DESIGNING OF THE BYCYLINDER-CONIC DRUM FOR MINE LIFTING UNITS

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Summary. **The spatial curve on conical surface of the bycylinder-conic drum for mine of lifting plant which provides the necessary density of winding the rope on the drum is obtained in the article. The curve is described in the function of the natural parameter. It lets you calculate the length of the rope and on this basis to determine the torque at any position settings.**

Keywords: **bitsylindrokonichnyy drum, tapered curve, involute circle, arc length, natural setting.**

Formulation of the problem. To lift-descent people, equipment, materials, and for the recovery of minerals through the vertical mine shafts to a depth of 1000 meters using bitsylindrokonichni mine hoisting installations [1]. Their drum consists of two conical and cylindrical three parts (Fig. 1). If loads as cabins are at the same height on the ends wound on a cylindrical portion of the rope, the moments of forces that arise from them are balanced. However, this equilibrium is disturbed quickly when lifting, lowering transport, because weight plays a significant role rope. This causes significant fluctuations in electric power for installation.

Analysis of recent research. Fig. 1 shows two loads P_1 and P_2, suspended from cables, which is wound on the cylinder of large diameter (radius R). When rotating the cylinder a load is lowered and the other raised. Provided that same cargo weight and shoulder R unchanging, ropes and weightless, torque will balance each other. However, because the rope has a weight, whose value is directly proportional to its length, balance points when using a cylindrical drum impossible. This can be achieved only at the time when the goods are at the same height (Fig. 1) and the weight of the cables from drum to transport flat. If you turn the drum at a certain angle balance is disturbed, because the length of rope around one cargo increased, and at the second the same amount decreased. The greater the angle of rotation of the drum around its axis, the greater the difference between the torque and the need to put more power to drive the drum.

To some extent balance the torque drum used at work conical transitions. When lifting its cargo rope (cable) initially wound on a small drum, but this time the rope cargo falls, twists of a large drum.

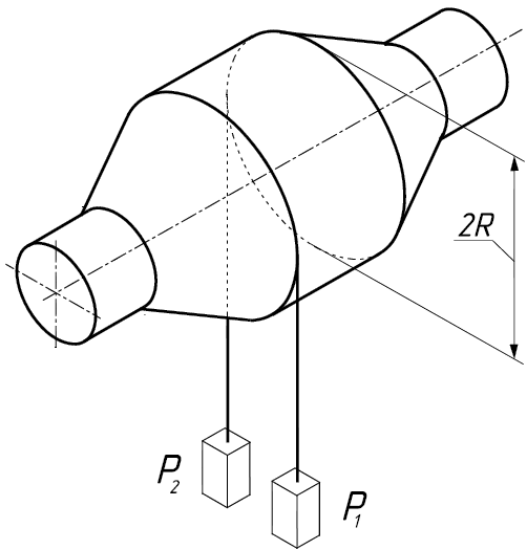

Fig. 1. Bitsylindrokonichnoho drum work surface and location of its works on lifting and lowering.

Not reaching the middle of the barrel, the rope lifted load begins on namotuvatysya conical spiral. This decreases the overall weight by reducing the length of the rope and simultaneously increases the value of the arm that allows certain way to balance the torque. In general, there is a partial equilibration growing weight difference ropes.

Among the natural curves as a function of the parameter on the surface of a cone [2] is spiral curves, but the distance between adjacent coils along the generators of the cone is too uneven. Because of this there is the problem of finding a conical curve that would meet the requirements.

The wording of Article purposes. Find a curve on the surface of the cone, which could be necessary density of uniformly wound in the grooves on the surface of the cone and that it described as a function of the length of the arc.

Main part. The problem can be solved by bending flat blanks with image of spiral conical surface so that the origin of the workpiece plane moved to the top of the cone.

Flat spiral, in which the distance between adjacent coils in the radial direction is equally known. This spiral of Archimedes. However, its parametric equation can not be written as a function of a natural setting. There is another spiral like for your properties to the spiral of Archimedes. This involute range (Fig. 2). In the formation of the circle involute point system Frenet-Serret formulas also moves linearly from the center, but the trajectory of this movement shifted to the constant a and from the center of the circle O (Fig. 2b). So was the smaller and the more involute circle similar to a spiral of Archimedes. But if the spiral of Archimedes equation is not natural, it is natural circle involute and parametric equation as a function of the length of the arc.

