$j = \frac{E}{4\pi^2(1-\mu^2)} \int_{R_H}^{R_h}\int_0^{2\pi} [\frac{H(r_h - r_H)r^2\cdot c^2\sqrt{r^2+c^2}\sin^2\varphi}{[r_h - r_H + (\frac{H}{h}-1)(r - r_h)]\left(r^2+c^2\right)} + \frac{H^3(r_h - r_H)^3}{12(r_h - r_H + (\frac{H}{h}-1)(r - r_H))^3} \times$$
$$\times \left(1 + \frac{r^2}{r^2+c^2}\right)^2 \frac{\cos^2\varphi}{\sqrt{r^2+c^2}} + 2(1-\mu)\frac{c^4 r^2 \sin^2\varphi}{(r^2+c^2)^3\sqrt{r^2+c^2}}]d\varphi dr. \tag{12}$$

For wide-wind SB (Fig. 2 c), the stiffness of one wind is as follows

$$j = \frac{EH_c}{4\pi^2(1-\mu^2)} \int_{R_H}^{R_h}\int_0^{2\pi} [\left(\frac{rc\sin\varphi}{r^2+c^2}\right)^2 \sqrt{r^2+c^2} + \frac{H_c^2\cdot}{12}((1+\frac{r^2}{r^2+c^2})^2 \frac{\cos^2\varphi}{\sqrt{r^2+c^2}} + 2(1-\mu)\frac{c^4 r^2 \sin^2\varphi}{(r^2+c^2)^3\sqrt{r^2+c^2}}]d\varphi dr \tag{13}$$

where $H_c = H = h$ is wind thickness. Where is the thickness of the coil.

The total rigidity of SB on the length of one wind, consists of the rigidity of the frame and the rigidity of the wind:

$$j_\varepsilon = EJ_{on} / T + j = EJ_{on} / N(1 + jT / EJ_{on}) = E\tilde{J}_\varepsilon / T, \tag{14}$$

where $\tilde{J}_\varepsilon$ is conditional geometric stiffness of the auger part; J_{on} is axial moment of inertia of the frame cross section; $J_{on} = 0,25\pi R_H^4$ for solid frame:, $J_{on} = 0,25\pi(R_H^4 - R_v^4)$ for hollow frame:, where R_v is the inner radius of the frame.

While winding the strip blank on the mandrel fixed in the cartridge, with simultaneous welding of such a blank to the mandrel, the amount of deflection of the mandrel with fixed spiral is determined based on the use of the formula for calculating the cantilever beam:

$$f = Pl^3 / 3E\tilde{J}_\varepsilon + ql^4 / 8E\tilde{J}_\varepsilon = f_1 + f_2, \tag{15}$$

where l is the length of SB; q is running weight load from the action of the mandrel and SB own weights; P is the total force applied to the mandrel when winding the strip blank on the edge; f1 is deflection from the action of the bending force of the strip; f2 is deflection from the weight of the mandrel and spiral.

The bending force of the strip blank is determined by formula [1]

$$P_z = \beta_\sigma H_0(\sigma_{T.0} + \Pi \ln\sqrt{R_h R_H})^4 \sqrt{R_h / R_H}(R_h^2 + 2R_H\sqrt{R_h R_H} - 3R_h R_H) / 3(l + (\mu_p + tg\gamma_p)R_h,$$
$$\text{or} \quad P_z = M_H / \{R_M[l + (\mu_p + tg\gamma_p)R_h]\}, \tag{16}$$

where B_σ is the coefficient that depends on the ratio of the main stresses; $\sigma_{T.0}$ is extrapolated yield strength; Π – linear modulus of strengthening; R_M – coefficient that takes into account the design of the mandrel; R_M =1,05…1,25, μ_p is coefficient of friction between deflection and blank mandrel; μ_0 – coefficient of friction of the strip on the mandrel; γ_p – neutral angle of contact of the roller with the strip blank (determined by the amount of strip shrinkage due to interaction with the roller); l – arm of the bending force application.

