

UDC 514.18

DOI: 10.31548/machenergy.13(4).2022.81-88

Serhii Pylypaka

Full Doctor in Technical Sciences, Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
<https://orcid.org/0000-0002-1496-4615>

Tetiana Kresan

PhD in Technical Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
<https://orcid.org/0000-0002-8280-9502>

Vyacheslav Hropost*

Postgraduate Student
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
<https://orcid.org/0000-0001-9363-3955>

Vitalii Babka

PhD in Technical Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
<https://orcid.org/0000-0003-4971-4285>

Iryna Hryshchenko

PhD in Technical Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
<https://orcid.org/0000-0002-1000-9805>

**Calculation of the bending parameters
of a flat workpiece into a twist of a helicoid torso**

Abstract. Helical surfaces are deployable and non-deployable. The first is the surface of a helical conoid widely used in technology, known as the screw. The second one is the surface of an unfolding helicoid or torso-helicoid. In both cases, the surface is formed from a blank - a sweep in the form of a flat ring. If in the first case the sweep can be calculated approximately, since the exact one does not exist due to the properties of non-expanded surfaces, then in the second case it is calculated exactly. However, this does not mean that it is just as possible to form a ready-made product from it - a twist of a helicoid torso. In contrast to non-expanded surfaces, during the manufacture of which the workpiece is subjected to complex stretching and compression deformations, an expanded surface can be obtained by bending with minimal plastic deformations, the magnitude of which depends on the thickness of the sheet. Bending occurs along rectilinear generators, which are theoretically located on the workpiece. In the process of bending, the location of these generators should not change. In the theory of differential geometry, such a process can be described

Article's History: Received: 16.06.2022; Revised: 04.10.2022; Accepted: 23.11.2022.

Suggested Citation:

Pylypaka, S., Kresan, T., Hropost, V., Babka, V., & Hryshchenko, I. (2022). Calculation of the bending parameters of a flat workpiece into a twist of a helicoid torso. *Machinery & Energetics*, 13(4), 81-88.

*Corresponding author

analytically and is called continuous bending. With regard to the manufacture of the twist of the torso-helicoid, this means a gradual increase in the step to the desired value. The work contains parametric equations that describe this method of bending. At the same time, not only stretching of the workpiece along the axis of the coil occurs, but also its twisting around the axis. A comparison of these two movements was made and it was found that the relationship between them is not linear. The work gives a formula describing this dependence. According to it, when the workpiece is uniformly stretched along the axis, the angle of its twist around the axis increases according to a dependence close to quadratic. In the work, examples of the use of the torso-helicoid are given, the surface is visualized, and graphs are constructed. Confirmation of the reliability of the obtained results is the first found quadratic form of the torso-helicoid, which does not change when the surface is bent

Keywords: surface area; conveyor screw; continuous divination; parametric equation; traction; torsional twisting

INTRODUCTION

The production of these surfaces differs significantly from one another. When forming a flat workpiece into the surface of a helical conoid, significant plastic deformations occur, stretching the inner part of the surface adjacent to the shaft and compressing the outer part. During the formation of the helicoid torso, bending occurs along straight lines, and the plastic deformations are minimal and caused by the thickness of the sheet material of a workpiece. If for an unexpanded surface a conditional sweep can only be constructed approximately, then for an expanded surface it is constructed exactly. To form a spreadable surface from a flat workpiece by bending it, it is necessary to know the dynamics of the process.

The scientific novelty is that an analytical description of the continuous bending of the helicoid torso has been obtained, which allows making recommendations for its practical manufacture.

Screw surfaces are widely used in the tasks of transportation of technological material. They can be stationary in gravity descents [1; 2]. In paper [3], it is carried out on a stationary surface under the action of the force of the particle's own weight, which is used in gravity descents. The productivity of helical surfaces for transporting technological material depending on the size of the pitch of the turn is considered in the paper [7]. They are very common

in agricultural production [8-10]. In paper [11], the surface (torso-helicoid) is mobile. Papers [3; 11] show the use of a helicoid torso for transporting particles of technological material, while this transportation can be of different nature. Therefore, a significant part of the papers is devoted to improving the designs of screw devices and the technology of manufacturing spiral turns [12-14]. It rotates around its own axis and thereby sets the particle in motion. The technical and economic justification of their production is described in paper [15].

The research purpose was an analytical description of the process of continuous bending of a flat ring in the form of a sweep of a twist of a helicoid torso into a finished product.

MATERIALS AND METHODS

To achieve the research purpose, the methods of differential geometry, which relate to the internal theory of surfaces, were used. According to the theory of the internal geometry of the length of the lines on the surface, the angles between them do not change when the surface is bent.