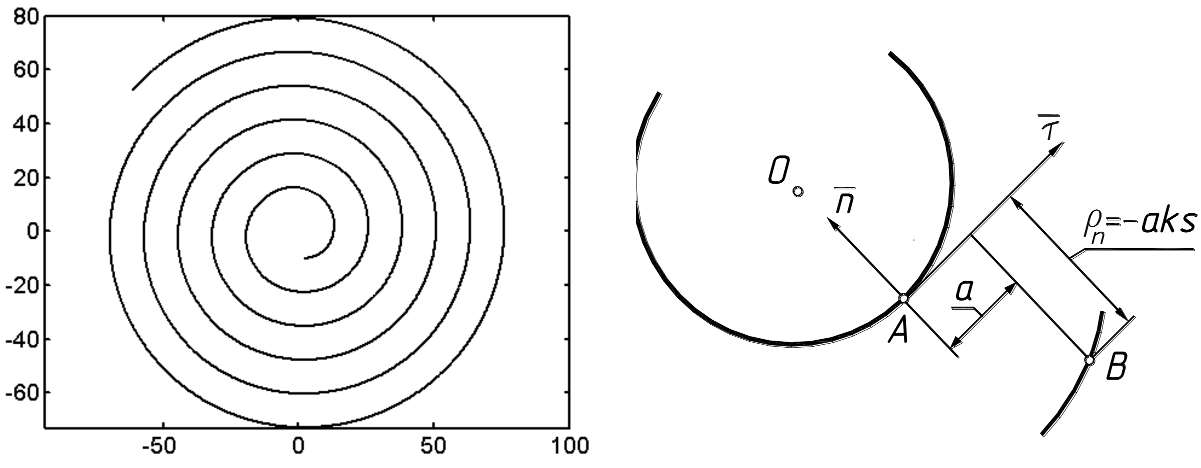

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Fig. 2. involute range and location of its formation:
and) spiral; b) scheme helix formation using Frenet-Serret formulas.

Write parametric equations cone:

$$X = u\cos\beta\cos v;$$
$$Y = u\cos\beta\sin v; \qquad (1)$$
$$Z = u\sin\beta,$$

where β - the angle of generators of the cone to the horizontal plane - a constant; u, v - surface independent variables, and u - straight generatrix cone length, v - angle point on the surface around the axis of the cone.

Find the partial derivatives and linear element (first fundamental form) surface (1):

$$\frac{\partial X}{\partial u} = \cos\beta\cos v; \qquad \frac{\partial Y}{\partial u} = \cos\beta\sin v; \qquad \frac{\partial Z}{\partial u} = \sin\beta;$$
$$\frac{\partial X}{\partial v} = -u\cos\beta\sin v; \qquad \frac{\partial Y}{\partial v} = u\cos\beta\cos v; \qquad \frac{\partial Y}{\partial v} = 0. \qquad (2)$$

$$E = \left(\frac{\partial X}{\partial u}\right)^2 + \left(\frac{\partial Y}{\partial u}\right)^2 + \left(\frac{\partial Z}{\partial u}\right)^2 = 1;$$
$$G = \left(\frac{\partial X}{\partial v}\right)^2 + \left(\frac{\partial Y}{\partial v}\right)^2 + \left(\frac{\partial Z}{\partial v}\right)^2 = u^2\cos^2\beta; \qquad (3)$$
$$F = \frac{\partial X}{\partial u}\frac{\partial X}{\partial v} + \frac{\partial Y}{\partial u}\frac{\partial Y}{\partial v} + \frac{\partial Z}{\partial u}\frac{\partial Z}{\partial v} = 0;$$
$$dS^2 = du^2 + u^2\cos^2\beta\, dv^2.$$