The total effort applied to the mandrel

$$P = \sqrt{P_z^2 + P_x^2} = \sqrt{P_z^2 + (P_z tg\gamma_p)^2} = P_z / \cos\gamma_p \tag{17}$$

The magnitude of the running weight load can be determined on the basis of N. L. Narska formula:

$$q = \pi\rho_m \left\{ R_H^2 - R_v^2 + \frac{(H+h)}{2T}\left(\left(\frac{T}{2\pi}\right)^2 \ln\left| \frac{R_h + \sqrt{R_h^2 + \left(\frac{T}{2\pi}\right)^2}}{R_H + \sqrt{R_H^2 + \left(\frac{T}{2\pi}\right)^2}} \right| + R_h\sqrt{R_h^2 + \left(\frac{T}{2\pi}\right)^2} - R_H\sqrt{R_H^2 + \left(\frac{T}{2\pi}\right)^2} \right) \right\}, \tag{18}$$

where ρ_m is the specific weight of the material: ρ_m = 7.8·103 kg/m^3.

For the case of continuous mandrel R_v=0.

The sizes of mandrels should correspond to the sizes of bearing pipes according to GOST 8732-78, GOST 8734-75.

Discussion of the results. Figures 3–5 show the results of calculations of stiffness and deflections of various SB (material of blanks – steel 08kp, E=2.1*10^{5}MPa, $\mu = 0,26$).

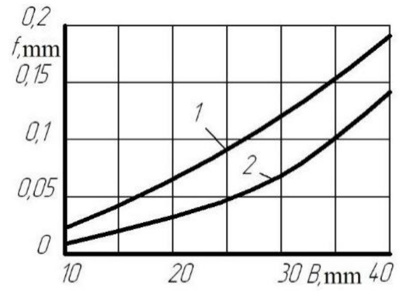


Figure 3. The dependence of the deflection of the helical section of the mandrel with diameter d=40 mm on the width of the strip during strip winding. Fastening of the mandrel in the cartridge with pressed back center: 1 – H_0=2 mm; 2 – H_0=3 mm

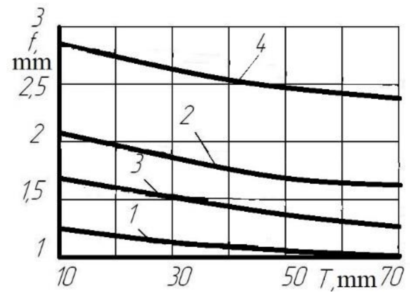


Figure 4. Dependence of the deflection of the screw section of the mandrel on pitch T during winding of the strip with 15 mm width and H0=10 mm thickness on the mandrel with diameter d=30mm: 1 – l=1000 mm, R_v =0мmm; 2 – l=1200 мmm, R_v =0mm; 3 – l=1000 mm, R_v =11mm; 4 – l=1200 mm, R_v =11 mm

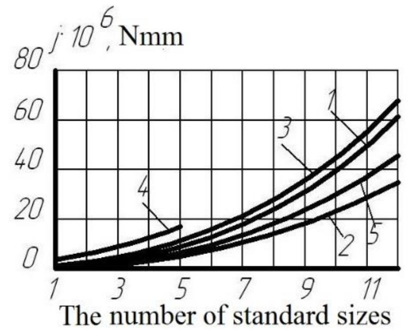


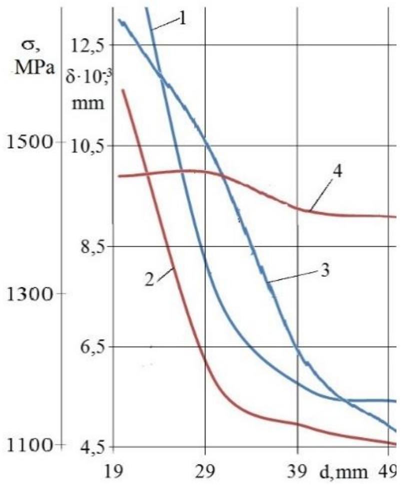
Figure 5. Dependences of stiffness of winds with different sizes of spirals according to GOST 7505-75 for different types of SB: 1 – rolled, which are received by the method of asymmetric compression of strips between rolls; 3 – winded, which are obtained by the method of strips winding by edge on the mandrel; with profile of wind cross section: 2 – rectangular; 4 – hyperbolic; 5 – trapezoidal