A flat blank in the form of a ring with a cutout can be bent in different ways. If the straight lines along which the bending occurs are located radially, i.e., towards the center of the ring, then with gradual bending along them the ring will turn into a truncated cone (Fig. 1).

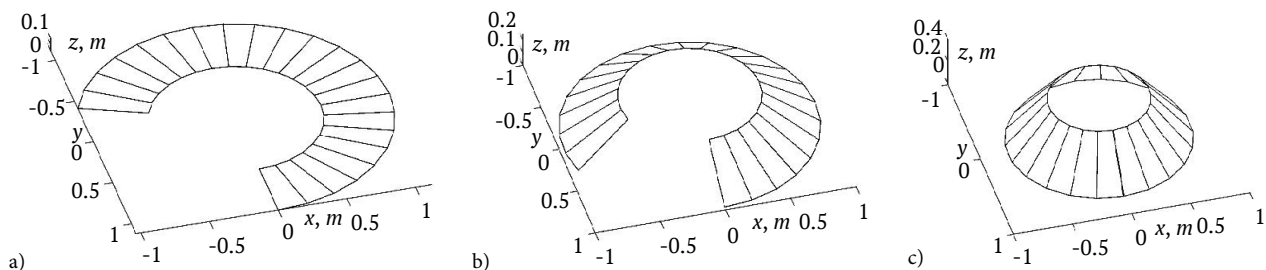


Figure 1. Graphic illustrations of the gradual bending of a flat ring into a truncated cone: a) flat ring with a cutout; b) intermediate stage during bending; c) truncated cone

In fact, bending is reduced to twisting the ring around a vertical axis passing through its center until the moment when the extreme limiting lines converge. Twisting can be continued further. Then the surface of the cone will overlap,

and the angle of inclination of its rectilinear generators to the base will increase. However, a flat ring can be bent in another way, when the straight lines of the bend are located at a certain angle to the radial direction (Fig. 2a).

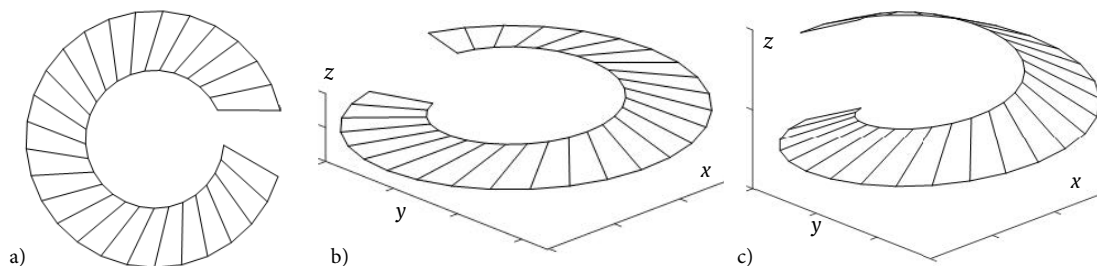


Figure 2. Graphical illustrations of the gradual bending of a flat ring into an expanding helicoid: a) flat ring with a cutout; b) intermediate stage during bending; c) twist of a helicoid torso

When a flat ring is uniformly bent along such lines, it is not only twisted around the vertical axis, but also stretched along it (Fig. 2b, 2c). Figure 4 shows the frontal (Fig. 3a) and horizontal (Fig. 3b) projections of one turn

of a helicoid torso. The limiting circles of the ring turned into helical lines located on cylinders of radius r and R . The value H , by which the ring was stretched, is the pitch of a helicoid torso.

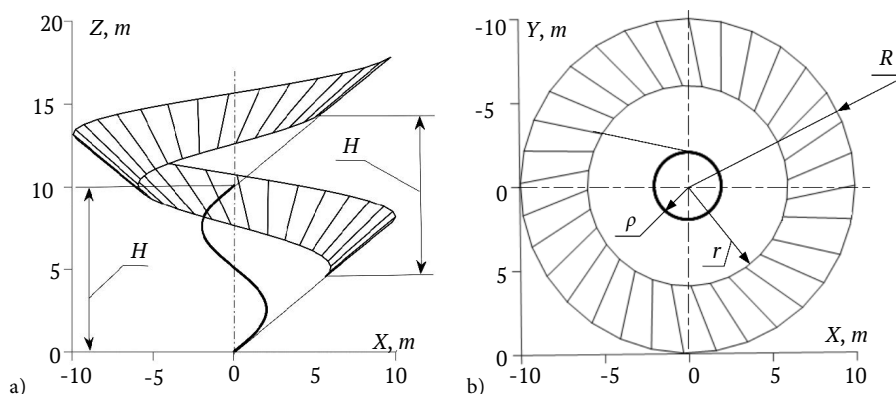


Figure 3. Twist of an unfolding helicoid, which turned into a flat ring: a) frontal projection; b) horizontal projection

In addition to the dimensions r , R and H , there is another dimension ρ , which depends on the direction of the straight lines, along which bending occurs. This is the size of the radius of a cylinder, on which the helical line of pitch H is located. If you extend the bend lines, then they will all be tangent to this helical line, which is called the turning edge. During the reverse deformation of the twist of a helicoid torso into a flat ring, the edge of the return is also deformed – its pitch decreases and turns into an arc of a circle on a developed view.

