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RESEARCH OF TECHNOLOGICAL PROCESS OF SCREW TOOLS MANUFACTURING AND CALIBRATING

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Summary. *Equipment for continuous transportation of bulk and granular materials is the basis for complex mechanization of loading-unloading operations, which increase work output and production efficiency. The engineering design for screw tools with variable step manufacturing and calibration has been developed. Both analytical dependencies for determination of strengthened turns unbending efforts and necessary drive torque for screw blanks calibration have been obtained. Graphic dependencies of drive torque changes on turn width and thickness and its angle for 08kp steel have been given.*

Key words: *production process, coiling, calibration, screw blanks*

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Problem setting and the latest research analysis. The mechanisms with screw devices have been widely spread in all branches of economy due to the concentration of different operations in combination with transportation. The main advantages of screw mechanisms (SM) are considered to be the continuous relocation of bulk and granular substances, simple design and reliability, possibility of full automation with regulation and control, cargo transportation along curvilinear trajectories etc.

Currently, the designing and calculations for transport & technological mechanisms are carried out due to typical schemes disregarding the peculiarities and specific features of production.

The popular technological processes (TP) to produce the screw devices based on stripe bending over the mandrel are mentioned in a number of scientific issues of M. Zubtsov [1], E. Popov [2], M. Lysov [3], K. Shevchenko [4], B. Hevko, M. Pylypets [5, 8], V. Romanovskyy, V. Vasylkov [9] and many others. These elaborations are required to provide both waste-free and resourse saving production. In particular, they are screw-shaped profiles and spirals being widely used in modern machine building for maintenance and multifunctional purposes [8]. So the main problem during their creation and substantiation of parameters for the newly made devices, which diversify the technological facilities, is development of substantiation for their parameters during unbending of screw blanks (SB) that were wound in close turns. However, due to the diversity of technological processes, there is a bare necessity of further research and specification of various theoretical and practical parameters.

Research goals. The latter are the elaboration of technological process of screw devices winding into close item and calibrating of screw spirals turns due to given step.

Research project implementation. The device's technological capacities diversification has been put into the basis of production and calibration of the screw elements with given step. The device provides the reliable contact between the blank and holder. It facilitates the waste avoiding and economizing of materials. The application of such device (Figure 1) with the purpose to produce the screw elements with given step decreases the production time and secures high accuracy in outer and inner diameters and step of the screw blank.

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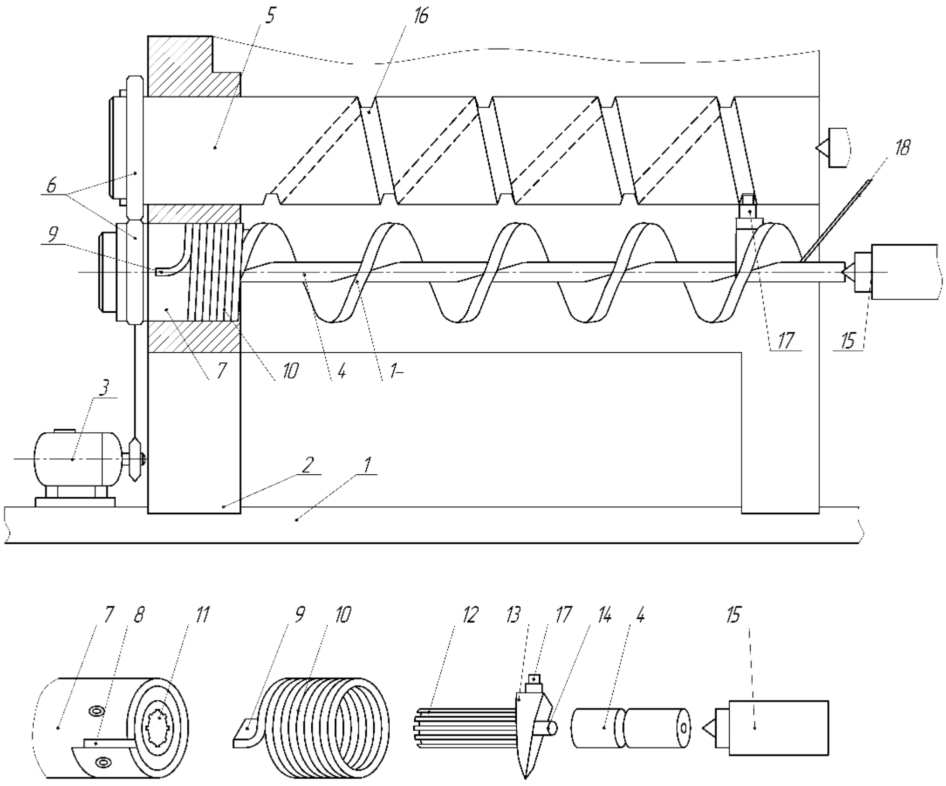