From these figures it is evident that the deflection magnitude increases with the increase of strip width and decrease of winding pitch and is the smallest when fastened according to scheme 1 *b* and located within the tolerance range for HF manufacturing. The highest rigidity is characterized by spirals with hyperbolic profile of the wind cross-section, and the lowest – with rectangular. Within the range *B/H* < 25, the AB stiffness is larger than the stiffness of HF obtained by rolling method.

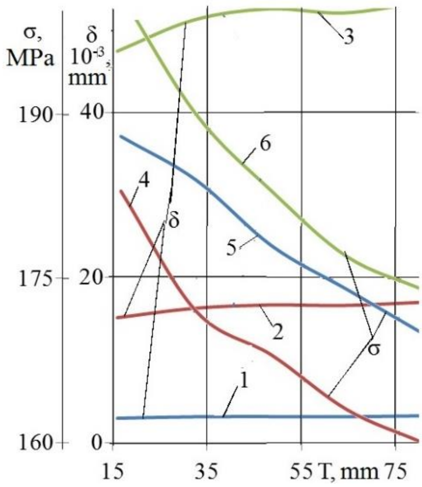
Experimental investigations of AB deformations in the process of their manufacturing by cold winding of strip billets on the mandrels were carried out for two schemes of mandrel fixing: in the chuck with cantilever placement of the mandrel; in the cartridge under pressure by the center of rear headstock. Strip billets made of AISI 1010 steel with the following dimensions of their cross-section profiles 20x1 mm, 15x1 mm on pitch 22 mm and 16 mm respectively were used. The billet with cross-sectional dimensions of 10x15 mm was wound in pitches 15 mm; 30 mm; 50 mm; 65 mm; 80 mm, the mandrel with diameter 30 mm. The billet with cross-sectional dimensions 15x2 mm was wound in pitches 2.5 mm (obtaining the billet with closed winding) on 20 mm mandrel's diameter with different forces P_{pr} (1400 N; 1000 N; 700 N; 350 N) of the billet pre-pressing. The lengths of the mandrels and their ribbed parts were as follows: L_{aug} = 60 mm, at L_{man} = 120 mm; L_{aug} =120 mm, at L_{man} = 240 mm; L_{aug} =180 mm, at L_{man} = 360 mm. Mandrels with diameters 20 mm; 30 mm; 40 mm; 50 mm were used in the investigations.

The magnitude of maximum deflection and stress on the mandrel depending on its diameter, pitch of the wound strip, the length L_{aug} of the ribbed part of the mandrel, at the point when $L_{man} = L_{aug}$ for cantilever mounting of the mandrel and $L_{man} = 0{,}5\ L_{aug}$ for fixing in the chuck with pressed headstock were investigated. The investigations was carried out according to the method described in paper [1].

From Fig. 6 we can see that with the increase of mandrel diameter its deflection decreases. This is caused by both the increase in the moment of inertia of the mandrel cross-section, and the decrease in the bending force and the winding moment. The decrease of the above mentioned force factors is explained by the decrease in the material hardening due to the lower degree of billet deformation.



