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EXPERIMENTAL INVESTIGATION OF THE INFLUENCE OF THE DEVIATION ANGLE OF THE ROPE ON ITS DURABILITY

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All ropes, according to the rules of the State Labour Service, count on the static load without taking into account the bending and torsional stresses. The estimating the rope is based on the density of the rope and the maximum straight length. The operating conditions of rope are very different from the conditions of their work on the running machine. However, experimental studies conducted by scientists help to determine the influence of various factors on the durability of ropes. Based on these experiments, the rope estimation methods were developed.

The use of the proposed machine with a rocker mechanism for fatigue tests will expand the empirical data on the rope wear at different angles; therefore, will increase the durability of the use of ropes in lifting machines.

Key words: *rope of the deflection angle, load, stress, durability, fatigue, wear.*

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Introduction. The current level of technology development requires new regulations for the reliability and durability of load hoisting ropes. When choosing the design of ropes you need to consider the conditions in which they will be operated and make calculations based on these conditions.

Experimental studies conducted by *B.S. Kovalskyi*, *D.H. Zhytkov*, *K.M. Maslenikov*, *A.I. Kolchyn*, *I.F. Nikitin* and others have shown that the durability of the rope depends on its design, operating modes and cannot be determined only by static strength.

Problem statement. When winding the rope on the drum or when bending the rope on the blocks of pulleys there is a deviation of the ropes from the rotation plane of the blocks. When increasing the angles of deviation, there may be very negative effect caused by the fact that the deflected rope slides on board of the block stream, while wearing itself and leads to wear of the stream of the block. As the deflection angle increases, the contact line of the rope with the board of the block stream and the relative speed of displacement of the rope increases. The angles of deviation are limited taking into account the ratio D / d, where D is the diameter of the block, d is the diameter of the rope and the mode of operation of the lifting mechanism. When deflecting the rope on the drum, it is necessary to take into account the possibility of jumping rope into another groove and breaking the rope on the rowing grooves. The works of *Unold, Matthyas* and *B.S. Kovalskyi* were devoted to this issue.

Analysis of current research and publications related to the problem. In [1] the modeling of metal wire ropes under the action of axial tensile and bending load is considered. The authors' studies are based on the hypothesis of the absence of friction between the wires, which is taken in the form of a thin curved rod. It has been determined that on the one hand the twisting of the rope leads to increase in the overall stress in the cross sections of the wire, and on the other hand, the fixing of the ends of the rope leads to increase in contact stress, especially at point contact.

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The authors have concluded that the problem of contact stress in multi-row ropes is a rather difficult task and requires further study.

In [2], the actual stress state of the elements of steel spinning ropes is determined. The dependence of the stress-strain state of the rope on the value of the effective pre-stresses is proved. The authors have made conclusions that increasing the twist pitch of the rope reduces the contact stresses and, thus, it increases the safety of lifting.

The work [3] is devoted to the theoretical research of steel ropes with axial tensile load. It has been shown in the illustrated example that the central wire is loaded with 15.58% of the total load of the spiral l, in other sections of the wire 84.4% of the load. The total twist causes a voltage of 5400.4 N.mm in the outer wires. The authors have concluded that the tensile stress in the central wire is much lower than in the outer wires.

In [4] the technical modeling of steel stretched ropes under the action of tension, torsion and bending is considered. Studies have shown that the stresses from the action of contact forces increase with decreasing axial forces in the wires. The proposed formula for the stress state of the cross section is made in a three-dimensional end element in the form of a final beam. For this purpose, a static and dynamic analysis of this element under the action of shear and rotation has been performed. Particular attention is paid to the residual contact forces that correspond to the bending processes.

In [5] the problem of determining the stress in the wires of the rope that is wound on the drum and the block is analysed. A formula was obtained to determine the additional loads in the rope depending on the geometric parameters of the rope and the bending radius of the rope when bending it on the drum or block. The calculations obtained by this formula were compared with experimental data conducted by *I.F. Nikitin.* The difference was about 5%.

The influence of the deflection angle on the durability of the rope and blocks was studied in the research paper [6].

Based on the research, it is concluded that the greater the deflection angle of the rope that strikes the block, the greater the value of the wear of the rope block and the reduced amount of rope operation time [7] (Fig. 1).

