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Determining Bandages Rolling Surfaces Shape and Forming Bands and Support Rollers of Heavy Processing Barrels

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Abstract: The questions about dependence of parameters of contact spot of rolling surfaces and rollers of technological drums on their mutual alignment and form accuracy were considered. Proposed design diagrams and mathematical relationships to define the shape forming rolling surfaces in order to ensure optimal conditions for the contact. Design diagrams and mathematical dependences to defining the shape of forming rolling surfaces in order to ensure optimal conditions of the contact were proposed.

Key words: Bandage · Support roller · Geometrical form accuracy · Processing barrels · Contact spot · Rolling surface · Contact optimal conditions

INTRODUCTION

At present rotating technology drums (TD), mainly for the physics and chemical treatment and transportation of materials is widely used in the industry. Such aggregates are drum dryers, rotary calcining kilns for lime burning, clinkers, carbon production, etc. Figure 1 shows the structure of TD - rotating cement kiln 5 × 185 for cement clinker burning.

TD comprises a body made of sheet steel, the outer surface of which is set from 2 to 8 bandages. Bandages with rolling surfaces lean on the support rollers and at the cost of drive with ring gear is carried rotational motion at a given frequency. Considerable mass of TD and high unit loading on each support, impose certain requirements on the shape and location of the contact between bandage and support rollers.

Main Part: A number of papers [1-5] devoted to the study of the conditions of contact surfaces TD. It is obvious that the parameters of the contact is greatly influenced by: the relative rotation axes rolling surfaces and roll band, as well as the accuracy of their shape [6, 7]. The form of rolling surfaces can have both original error resulting in the manufacture and assembly of parts support TD and error acquired during a certain period of operation (mainly as a result of plastic deformation of rolling surfaces). Plastic deformation process is observed in those areas rolling surfaces where surface pressure exceeds the yield stress of the material. Eventually both surfaces break in with each other and their shape will continuously vary. Obviously, the change in shape of the roller surface will be more intense than in the bandage. This is due to the difference in their speeds and mechanical properties of the materials from which they are made. In other words - the form of bandage rolling surface will have a direct influence on the formation of the rolling surface of the roller. Thus the optimal form of roller surface for the certain shape of bandage with relative rotation axes will take place. [1] Currently, to obtain the desired shape of bandages working surfaces and rollers is used remediation technology and special equipment [8-10], which allow a predetermined value by removing the allowance to achieve the required accuracy of the form rolling surfaces. In any case, the contact zone study of bandage and roll at their installation and subsequent operation is urgent and allows solving the problem of optimum shape and their rolling surfaces.

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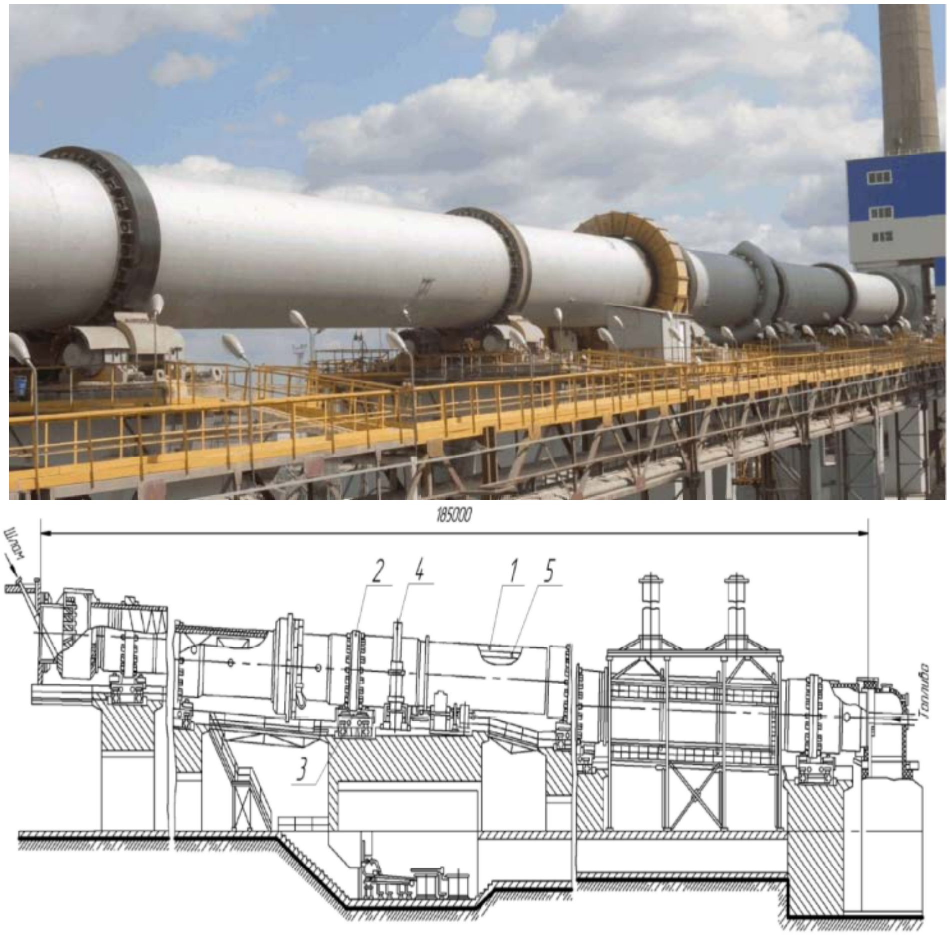