It is known from differential geometry that the length of the turning edge and its curvature do not change when the unfolded surface is bent [16; 17], although the shape of the turning edge itself changes and it becomes a flat curve on a developed view. In our case, when the turning edge is deformed by stretching, the arc of the circle will turn into a spiral line with an increase in its pitch H_i . Since the length of the deformed helical line does not change, it is clear that the radius ρ_i will also decrease during such deformation. It was controlled the bending of a helicoid torso through the deformation of its turning edge (helix line) in the described way. The parametric equations of a helical line as a function of the length s of its arc have the following form:

$$Rx = \rho \cos \frac{s}{\sqrt{\rho^2+h^2}}; y = \rho \sin \frac{s}{\sqrt{\rho^2+h^2}}; z = \frac{hs}{\sqrt{\rho^2+h^2}}, \quad (1)$$

where h is the helical parameter that is related to the pitch H by the dependence $H=2\pi h$, ρ is the radius of the cylinder, on which the helical line is located.

The curvature of the helical line is constant and depends on two parameters: ρ and h . After deformation, the helical line will remain helical, but with other parameters ρ_i and h_i . On the basis of the well-known expression of the curvature of a helical line [17], we equate it with each other before and after deformation:

$$\frac{\rho}{\sqrt{\rho^2+h^2}} = \frac{\rho_i}{\sqrt{\rho_i^2+h_i^2}}. \quad (2)$$

Equality (2) can be solved with respect to ρ_i or h_i . Let's solve it with respect to h_i , since in this case the solution will be simpler:

$$h_i = \sqrt{\frac{\rho_i}{\rho} (\rho^2 + h^2 - \rho\rho_i)}. \quad (3)$$

Let's substitute into equation (1) the new notation ρ_i (new value of the radius) instead of ρ and expression (3), i.e., the new value of the screw parameter, instead of h_i , and we will obtain the following parametric equations:

$$\begin{aligned} x_i &= \rho_i \cos \sqrt{\frac{\rho}{\rho_i(\rho^2+h^2)}} s; & y_i &= \rho_i \sin \sqrt{\frac{\rho}{\rho_i(\rho^2+h^2)}} s; \\ z_i &= \sqrt{1 - \frac{\rho\rho_i}{\rho^2+h^2}} s. \end{aligned} \quad (4)$$

The resulting parametric equations (4) describe a set of helical lines of the same curvature. Their parameters (pitch and radius) depend on the value of the constant ρ_i . When $\rho_i = \rho$, equation (4) turns into equation (1), i.e., describes the original helical line. In the partial case, the spiral line turns into a flat circle. This happens when $h_i = 0$. Let's equate expression (3) to zero and solve it with respect to ρ_i :

$$\rho_i = \frac{\rho^2 + h^2}{\rho}. \quad (5)$$

The value of the radius ρ_i is the maximum possible, otherwise the radical expression in the last equation (4) will take on a negative value. When reducing ρ_i from the maximum value (5) to ρ , the line (4) will transform by increasing the pitch from the circle to the original helical line. With a further decrease in ρ_i , the pitch of the spiral line will increase, but when $\rho_i = 0$, the line according to equations (4) cannot be obtained, since the root expressions in the first two equations (4) become undefined. This is explained by the fact that at $\rho_i = 0$, the spiral line should turn into a vertical straight line, which is impossible under the condition of a given constant curvature, since the curvature of the straight line is zero.

The helical line (4) is a guide for the formation of a helicoid torso. Its surface is formed by a set of rectilinear generators tangent to the helical line. The directional vector of these generators is the expression of the first derivatives of equations (4). Since the helical line (4) is given by the equations as a function of the length s of its arc, the derivatives will represent the projections of the unit direction vector. The parametric equations of the surface will be written as a set of tangent lines to the helical line (4), the direction of which is specified by a unit vector:

$$\begin{aligned} X_i &= \rho_i \cos \sqrt{\frac{\rho}{\rho_i \sqrt{(\rho^2 + h^2)}}} s - u \rho_i \sqrt{\frac{\rho}{\rho_i \sqrt{(\rho^2 + h^2)}}} \sin \sqrt{\frac{\rho}{\rho_i \sqrt{(\rho^2 + h^2)}}} s; \\ Y_i &= \rho_i \sin \sqrt{\frac{\rho}{\rho_i \sqrt{(\rho^2 + h^2)}}} s + u \rho_i \sqrt{\frac{\rho}{\rho_i \sqrt{(\rho^2 + h^2)}}} \cos \sqrt{\frac{\rho}{\rho_i \sqrt{(\rho^2 + h^2)}}} s; \\ Z_i &= \sqrt{1 - \frac{\rho \rho_i}{\rho^2 + h^2}} s + u \sqrt{1 - \frac{\rho \rho_i}{\rho^2 + h^2}}, \end{aligned} \quad (6)$$

where u is the second variable of the surface – the length of the rectilinear generator, the count of which starts from the point of contact with the helical line.