How to set a line on the surface (1), setting the beer relation between internal coordinates as $u = u(v)$, $v = v(u)$ or through an intermediate variable (eg, s – $u=u(s)$, $v=v(s)$), on the surface of the cone (1) will be described line. The same internal equation ask the appropriate line on the scan, if known scanning parametric equations, which are based on the immutability of coordinate lines lengths and angles between them, that is based on the first fundamental form held constant for the surface and its sweep. For example, in [3] obtained parametric equation sweep cone:

$$X_{ð} = u\cos\beta\cos(v\cos\beta);$$
$$Y_{ð} = u\cos\beta\sin(v\cos\beta). \qquad (4)$$

It is easy to verify that the coefficients of quadratic forms first scan (4) and the very first fundamental form are the same as the expression (3) obtained for the cone. Thus, the substitution of certain internal parametric equation in equation (1) and (4) give a line both cone (1), and in its sweep (4). Our task is to: find inner circle involute equation to sweep cone because the substitution in (1) will make the corresponding spatial curve on the cone.

Parametric equations involute circle radius as a function of arc length *s* are as follows:

$$x = a\cos\sqrt{\frac{2s}{a}} + \sqrt{2as}\sin\sqrt{\frac{2s}{a}};$$
$$y = a\sin\sqrt{\frac{2s}{a}} - \sqrt{2as}\cos\sqrt{\frac{2s}{a}}. \qquad (5)$$

To find the equation of involute inner circle to sweep cone as *u=u(s)*, *v=v(s)*, together equate equations (4) and (5). Obtain a system of two equations:

$$\begin{cases} u\cos\beta\cos(v\cos\beta) = a\cos\sqrt{\frac{2s}{a}} + \sqrt{2as}\sin\sqrt{\frac{2s}{a}}; \\ u\cos\beta\sin(v\cos\beta) = a\sin\sqrt{\frac{2s}{a}} - \sqrt{2as}\cos\sqrt{\frac{2s}{a}}. \end{cases} \qquad (6)$$

Solving system (6) with respect to *u* and *v*, we get:

$$u = \sqrt{a(a+2s)};$$
$$v = \frac{1}{\cos\beta}\operatorname{Arctg}\left[\frac{(a+2s)\sin\left(2\sqrt{2s/a}\right) - 2\sqrt{2as}}{a - 2s + (a+2s)\cos\left(2\sqrt{2s/a}\right)}\right]. \qquad (7)$$

When substituting expressions (7) cone equation (1) obtain parametric equations spatial curve on the surface as a function of the natural parameter *s*. However, its construction does not produce the desired result (Fig. 3), since the curve has a straight section. This is because the involute range (5) takes its turns the entire area around the origin, while the scan cone (4) is a specific sector with a central angle whose value depends on the angle β. This discrepancy leads to gaps curve on the surface of the cone (Fig. 3).

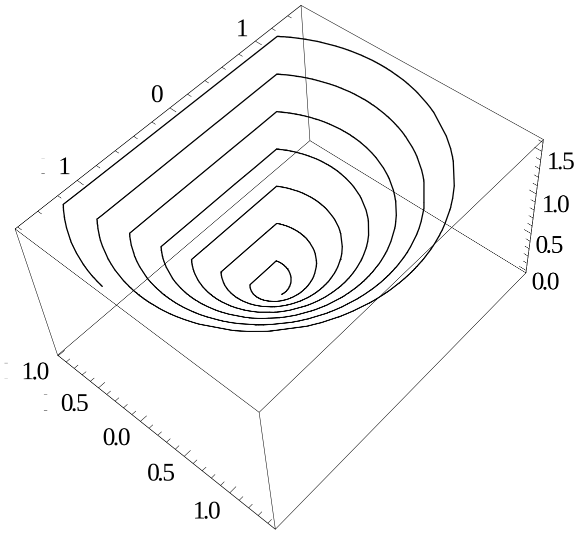


Fig. 3. Curve, given the internal equations (6), built on the surface of the cone (1).