Fig. 1: General view and scheme of technological drum (rotating cement kiln 5×185 m)

In the initial moment, assuming that bandage and roller have cylindrical surface, turning their axes, the contact spot will be minimal in size and have an elliptical shape. Specific pressure in the contact spot will greatly exceed the yield strength of the material and the roller will be the subjected to deformation. Let's assume that the bandage does not have wear, will seek to roll out the roller surface corresponding to the shape-sheeted hyperboloid. In this case, the rolling contact surfaces will take place in a straight line.

Under these conditions the length of the roller and bandage contact line may be determined by the formula:

$$l = \frac{l_p}{\cos\alpha},$$

Where l_p The length of the roller rolling surface, [alfa] - is rotation angle of the roller rolling surface relative to the axis of the bandage rolling surface.

The length of the roller and bandage contact line of the projection on a plane perpendicular to the roll axis (Fig. 2) will be equal to:

$$l'' = l_p \cdot \mathrm{tg}\alpha$$

Let's divide line l'' into n equal segments $A_1 A_2 = A_{n-1} A_n$

Then define the length of the segments $A_2O, A_3O, \ldots, A_nO$:

$$A_2O = \frac{A_2B_2}{\cos\beta_2}$$

But, $A_2B_2 = A_1B_1 = \ldots = A_nB_n$ therefore:

$$A_2O = \frac{A_1B_1}{\cos\beta_2}.$$

As $A_1O = r_1 = R$, from right-angled triangle $A_1O\,B_1$ we have:

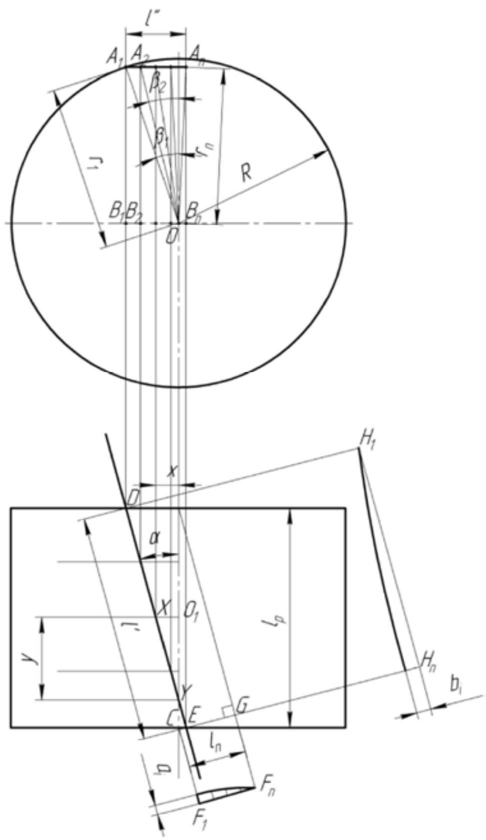

Fig. 2: Design diagram for determining the shape of the forming surface roller bearings

$$A_1B_1 = R\cdot\cos\beta_1\cdot$$

To find the angle [beta]1 it is necessary to know the length of the segment B_1O, which is defined as: $B_1O = l'' - CE$,

where $CE = YE\cdot\sin\alpha = \left(\frac{l'}{2} - XY\right)\cdot\sin\alpha$, a $XY = \frac{y}{\cos\alpha}$