The coefficients of the first quadratic form of the torso-helicoid (6) have the following form:

$$\begin{aligned} G &= \left(\frac{\partial X_i}{\partial s}\right)^2 + \left(\frac{\partial Y_i}{\partial s}\right)^2 + \left(\frac{\partial Z_i}{\partial s}\right)^2 = \frac{h^4 + \rho^4 + \rho^2(2h^2 + \rho^2)}{(h^2 + \rho^2)^2}; \\ F &= \frac{\partial X_i}{\partial s} \cdot \frac{\partial X_i}{\partial u} + \frac{\partial Y_i}{\partial s} \cdot \frac{\partial Y_i}{\partial u} + \frac{\partial Z_i}{\partial s} \cdot \frac{\partial Z_i}{\partial u} = 1; \\ E &= \left(\frac{\partial X_i}{\partial u}\right)^2 + \left(\frac{\partial Y_i}{\partial u}\right)^2 + \left(\frac{\partial Z_i}{\partial u}\right)^2 = 1. \end{aligned} \quad (7)$$

Thus, the quadratic form will be written as follows:

$$\begin{aligned} dS^2 &= Gds^2 + 2dsdu + Edu^2 = \\ &= \frac{h^4 + \rho^4 + \rho^2(2h^2 + \rho^2)}{(h^2 + \rho^2)^2} + 2dsdu + du^2. \end{aligned} \quad (8)$$

The quadratic form (7) does not include the parameter ρ_i . Its value affects the shape of the surface (6), but does not affect the quadratic form itself. This indicates that equation (6) is the equation of continuous bending of a helicoid torso by a uniform decrease of its pitch from the initial value to zero when the helicoid torso turns into a sweep and vice versa – from the sweep to the finished surface. When $\rho_i = \rho$, equation (6) describes the initial surface of the helicoid torso, and when ρ_i is equal to the value given in (5) – its sweep. In order to construct the required surface section, it is necessary to know the limits of change of parameters s and u . One turn of the surface corresponds to a 360° rotation of the turning edge point (1). Let's equate the expression that determines the current value of the angle to 360°, and solve it with respect to s :

$$\frac{s}{\sqrt{\rho^2 + h^2}} = 2\pi \text{ from which } s = 2\pi\sqrt{\rho^2 + h^2}. \quad (9)$$

Therefore, the parameter s (independent variable) should vary between zero and the value (9). The second independent variable u is the distance of a point on the rectilinear generator from the turning edge. Therefore, it should vary from ur , which corresponds to the internal limiting spiral line of radius r (Fig. 3b) to uR , which corresponds to the external limiting spiral line of radius R . These spiral lines on the horizontal projection are projected by circles of radius r and R . Let us find the distance L from the axis helicoid torso to an arbitrary point of the initial surface according to the well-known formula:

$$L = \sqrt{X_i^2 + Y_i^2} = \rho \sqrt{\rho_i \left(\rho_i + \frac{\rho u^2}{\rho^2 + h^2}\right)}. \quad (10)$$

Let us set the initial surface at $\rho_i = \rho$, then substitute this value into (10) and solve with respect to u :

$$u = \frac{1}{\rho} \sqrt{(L^2 - \rho^2)(\rho^2 + h^2)}. \quad (11)$$

If we substitute the values of ρ and h into formula (11), and the value of the radius r instead of L , we will get the value of ur . Accordingly, by replacing L with R , we find the value of uR . The difference between these $uR - ur$ values is the length of the rectilinear generators within the flat ring, along which it is bent, so they are unchanged in the bending process. Let's substitute (11) into (10), and after simplifications we get:

$$L_i = \sqrt{\rho_i \left(\frac{L^2}{\rho^2} + \rho_i - \rho\right)}. \quad (12)$$

Formula (12) makes it possible to monitor the change of the radii ρ , r and R in the process of bending the surface depending on the value of ρ_i . For example, when $\rho_i = \rho$ (initial surface) we have: $L_i = L$. This means that when substituting the radii ρ , r and R instead of L , we get the same values. To obtain the values of ρ_o , r_o , and R_o on the sweep (i.e., L_o), we must substitute the corresponding value of ρ_o from (5) into formula (12). After substitution, we get:

$$L_o = \frac{1}{\rho} \sqrt{(L^2 + h^2)(\rho^2 + h^2)}. \quad (13)$$

The obtained values of the design parameters are sufficient for the construction of the sweep.