To avoid such a situation and build on the cone smooth curve, progress follows. We use only the first dependence *u=u(s)* of dependencies (7), and the second dependence *v=v(s)* find. To do this, use the first fundamental form (3), which for a natural curve in the function parameter takes the form:

$$\left(\frac{du}{ds}\right)^2 + u^2\cos^2\beta\left(\frac{dv}{ds}\right)^2 = 1. \tag{8}$$

Substituting in (8) the dependence $u = u(s)$ of (7) and its derivative $du/ds = a/(a+2s)$ differential equation and get:

$$\frac{a^2}{a(a+2s)} + a(a+2s)\cos^2\beta\left(\frac{dv}{ds}\right)^2 = 1. \tag{9}$$

The resulting differential equation (9) is reduced to integral that can integrate. So we get a new dependence *v=v(s)*:

$$v = \frac{1}{\cos\beta}\left(\sqrt{\frac{2s}{a}} - \text{arctg}\sqrt{\frac{2s}{a}}\right). \tag{10}$$

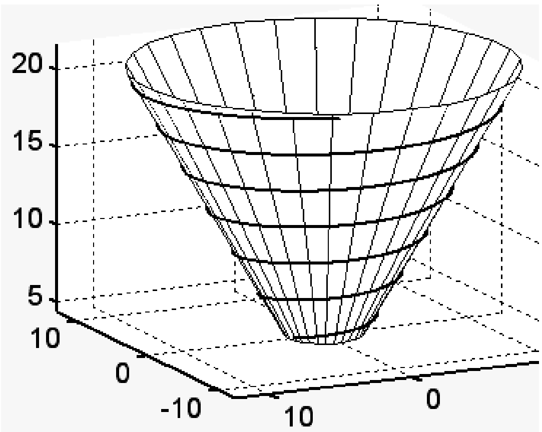
Substituting (10) and first-dependence (7) (1) gives the parametric equation of the conic curve as a function of the natural setting:

$$x = \cos\beta\sqrt{a(a+2s)}\cos\left[\frac{1}{\cos\beta}\left(\sqrt{\frac{2s}{a}} - \text{arctg}\sqrt{\frac{2s}{a}}\right)\right];$$

$$y = \cos\beta\sqrt{a(a+2s)}\sin\left[\frac{1}{\cos\beta}\left(\sqrt{\frac{2s}{a}} - \text{arctg}\sqrt{\frac{2s}{a}}\right)\right]; \tag{11}$$

$$z = \sin\beta\sqrt{a(a+2s)}\ .$$

In curve constructed by equations (11), there are no disadvantages inherent curve shown in Fig. 3. The curve has a natural character and meets the requirements that were put to her. Fig. 4 curves constructed on the surface of the cone angle of its generators $\beta = 60^0$ and turns of different densities, depending on the value of *a* constant.



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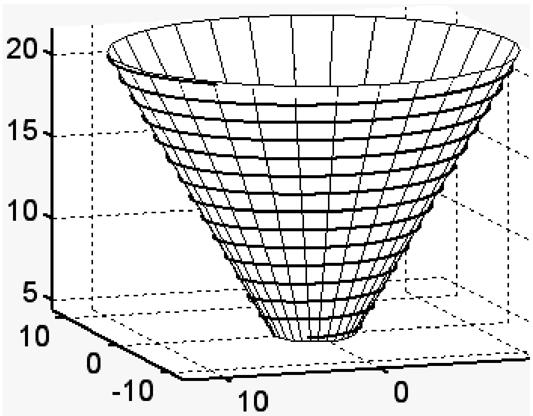
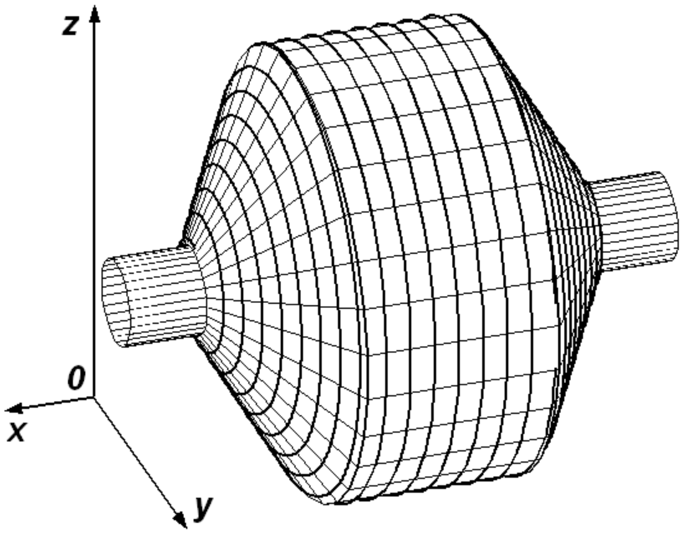


