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ECONOMIC ASPECTS OF NEW METHODS OF ROPE DRUM CALCULATIONS

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When designing machine parts, very often overestimated safety margins are used in calculations, which leads to an unjustified increase in the metal consumption of the machine. When winding a rope on a drum, compressive, bending and torsional stresses arise in its wall. The main ones are compressive stresses, which are determined according to the theory of the stress state of the ring, which is loaded with pressure uniformly distributed over its outer surface.

The compressive stress is determined by the formula [1]

$$\sigma_{ct} = \frac{S_{\max}}{\delta t} \leq \left[\sigma_{ct}\right] \quad (1)$$

Where: $\left[\sigma_{ct}\right]$ – is the permissible stress, which depends on the operating mode group and the material of the drum.

The bending stress in the drum wall is determined by the formula

$$\sigma_u = \frac{M_u}{W_u} = \frac{M_u D}{0{,}1\left(D^4 - D_1^4\right)} \quad (2)$$

Where: M_u – is the bending moment; S_{mas} – maximum rope tension; W_u – bending moment of the cross-section of the drum;

Stress from torque

$$\tau_{kp} = \frac{M_k}{W_{kp}} = \frac{M_{kp} D}{0,2\left(D^4 - D_1^4\right)} \qquad (3)$$

Where: M_k – is the torque; W_{kp} – moment of torsional resistance of the cross-section of the drum.

The total stresses for steel drums are usually determined by the following formula

$$\sigma_{cym} = \sqrt{\left(\sigma_{ct} + \sigma_u\right)^2 + 3\tau_{kp}^2} \qquad (4)$$

The given method of calculating the crane drum is given in engineering calculations.

But it should be borne in mind that it is approximate, because the body of the drum is taken as a pipe of infinite length. In addition, it does not take into account the local stresses in the joint of the joint with the end wall and near the installed stiffeners. A more accurate calculation, if necessary, should be carried out by considering the drum as a cylindrical shell, which obeys both compressive stresses and bending stresses near the end walls and stiffeners, if any.

In addition, it should be taken into account that the wall of the drum, which is loaded with radial pressure from the turns of the rope, may lose stability.

When calculating the stability, the margin of stability of the cylindrical wall is taken from the condition

$$n = \frac{\sigma_{kp}}{\varphi \sigma_{ct}} \geq [n] \qquad (5)$$

Where: $[n]$ – the recommended safety margin; $[n]$=1.7 for steel drums, $[n]$=2.0 for cast iron drums, σ_{kp} – critical stress in the cylindrical wall.

$$\sigma_{kp} = 0,92 E_b \frac{\delta}{l} \sqrt{\frac{2\delta}{D}} \qquad (6)$$

Where E_b is the modulus of elasticity of the drum wall material, φ – the coefficient that takes into account the influence of the deformation of the wall of the drum and the rope.

$$\varphi = \left(1 + \frac{E_k F_k}{E_b \delta t}\right)^{-\frac{1}{2}}$$

Where: E_k – is the modulus of elasticity of the rope; F - the cross-sectional area of all wires of the rope.

The critical stresses s σ_{kp} should not be more $0,8\sigma_t$ for steel drums and more $0,6\sigma_b$ for cast iron drums. Using refined methods of calculations, it is possible to significantly reduce the size of the drum.

The critical load of the drum can be determined by the formula [2]

$$p_{kp} = \frac{D\left(n^2-1\right)}{R^3}\left[1+\frac{\theta^4 R^6 E\delta}{DL^4 n^4\left(n^2-1\right)^2}\right] \tag{7}$$

Where: D is the cylindrical stiffness of the shell $D = \frac{E_b\delta^3}{12(1-\nu^2)}$, n – is the number of half-waves; θ – a coefficient that takes into account the stiffness of the connection of the frontal part with the front part

$$\theta = \pi\sqrt{\frac{\varphi_0^2+0,9\varphi_0+1,5}{\varphi_0^2+0,9\varphi_0+0,21}} \tag{8}$$

Where: $\varphi_0 = 2,6C\sqrt{\frac{R}{\delta}}\left(\frac{\delta}{\delta_l}\right)^3$;

$$C = \frac{1-\frac{r^2}{R^2}}{1+\nu+\left(1-\nu\right)\frac{r^2}{R^2}};$$

r – the hub radius; ν – Poisson's ratio; δ_l – the thickness of the forehead.

Calculations of rope drums show that with geometric parameters that correspond to real drums, the loss of stability of the rope takes place at n = 2...4, and n = 3 corresponds to the main mass of the structures.

At the same time, we will get the formula

$$p_{kp} = 0,15E\left[4,89\left(\frac{\delta}{R}\right)^3+\frac{\delta}{R}\left(\frac{R}{L}\right)^4\right] \tag{9}$$

Or $\sigma_{kp} = p_{kp}\frac{R}{\delta} = 0,15E\left[4,89\left(\frac{\delta}{R}\right)^2+\left(\frac{R}{L}\right)^4\right]$ (10)

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Фідровська Н.М. Канатні барабани / Н.Н. Фідровська .- Монографія.- Харків, «НІМІ». -2012.-195с.