a



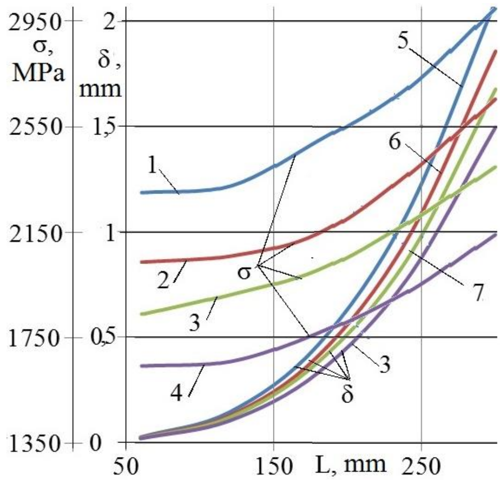
b

Figure 6. Dependences of the magnitude of the maximum deflection of the mandrel and the magnitude of stresses in the mandrel pressed by the pin of the rear headstock, on the diameter of the mandrel *(a)* and pitch *(b)* of the winding in the process of cold manufacturing from steel AISI 1010;
for scheme *a*: length of the mandrel L_{man} = 120 mm, length of the ribbed part of the mandrel L_{aug} = 60 mm, 1, 3 – strip 20x1 mm, T = 22 mm; 2, 4 – strip 15x1 mm, T=16 mm;
for the scheme *b*: parameters of the strip 10x15 mm, the mandrel with diameter d=30 mm:
1,4 – L_{aug} = 60 mm, L_{man} = 120 mm; 2, 5 – L_{aug} = 120 mm, L_{man} = 120 mm; 3, 6 – L_{aug} = 180 mm, L_{man} = 3620 mm; the length of the ribbed part of the mandrel L_{aug} = 60 mm:
1 - strip 20x1 mm, T = 22 mm; 2 – strip 15x1 mm, T = 16 mm

The reduction of stresses on the mandrel (Fig. 6) during winding of the strips with cross sections 20x1 and 15x1 is caused in the first case by larger wind pitch (20%). The increase of the wind pitch results in the increase of mandrel rigidity.

The greatest rigidity of the mandrel is in the case when $T \to \infty$, i.e. when the mandrel is a rod with longitudinal rib (Fig. 7). In addition, the magnitude of stresses is influenced by the length of the smooth spiral part, the stiffness of which is less compared to the part of the mandrel with the winds of SB placed on it. Therefore, a significant reduction in deflection and stress on the mandrel is observed only in the case of winding the strip on the cantilever mandrel. In the case of two-support fixing of the mandrel, the influence of the pitch factor T is insignificant.

It is known, that in the manufacturing of SB with closed winding, the magnitude of force Рзг of strip bending is significantly affected by the amount of pre-compression force Рпр. The increase of the value Рпр, for example from 350 N to 1400 N results in the increase of the bending force of the strip from 1250 N to 1750 N and deflection by 20%. Accordingly, such increase in force factors leads to the increase in the magnitude of stress and deflection (Fig. 8) on the mandrel. While winding the strip on cantilever mandrel with small diameter 20–30 mm, the magnitude of its deflection is 4–5 times greater than in case of winding on the frame, pressed by the rear center.