Figure 1. Mechanism for manufacturing and calibrating of screw tools with variable step

With this purpose we designed the device for production and calibration of screw working tools with variable step (Figure 1.), which is represented in the form of case 1, support 2 with electric engine 3 in the lower part that connected to lower screw working shaft 4 and calibrating shaft 5 via gear drive 6. The device consists of immobile case 7 with axial gutter 8 interacting with the ending 9 of screw spiral 10, which is closely wound. In the middle of immobile case 7 there is mounted a slit bush 11 on the bearings that interacts with mobile slit shaft 12.

On the right-hand nose of slit shaft 12 there firmly welded a chock 13 with firmly mounted cylindrical pin 14 on its free nose that interacts with the central hole of screw working shaft 4 with wound screw spiral 10 with invariable step under the chock 13. Another nose of the shaft of screw working tool 4 is firmly pressed against the rear center 15.

The trapezoid slit 16 with variable step, which is stipulated with technical requirements to screw working tool, is made on the outer shaft diameter (caliber in fact). The trapezoid slit 16 interacts with V-type calibrating element 17 that is firmly mounted on the wide chock side 13 on the relatively mobile cylindrical pin.

The device works as follows. After winding of screw blank the spiral 10 with close turns is mounted with unbent nose 8 into slit 9 of cylindrical immobile case 7 and fixed by known way. Further, via the central hole in turns 10 they mount the slit shaft 12 with the fixed chock on its right-hand nose. The cylindrical pin 14 is mounted on the chock’s ending with central hole shaft 4 pressed with rear center 15. The trapezoid calibrating element 17 goes into V-type slit 16 of calibrating shaft 5. During rotation of slit bush 11 with slit shaft 12, chock 13 they make preliminary unbending up to its entire length. The variable step spiral calibration due to technical requirements is made with calibrating element 17 via V-type slit 16 for the next operations. During preliminary calibration the spiral 10 is spread up to entire length of screw working tool shaft. 4.

After calibrating operations they weld the screw spiral 10 to shaft 4 from the right side. Having welded the turn of spiral 10 with electrode 18, they wind in 1 … 3 turns the device according to technical requirements. The next welding is repeated after the next calibration of turns.

That is why; due to the necessity to design the working tools, there is presented the calculation scheme of the device for calibration of screw blank turn on a step for the working tools of conveyors (Figure 2). The winding process can be regarded as bending of wide stripe. The tensioned & deformed condition in these locations is represented as bulk condition of tensions and plane condition of deformations. Due to Figure 1, accounting on contemporary inner bending radius r_1 of the stripe across the whole width of screw blank using the polar coordinate frame with a pole coinciding with center of r_1 radius at the moment of deformation. The equilibrium equation is as follows [1]:

$$\rho \cdot \frac{d\sigma_\rho}{d\rho} + \sigma_\rho - \sigma_\theta = 0, \qquad (1)$$

where σ_ρ – radial tensions, mPa; σ_θ – tangential tensions, mPa.

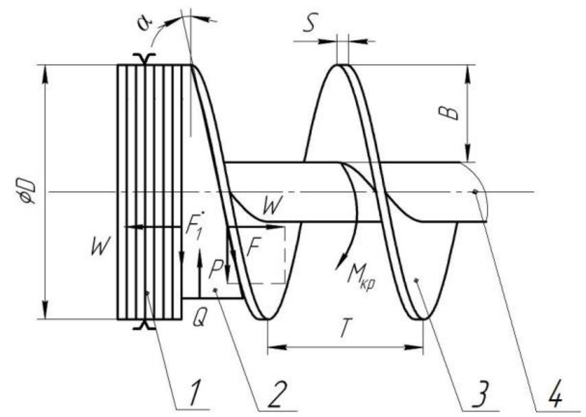

Figure 2. Design model of a mechanism for screw blank turn calibrating per a step:
1 – close-coiled blank, 2 – chock; 3 – screw blanks calibrated turns; 4 – shaft

The equation of plasticity in simplified form due to energy theory under condition σ_ρ and σ_θ are the ultimate main tensions taking into account the reinforcement is [2, 4, 9] (definition for compression area and extension area)

compression area:

$$\sigma_\rho - \sigma_\theta = -\beta \cdot \left(\sigma_{T.0} - \Pi \cdot \ln \frac{\rho}{\rho_n} \right). \qquad (2)$$

extension area:

$$\sigma_\rho - \sigma_\theta = \beta \cdot \left(\sigma_{T.0} + \Pi \cdot \ln \frac{\rho}{\rho_n} \right), \qquad (3)$$

where β – ratio indicating the impact of average main tension σ_z; $\sigma_{T.0}$ – extrapolated fluidity boundary, mPa; Π – linear reinforcement module, mPa; ρ_n – radius of neutral surface deformation, mm; ρ – polar coordinate of bending radius, mm.