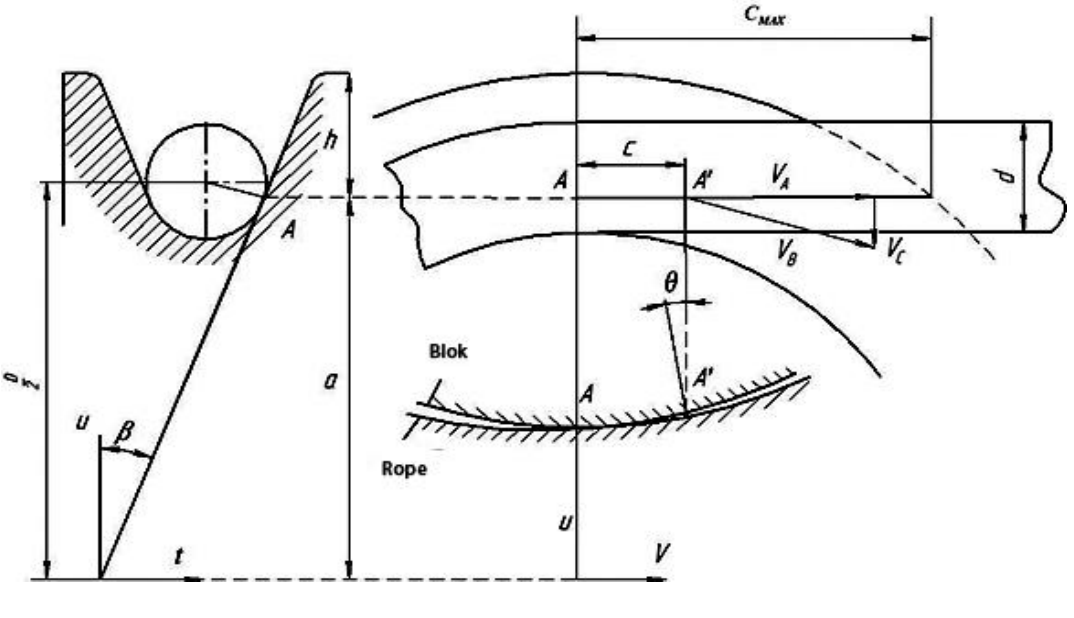


Fig. 1 *Rope deflection on the block*

Presentation of the main material. We obtained an analytical dependence to determine the permissible angle of deflection of the rope that strikes the block. If we can allow the adhesion of rope to the side of the block over a length c, then the maximum angle will be determined by the formula:

$$tg\gamma = \frac{4(\omega l - th\omega l)}{D\omega l} + tg\theta \qquad (1)$$

$tg\theta$ – the angle of rotation at the point of separation from the surface of the block; D – block diameter; 2l – distance between blocks; T – rope tension; B – the rigidity of the bend of the rope; k – constant for ropes of a certain construction; d – rope diameter.

$$tg\theta = \left(\frac{dt}{dv}\right)_{v=c} = \left(\frac{vtg\beta}{\sqrt{a^2+c^2}}\right)_{v=c} = \frac{ctg\beta}{\sqrt{\left(\frac{D}{2}-h\right)^2+c^2}} \qquad (2)$$

The object of experimental research is an experimental setup to determine the durability of the rope depending on the geometric parameters of the rope and the rope block (Fig. 2).

For experimental research, we made a machine with a rocker mechanism, which consists of an electromotor, a cylindrical transmission, a worm gear and rope blocks. The machine is additionally equipped with a crank-rocker mechanism connected to the output shaft of the worm gear, and the rope blocks are fixed separately from the mechanism for adjusting the angles of the rope.

The machine with a rocker mechanism for fatigue testing of the rope consists of a frame (1), which is connected to the floor by means of an anchor fastening (2). The electromotor (3) is fixed on the frame, which by means of a cylindrical transmission (4) drives a worm gear (5), at the end of which a crank (6) is fixed, which enters the groove of the rocker arm (7), which is hinged to the frame (1). At the other end of the rocker arm is attached a rope (8), which passes through the blocks (9) and (10), and is connected by a lifting eye nut (11) with the rod (12), directly on which the load (13) is put (Fig. 3).

