Geometrical Identification of Cylindrical Carrier of Axial Bearings with Big Diameters

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The paper deals with the analysis of deformation of cross section of cylindrical carrier of axial bearings with big diameters at portal cranes. Fundamental theory on calculating plates and shells with restrictions about proper function of these bearings, helps to define relations for determining required height of cylindrical carrier with the following conditions being met: first, the change of cylindricality of upper part has to be as small as possible; second, movements of supporting points of support surface for connecting axial bearing must not exceed the allowed value. Finally, the expressions for determining height of cylindrical carriers are presented and they can be used by construction engineers when designing optimal connection between rotating platform and carrying structure of portal cranes through axial bearings having big diameters.

Keywords: Cylindrical carrier, Axial bearing, Deformation, Allowed movement, Carrier height

1. INTRODUCTION

Application of axial bearings with big diameters is widely used in means of transport mechanization, especially in portal cranes (Figure 1). The bearing (3) (Figure 2) connects the rotating platform (2) with the cylindrical carrier (4) of the carrying structure (5) in the portal crane. Platform is rotated by planetary reducer (1).

Figure 1: Portal crane with axial bearing

Structural designs of portal carrying structures with stiff cylindrical carrier and flexible upper and lower portal elements offer an opportunity to partially eliminate the influence of roughness of tracks on elimination of deviation from horizontal supporting areas of cylindrical carrier to which axial bearing is screwed. When external loads, in the form of moment M, axial forces F_a and radial forces F_r, are conveyed primarily in the boom plane, there is angular turning of the segments of supporting areas of cylindrical carrier.

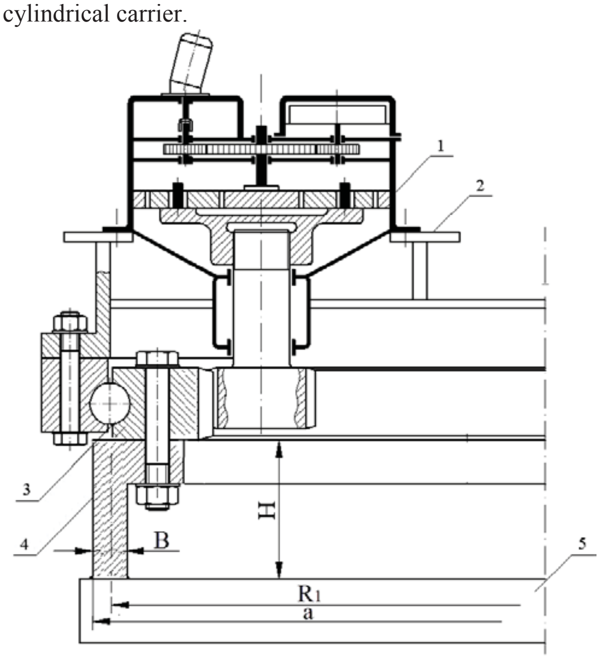

Figure 2: Axial bearing with cylindrical carrier

The angular turning of cross section of cylindrical support has to be within the limits in order to provide safe and reliable operation of the axial bearing.

2. THEORETICAL FUNDAMENTALS ON CALCULATING CYLINDRICAL CARRIERS

If theoretical fundamentals on plates and shells are applied [1], we can define with great accuracy the

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height of cylindrical carrier H (Figure 2) which results in considerable decrease of deformation of supporting area of cylindrical carrier over which the axial bearing lies. Cylindricality is not changed [2] if the dependence is defined:

$$\beta \cdot H \geq 3 \tag{1}$$

The parameter β is calculated from the following relation:

$$\beta = \sqrt[4]{\frac{3\left(1-\nu^2\right)}{B^2 \cdot R_1^2}}$$

where:

H – height of cylindrical carrier,
ν – Poisson quotient ($\nu = 0.3$ for steel),
R_1 – curve radius of cylindrical carrier,
B – thickness of cylindrical carrier.

Expression (1) gives the smallest height H at which the change of carrier cylindricality is not practically conveyed from the lower part to the upper part:

$$H \geq \frac{3\sqrt{R_1 \cdot B}}{\sqrt[4]{\left(1-\nu^2\right)}} \tag{2}$$

After substituting values of ν, we get [1]

$$H \geq 2,5\sqrt{R_1 \cdot B} \tag{3}$$

The analysis of derived constructions, for the relation between radius and thickness of cylindrical carrier $R_1 / B = 20 \div 30$, results in

$$H \geq \left(0,45 \div 0,56\right) R_1 \tag{4}$$

The external loads M, F_a and F_r, which are transferred to the cylindrical carrier through the axial bearing, have various influences on turning of the cross section on the cylindrical carrier (Figure 3).

Due to small dimensions of axial bearing sections, their stiffness can be ignored in further analysis.

