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♦

СЕРИЯ ГЕОЛОГИИ И ТЕХНИЧЕСКИХ НАУК

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INVESTIGATION OF THE KINEMATICS OF ROLLING RIBS AND PIPES ON A CONTINUOUS RADIAL-SHIFTING MILL OF A NEW CONSTRUCTION

Abstract. When using a continuous cast piece to press bars or pipes in a new mill, the deformation must be carried out in the most efficient way, so that a better structure of the metal can be obtained. For a new continuous pressing mill, a possible solution to this problem is to use helical rolls with rational geometric dimensions of the protrusions and hollows. The use of helical rolls with rational sizes of protrusions and hollows will intensively deform the metal of the workpiece within the required reduction of the workpiece. In the study of kinematics of pressing, helical rolls with different sizes of protrusions and hollows were used. Their use made it possible to establish the dependence of the rate of metal yield from the deformation center on the technological regimes of deformation in helical-shaped rolls and to determine the more effective geometric dimensions of the protrusions and hollows of these rolls. It is shown that the deformation of the metal during rolling on the radial-shear mill is realized with sliding of the workpiece relative to the rolls. Slip occurs due to the discrepancy between the speed of the screw movement of the workpiece in the area of deformation of the speed of rotation of the rolls. The quality of steel products depends on the magnitude of sliding, as well as other technical and economic indicators of production. It is established that when rolling on a radial-shear mill, the speed of the workpiece movement is less than the speed of the rolls. The kinematics of the process is analyzed analytically and formulas are derived to determine the rate of roll slippage relative to the workpiece in the zones of the hollow of the workpiece.

Keywords: helical-shaped rolls, matrix, process kinematics, rod, workpiece, slippage, tangential and axial components of slip and velocities.

Introduction. Rods and pipes are widely used in all industries. They are used, both in the form of finished products, and in the form of semi-finished products for the production of a number of metal products. It should be noted that at present there is a significant interest in ponds and pipes, which has ultrafine-grained (UFG) or nanocrystalline (NC) structure. This is due to the unique physical and mechanical properties of such materials, which are significantly higher than the similar properties of coarser polycrystalline materials [1-6].

One of the most promising ways to obtain a UFG or NC structure in metallic materials is the use of severe plastic deformation (SPD), when a combination of nonmonotonic and intense deformation breaks down the metal structure [1-6]. When using a nonmonotonic SPD, without changing the shape and geometric dimensions of the workpiece, the angle between the directions of deformation is changed consequently by 90° and 180°. Such deformation leads to the development of macro-shear deformations along its cross-section, which contributes to the intensive generation of new dislocations, the evolution of the dislocation structure, and the rearrangement of the small-angle boundaries of the structure fragments into high-angle structures [7]. Particularly widely used is the method of equal-channel angular (ECA) pressing [4-6]. It should be noted that to date, none of the methods of SPD, including ECA-pressing, does not allow obtaining industrial products that are acceptable in shape and size [7]. First of all, this concerns the possibility of structuring metal in long products, such as bars, pipes and wires.

Of the SPD methods that allow to obtain long-length products with significant changes in microstructure and mechanical properties, it is necessary to note the cross-screw rolling, or rather its appearance, singled out by its authors in a separate way with the name "Radial Shear Rolling" (RSR) [8-12]. RSR is defined as a special case of stationary helical rolling in the region of large feeding angles (16–18 deg, and more), in rolls with special calibration for deformation of continuous workpieces of constant cross-section.

At the heart of the RSR method is the trajectory control of the motion of the deformable metal [9,13]. In the focus of deformation, a helicoidal outflow of metal is created with the braking of the outer layer of the preform and the acceleration of the internal layer. In this case, in the outer layer each element undergoes compression deformation along the radius of the workpiece and the direction of flow (along the screw path). Multidirectional flows cause intensive shearing movements in the volume of rolled metal, which leads to a considerable grinding of the structural structure. The metal acquires a characteristic finely dispersed structure that is practically not available for other stationary methods of metal processing. In terms of its morphological pattern, structure and properties, the metal after the RSR becomes a material of new quality. There is a complex increase and stabilization of the physico-mechanical and service properties of the metal at a level exceeding the traditional properties of the material [11].

In terms of the overall structure, the RSR mills are identical to the helical rolling mill used for the production of seamless hot-rolled pipes [13]. The main difference between these technological processes is that during the production of pipes, a "loosening" of the central zone of the circular billet (pipe piercing) is created, and during the process of the RSR, the metal of the billet is consolidated throughout the cross section. The theory, technology and equipment for the implementation of the RSR process are presented in [10-12].