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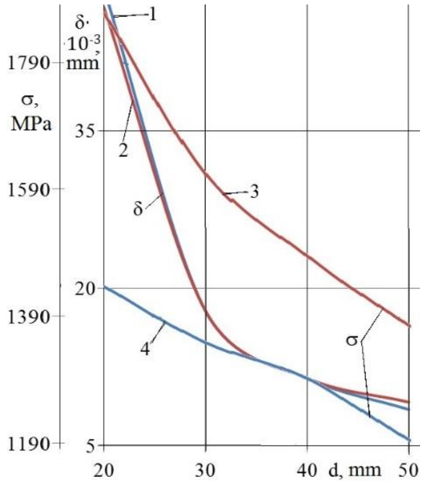
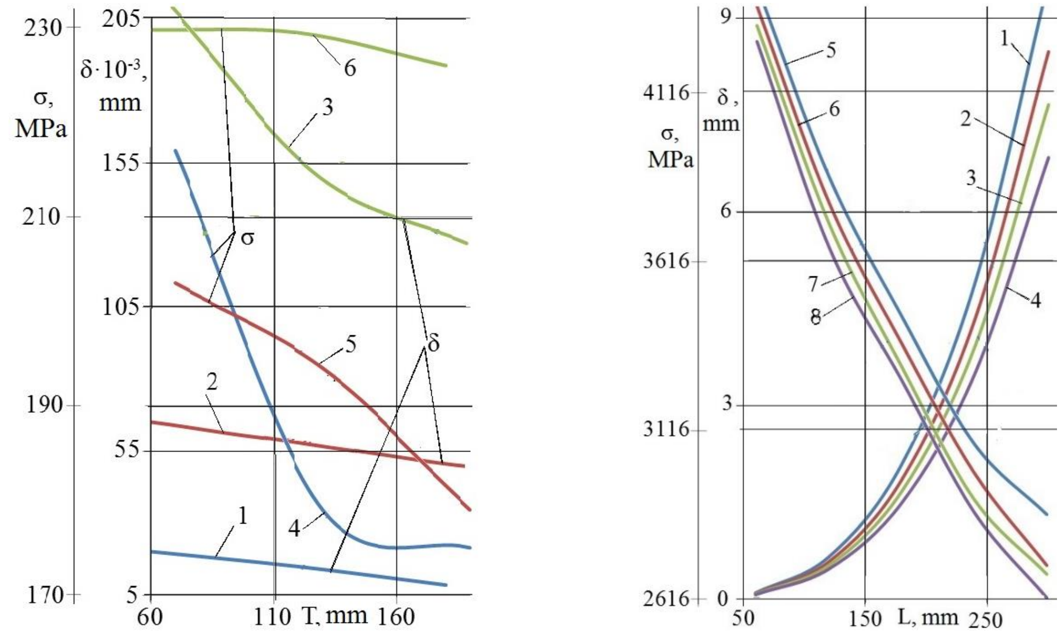


b

Figure 7. Dependences of the deflection of the mandrel and the stress in the mandrel pressed by the pin of the rear headstock on pitch *(a)* and the length of the ribbed part of the mandrel *(b)*, which occur during cold winding of AISI 1010 steel strip; for scheme *a*: cross-section of the strip 10x15 mm, mandrel diameter d= 30 mm and its length L_{aug} = 60 mm: 1 – L_{aug} = 60 mm, L_{man} = 120 mm; 2 – L_{aug} = 120 mm, L_{man} = 240 mm; 3 – L_{aug} = 180 mm, L_{man} = 360 mm; for schemes *b*: auger blank with closed winding, strip parameters 15x2 mm, mandrel diameter d = 20 mm, winding pitch T = 2.5 mm for the magnitudes of the billet pre-pressing force: 1. 5 – P_{pr} = 1400 N, P_{ben} = 1750 N; 2. 6 – P_{pr} = 1000 N, P_{ben} = 1550 N; 3.7 – P_{pr} = 700 N, P_{ben} = 1400 N; 4. 8 – P_{pr}= 350 N, P_{ben} = 1250 N

While using short mandrels with larger diameter (more than 50 mm), the magnitude of the deflections on the cantilever mandrel is greater than in case with mandrels with rear headstock pressing, but the magnitudes of the deflection are placed within one order.

While winding the strip with cross-sectional dimensions 20x1 mm, the magnitude of stresses on the auger blank is greater than winding the strip with cross-sectional dimensions 15x1 mm. This is due to significant increase in bending force of the strip, while the increase in the stiffness of the mandrel due to the increase in the pitch of the wind is negligible (the pitch difference is 6 mm). The use of cantilever smooth mandrels for manufacturing AB with significant length and pitch of the wind is unreasonable. The presence of screw protrusions and depressions on the mandrel for inserting the strip during the process of winding the strip with the rib on the mandrel expands the possibilities of using such equipment due to their increased rigidity compared to smooth frames.