Due to the fact that during bending of wide stripe of axial deformation ε_z are equal to zero that is relevant to the condition of plain condition of deformation, the coefficient β is 1,15. The radius of neutral surface deformation is defined with the equation [2, 5]:

$$\rho_n = \sqrt{R_1 \cdot r_1}\,, \tag{4}$$

where R_1 – outer radius of stripe bending along the bending lines, mm.

Having solved the equation system (2), (3), (4) by application of ultimate conditions where extension areas $\sigma_\rho = 0$ at $\rho = R_1$, and for compression area $\sigma_\rho = 0$ at $\rho = r_1$, we will find formulas characterizing the tension distribution σ_ρ і σ_θ relying on material reinforcement [1]:

for extension area:

$$\sigma_\rho = -\beta \cdot \left(\sigma_{T.0} + \frac{\Pi}{2} \cdot \ln \frac{\rho \cdot R_1}{\rho_n^2} \right) \cdot \ln \frac{R_1}{\rho}\,; \tag{5}$$

$$\sigma_{\theta_{\text{stretching}}} = \beta \cdot \sigma_{T.0} \cdot \left(1 - \ln \frac{R_1}{\rho} \right) + \beta \cdot \frac{\Pi}{2} \cdot \left(2 \cdot \ln \frac{\rho}{\rho_n} - \ln \cdot \frac{R_1 \cdot \rho}{\rho_n^2} \cdot \ln \frac{R_1}{\rho} \right); \tag{6}$$

for compression area:

$$\sigma_\rho = -\beta \cdot \left(\sigma_{T.0} + \frac{\Pi}{2} \cdot \ln \frac{\rho_n^2}{\rho \cdot r_1} \right) \cdot \ln \frac{\rho}{R_1}\,; \tag{7}$$

$$\sigma_{\theta_{\text{compression}}} = -\beta \cdot \left(\sigma_{T.0} \cdot \left(1 + \ln \frac{\rho}{r_1} \right) + \frac{\Pi}{2} \cdot \left(2 \cdot \ln \frac{\rho_n}{\rho} + \ln \frac{\rho_n^2}{\rho \cdot r_1} \cdot \ln \frac{\rho}{r_1} \right) \right). \tag{8}$$

Curvature radius of unbent turn was determined on the basis of preliminary research [3]:

$$\rho_0 = \frac{T}{\dfrac{4k^2(1+n)}{n} \cos^2 \varphi_0 \cos \delta - 4k \left(\cos \varphi_0 \right)^{\frac{2}{1+n}} \left[\dfrac{\sqrt{2}}{4} B(p', q') - \Psi_2(k, \varphi_0) \right] \sin \delta}\,, \tag{9}$$

where T – turns step, mm; k, φ_0 – ellipsis parameters; n – constant of approximating curve for material reinforcement of screw blank; δ – unbending force angle, degree; $B(p', q')$ – Gamma-function; $\Psi_2(k, \varphi_0)$ – ellipsis integral function.

Drive torque and axial force necessary for winding of the spiral upon the holder depends on holder's design and is determined with correlation [5]

$$M_{\text{tor}} = k_m P \left[l + (\mu_p + tg\gamma_p) R \right], \tag{10}$$

$$N = (\mu_p + \mu_0 + tg\gamma_p) P\,, \tag{11}$$

where P – radial force on slope section of chock, H; k_m – coefficient taking into consideration the holder's design; l – force lever arm for winding; γ_p – bending angle; R – outer radius.

The turn unbending process can be associated with bending of wide stripe. The tension & deformation condition in these areas is presented as bulk tension condition and flat deformation condition. Due to Figure 2 and contemporary inner bending radius r_1 of the stripe across the whole width of screw blank, we will use the polar coordinates with the pole coinciding with r_1 radius center at the deformation moment.