The first industrial tests of radial-shear rolling technology were carried out at the Verkhne-Saldinsky metallurgical production association [11]. Using the results obtained, the RSR-130 radial shear rolling mill was designed and put into operation, designed to produce high-quality bars of titanium alloys. The design of the mill allows for reverse rolling. The working cage of the RSR-130 is made in the form of a cast die-cast frame, in cylindrical bores at which the drums with rigidly fixed roller assemblies are placed at an angle of 120°. The distance between them is changed by moving the drums into the guide rails by means of the roll setting mechanism. The rotation of the rolls to the required feed angle is achieved by rotating the drums in the cylindrical bores of the frame by the action of the rotation mechanisms of the drum. In the working position, the lid adjoins the base of the frame with support surfaces and is pressed with a tie, ensuring the integrity and high stiffness of the frame together with the hinged connection and screed.

As a way of conducting transshipment in the line of the RSR-130 mill, a scheme for changing the rolls is provided by tilting the lid of the stand with the drum in it [12]. When transshipment, the lower rollers with rolls openly located at the bottom of the frame are replaced by a crane. To replace the upper drum with the roller, a special stand is used.

It should be noted that the RSR mill consists of two stands [12]. The roughing stand works in reverse mode. It produces 9-11 passes with single draw coefficients of 1.15–1.25. Such a regime excludes the possibility of deformation heating, since the temperature range of deformation of titanium alloys is rather narrow. The maximum diameter of the blank for the roughing stand is 160, and the minimum rolling diameter after rolling is 75 mm. The design of the finishing stand is similar to roughing. It produces a single pass and ensures high accuracy of the produced bars, minimal curvature and a smooth surface. The maximum diameter of the roll for the finishing stand is 110, and the bar after rolling is 65 mm. That is, the deformation capabilities of the roughing stand in this case are not fully used.

The rod produced in the RSR-130 mill with a diameter of 75–90 mm is fed to the longitudinal rolling mill 450 and rolled onto bars of 18–65 mm in diameter [12]. The resulting bars have a homogeneous globular metal structure.

In work [12] the technical characteristics of working stands of the RSR are presented. On the largest of them, RSR-500 uses a maximum diameter 450 billet and a minimum diameter of 120 mm is rolled in a roughing mill and 150 and 90 mm respectively in a finishing stand. The rough cage is reversible, several passages are made in it, in the finishing is one pass.

Thus, the disadvantage of RSR mills is the impossibility of rolling bars by continuous mode, the relatively complex design of equipment and the use of a large number of passes to produce bars with precise geometric dimensions and ultrafine-grained structure.

In the present work, a new combined method for creating a stable submicrocrystal structure is proposed: intense plastic deformation by the method of radial shear rolling with a combination of pressing (figure 1) [14].

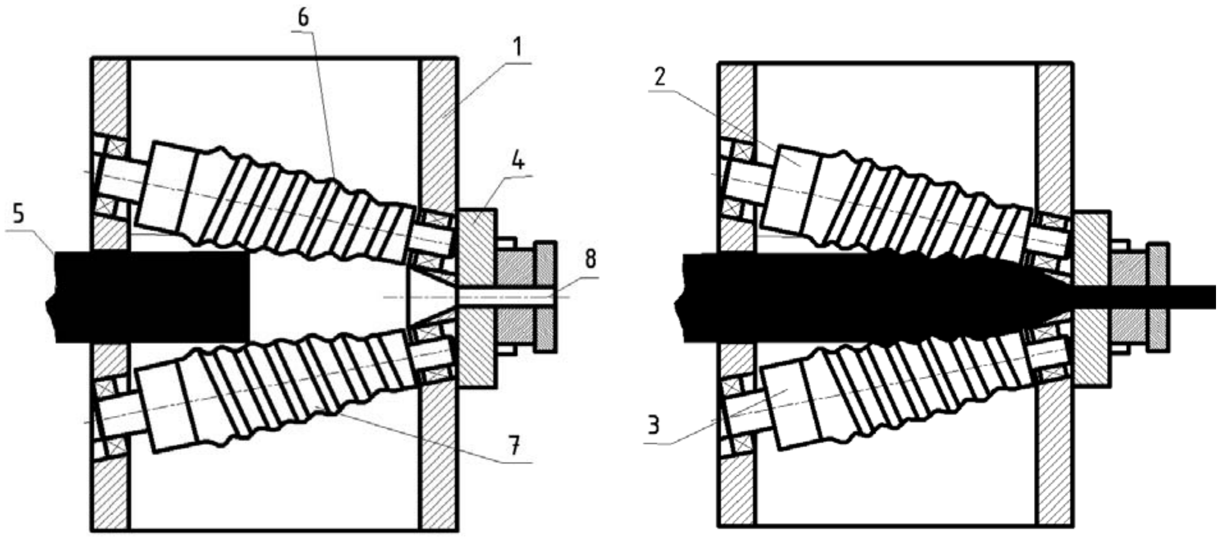

Figure 1 – Device for continuous pressing of rods: 1 - working stand,
2 and 3 - rolls; 4 - matrix; 5 - blank; 6 and 7 - are projection sand hollows of the rolls; 8 - aperture of a pressmatrix

The device for continuous pressing of rods comprises a main drive, a work stand, rolls rotating in one direction and a die. The rolls have smooth and undulating cone-shaped gripping and crimping portions, respectively, and calibrating cylindrical portions. The protrusions or hollows of wavy cone-like sections having the same width and corresponding height or depth are made along a helical line with an angle between the tangent to the helical line and a line passing through the point of tangency along the generatrix perpendicular to the base of the roll equal to 45° to 60°.

