DOI 10.32820/2079-1747-2022-30-5-9
УДК 621.863

THE STABILITY OF THE ROPE DRUM

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The stability problems of rope drums are quite relevant. The rope drum is a thin-walled shell in most cases, which under the influence of external pressure created by the rope can lead to loss of stability. The issues of stability for the drum shell, which is loaded with turns of the rope, are very important, because they are directly related to the safety and reliability of the rope hoist.

The studies made it possible to obtain a new methodology for calculating cylindrical shells for stability, which takes into account not only the length of the shell, but also the rigid connection with the front lip. In addition, a calculation formula was obtained for determining the critical pressure of the oval shell, which bears much similarity to the experiments of American scientists.

The paper also examines the effect of thickness variation on the critical load of the drum is also examined. The conducted studies allow concluding that the parameters of the rope drums completely eliminate the need to install rings and stiffeners. Also, as a result of the study, it was found that the shell of the crane drum under the influence of radial load cannot lose stability. Findings show that in all cases, the gain margin of the shell for the cable drum is greater than the strength.

Keywords: rope drum, shell stability, critical pressure, maximum load, stiffeners.

Фідровська Н.М. Слєпужніков Є.Д., Нестеренко В.В., Коровко А.В. «Стійкість канатних барабанів».

Проблеми стійкості канатних барабанів являються досить актуальними. Канатний барабан являється в більшості випадків тонкостінною оболонкою, яка під дією зовнішнього тиску, який створюється канатом, може привести до втрати стійкості. Питання стійкості обичайки барабана, який, навантажений витками канату являються дуже важливими, тому що з ними пов’язана безпосередньо безпека і надійність канатного підйому.

Провенеді дослідження циліндричних оболонок дозволили отримати нову методику розрахунків на стійкість, яка враховує не тільки довжину оболонки, але і жорсткість з’єднання з лобовинами. Крім цього, було отримано розрахункову формулу для визначення критичного тиску овальної оболонки, яка дає досить добре співпадання з експериментами американських вчених.

В роботі також було розглянуто вплив різностінністі на критичне навантаження барабану. Проведені дослідження дозволили зробити висновок про те, що параметри канатних барабанів дозволяють повністю виключити необхідність встановлення кілець і ребер жорсткості. Також в результаті дослідження було встановлено, що обичайка кранового барабану під впливом радіального навантаження не може втратити стійкість. Дослідження показали, що у всіх випадках запас стійкості обичайки канатного барабану більший, ніж на міцність.

Ключові слова: канатний барабан, стійкість обичайки, критичний тиск, критичне навантаження, ребра жорсткості.

Introduction

The reliability of the cable lift depends mainly on the strength and stability of the rope drum. If the thickness of the shell obtained by the calculation for the strength is not provided, then either its thickness must increase or there is a need to install the elements of rigidity. The first way leads to an increase in the metal content of the drum, and the second one also complicates the manufacturing technology. To ensure the stability of the rope drum shell, reinforcement elements - rings or longitudinal stiffeners - are used, although this design has several disadvantages.

During the operation of the lifting devices, there are some cases of cable drums destruction. But the reason for this a tense state was always which did not threaten the loss of stability of the shell, but which led to the destruction of the fatiguing nature. The complexity of the drum manufacturing technology cannot be justified and, on the contrary, it is necessary to release the construction from the unnecessary elements in terms of stability. Therefore, reducing the metal content of the rope drum shell and ensuring its reliable operation is a very urgent task for modern craning.

Literary data analysis and problem statement

In work [1], the tension state of shells and diaphragms of mine lifting machines is considered on the example of mine lifting machine SHPM BCC 8 / 5x2,7, which is intended for operation at depths up to 1200 meters. It has been observed that cracks appear in the welded joints and breaks. Crack repair was performed by removing the welded metal and re-welding.

In work [2] the studies results of rope drums having rigidity rings are given. It has been shown that the rope drums accept cyclic loads and local peak tensions, especially at weld joints. This is the cause of the appearance and development of fatiguing joints. A program for calculating the tension-strain state of the shell without reinforcing elements and with rings of rigidity is made. The stability issues of the rope drum custom were not observed in the article.