After appropriate substitutions and transformations we obtain:

$$CE = \left(\frac{l'}{2} - \frac{y}{\cos\alpha}\right)\cdot\sin\alpha = \frac{l_p\cdot\sin\alpha}{2\cdot\cos\alpha} - \frac{y\cdot\sin\alpha}{\cos\alpha} = \frac{l_p\cdot tg\alpha}{2} - y\cdot tg\alpha,$$

$$B_1O = l_p\cdot tg\alpha - \frac{l_p\cdot tg\alpha}{2} + y\cdot tg\alpha = \frac{l_p\cdot tg\alpha}{2} + y\cdot tg\alpha,$$

From the right-angled triangle $A_1O\,B_1$ we have:

$\sin\beta_1 = \frac{B_1O}{A_1O}$ and therefore:

$$\beta_1 = \arcsin\frac{B_1O}{A_1O} = \arcsin\frac{B_1O}{R} = \arcsin\frac{tg\alpha\cdot(l_p + 2\cdot y)}{2\cdot R},$$

From the right-angled triangle we have: $A_2O\,B_2$,

In common case, the expression of desired length of the segments for all points B_i will take the form:

Formulas for determining the segments will have the following form:

$$B_iO = l_p\cdot tg\alpha - \frac{(i-1)\cdot l_p\cdot tg\alpha}{n} - \frac{l_p\cdot tg\alpha}{2} + y\cdot tg\alpha = l_p\cdot tg\alpha\cdot\left(0.5 - \frac{i-1}{n}\right) + y\cdot tg\alpha,$$

After appropriate substitutions and transformations we have:

$$A_1B_1 = R\cdot\cos\left(\arcsin\frac{l_p\cdot tg\alpha + 2\cdot y\cdot tg\alpha}{2\cdot R}\right),$$

$$\beta_i = arctg\left[\frac{l_p\cdot tg\alpha\cdot\left(0.5 - \frac{i-1}{n}\right) + y\cdot tg\alpha}{R\cdot\cos\left(\arcsin\frac{l_p\cdot tg\alpha + 2\cdot y\cdot tg\alpha}{2\cdot R}\right)}\right]$$

$$A_iO = \frac{R\cdot\cos\left(\arcsin\frac{l_p\cdot tg\alpha + 2\cdot y\cdot tg\alpha}{2\cdot R}\right)}{\cos\left\{arctg\left[\frac{l_p\cdot tg\alpha\cdot\left(0.5 - \frac{i-1}{n}\right) + y\cdot tg\alpha}{R\cdot\cos\left(\arcsin\frac{l_p\cdot tg\alpha + 2\cdot y\cdot tg\alpha}{2\cdot R}\right)}\right]\right\}}$$

Deviation value of surface circular parallelism ai projected on a plane perpendicular to the line DE, can be found by the formula:

$$a_i = R - A_iO$$

The value x is linked with y with the following dependence:

$$x = y\cdot tg\alpha$$

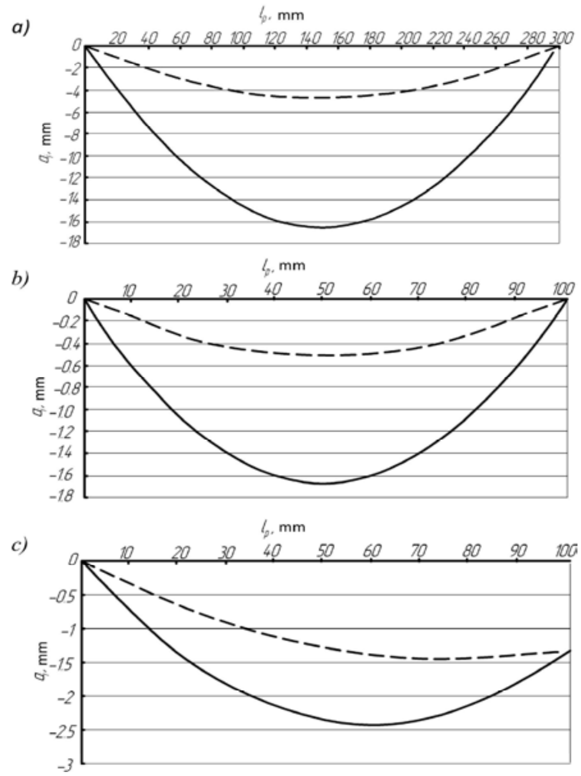

Fig. 3: The shape of the surface roller bearings on a plane perpendicular to the axis of the bandage: a) α =0,3 rad; R=750 mm, l_p =1000 mm, x=1,5 mm; b) α =0,1 rad; R=750 mm, l_p =1000 mm, x =0 mm; c) α =0,1 rad; R=750 mm, l_p=1000 mm, x=10 mm

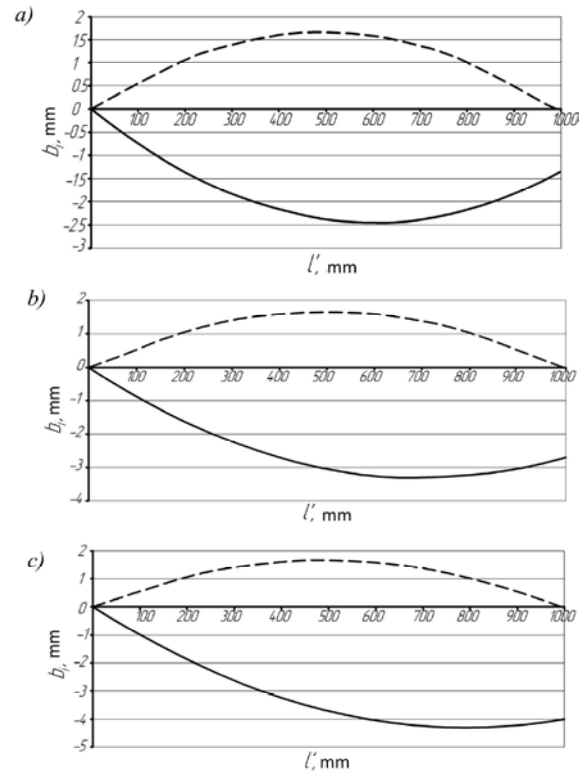

Fig. 4: Shape forming roller surface in bandage axial section (parallel to the line DE) when: a) =0,1 rad; α =10 mm; b) x=0,1 rad; α=20 mm; c) α =0,1 rad; x=30 mm

Values a_i и b_i bi are equal and lengths of a straight line, from which mark off ai and bi (for finding the coordinates of points from which the segment lengths ai and bi, perpendicular to this line) can be determined by the following formulas:

$$F_iF_{i+1} = \frac{l_r}{n} = \frac{l_p \cdot \sin\alpha}{n}, H_iH_{i+1} = \frac{l_p \cdot \cos\alpha}{n} \ .$$

Fig. 3 shows the shape of the surface roller bearings for various values of the angle and axial displacement of bandage relative to the roller, projected on a plane perpendicular to the axis of the bandage.

Form error generatrix support roller in a section, parallel to the line DE, the resulting calculation is shown in Fig. 4.

As can be seen from Fig. 4, roller and bandage surfaces (shown in dotted line) are not the same, so that their surfaces are in contact, the roller should have the