The rods are pressed in the following way. The workpiece is fed into the gap between the rolls, and is gradually deformed by the protrusions and valleys of corrugated cone-shaped areas. With this deformation, the workpiece rotationally translates in the direction of rolling and extruded through the aperture of a press matrix.

The use of this method and the pressing device ensures the rolling of the bars by a continuous mode, efficient grinding of the metal structure throughout the cross section of the workpiece due to the development of shear deformations and reduction of the rolling force. Effective grinding of the structure creates the conditions for obtaining high-quality products.

The purpose of the work is to study the kinematics of the deformation process and physical and mechanical phenomena in the process of continuous pressing of rods on a new plant and to obtain new scientific knowledge about the laws of the mechanics of rolling processes in screw-like rolls, depending on the specific features of the technologies used and the design of the tool, the development of techniques for searching for effective deformation modes, ensuring the production of quality rods.

Materials and the method of the experiment. When using a continuous cast piece for pressing bars or pipes on a new mill, the deformation must be carried out in the most efficient way so that a better structure of the metal can be obtained. For a new continuous pressing mill, a possible solution to this problem is to use helical rolls with rational geometric dimensions of the protrusions and valleys. The use of helical rolls with rational sizes of protrusions and valleys will intensively deform the metal of the workpiece within the required reduction of the workpiece. To determine the effective geometric dimensions of the protrusions and cavities of these rolls, the kinematics of the process of pressing the rods on a new mill was investigated.

It is known [15-17] that when the circumferential speed of the circular roll stock preparation is exceeded, rolling is carried out ahead of time, therefore, η > 1, and vice versa, when the circumferential speed of the peripheral speed rolls is exceeded, the rolling stock is lagged, therefore, η < 1.

It should be noted that when rolling ahead and behind, the flow of metal along the roll surface is carried out with sliding [16,17]. In this case, the slip, appearing when rolling in screw-like rolls ahead of time, does not affect the quality of the rods. However, when rolling in screw-like rolls with a lag in the bars, surface and internal defects may appear.

In general case the slip value can be determined by the speed coefficient during rolling in helical rolls in the absence of axial movement of the workpiece [15, 16]:

$$\eta_i = \frac{\upsilon_i}{\upsilon_i},$$

where υ_i - circumferential velocity of the corresponding workpiece surfaces; υ_i – circumferential roll speed corresponding to these surfaces.

It should be emphasized that the lower the speed coefficient, the greater the slip between the workpiece and the rolls [17].

The circumferential velocity of any point on the surface of a screw-like roll of diameter D_i can be determined from the formula [15, 16]:

$$\upsilon_i = \frac{\pi \cdot D_i \cdot n}{60}, \quad (1)$$

where n – rotational speed.

When investigating the kinematics of the radial shear rolling process, it is necessary to take into account the position of the helical rolls with respect to the rolling axis, i.e., the feed angle β. In this case, it is necessary to emphasize that the rotational-translational movement of the preform in the deformation region is divided into tangential and axial components [16-18]. The tangential components of the speed of the roll impart a rotational motion to the workpiece, the axial components are translational motion.

It has been established [16, 17] that the tangential and axial components of the slip more significantly affect the productivity of the process, the surface defects of the rods, and the intensity of the deformation effect of the rolls on the metal structure. Consequently, the tangential and axial components of the slip, respectively, influence the study of the structure of the peripheral and axial zones of the workpiece. With radial shear rolling, the tangential and axial velocity components are used to estimate the tangential and axial slip components. With the increase in these coefficients, the quality of the rod surface is increased. For the quantitative determination of the tangential and axial components of the slip in any section of the deformation center:

$$\eta_{\tau i} = \frac{\upsilon'_{\tau i}}{\upsilon_{\tau i}}, \quad (2)$$

$$\eta_{oi} = \frac{\upsilon'_{oi}}{\upsilon_{oi}}, \quad (3)$$

where $\eta_{\tau i}$, η_{oi} – coefficients of tangential and axial velocity components at different points of the workpiece surface; $\upsilon'_{\tau i}$, υ'_{oi} and $\upsilon_{\tau i}$, υ_{oi} – tangential and axial velocity components at various points of the surface of the workpiece and the roll.

When studying the kinematics of radial shear rolling, the velocity components at various points of the rod surface are usually determined by the following formulas [17]:

$$\upsilon_{\tau i} = \upsilon_i \cdot \cos\beta; \quad (4)$$

$$\upsilon_{oi} = \upsilon_i \cdot \sin\beta. \quad (5)$$

Using the law of constancy of seconds volumes [15], we express the axial rolling speed in the helical-shaped rolls in the examined cross-section through the bar speed at the exit from the deformation center.