In work [3], an empirical method for creating a parametric model of a mine lifting drum was developed. Drum stability issues were not observed.

In work [4], a numerical simulation of the lifting mechanism dynamics in a cable crane was developed. Drum stability issues were not observed.

In work [5], a simulation of the lifting mechanism was carried out. The four mass dynamic modelwas applied. Based on the choice of the nature change in the acceleration of the mechanism of lifting the load is eliminated dynamic loads in the rope during the established movement. Drum stability issues were not observed.

In work [6], a mathematical model for lifting a crane load was developed. The result is a graphical dependence of the effort change in the elements of the crane when changing individual parameters of the system. Drum stability issues were not observed.

In work [7] The dynamic models of the lifting mechanism with distributed parameters, which were described by differential equations in partial derivatives are applied. Drum stability issues were not observed.

All this suggests that a study of the rope drum stability is necessary.

Therefore, our study focuses on the theory of the stability of the drum shell to identify noticeable reserves and the possibility of using more rigid, more technological and in many cases less metal drums.

Purpose and objectives of research

The purpose of the study is to determine the methodology for calculating rope drums when designing hoisting machines.

To achieve this goal, the following tasks were set:

- to conduct research of a rope drum under the influence of external load;
- to determine the parameters and their influence on the critical load of the cable drum;
- to develop a new methodology for calculating the stability of the rope drum.

Calculation of the cable drum stability

The loss of drum flangel stability, which is loaded with coils of rope, can lead to an accident, significant losses on repair work. Therefore, in the design of rope drums in most cases, the calculation of the stability of the shell is conducted.

The critical tension can not exceed 0,8 σt for steel drums and it is not more than 0,6 σb for cast iron. If the actual margin of resistance is less than the recommended one then it is offered, either to increase the thickness of the shell, or to install the elements of rigidity (stiffeners).

In the study materials, when calculating the stability margin of stability of the cylindrical flunge of druml is considered that:

$$n = \frac{\sigma_{kp}}{\phi \cdot \sigma_{ct}} \geq [n], \tag{1}$$

where [n] is the recommended safety margin,

[n] = 1,7 - for steel drums,

[n] = 2 for cast iron drums.

σcr is the critical tension in a cylindrical flunge by Papkovich formula

$$\sigma_{kp} = 0.92 \cdot E_b \cdot \frac{\delta}{l} \cdot \sqrt{\frac{2\delta}{D_b}}, \tag{2}$$

The influence coefficient of the deformation flunge of drum and rope is calculated by the formula:

$$\phi = \left(1 + \frac{E_k \cdot F_k}{E_b \cdot \delta \cdot t}\right)^{-\frac{1}{2}}, \tag{3}$$

where Ek is the elastic modulus for the steel rope,

Fk is the cross-sectional area of all rope wires.

The analysis of the solutions used in the theory of stability showed that for the parameters of the crane drums the values of the stability factor of the shell are overestimated.

In Fig. 1 the parameters of the real drums and the results of the calculations are given.

The curve a corresponds to dependencies (1). The curve b – Papkovich`s dependencies (2).

Taking into account the influence of the elastic connection of the front with the shell, the calculation should be made by (6).

For δ = δl and r / R = 1/2 we obtain the curve в.

A method of variational calculus was used to estimate pcr using the Euler equation of the mixed variational task in the development by S.M. Kan [8]

To calculate the elasticity of fixation of edges of cylinder of drum with frontal surfaces there is used coefficient θ

$$\theta = \pi \sqrt[4]{\frac{\psi_0^2 + 0,9\psi_0 + 1,5}{\psi_0^2 + 0,9\psi_0 + 0,21}}, \tag{4}$$

ISSN 2079 – 1747 Машинобудування, 2022, №30
DOI 10.32820/2079-1747-2022-30

where

$$\phi_0 = 2.6 \cdot C \cdot \sqrt{\frac{R}{\delta}} \left(\frac{\delta}{\delta_{\mathring{a}}}\right)^3, \quad C = \frac{1 - \frac{r^2}{R^2}}{1 + v + (1 - v) \cdot \frac{r^2}{R^2}}, \tag{5}$$

where δl is the thickness of the front flange,
r is the radius of the front,
v is the Poisson's coefficient.
The dependence of the coefficient θ from the parameters of the drum is shown in Fig. 2.