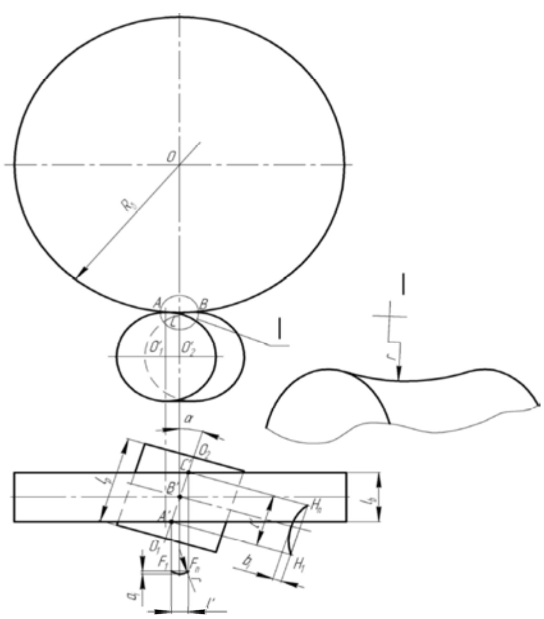

Fig. 5: Design scheme of determining the roller surface shape corresponding to the cylindrical shape of the bandage

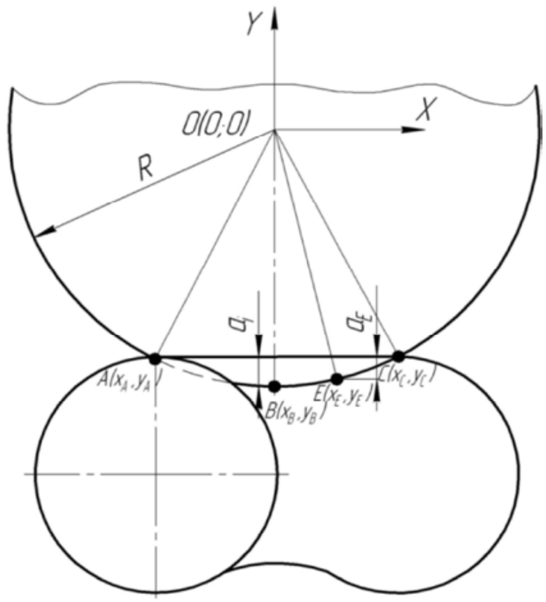

Fig. 6: Design scheme of determining the coordinates of points on the contact surface

same surface curvature as that of the bandage and it is apparent that this shape will not correspond to the shape of one sheet hyperboloid.

Fig. 5. Design scheme of determining the roller surface shape corresponding to the cylindrical shape of the bandage

As $R_б=r$, the roller must contact with the bandage over the entire width of the bandage, i.e. the entire length of the arc ABC (Fig. 6).

To determine the shape of the generatrix surface of the rolling, we divide the line AC (and respectively arc ABC) into n equal parts. As the origin of coordinates we will take bandage axis. Thus,

$$OA = OB = OE = OC = R.$$

Quantity, characterizing the deviation from cylindrical shape projected on a plane, perpendicular to the bandage axis, at an arbitrary point E on the arc ABC is equal to:

$$\alpha_E = y_c - y_E, OE^2 = R_?^2 = x_E^2 + y_E^2$$

Fig. 6 shows, that:

$$x_E = \frac{l'}{2} - \frac{l' \cdot (i-1)}{n} = \frac{l' \cdot (n - 2 \cdot i + 2)}{2 \cdot n},$$

where $i = \in [1: n]$.

Therefore:

$$y_E = \sqrt{R^2 - \frac{l'^2 \cdot (n - 2 \cdot i - 2)^2}{4 \cdot n^2}}$$

Define y_c:

$$R_{\partial}^2 = x_C^2 + y_C^2, OB^2 = R_?^2 = x_B^2 + y_B^2 \,;\, .$$

As the point B lies on the vertical axis of symmetry, i.e. on the axis Y, the coordinates $x_B=0$. Thus, the coordinates y_B and y_c are equal to:

$$y_B = R, \; y_C = \sqrt{R^2 - \frac{l'^2}{4}}$$

Then:

$$a_E = \sqrt{R^2 - \frac{l'^2}{4}} - \sqrt{R^2 - \frac{l'^2 \cdot (n - 2 \cdot i - 2)^2}{4 \cdot n^2}} \, .$$

And:

$$l' = l_b \cdot tg\alpha \, .$$

More generally, the end formula will be:

$$a_i = \sqrt{R^2 - \frac{l_b{}^2 \cdot tg^2\alpha}{4}} - \sqrt{R^2 - \frac{l_b{}^2 \cdot tg^2\alpha \cdot (n - 2 \cdot i - 2)^2}{4 \cdot n^2}} \, .$$