The condition of the constancy of the seconds volumes for rolling in screw-like rolls can be written in the form:

$$\upsilon_{i,0}F_{i,0} = \upsilon_{i,1}F_{i,2} = \upsilon_{i,2}F_{i,2} = \upsilon_{i,3}F_{i,3} = ... = \upsilon_{i,k}F_{i,k}, \quad (6)$$

where $\upsilon_{i,j}$ – axial flow velocities of the workpiece metal in the depressions or protrusions of the screw-like roll; F_{ij} - cross-sectional area of the workpiece, deformed in the corresponding sections of the screw-like roll and at the exit from the deformation center; $\upsilon_{ik}F_{ik}$ - the axial velocity and cross-sectional area of the workpiece at the exit from the deformation center, respectively.

From (6) we obtain the following formula:

$$\upsilon_{i,j+1} = (\upsilon_{i,j}F_{i,j})/F_{i,j+2} = \upsilon_{i,j}\cdot\mu_{ij},$$

where μ_{ij} – coefficient of drawing the workpiece, deformable in the corresponding section of the screw-like roll.

It should be noted [15], that for any point lying on the surface of a helical-shaped roll and located in some section remote from one of the ends of the rolls, we can write the following equations (without gliding):

- circumferential speed of the roll:

$$\upsilon_{xв} = \omega_в \cdot R_x, \quad (7)$$

where R_x – the radius of the roll in the examined section; $\omega_в$ – angular velocity of the roll (without slip);

- circumferential rotational speed of the workpiece at the feed angle β:

$$\upsilon_{тз} = \upsilon_{xв}\cdot\cos\beta = \omega_в\cdot R_x\cdot\cos\beta; \quad (8)$$

- axial billet speed at feed angle β:

$$\upsilon_{oз} = \omega_в R_x\cdot\sin\beta; \quad (9)$$

- the angular velocity of the billet in the considered section (without slip):

$$\omega_з = \omega_в\cdot\cos\beta(R_x/r_x), \quad (10)$$

where r_x − radius of workpiece in the examined section.

In operation, the angle of elevation of the helical line β'of the screw-like roll was used as an additional parameter in determining the kinematic conditions of the deformation process in the mill:

$$tg\beta' = \frac{S}{\pi \cdot d},$$

where S – pitch of helix; d – diameter of the workpiece.

The values of S and d were determined by specifying the dimensions of the screw line on the helical-shaped rolls. The speeds of the translational and rotational motion of the workpiece during the motion along the helical line were determined, using the relations (2) - (5) will be equal to:

$$\upsilon'_{oi} = \upsilon_i \cdot \eta_в \cdot \sin\beta' = \eta_{oi}\upsilon_{oi} = \cdot\eta_{oi} \cdot \upsilon_i \cdot \sin\beta; \quad (11)$$

$$\upsilon'_{тi} = \upsilon_i \cdot \eta_в \cdot \cos\beta' = \eta_{тi}\upsilon_{тi} = \cdot\eta_{тi} \cdot \upsilon_i \cdot \cos\beta, \quad (12)$$

where $\eta_в$, – coefficient of speed along the screw line of the helical roll.

From relations (11) and (12), we can establish the following relationship between the angles β and β', which can later be used to determine the tangential velocity coefficient:

$$tg\beta' = \frac{\eta_{oi}}{\eta_{тi}} tg\beta \quad \text{or} \quad \eta_{тi} = \eta_{oi}\frac{tg\beta}{tg\beta'}. \quad (13)$$

In the method of continuous pressing, the extrusion of metal through the die aperture is effected by contact friction of the rotating screw-like rolls formed on the contact surface and by the deformable bar stock. In this connection, the value of the contact area of the workpiece with the tool largely determines the pressing pressure, the torque in the screw-like rolls and the power of the electric drive of the installation, etc. When two (3) rotating rolls are grasped by the bar stock, it is crimped and moved along the rolls due to its rotational and translational motion. After this, the metal is completely filled with the protrusions and hollows of the helical rolls and the growth of the contact area between them until the moment of reaching the forces of active friction sufficient to extrude the metal into the channel of the matrix.

Therefore, the gripping zones in the initial stage of deformation should provide the pressure necessary to completely fill the protrusions and hollows of the helical rolls and create pressure for metal extrusion.

As noted above, when pressing the bars, problems may arise due to the creation of insufficient pressure to extrude the metal and the poor quality of the products due to surface defects and the appearance of cracks on the surface of the workpiece. One of the reasons for the reduction in pressure and the formation of defects is the slippage of the working surface of the rolls relative to the compressible workpiece.

In order to determine the slippage of the roll relative to the workpiece and to identify the most effective deformation mode and the tool design at which minimal slip is observed, using the procedure given in [19], the kinematics of the deformation process using a new continuous pressing device was researched.