Fig. 1 – Parameters of cable drums

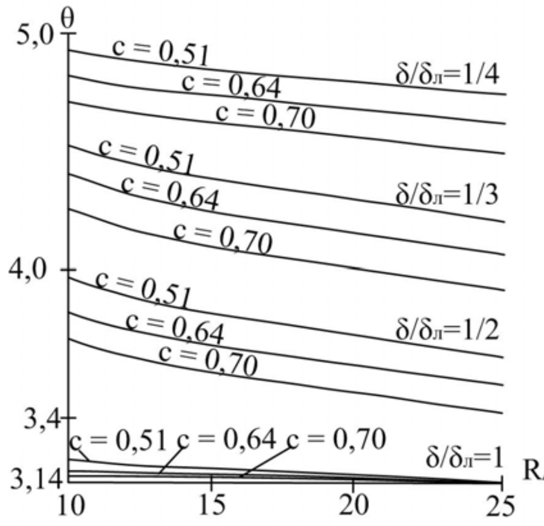

Fig. 2 – The dependence of the coefficient θ from the parameters of the drum

The critical pressure for the rope drum shell can be determined from the formula:

$$p = \frac{D\left(n^2 - 1\right)}{R^3} \left[1 + \frac{\theta^4 R^6 E \delta}{D L^4 n^4 \left(n^2 - 1\right)}\right], \tag{6}$$

where D is the cylindrical rigidity of the drum

$$D = \frac{E \cdot \delta^3}{12 \cdot (1 - v^2)}. \tag{7}$$

The case where the cylindrical shell is not fully loaded but only a section with width V is very interesting and also needs research. The calculated formula for critical pressure was obtained [9]:

$$p_{kp} = \frac{\frac{D \cdot (n^2 - 1)}{R^3} \cdot \left[1 + \left(\frac{\pi}{L}\right)^4 \cdot \frac{R^6 \cdot E \cdot \delta}{D \cdot n^4 \cdot (n^2 - 1)^2}\right]}{\frac{b}{L} - \frac{1}{2 \cdot \pi} \cdot \left[\sin \frac{\pi \cdot (L + b)}{L} - \sin \frac{\pi \cdot (L - b)}{L}\right]}, \tag{8}$$

The experiments made it possible to make a comparative characteristic of fig. 6.

Initial deviations from the geometric shape of the shell reduce its stability. A formula was obtained for the critical pressure of an elliptical shell [9]:

ISSN 2079 – 1747 Машинобудування, 2022, №30
DOI 10.32820/2079-1747-2022-30

$$p_{кр} = \frac{1}{2k-1} \cdot \left[\frac{64 \cdot D \cdot \left(n^2 - 1\right)}{b^3 \cdot \sqrt{\left(7k^2 + 2k + 7\right)^3}} + \left(\frac{\theta}{L}\right)^4 \cdot \frac{E \cdot \delta \cdot b^3 \cdot \sqrt{\left(7k^2 + 2k + 7\right)^3}}{64 \cdot n^4 \cdot \left(n^2 - 1\right)} \right], \quad (9)$$

where k = a / b, a and b are the semi axis of the ellipse.

Conclusions

1. The studies have shown that the flange of the rope drum under the influence of external load, which occurs when winding the rope, with those ratios of radius and length of the drum and the thickness of the flange of the drum can not lose stability.

2. The obtained engineering technique for calculating the cable rope shell made it possible to conclude that, in all cases, the requirements for the local resistance of the shell are greater than for strength, that is, the stability does not cause flange thickening.

3. As we can see, the influence of ellipticity on the critical pressure in the area is possible for crane drums (b / a≥0,95) it does not exceed 14% according to [9] and 8% according to (30). The elastic connection of the front and the flange of drum significantly increases the critical load. The initial possible ovality of the drum shell does not significantly affect the critical load.

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Стаття надійшла до редакції 16 січня 2023 року