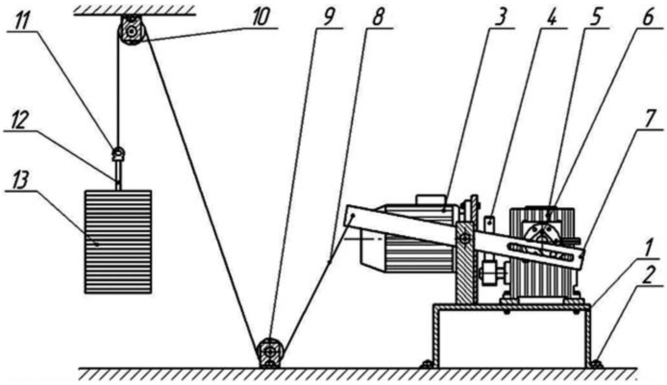
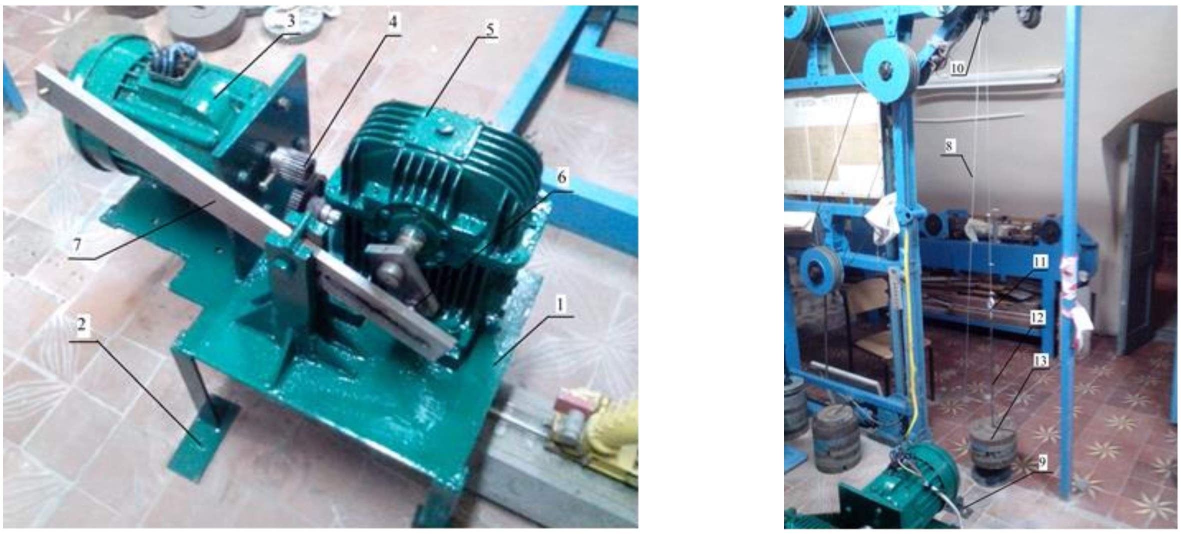


***Fig. 2.** Scheme of experimental setup:*
1 – frame, 2 – anchor, 3 – electromotor, 4 – cylindrical transmission, 5 – worm gear, 6 – crank, 7 – rocker, 8 – rope, 9, 10 – rope blocks, 11 – lifting eye nut, 12 – rod, 13 – load.



a) ***b)***

***Fig. 3** Experimental stand, a – top view, b – side view*

At the first stage, the study of the influence of the deflection angle of the rope which runs from the block has been carried out. Three values of angle 3º, 5º, and 7º and three blocks with diameters of 96 mm, 72 mm and 48 mm were selected. The angle was $2\beta = 11°$. The rope was stretched with a load of 500N. The results of the obtained values are shown in table.

Based on the obtained experimental data, which are given in the fourth section, the formula for the coefficient of influence of the angle of deviation of the rope on the durability of the rope was derived:

$$f = 0{,}01045\gamma^2 - 0{,}1672\gamma + 1{,}361 \quad (3)$$

Our research made it possible to clarify the method of calculating the rope by service life. To do this, we introduce four additional coefficients in Kowalski's formula:

$$D = \frac{ABC}{f}\left(d + abc\frac{T}{d}\right) \qquad (4)$$

Table

Testing of a steel wire rope 0 (with linear contact of wires between layers) for durability at different angles of deviation and the block with a diameter of 48 mm.

Test number	Degrees deviation of a rope		
	3º	5º	7º
1	9959	9572 9375	2654 2795
2	10134 9993	9468 9377	2807
3	9973	9260 9395	2789
4	9853 9979	9396	2689 2777
5	10031 9984	9347	2815
6	9968	9284 9398	2795
7	9899 9966	9254 9385	2699 2755
8	9916 9993	9511 9395	2824
9	10054 9972	9436	2789
10	9973	9456	2694