When the workpiece is deformed and pressed through the matrix by rotating rolls, the workpiece performs translational and rotational motion (figure 2). It is assumed that during rolling by screw-like rolls, the corresponding sections of the workpiece 1 rotate at an angular velocity ω_i, and the sections of the rolls 2, that are corresponded to these sections of the workpiece, have an angular velocity ω_{1i}. At the same time, in the corresponding sections of the workpiece, there are circles with a radius r_{oi} and corresponding radii R_{oi} on the roll, where the linear velocities of the workpiece and rolls υ_i are the same.

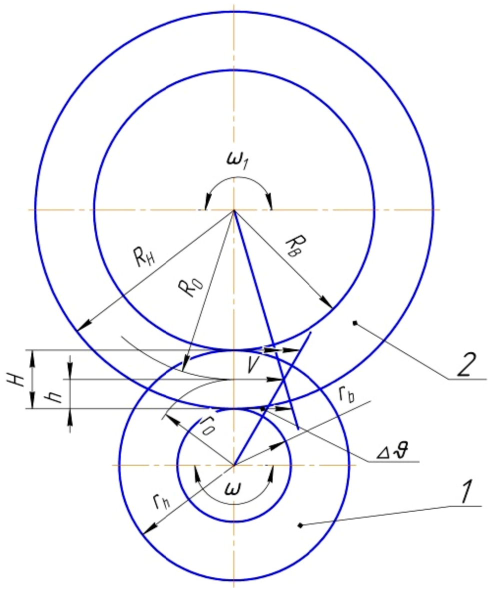

Figure 2 – Scheme for calculating the kinematics of the rolling process in helical-shaped rolls

In this case, the angular velocities of the workpiece and rolls in the corresponding sections can be determined by the formula:

$$\omega_i = \frac{\upsilon_i}{r_{oi}}, \quad \omega_{1i} = \frac{\upsilon_i}{R_{oi}}. \tag{14}$$

The points of the metal of the workpiece located in the hollow of the rolls have the following linear velocity:

$$\upsilon_{вз.i} = \omega_i \cdot r_{вi} = \frac{r_{вi}}{r_{oi}} \upsilon_i. \tag{15}$$

The points on the projecting roll surface have the following linear velocity:

$$\upsilon_{нв.i} = \omega_{1i} \cdot R_{Hi} = \frac{R_{Hi}}{R_{oi}} \upsilon_i. \tag{16}$$

Slippage of the workpiece and the roll in the corresponding sections characterize the following difference in speeds:

$$\Delta V_i = \upsilon_{нв.i} - \upsilon_{вз.i} = \left(\frac{R_{Hi}}{R_{0i}} - \frac{r_{вi}}{r_{oi}} \right) \cdot \upsilon_i. \tag{17}$$

In this case, the relative rate of slippage in the hollows of the workpiece can be determined from formula:

$$\vartheta_i = \frac{\Delta V_i}{\upsilon_i} = \frac{R_{Hi}}{R_{oi}} - \frac{r_{вi}}{r_{oi}}. \tag{18}$$

On the basis of the analysis of the above formulas, we found that the slippage of blanks relative to the rolls depends on the position of the radii r_{oi}andR_{oi} of the circles, where the velocities are the same. The position of these circles depends on the shape of the hollows of the workpiece, the friction value, the temperature of the workpiece and rolls, and other factors. The locations of the circles were estimated using the coefficient.

$$k_i = \frac{h_i}{H_i}, \tag{19}$$

where h_i – the distance from the hollow of the workpiece to the point on the workpiece and the roll with identical speeds in the corresponding sections; H_i – the height of the workpiece protrusion in the corresponding sections.

In this case, the relative rate of slippage in the corresponding section can be determined from formula:

$$\vartheta_i = \frac{R_{Hi}}{R_{Hi} + k_i \left(R_{Hi} - R_{вi} \right)} - \frac{r_{нi}}{r_{вi} + k_i \left(r_{нi} - r_{вi} \right)}. \tag{20}$$

Results and discussion. In the study the calculation of the relative slip velocity in the valley of the rolls was performed. At the same time, the coefficient «*k»* was varied in the range of 0.3–0.8. Table and figure 3 present results of the calculations.

Analysis of the results shows that the relative slippage speed of the workpiece relative to the rolls depends on the coefficient *k*. With an increase of *k*, the relative speed of slip also increases. The calculated results showed that the lower the relative slip speed, the better the conditions for extruding the metal of the workpiece and the probability of cracks and peeling on the surface of the pressed bars decreseases.