RESULTS AND DISCUSSION

Helical linear surfaces can be of two types – deployable and non-deployable. An example can be a reinforced auger of a grain harvester, which comprises two helical surfaces. Figure 4a shows a fragment of the auger, and Figure 4b shows

a fragment of a twist constructed with the help of a computer based on the equations of these surfaces. The active turn, marked with the number 1, is unexpanded and represents the surface of a helical conoid. Turn 2 serves to strengthen the main one and is an expanding surface – a helicoid torso.

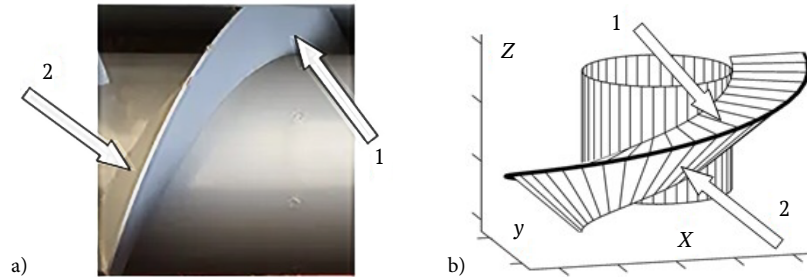


Figure 4. Graphic illustrations of the structure of the auger of a grain harvester: a) fragment of the auger of a natural product; b) fragment of the auger, the surfaces of which are built with the help of computer software

Let's consider an example. Let's bend a helicoid torso with the given dimensions $H=10$ ($h=1.6$), $\rho=2$, $r=6$, $R=10$. Let's find the extent, to which the independent variables s and u . From expression (8), we find that $s=16.09$. Therefore, $s=0...16.09$. The alternate substitution of r and R instead of L in formula (10) gives the limits of the distance change $u=7.2...12.5$. According to formula (5), we find the maximum possible value of ρ_i , which corresponds to the sweep of the twist of a helicoid torso: $\rho_i=3.28$. Therefore, ρ_i can have values within $\rho_i=2...3.28$. When $\rho_i=2$, we have the initial surface, the projections of which are shown in Figure 4. It was gradually increased the value of ρ_i . In Figure 5, projections of the surface at different values of the

constant ρ_i are constructed according to equations (6). It should be noted that in equations (6), we change only ρ_i , while other parameters, including the limits of change of independent variables s and u , remain preliminary. When substituting $L=r=6$ and $L=R=10$ in (13) alternately, we find the values of the radii of the bounding circles on the sweep: $r_o=7.95$ i $R_o=12.97$, as well as $\rho_o=3.28$, i.e., the initial values of the corresponding radii r , R , and ρ increased from 6, 10, and 2 to 8, 13, and 3.3, respectively. It should be noted that the obtained results are broader in comparison with those known, for example, in paper [9]. In this paper, the original surface and its sweep without intermediate positions during bending are given.