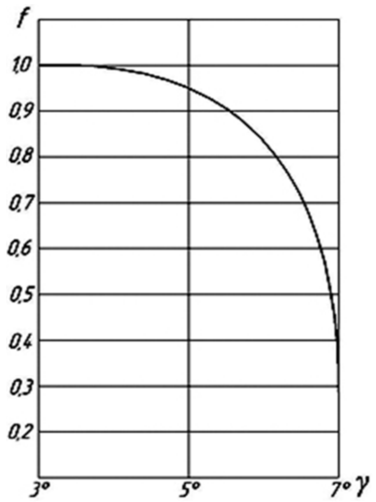


Fig. 4 *– A coefficient f*

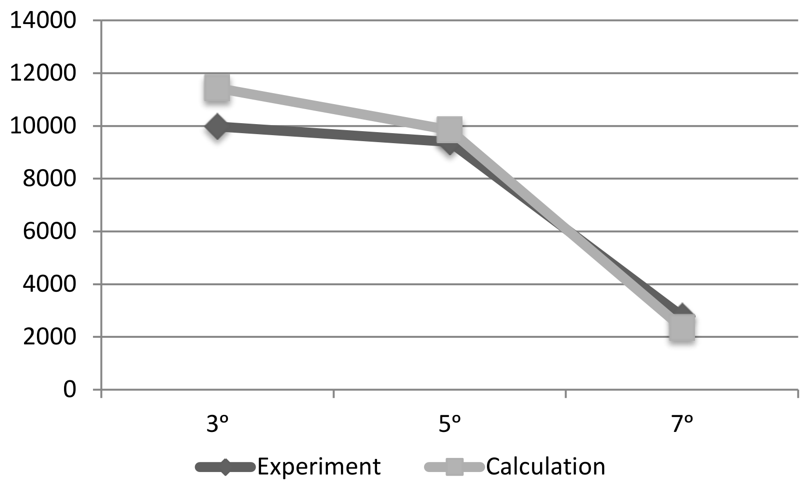


Fig.5 *Estimated and average value of rope strength tests for durability at different angles of deviation*

f – a coefficient that takes into account the angle of deflection of the rope when leaving the block (3) (fig. 4);
a – a coefficient that depends on the material of the block (steel – 1,1; cast iron – 1,0; duralumin – 0,8; nylon – 0,6);
b – a coefficient that reflects the influence of the radius of curvature of the stream r and depends on the tension of the rope and the direction of twisting;
c – a coefficient that takes into account the metal filling of the rope section. For six-strand ropes type (with point contact of wires between layers) c = 0.21, (with linear contact of wires between layers) c = 0.20, for eight-stand ropes c = 0.23:
A – a coefficient that establishes the relationship of the value $\frac{D}{d}$ with the number of cycles N;
B – a coefficient that takes into account the influence of the rope structure;
C – coefficient that takes into account the influence of wire size on the endurance limit at pulsating contact stresses.

The estimated and average value of rope strength tests for durability at different angles of deviation are shown in Figure 5.

Conclusions. The question of the deflection of the rope on the drum and the block is the subject of special discussion in the process of designing lifting machines. When solving the problem of the limiting angle of deflection of the rope on the drum, some assumptions were made that reduced the accuracy of the calculation. The article presents new dependencies that give an opportunity to take into account the distance between the blocks, they are more accurate. The experiments have confirmed the obtained analytical solutions.

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KANATIN SAPMA BUCAĞININ ONUN UZUNÖMÜRLÜLÜYÜNƏ TƏSİRİNİN EKSPERİMENTAL TƏDQİQİ

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Bütün kanatlar Dövlət Əmək Xidməti qaydalarına uyğun olaraq, əyilmə və burulma gərginliyi nəzərə alınmadan statik yük üçün nəzərdə tutulub. Kanatın hesablanması onun sıxlığına və maksimal xətti uzunluğuna əsaslanır. Kanatın işinin real şəraiti, hərəkətdə olan maşının iş şəraitindən çox fərqlənir. Lakin alimlər tərəfindən keçirilmiş eksperimental tədqiqatlar kanatların uzunömürlüyünə müxtəlif amillərin təsirini müəyyən etməyə kömək edir. Məqalədə eksperimentlər əsasında kanatların hesablanma metodikası işlənib və öz əksini tapmışdır.

Yorğunluğun sınaqdan keçirilməsi üçün təklif olunan çarxqollu mexanizmli maşınların istifadəsi, kanatın müxtəlif bucaqlar altında yeyilməsinə aid empirik məlumatları genişləndirəcək və beləliklə, qaldırıcı maşınlarda kanatlardan istifadənin uzunömürlüyü yüksələcək.

Açar sözlər: *kanatın sapma bucağı, yük, gərginlik, uzunömürlük, yorğunluq, yeyilmə.*

ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ ВЛИЯНИЯ УГЛА ОТКЛОНЕНИЯ КАНАТА НА ЕГО ДОЛГОВЕЧНОСТЬ

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Все канаты, согласно правилам Государственной службы труда, рассчитывают на статическую нагрузку без учета изгибающих и крутильных напряжений. Расчет каната основан на плотности каната и максимальной прямой длине. Реальные условия работы каната сильно отличаются от условий их работы на ходовой машине. Однако экспериментальные исследования, проведенные учеными, помогают определить влияние различных факторов на долговечность веревок. На основе этих экспериментов были разработаны методы расчёта канатов.

Использование предлагаемой машины с коромысловым механизмом для испытаний на усталость расширит эмпирические данные об износе каната под разными углами, и, таким образом, повысится долговечность использования канатов в подъемных машинах.

Ключевые слова: угол отклонения каната, нагрузка, напряжение, долговечность, усталость, износ.

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