As Figure 3a shows, the axial force F_a is equally transferred along the periphery of cylindrical carrier. At portals with four legs the quarter of the value F_a loads the cylindrical carrier causing the turning of its cross section which is defined by turning angle φ:

$$\varphi_{Fa} = \frac{F_a\left(a-R_1\right) \cdot R_1^2}{8\pi R_1 E I_x} = \frac{F_a\left(a-R_1\right) \cdot R_1}{8\pi E I_x} \tag{5}$$

Load caused by the moment M (Figure 3b) can be replaced with the couple $2F_M R_1$, so the moment force being transferred through the cylindrical carrier causes turning of its cross section for the angle φ_M:

$$\varphi_M = \frac{M\left(a-R_1\right) \cdot R_1^2}{4R_1^2 \pi E I_x} = \frac{M\left(a-R_1\right)}{4\pi E I_x} \tag{6}$$

Total angular turning of the cross section of the cylindrical carrier is:

$$\begin{gathered} \varphi = \varphi_{Fa} + \varphi_M = \frac{F_a\left(a-R_1\right) \cdot R_1}{8\pi E I_x} + \frac{M\left(a-R_1\right)}{4\pi E I_x} \\ \varphi = \frac{\left(a-R_1\right)}{4\pi E I_x}\left[\frac{F_a R_1}{2} + M\right] \end{gathered} \tag{7}$$

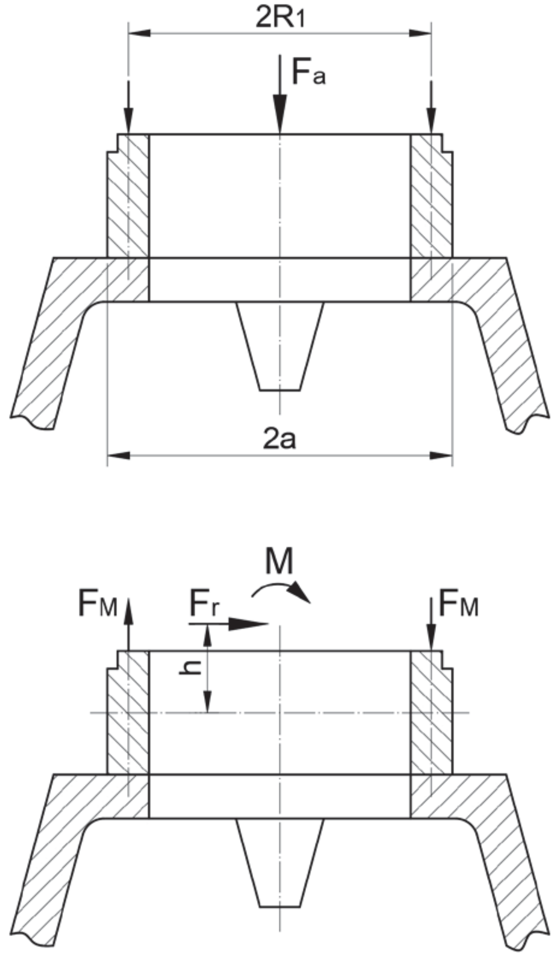

Figure 3: Loads transferred from the axial bearing to the cylindrical carrier

The radial force F_r (Figure 2b) acts on the small arm h, so its influence on the turning of the cylindrical carrier section is negligible.

Movements of supporting points of the cylindrical carrier in the vertical direction Δ can be defined through the turning angle of the cross section:

$$\Delta = a \cdot \varphi \tag{8}$$

but the movement has to be smaller or equal to maximally allowed movement Δ_{max} whose value for the axial bearing with big diameters is as follows [4]:

$$\Delta_{\max} = 0,1mm \text{ for the diameter of } 1m \tag{9}$$

Defined relation (9) provides proper function and long lifetime.

After substituting (7) into (8) and having in mind the restriction (9), it follows:

$$\frac{\left(a-R_1\right)}{4\pi E I_x}\left[\frac{F_a R_1}{2} + M\right] \leq \frac{\Delta_{\max}}{a} \tag{10}$$

The moment of inertia for the right-angled cross section of the cylindrical carrier is defined by the following expression:

$$I_x = \frac{BH^3}{12} \tag{11}$$

When expression (11) is taken into expression (10) and when respective figures are reduced and rounded, we get the formula for calculating the height of the cylindrical carrier:

$$H \geq \sqrt[3]{\frac{a\left(a-R_1\right)\left[\frac{F_a R_1}{2}+M\right]}{\Delta_{\max}\cdot E\cdot B}} \tag{12}$$

For a portal crane having:

$F_a = 16000\,kN$, and

$M = 575000\,kNcm$

the adopted axial bearing has the following basic parameters (Figure 4) [3]:

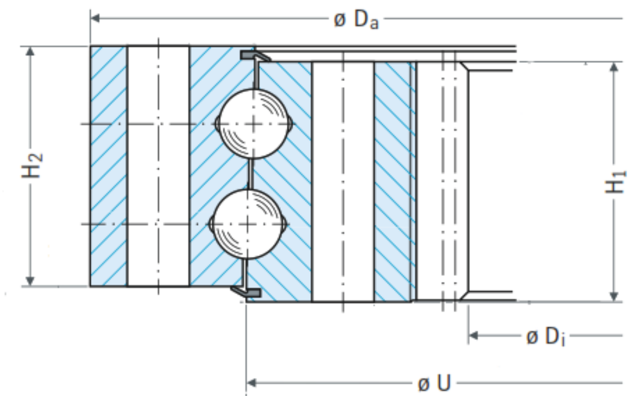

Figure 4: Axial bearing

External diameter of supporting ring $U = 2915\,mm$,

Internal diameter of supporting ring $D_1 = 2715\,mm$,

Height of internal ring $H_1 = 117\,mm$,

Height of external ring $H_2 = 150\,mm$

These parameters are used to define the radii of the cylindrical carrier and its thickness:

$a = 1500\,mm$,

$R_1 = 1470\,mm$,

$B = 60\,mm$.

Now we can determine the height of the cylindrical carrier by expression (12):

$$H \geq \sqrt[3]{\frac{a\left(a-R_1\right)\left[\frac{F_a R_1}{2}+M\right]}{\Delta_{\max}\cdot E\cdot B}}$$

$$H \geq \sqrt[3]{\frac{150\left(150-147\right)\left[\frac{16000\cdot 147}{2}+575000\right]}{2,915\cdot 0,01\cdot 2,1\cdot 10^4\cdot 6}}$$

$$H \geq 47,44\,cm \sim 50\,cm$$

Cylindrical carriers of axial bearings with big diameters (more than 3m) are made of thinner plates in the form of box-like cross section.

If the thicknesses of horizontal and vertical steel plates of which the cylindrical carrier is made are equal, i.e. if $\delta_1 = \delta_2 = \delta$, then the moment of inertia of the cross section (Figure 5) is defined by the following expression:

$$I_x = \frac{\delta(H+\delta)^3}{6} + \frac{(B-\delta)\delta H^2}{2} \tag{13}$$

where:

H – height of the cylindrical carrier,

B – width of the cylindrical carrier,

δ – thickness of the plates.

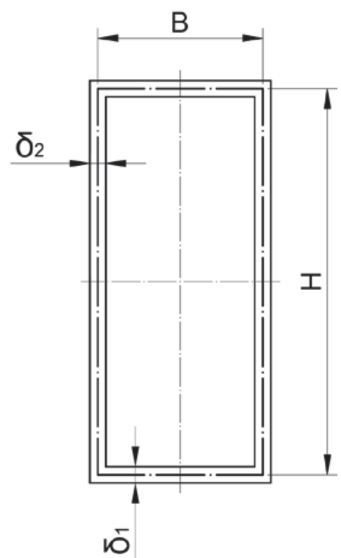

Figure 5: Cross section of the box-like cylindrical carrier

If the elements with the multipliers δ^3 and δ^4 are neglected, the expression (13) leads to the simplified expression for the moment of inertia of the box-like cross section, which is more acceptable in engineering practice:

$$I_x = \frac{\delta H^3}{6} + \frac{\delta H^2 B}{2} = \frac{\delta H^2}{2}\left(\frac{H}{3}+B\right) \tag{14}$$

To define loads of the mentioned portal crane (F_a and M) and geometrical parameters of axial bearing a and R_1, the moments of inertia are connected through expressions (10) and (14) so it follows:

$$I_x \geq \frac{a(a-R_1)(F_a R_1 + 2M)}{8\pi E\Delta_{\max}} = \frac{\delta H^2}{2}\left(\frac{H}{3}+B\right) \tag{15}$$

If the relation between the width and height of the cross section of box-like carrier is B = H/5, the minimum height of cylindrical carrier can be defined by the expression (15):

$$H \geq \sqrt[3]{\frac{a(a-R_1)(F_a R_1 + 2M)}{2\pi E\Delta_{\max}\delta}} \tag{16}$$

In the concrete case, after replacing the values into expression (16) and if δ = 1.0 cm, it follows that H ≥ 75 cm.

3. CONCLUSION

The selection of axial bearing with big diameter which connects the rotating platform and carrying structure of portal cranes, enables us to calculate the needed height of the cylindrical carriers of the bearings.

The constructed analysis leads to the conclusion that in geometrical identification of cylindrical carrier its height should have the value which does not change the cylindricality of carrier and deviations of supporting points of the area for bearing connection should not exceed allowed values. If the carrier height is calculated this way, lifetime of the bearing is significantly increased.

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