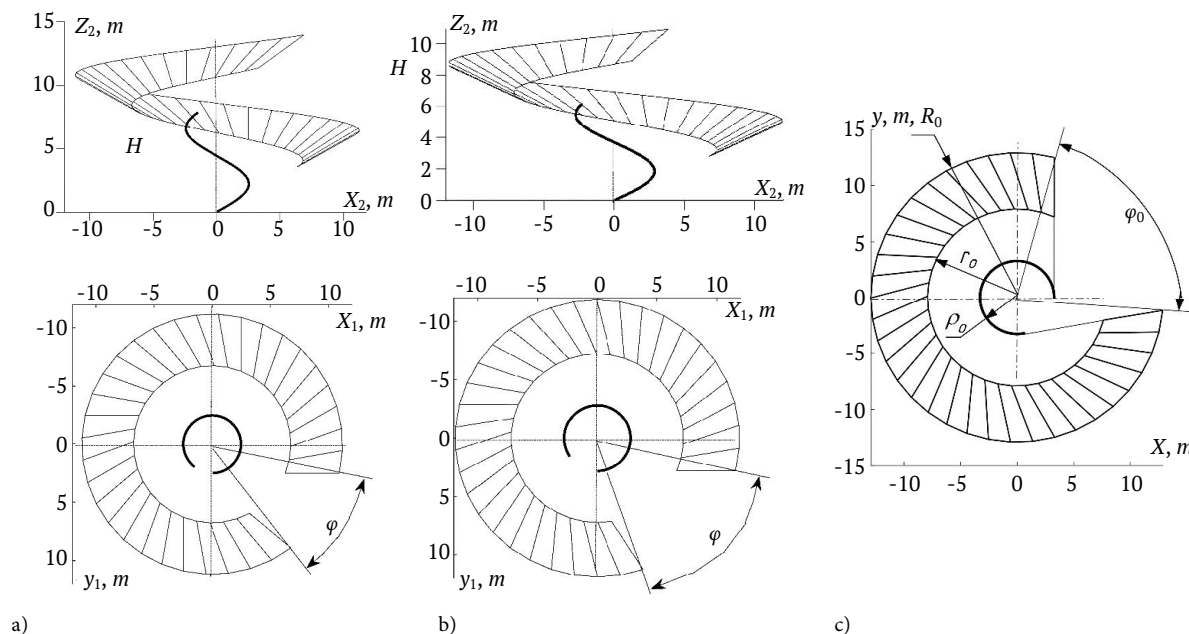


Figure 5. Helicoid torso projections constructed according to equations (6) at different values of ρ_i
 a) $\rho_i=2.5$; b) $\rho_i=2.8$; c) $\rho_i=3.28$ (sweep)

Analyzing the projections of the helicoid torsos as a result of bending the original one (Fig. 3), its intermediate

positions during bending (Fig. 5a and Fig. 5b) and ending with the sweep (Fig. 5c), it is possible to draw certain

conclusions, namely: when reducing the pitch of the coil, the angle φ appears, which was not present on the original surface and which acquired the maximum value on the sweep. In addition, the radii ρ , r , and R increase, which also reach the maximum values of ρ_o , r_o , and R_o on the sweep. The dimensions ρ_o , r_o and R_o determine the contours of the sweep of the coil, and ρ_o makes it possible to determine the direction of the straight lines, along which the bending occurs.

Let's find an expression for the angle φ . When the arc length s changes from zero to the value (8), equation (1) describes one turn of the helical line, i.e., the angle α in this case will be equal to 2π . The same will be the case for the helical line (4) under the condition that $\rho_i = \rho$. In other cases, when $\rho_i \neq \rho$ the angle α will be smaller than 2π , i.e., the angle will appear as the difference $2\pi - \alpha_i$. Taking into account this and the value of s from (8), we can write the following:

$$\phi_i = 2\pi - s \sqrt{\frac{\rho}{\rho_i(\rho^2 + h^2)}} = 2\pi \left(1 - \sqrt{\frac{\rho}{\rho_i}}\right). \quad (14)$$

When $\rho_i = \rho$, i.e., in the initial surface, the angle $\varphi = 0$. By increasing ρ_i , we will obtain certain values of the angle φ_i . At the maximum possible value of ρ_i according to (5), we will get the angle φ_o on the sweep. Let's substitute ρ_i from (5) into (14) and get:

$$\phi_o = 2\pi \left(1 - \frac{\rho}{\sqrt{\rho^2 + h^2}}\right). \quad (15)$$

For the given $h=1.6$, $\rho=2$, using formula (15), we find that $\varphi_o = 79^\circ$. The found values of ρ_o , r_o , R_o and φ_o are sufficient to construct a flat ring – the sweep of one turn of a helicoid torso – and determine the direction of the straight lines, along which bending occurs. Therefore, when a flat ring is bent into the surface of a helicoid torso, deformation occurs with its simultaneous stretching along the axis and

twisting around the axis. Let's find an analytical relationship between these two movements.

Pitch H_i can be found if we multiply the helical parameter h_i (3) by the angle α_i . It can also be found as the z_i coordinate in equations (4) at the value of s from (8). In both cases, we get the following:

$$H_i = 2\pi \sqrt{\rho^2 + h^2} - \rho \rho_i. \quad (16)$$

When stretching the ring, it must simultaneously twist around the axis from the angle $2\pi - \varphi_o$ (Fig. 5c) to the angle 2π (Fig. 4b). Within these limits, the angle α_i changes, the expression of which according to (14) is written as follows:

$$\alpha_i = 2\pi \sqrt{\frac{\rho}{\rho_i}}. \quad (17)$$

Excluding ρ_i from expressions (16) and (17), we find the dependencies $\alpha_i = \alpha_i(H_i)$ or $H_i = H_i(\alpha_i)$:

$$\alpha_i = \frac{4\rho\pi^2}{\sqrt{4\pi^2(\rho^2 + h^2) - H_i^2}} \cdot H_i = \frac{2\pi}{\alpha_i} \sqrt{\alpha_i^2(\rho^2 + h^2) - 4\pi^2\rho^2}. \quad (18)$$

Figure 6a plots the dependence of $\alpha_i = \alpha_i(H_i)$ on the set parameters of the loop. Pitch H_i changes from zero to the final value $H=10$. At the same time, the angle α_i changes from the initial value of 281° to the final value of 360° . The difference between these values gives the angle φ_o , i.e., in fact, it is a graph of the dependence $\varphi = \varphi(H_i)$. It shows that with uniform stretching of a workpiece, its twisting occurs unevenly: at first the angle grows slowly, and then its growth accelerates according to a dependence close to quadratic. The workpiece could be stretched further with simultaneous twisting. At the same time, the angle of rise of the helical line (turning edge), which is the angle of inclination of the rectilinear generators to the horizontal plane, increases.