a *b*

Figure 8. Dependence of the magnitude of deflection and stress in the cantilever mandrel on pitch *(a)* and the length of auger part of the mandrel with closed winding *(b)* in the process of cold winding of AISI 1010 steel strip: for option *a*: cross-section of the strip 10x15 mm, mandrel diameter d = 30 mm: 1, 4 – L_{aug} = 60 mm; 2, 5 – L_{aug} = 120 mm; 3, 6 – L_{aug} = 180 mm; for option *b*: cross-section of the strip 15x2 mm, mandrel diameter d = 20 mm, pitch T = 2.5 mm, the magnitude of the pre-pressing force of the billet: 1.5 – P_{pr} = 1400 N, P_{ben} = 1750 N; 2, 6 – P_{pr} = 1000 N, P_{ben} =1550 N; 3, 7 – P_{pr} = 700 N, P_{ben} = 1400 N; 4, 8 – P_{pr} = 350 N, P_{ben} = 1250 N

Conclusions. Analytical dependences for estimating the stiffness of various auger blanks in the processes of their production by winding strip blanks by rib on the mandrel are obtained. This makes it possible to determine the profiles of winds with the highest rigidity and estimate the accuracy of such blanks. The regularities of deflection of the combined auger blank with open and closed windings in different ways of its fixing in the process of cold winding of strip blank by rib on the mandrels are established. The obtained results can be used in the design of technological mandrels and support elements of auger blanks for the processes of their manufacturing based on the use of technological method of winding strips on the rib. According to the current trends in the introduction of computer-integrated technologies into educational process [12], the developed methodology can be implemented using modern software and recommended for implementation in the educational process in training specialists in «Applied Mechanics».

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ДОСЛІДЖЕННЯ ПРОГИНІВ НАВИВНИХ ГВИНТОВИХ І ШНЕКОВИХ ЗАГОТОВОК У ПРОЦЕСАХ ЇХ ВИГОТОВЛЕННЯ

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Резюме. *Отримано аналітичні залежності для оцінювання жорсткості різнопрофільних шнекових заготовок у процесі їх виготовлення способом холодного навивання смугових заготовок ребром на оправу, що дозволило визначити профілі витків із найвищою жорсткістю та оцінити точність таких заготовок. Встановлено закономірності прогину комбінованої шнекової заготовки із відкритою і закритою навивками у різних способах її закріплення у процесі холодного навивання смугових заготовок ребром на оправи. Зокрема показано, що величина прогину зростає зі збільшенням ширини смуги та зменшенням кроку навивки і є найменшою при закріпленні за схемою з підтисканням опорного елемента заднім центром задньої бабки токарного верстата й лежить у межах поля допуску на виготовлення шнекових заготовок. Збільшення питомої висоти витка заготовки ускладнює процес навивання та призводить до значного збільшення силових факторів, що відображається на зростанні величини прогину оправи. При отриманні гвинтових заготовок із закритою навивкою витків збільшення величин зусиль попереднього радіального та осьового підтискання призводять до зростання прогину оправи. Наявність на оправах гвинтових виступів і впадин для вкладання в них стрічки у процесі навивання стрічки ребром на оправу розширює можливості використання такого спорядження завдяки їх підвищеній жорсткості у порівнянні з гладкими оправами. При цьому збільшення кроку витка гвинтової оправи призводить до підвищення її жорсткості. На величину напружень і прогину впливає довжина частини гладкої спіралі, жорсткість якої менша у порівнянні з частиною оправи з розміщеними на ній витками навивної гвинтової заготовки. Відповідно до сучасних тенденцій упровадження комп'ютерно-інтегрованих технологій в навчальний процес, розроблена методика може бути реалізована з використанням сучасних програмних засобів і рекомендована для впровадження в навчальний процес у підготовці фахівців зі спеціальності «Прикладна механіка».*

Ключові слова: *гвинтова заготовка, шнекова заготовка, прогин, навивання.*

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