The results of calculating slip during rolling in helical rolls have shown that tangential and axial slip components are not very sensitive to the change in technological factors and mainly depend on the angle of rise of the helix line β' or the angle between the tangent to the helix and the line passing through the

Relative speed of sliding during rolling by screw-like rollers

k	$r_в$, mm	r_H, mm	$R_в$, mm	R_H, mm	r_0, mm	R_0, mm	ϑ,
0.3	15	24	71	80	17.7	73.7	0.476048
0.4	15	24	71	80	18.6	74.6	0.531868
0.5	15	24	71	80	19.5	75.5	0.580744
0.6	15	24	71	80	20.4	76.4	0.623652
0.7	15	24	71	80	21.3	77.3	0.661406
0.8	15	24	71	90	22.2	78.2	0.694684

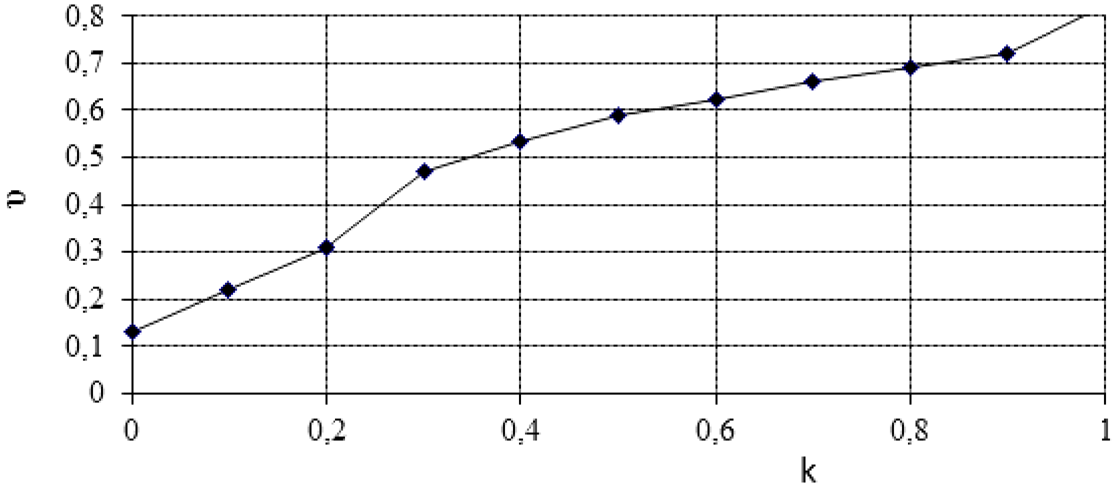

Figure 3 – Dependence of the relative slip velocity on the coefficient *«k»* when pressing by screw-like rollers

point of tangency along the generatrix perpendicular to the base felling. When the feed angle is not more than 1° and the helix line is not more than 45°, these component slides have equal values. As the angle of ascent decreases, the tangential component increases, and the axial component decreases. The reason for this distribution of tangential and axial slip components is the predominant metal flow along the valleys of the helical tool.

Various design and technological possibilities of the device for continuous pressing of rods are reflected in the kinematic conditions of deformation. Thus, for the considering device with screw-like rolls of tangential and axial velocity components at different points of the surface, the workpieces are equal at a feed angle of not more than 1° and lifting of the screw line 45°. As the angle of ascent decreases, the tangential velocity component increases, and the axial component decreases. At the same time, the circumferential velocities along the length of the deformation center are uneven.

Inequality of circumferential speeds during radial-shear rolling is caused by the influence of the design of the technological tool (helical-cone roller design). The ratio of the roll diameter D_i to the diameter d_i of the workpiece, and also the tangential slip along the length of the deformation center will be variable. Along with this, the screw movement of the metal in the deformation is realized with a constant angular velocity zone from the inlet to the exit from, if one does not take in to account the rolling with minor torsion of the rolled stock in screw-like rolls. In connection with this, further development of speed and slip between the helical rolls and the deformable workpiece can be used in the design of a radial-shear mill with screw-like rolls.

When the rods and tubes are pressed in the proposed device, rolling in a radial shear mill can be performed at large feed angles ($\beta > 20°$) and large single compressions ($\varepsilon \geq 5\%$). Under such rolling conditions, the deformation center will be relatively short, and the axial movement of the metal in the feed step is large. Under such rolling circumstances, the tangential component of the frictional forces will not develop much, and the tangential component of the rolling speed will be smaller in value in comparison with the analogous value of the roll [2]. In connection with this, at the proposed radial-shear mill tangential sliding can be significant, in comparison with other known mills.

Analysis of the calculation results showed that when rolling in screw-like rolls, the most rational values of the tangential and axial velocity and slip components can be used for rolling with a feed angle of 15-20 degrees with the helix angle of the screw-like roll equal to 25 to 30 degrees.

When rolling the proposed radial-shear mill with screw-like rolls, the widest areas of the contact surface of the workpiece with rolls are the initial zones of the deformation center. Therefore, these zones are the dominant areas where high-speed deformation conditions develop in the process of metal reduction. In comparison with the rest of the contact surface, the tangential component of the frictional forces will develop more. These sections give the workpiece an angular velocity and the corresponding metal flow velocity, depending on the geometric dimensions of the helical tool. It can be noted that the speed of these sections over the entire rolling period will be constant, while the velocity and geometric conditions of the metal flow will not coincide with other parts of the deformation center. For the rest of the pressed metal, the front zones of the deformation focus are the force and kinematic parameters. It should be noted that these sections adjust the velocity, geometric and other differences along the length of the deformation center to certain uniform boundary.