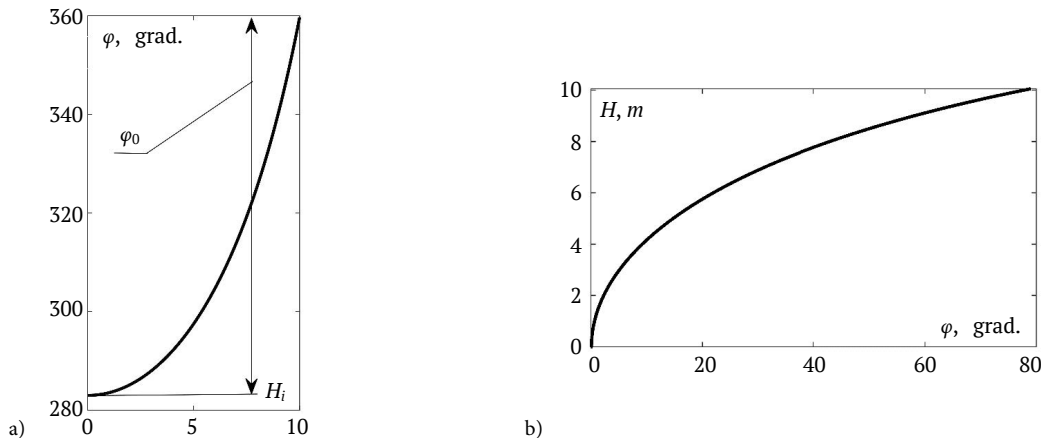


Figure 6. Graphs characterizing the relationship between the two movements when bending a workpiece into a helicoid torso turn: a) dependence of the angle of rotation φ with a linear increase in the pitch H ; b) dependence of the pitch H with a linear increase in the angle of rotation φ

Figure 6b shows the graph of the dependence $H=H(\varphi)$, which gives an idea of the regularity of the change of the pitch H during uniform twisting of the workpiece. With

a linear increase in the angle φ , the stretching of the workpiece does not occur uniformly: at the initial stage, the step increases rapidly and later this growth slows down.

CONCLUSIONS

When forming a coil of a helicoid torso from a flat workpiece, which is its sweep, it is necessary to correctly bend it. The theoretical description of the process of continuous bending makes it possible to identify the required ratio of two movements during the production of a coil by the bending method. In the process of forming the coil, it is necessary to ensure its stretching along the axis with simultaneous

twisting around the axis, and the ratio of these two movements is non-linear. This requires special equipment to obtain the finished product. A theoretical result was obtained, which indicates a non-linear dependence between these movements. Prospects for further research consist in the development of technological equipment for the implementation of the described method of bending a flat sweep into a finished product.