Analytical dependency for definition of turn unbending momentum M_{bend} accounting on reinforcement can be determined as an integral sum of momentums created by tangential tensions σ_θ:

$$M_{bend} = \int_{\rho_н}^{R_1} \sigma_{\theta stretching} \cdot \rho d\rho + \int_{r_1}^{\rho_н} \sigma_{\theta compression} \cdot \rho d\rho . \tag{12}$$

$$M_{bend} = \beta \cdot B \cdot \left[\sigma_{T.0} \cdot \frac{S^2}{4} + \Pi \cdot \left(\frac{R_1^2 + r_1^2}{4} \cdot \ln \sqrt{\frac{R_1}{r_1}} - \frac{R_1^2 - r_1^2}{8} \right) \right]. \tag{13}$$

Analytical dependency for definition of axial forces of turn's deformation is determined due to formula [7]:

$$W = \frac{2\beta \cdot B \cdot \left[\sigma_{T.0} \cdot \frac{S^2}{4} + \Pi \cdot \left(\frac{R_1^2 + r_1^2}{4} \cdot \ln \sqrt{\frac{R_1}{r_1}} - \frac{R_1^2 - r_1^2}{8} \right) \right]}{D}. \tag{14}$$

The required drive torque for calibration of screw blank per a step is determined as follows:

$$M_{tor} = \beta \cdot B \cdot \left[\sigma_{T.0} \cdot \frac{S^2}{4} + \Pi \cdot \left(\frac{R_1^2 + r_1^2}{4} \cdot \ln \sqrt{\frac{R_1}{r_1}} - \frac{R_1^2 - r_1^2}{8} \right) \right] \left[\mathrm{tg}(\alpha + \varphi) + \mathrm{tg}\,\varphi_1 \right], \tag{15}$$

where φ_1 – friction angle on the vertical plane of chock, degree; φ – friction angle on the slope plane of chock, degree.

On the basis of formula (15) there were built the graphic dependencies between drive torque for calibration of screw blank per a step and width and thickness of a turn and angle of chock for 08kp steel (Figures 3-5).

The graph show that the increase of width and thickness of a turn and angle of chock results in growth of drive torque for calibration of screw blank per a step.

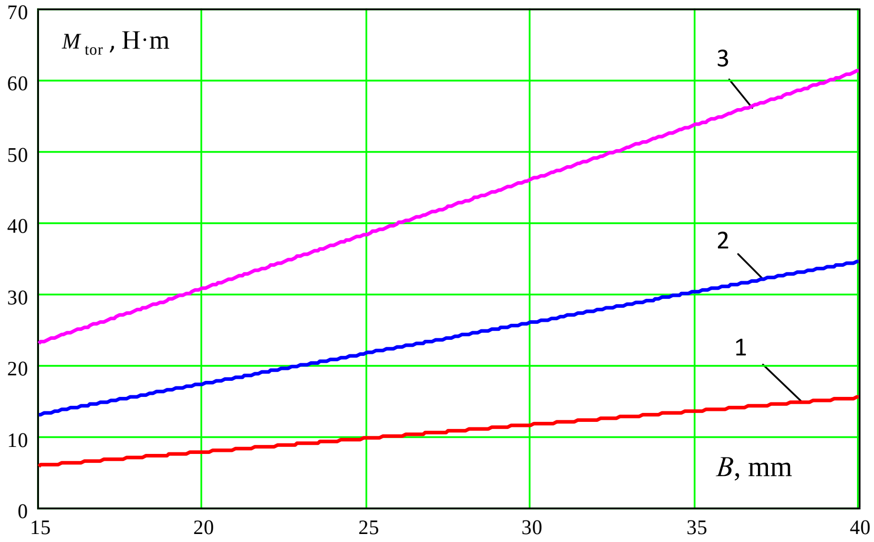

Figure 3. Graphs of dependencies of drive torque for screw blank step calibrating on turn width (08kp steel) α = 20 grad: 1 – S = 2 mm; 2 – S = 3 mm; 3 – S = 4 mm