The length of the roller surface at which the contact will occur, we obtain with the following formula:

$$l'' = \frac{l_b}{\cos\alpha} \, .$$

Values ai and bi are equal and the lengths of a straight line, from which mark off ai and bi (for finding the coordinates of points from which the lengths are ai and bi, perpendicular to this straight) can be determined using the following formulas:

$$F_iF_{i+1} = \frac{l'}{n} = \frac{l_b \cdot tg\alpha}{n}, \; H_iH_{i+1} = \frac{l_b \cdot \cos\alpha}{n} \,;\, .$$

Using these dependencies, we'll find the desired roller shape to ensure complete contact with the cylindrical shape bandage.

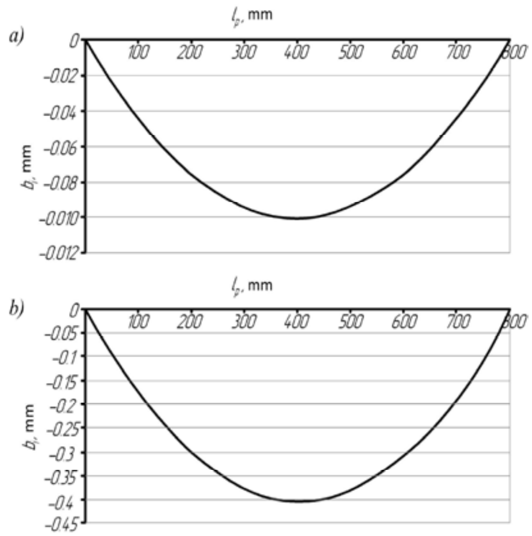

Fig. 7: The form of roller surface forming in projection on a plane, parallel to its axis, when: a) α =0,1 rad; x =0 mm; b) α =0,2 rad; x=0 mm

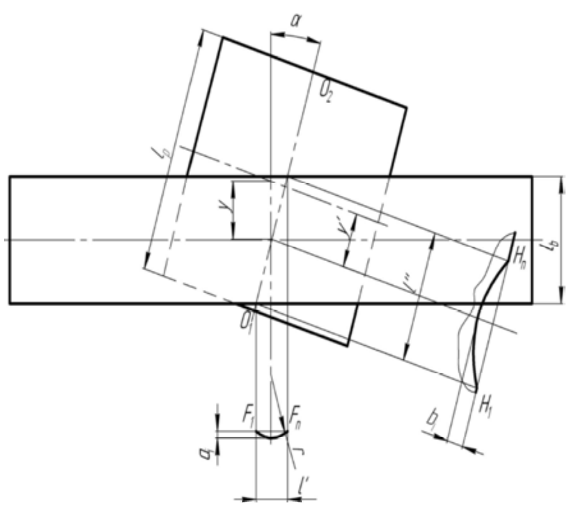

Fig. 8: Deflection of the contact area of bandage with roller by having their axial deflection

Fig. 7 shows the shape of the roller bearings surface for different values of the axis rotation of bandage and roller, the resulting calculation. Analysis of the results shows that by increasing the angle a, the curvature of the surface increases the roller rolling.

On-stream of technological bandages it is often observed bandage axial deflection relative to the roller. Obviously, when bandage and roller axial deflection on the value y (Fig. 8), area and zone of their contact on the value y ' will move:

$$y' = \frac{y}{\cos\alpha}$$

CONCLUSION

It has been found that the mutual arrangement of supports processing drums, such as bandages and cement kiln supporting rollers and form of their rolling surfaces substantially affect the parameters of the contact spot. Besides error defect of the given shape will also influence the contact interaction of the given parts during their operation. The above design diagrams and obtained mathematical dependences for determining the shape parameters forming rolling surfaces allow to obtain the mathematical models and perform simulation of the formation of contact spot and contact characteristics, depending on various conditions and geometrical parameters of supports.

Summary: Thus, the necessary shape forming surfaces rolling bandages and technological support rollers of large technological drums may be determined; when in the presence of their relative rotation may be provided optimal conditions for contact. Besides this condition can be treated when the bandage has or has not axial displacement relative to the support rollers.

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