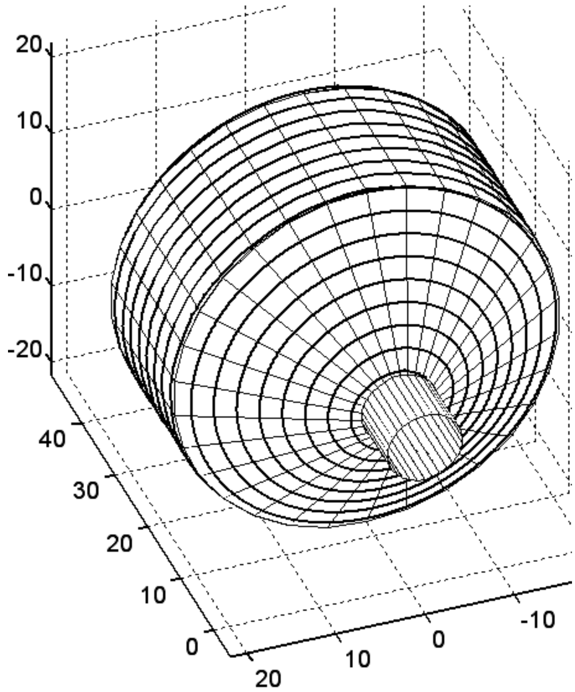
b

Fig. 4. The curves on the surface of the cone, constructed by parametric equations (11) with $\beta = 60^0$:
a) *a=0,5;* b) *a=0,1.*

If two identical cones with the same coiling direction of the curve to connect with each other so that they coincided more bases and end of lines, too, the point which moves along the curve of one cone to the side fundamentals continue its movement along the curve of the second cone, without changing This direction of rotation around a common axis cones. Through the movement of the first cone viddalyalasya it on its axis, and the transition to the second cone will approach. If between cones placed cylinder with a screw line, we get the items bitsylindrokonichnoho drum. Fig. 5,a drum rotated so that it is seen as a spiral curve on the cone smoothly into a spiral at middle cylindrical surface, and Fig. 5,b so that it is visible conical spiral curve on the surface.



a)



b)

Fig. 5. Cylinder drum lines coiling rope on its surface
a) shows all the working surface of the drum;
b) shows the conical and cylindrical parts.

Suppose Cylinder drum with a horizontal axis of rotation, wound rope and loads at its ends is as shown in Fig. 1, ie the average cylindrical portion is completely filled with rope and rope end hanging down on the verge of switching to a cone. Loads are at the same height (eg, mid rise), so their torque equal weight will be balanced. However, when a deviation from this provision appears a difference between the torque, which increases directly proportional to the difference between the distance cargo provided the lift-lowering carried cylindrical drum. However, in our case (Fig. 1) in violation of the balance rope cargo that falls, mosey begins with a conical surface, and the opposite end - namotuvatysya on a cylindrical surface. Due to the fact that the distance from the vertical rope that descends to the axis of rotation (shoulder) decreases, the difference torque will grow more slowly.

Conclusions. The resulting spiral bevel meets two main requirements: its parametric equations written in the function of a natural setting, and the form provides the necessary density for winding conical drum. This allows you to calculate the length of rope that is wound or zmotuyetsya with conical drum, and on this basis to determine torque in any position bitsylindrokonichnoho device. To determine the torque required to know the gravity of the cargo rope and shoulder, the value of which depends on the point rope separation from the surface of the cone. Weight tightrope directly proportional to the length of the attached load to the point of separation. In addition, tilting the generators of the cone to its base and changing winding density can calculate all necessary data, including long rope wound on a tapered drum.

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