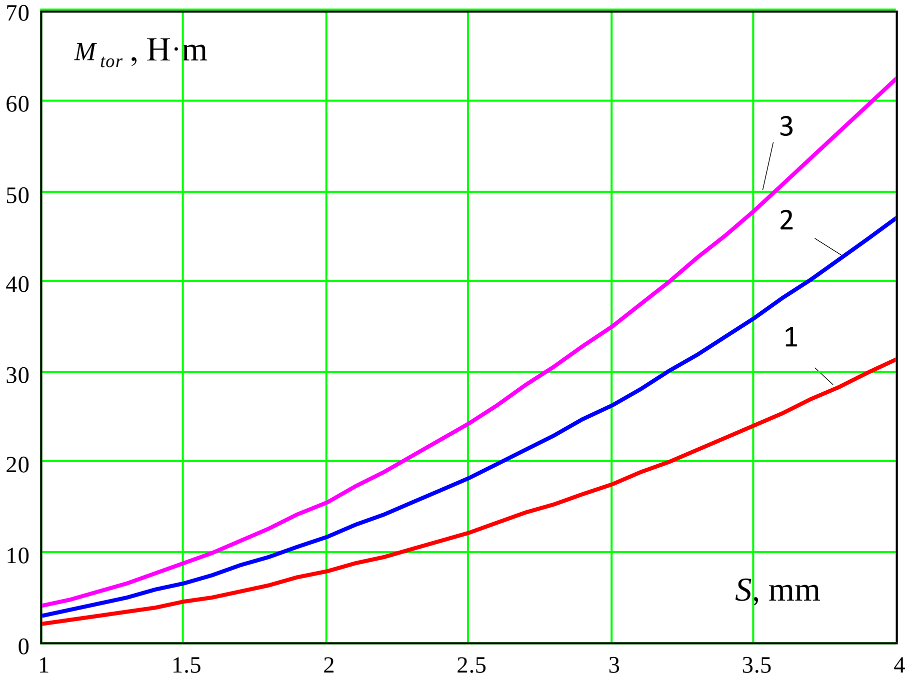

Figure 4. Graphs of dependencies of drive torque for screw blank step calibrating on turn thickness (08kp steel) α = 20 grad: 1 – B = 20 mm; 2 – B = 30 mm; 3 – B = 40 mm

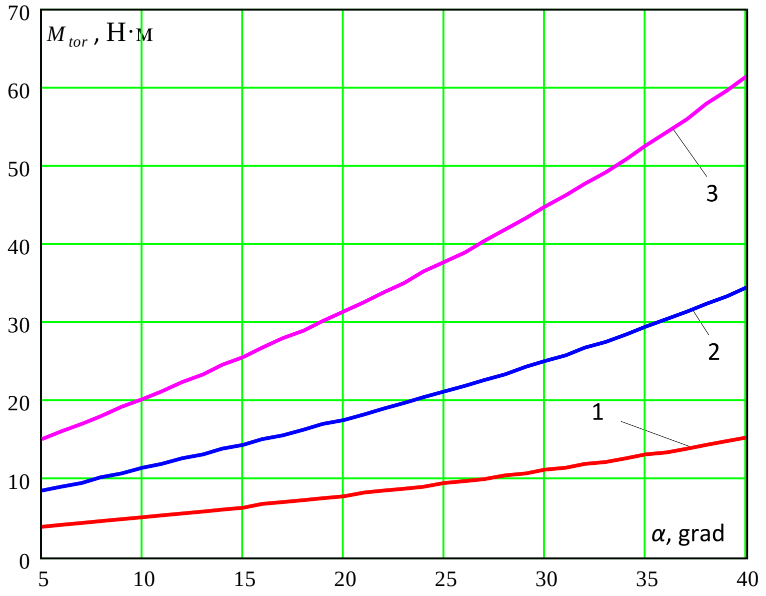

Figure 5. Graphs of dependencies of drive torque for screw blank step calibrating on wedge angle (08kp steel) α = 20 grad: 1 – S = 2 mm; 2 – S = 3 mm; 3 – S = 4 mm

Conclusions:

1. The application of newly designed device for calibration and production of screw working tools with variable step provides and increase of production output, minimization of material and energy consumption. It also diversifies a range of machines and mechanisms as well as their functional capacity.

2. There were spotted functional dependencies to determine the required taut momentum for calibration as well as the plasticity equation due to energy theory accounting on reinforcement and the dependency to determine the axial force of turns' deformation.

3. On the basis of suggested functional dependencies the authors built the graphs of changes in drive torque value during calibration of turns per a step depending on width and thickness of the spiral as well as on device chock's angle.

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ДОСЛІДЖЕННЯ ТЕХНОЛОГІЧНОГО ПРОЦЕСУ ВИГОТОВЛЕННЯ І КАЛІБРУВАННЯ ГВИНТОВИХ РОБОЧИХ ОРГАНІВ

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Резюме. *Технічні засоби неперервного транспортування сипких і зернистих матеріалів є основою комплексної механізації завантажувально-розвантажувальних робіт, які підвищують продуктивність праці та ефективність виробництва. Розроблено конструкцію пристрою для виготовлення і калібрування гвинтових робочих органів зі змінним кроком. Отримано аналітичні залежності для визначення зусилля розгинання витків зі зміцненням, а також необхідний крутний момент на приводі для здійснення калібрування гвинтових заготовок. Представлено графічні залежності зміни величини крутного моменту на приводі від ширини і товщини витка та його нахилу для сталі 08кп.*

Ключові слова: *технологія виготовлення, навивання, калібрування, гвинтові заготовки.*

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