REFERENCES

- [1] Volina, T.M. (2021). Screw descent, analytical description of which includes the equation of particle movement on an inclined plane. *Applied Geometry and Engineering Graphics*, 100, 89-98.
- [2] Kresan, T.A. (2020). Screw descent, analytical description of which includes the equation of particle movement on an inclined plane. *Machinery & Energetics. Journal of Rural Production Research*, 11(2), 49-57.
- [3] Volina, T. M. (2020). Research of particle movement on rough surface formed by screw movement of sinusoid under action of own weight. *Machinery & Energetics. Journal of Rural Production Research*, 11(3), 187-194.
- [4] Pankiv, V.R., & Tokarchuk, O.A. (2017). Investigation of constructive geometrical and filling coefficients of combined grinding screw conveyor. *INMATEH–Agricultural Engineering*, 51(1), 59-68.
- [5] Gevko, I.B., Leschuk, R.Ya., Gud, V.Z., Dmytriv, O.R., Dubyniak, T.S., & Navrotska, T.D. (2019). *Flexible screw conveyors: Design, manufacturing technology, experimental research*. Ternopil: Individual Entrepreneur V.A. Palianytsia.
- [6] Dubyniak, T.S. (2018). *Justification of structures and parameters of protective mechanisms of flexible screw conveyors* (Candidates thesis, Ternopil National Technical University named after Ivan Pulyu, Ternopil, Ukraine).
- [7] Grudovy, R.S. (2017). Examination of productivity of the spiral conveyer with equiincreased turn thread during. *Visnyk ZHNAEU*, 1(2), 139-147.
- [8] Kulykivskiy, V. L. (2018). Influence of screw conveyors on the grain quality indicators of cereals. *Scientific Journal "Engineering of Nature Management"*, 2, 108-114.
- [9] Klendiy, M.B., & Dragan, A.P. (2021), Substantiation of the design of the working body of the screw section of the combined tillage tool. *Perspective Technologies and Devices*, 18, 66-73.
- [10] Vanin, V.V., Hrubych, M.V., & Yurchuk, V.P. (2017). Geometric modeling of switching surfaces of the changed step for the design of voltage copies. *Visnyk Kherson National Technical University*, 3(62), 256-259.
- [11] Kresan, T.A. (2021). Movement of soil particles on surface of developable helicoid with horizontal axis of rotation with given angle of attack. *Machinery & Energetics. Journal of Rural Production Research*, 12(2), 67-75.
- [12] Gevko, B.M., Slobodian, L.M., Marunych, O.P., & Hupka, V.V. (2018). Design features of screw loaders of machines. *Technical Service of Agro-Industrial, Forestry and Transport Complexes*, 12, 125-129.
- [13] Hevko, I.B., Hud, V.Z., & Kruglik, O.A. (2018). Synthesis of the spiral crews coiling methods. *Perspective Technologies and Devices*, 12, 39-47.
- [14] Lyashuk, O.L., Dyachun, A.E., Klendiy, V.M., Teslia, V.O., Navrotska, T.D., & Radik, M.D. (2018). Study of the dynamics of the process of calibration of the turn of a conical screw workpiece per step. *Technical Service of Agro-Industrial, Forestry and Transport Complexes*, 12, 39-47.
- [15] Lyashuk, O.L., Dyachun, A.E., Tretyakov, O.L., Navrotska, T.D., & Kruglyk, O.A. (2019). Technical and economic justification of the process of manufacturing screw working bodies. *Bulletin of the Petro Vasylenko Kharkiv National Technical University of Agriculture*, 198, 244-251.
- [16] Milinsky, V.I. (1934). *Differential geometry*. leningrad: KUBUCH.
- [17] Vygodsky, M.Ya. (1949). *Differential geometry*. moscow: GITTL.

Сергій Федорович Пилипака

Доктор технічних наук, професор
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
<https://orcid.org/0000-0002-1496-4615>

Тетяна Анатоліївна Кресан

Кандидат технічних наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
<https://orcid.org/0000-0002-8280-9502>

Вячеслав Іванович Хропост

Аспірант
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
<https://orcid.org/0000-0001-9363-3955>

Віталій Миколайович Бабка

Кандидат технічних наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
<https://orcid.org/0000-0003-4971-4285>

Ірина Юріївна Грищенко

Кандидат технічних наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
<https://orcid.org/0000-0002-1000-9805>

**Розрахунок параметрів згинання
плоскої заготовки у виток торса-гелікоїда**

Анотація. Гвинтові поверхні є розгортні і нерозгортні. До перших відноситься широко використовувана в техніці поверхня гвинтового коноїда відома під назвою шнек. До других – поверхня розгортного гелікоїда або торса-гелікоїда. В обох випадках поверхню формують із заготовки – розгортки у вигляді плоского кільця. Якщо в першому випадку розгортка може бути розрахована наближено, оскільки точної не існує в силу властивостей нерозгортних поверхонь, то в другому випадку вона розраховується точно. Однак це не означає, що так само точно можна сформулювати із неї готовий виріб – виток торса-гелікоїда. Більш детальне вивчення цієї проблематики зумовлює актуальність досліджень. Метою дослідження є опис процесу неперервного згинання плоского кільця у вигляді розгортки витка торса-гелікоїда у готовий виріб. Для цього була задіяна теорія і методи диференціальної геометрії. В роботі складено параметричні рівняння, які описують такий спосіб згинання. При цьому відбувається не тільки розтягування заготовки вздовж осі витка, а і його скручування навколо осі. Здійснено порівняння цих двох рухів і з'ясовано, що залежність між ними не є лінійною. В роботі наведено формулу, що описує цю залежність. Основним результатом є отримання цієї залежності, яка служить основою для практичної реалізації формування витка торса-гелікоїда із плоскої заготовки способом згинання. В роботі наведено приклади застосування торса-гелікоїда, зроблено візуалізацію поверхні, побудовано графіки. Підтвердженням достовірності отриманих результатів є знайдена перша квадратична форма торса-гелікоїда, яка не змінюється при згинанні поверхні. Матеріал статті буде корисним спеціалістам, що займаються холодним гнуттям плоских листових заготовок

Ключові слова: поверхня; шнек; неперервне згинання; параметричні рівняння; розтягування; скручування