Thus, when rolling in a radial-shear mill with helical rolls, tangential sliding can be influenced by changing the feed angle and the angle of the helix. As the feed angle and the angle of elevation of the helical line increase, the tangential velocity coefficient increases. Changes in speed, boundary, dimensional and other conditions of rolling in screw-like rolls it is possible to adjust the coefficient of tangential velocity.

It should be noted that axial slip, in contrast to tangential sliding, has a more complex dependence on the design of the helical roll and technological factors. Axial slip varies in sufficiently wide intervals with a change in the feed angle and the angle of the helix and the geometric dimensions of the screw-like swath and the array of the device. From the above, the relationship of axial slip to rolling regimes, structural features of the radial-shear mill (cage) and, in general, to pressing technology, is not quite evident. On the basis of recent data, it can be noted that, unlike tangential slip, it is promising to find ways to control axial slip. Optimization of ways to control the values of axial slip can significantly improve the quantitative and qualitative performance of the equipment.

Axial slip occurs over the entire length of the deformation center, its magnitude increases in the direction of the matrix in accordance with the growing values of the extruded workpiece. It should be noted that for rolling slip is a natural process, without which it is impossible to carry out the pressing process. However, its presence, in the case of a significant delay in the speed of rotation of the workpiece from the speed of the rolls, can reduce the quality parameters of the rod surface and reduce the productivity of the installation. The results of the calculation showed that the smaller the height of the protrusion of the helical rolls, the greater the slip. However, in accordance with the law of constancy of seconds volumes, an increase in the rate of deformation in the initial sections of the workpiece will lead to an increase in the speed of axial displacement at the end of the deformation center and in the matrix.

The proposed design of the radial-shear mill allows wide variation of the value of the coefficients of tangential and axial velocities. When rolling on a radial-shear mill with screw-like rolls with a small angle of lift of the helical line, the tangential velocity coefficient is larger and the axial velocity coefficient is less than on the helical-shaped rolls with a large angle of the helix. It can be noted that when rolling in screw-like rolls with a large angle of elevation, the axial component of metal velocity predominates significantly in the kinematics of the process, rather than the tangential component, as in helical-shaped rolls with a small angle of ascent. Therefore, the process of pressing bars on the proposed device will be more dependent on factors that negatively affect the axial slip.

Analysis of the data obtained shows that tangential and axial slip are significantly influenced by factors that change the coefficient of friction at the contact surface of the metal with the tool. First of all, this refers to the roughness of the rolls and the presence of helical protrusions and depressions on their surfaces. With a smooth surface of the rolls, the axial velocity coefficient decreases, and in the presence of roughnesses or screw-like protrusions and depressions on the surface of the rolls, it increases and will be the greater, the larger the protrusions and depressions of the rolls.

According to the results of the research, it was established, in comparison with screw-like rolls, that rolls with smooth working surfaces can not provide high speed parameters of rolling. This is due to the fact that rolling in such rolls is carried out with a lag of the axial component of the speed of the rod from the speed of the rolls. The most noticeable effect on axial slip is the angle of the helix of the helical rolls. When the workpiece is deformed in screw-like rolls with a small angle of lifting of the helical line, the tangential component of the workpiece speed exceeds by two or more times the axial component of the speed of the rolls. On these rollers, with an angle of 45°, the tangential component approaches the axial component of the billet speed. When pressing rods using screw-like rolls, the productivity of the device also increases.

The presence of screw-shaped protrusions and valleys on the surface of the rolls does not allow the workpiece to rotate in the center of deformation and contributes to an increase in the pitch of the metal, and thus to its stretching by the feed step. It is known [17] that with a larger feed step, the single compressions increase and so do, the surface quality of the rod.

Large single compressions and metal movements along the helical line intensively deform the structure of the metal of the billet [19, 20]. Therefore, in comparison with the rollers, an even surface, the screw-like rolls at a high rolling speed will grind the metal structure well, both in the axial and peripheral zones of the rod. This is most important when pressing continuously cast billets, when the axial porosity of the rod can not be eliminated by the technological conditions of rolling due to an increase in the reduction of the metal. In this case, the use of screw-like rollers, which, due to the development of intense plastic deformation, provides a good study of the structure of the metal, an increase in the productivity of the installation and an improvement in product quality are achieved.

It is found that in the proposed tool the opposite arrangement of the projections or valleys of the rolls relative to each other also allows intensively deform the metal structure.

Conclusions.

1. Formulas have derived that allow to determine the slippage speed of the roll relative to the workpiece in the zones of the hollow of the workpiece.
2. An analysis of the results obtained showed that the low slippage speed of the workpiece relative to the roll takes place at small values of the coefficient k.
3. It is shown that when rolling in screw-like rolls, sliding occurs due to the discrepancy between the speed of the screw movement of the workpiece in the area of deformation of the rotation speed of the rolls.
4. It is established that the use of helical rolls with rational sizes of protrusions and valleys intensively deforms the metal of the workpiece within the required reduction of the workpiece.
5. Using the kinematics of the rolling process in a radial-shear mill, the dependence of the velocity of the metal exit from the deformation center on the technological deformation modes was established, and the more effective geometric dimensions of the protrusions and valleys of these rolls were defined.

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ҚҰРЫЛЫМЫ ЖАҢА ҮЗДІКСІЗ РАДИАЛЬДЫ-ЫҒЫСТЫРУ ОРНАҒЫНДА ШЫБЫҚ ПЕН ҚҰБЫРДЫ ИЛЕМДЕУ ПРОЦЕСІНІҢ КИНЕМАТИКАСЫН ЗЕРТТЕУ

Аннотация. Жаңа қондырғыда құбыр мен шыбықты баспақтап жасаған кезде үздіксіз дайындаманы қолдану, металл құрылымын жақсы өңдеуді қамтамасыз ететінтым нәтижелі тәсілмен деформация іске асыруды қажет етеді. Жаңа үздіксіз баспақтау қондырғысы үшін осындай мәселені шешудің жолы болып, шығыңқылығы мен ойымдарында ұтымды өлшемдер бар бұрандалы пішінбіліктерді қолдану саналады. Шығыңқылығы мен ойымдарында ұтымды өлшемдер бар бұрандалы пішінбіліктерді қолдан кезде, талап етілетін жаншу шегімен дайындаманың құрылымын қарқынды деформациялауға болады. Баспақтаудың кинематикасын зерттеген кезде шығыңқылығы мен ойымдарында әртүрлі өлшемдер бар бұрандалы пішінбіліктерді қолданылды. Осы бұрандалы пішінбіліктерді қолдану, деформациялаудың технологиялық режімдеріне байланысты деформация ошағынан металдың шығу жылдамдығын және осы пішінбіліктердің шығыңқылығы мен ойымдарының нәтижелі геометриялық өлшемдерін аныктауға мүмкіндік берді. Радиальды-ығысу орнағында илемдеген кезде металды деформациялау, дайындаманың пішінбілікке қатысты сырғанауымен іске асырылатындығы мақалада көрсетілді. Деформация ошағында дайындаманың бұрандалы қозғалысының жылдамдығы пішінбіліктің айналу жылдамдымен сәйкес келмеуінен сырғанау пайда болатындығы жұмыста айтылды. Сырғудың мөлшерінен өнімнің сапасы және тағыда басқа өндірістің техника-экономикалық көрсеткіштерді тәуелді болатындығы мақалада анықталды. Радиальды-ығысу орнағында илемдеген кезде дайындаманың қозғалыс жылдамдығы пішінбілік жылдамдығынан кіші болатындығы жұмыста табылды. Жұмыста, дайындаманың ойым аймағында деформацияланатын дайындамаға қатысты пішінбіліктің сырғанау жылдамдығын анықтауға мүмкіндік беретін формулалар шығарылған.

Түйін сөздер: бұрандалы пішінбілік, ұяқалып, процестің кинематикасы, шыбық, дайындама, сырғанау, сырғанау мен жылдамдықтың тангенциалды және осьтік құраушылары.

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ИССЛЕДОВАНИЕ КИНЕМАТИКИ ПРОЦЕССА ПРОКАТКИ ПРУТКОВ И ТРУБ НА НЕПРЕРЫВНОМ РАДИАЛЬНО-СДВИГОВОМ СТАНЕ НОВОЙ КОНСТРУКЦИИ

Аннотация. При использовании непрерывнолитой заготовки для прессования прутков или труб на новой установке деформация должна осуществляться наиболее эффективным способом, чтобы можно было добиться лучшей проработки структуры металла. Для новой установки непрерывного прессования возможным решением такой задачи является использования винтообразных валков с рациональными геометрическими размерами выступов и впадин. Применение винтообразных валков с рациональными размерами выступов и впадин, будет интенсивно деформировать металл заготовки в пределах требуемого обжатия заготовки. При исследовании кинематики прессования были использованы винтообразные валки с различными размерами выступов и впадины. Их использование позволило установить зависимость скорости выхода металла из очага деформации от технологических режимов деформирования в винтообразных валках и определить более эффективные геометрические размеры выступов и впадин данных валков. Показано, что деформация металла при прокатке на радиально-сдвиговом стане осуществляется со скольжением заготовки относительно валков. Скольжение возникает вследствие несоответствия скорости винтового перемещения заготовки в очаге деформации скорости вращения валков. От величины скольжения зависят качество металлопродукции, а также другие технико-экономические показатели производства. Установлена, что при прокатке на радиально-сдвиговом стане скорость перемещения заготовки меньше скорости валков. Аналитическим способом исследована кинематика процесса и выведены формулы, позволяющие определять скорость проскальзывания валка относительно заготовки в зонах впадины заготовки.

Ключевые слова: винтообразные валки, матрица, кинематика процесса, пруток, заготовка, скольжение, тангенциальные и осевые составляющие скольжения и скоростей.

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