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DETERMINATION OF THE INFLUENCE OF THE GEOMETRIC PARAMETERS OF ROPE BLOCKS ON THE DURABILITY OF THE ROPE

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Abstract. Problem. *The durability of crane ropes is very important, as it ensures not only the main costs of operating the lifting machine, but also the safety of loading and unloading operations The operating conditions of the rope have a very significant effect on the period of its use, but they are not always taken into account. Yes, the method of calculating the rope, which is reflected in the standard, does not take into account the operating conditions of the rope, so it is very difficult to accurately predict its durability. In modern educational and reference literature, the influence of the size and geometry of rope blocks on the durability of lifting ropes is underestimated. The main criterion that is taken into account when choosing a rope according to existing methods is the tensile strength of the rope, although as shown by the research of many famous scientists, the wires of the rope break precisely as a result of bending on the blocks and the drum. The diameter of the block is selected depending on the diameter of the rope and the mode of operation of the lifting mechanism. The material of the block and its geometry are not taken into account at all when choosing the type of rope and its diameter, while the wear of the surfaces of the rope and the block greatly affects the durability of these elements of the lifting mechanism. Determining the factors that affect the wear of the rope and the reduction of its durability is quite an important task and requires not only theoretical, but also experimental research. At the same time, ropes of different designs and diameters were considered. At the same time, ropes of different designs and diameters were considered. This made it possible to evaluate the influence of various elements of the rope and the block on the predicted durability of the rope. The conducted research made it possible to improve the formula of B. Kovalsky, which he proposed for choosing the diameter of the rope according to the service life. The dependence of the influence of the opening angle of the block groove, which is determined from the condition of the reduction of rope torsion during its deviation, on the durability of the rope was obtained. In order to obtain a more realistic picture of the load of the rope that bends on the block and drum, the calculation scheme was improved and the number of factors that have a significant impact on the durability of the rope was increased. The results of the research significantly bring the rope load conditions during bending on the block and drum closer to real values.*
Key words*: rope, lifting mechanism, rope block, rope durability, rope deflection angle.*

Introduction

The method of rope calculation, which is currently used by the standard, does not correspond to modern conditions of rope operation and does not provide its necessary durability. In those calculations that are given in the educational and reference literature, he underestimates the influence of the geometric and elastic parameters of the blocks on the durability of the ropes. The rope is selected only from the conditions for stretching, at the same time, as it has been experimentally proven, that the breakage of the wires in most cases occurs precisely when the rope passes through the block.

Experimental studies carried out by B. Kovalsky [1], D. Zhitkov, K. Maslennikov, A. Kolchinim, I. Nikitin [2] others showed that the durability of the rope depends on its design, operating modes and cannot be determined only by static strength.

It was believed that the main cause of rope failure was material fatigue. Each wire rope withstands a certain number of bends, so it is necessary to experimentally determine the relationship between the service life of the rope and various factors that cause its wear.

Analysis publications

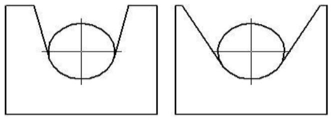
Comprehensive research into the durability of steel wire ropes has been carried out by scientists such as B. Kovalsky [1], K. Maslennikov, V. Verkle [3], N. Markman [4], D. Zhitkov, V. Malinovsky [5].

Studies have been carried out that are aimed at creating the foundations of the structural mechanics of a steel rope, which is based on the general principles of the mechanics of a deformed body and takes into account the specifics of the rope as a complex unit. M. Glushko [6] created the foundations of the theory of calculations, which allow one to accurately estimate the magnitude of the stresses that arise in steel hoisting ropes.

In [7], the torsion of the rope, which is caused by its deviation, was studied and it was Table 1. Values of coefficients shown that it depends on the opening angle of the groove. And the greater the angle of deviation, the greater the torsion of the rope (Table 1).

The opening angle of the groove of the block is determined from the condition of reducing the torsion of the rope during its deviation. Table 1 shows the dependence of the rope torsion on the angle of deviation when working on pulleys with different opening angles of the block groove.

Table 1 – Dependence of the rope torsion on the angle of deviation when working on blocks with different groove angles

Influence of the angle of deviation and the opening angle of the block stream on the torsion of a steel rope with a diameter of 20.0 mm				 30 градусів 60 градусів			
Deviation angle, deg	1	1.5	2	2.5	3	4	5
Dependence of rope torsion on deviation angle for a 30 degree opening angle							
Torsion from deviation, deg/m	172	286	401	516	573	802	976
Dependence of rope torsion on deviation angle for a 60 degree opening angle							
Torsion from deviation, deg/m	115	172	229	286	344	401	516

Statement of the problem

Operating experience shows that the pulley opening angle, which is recommended in normal conditions, does not meet the operating conditions of the traveling ropes. The side surfaces of the pulley grooves, which are made according to these standards, have intense wear due to an insufficient opening angle. Therefore, the pulleys of traveling blocks should have an opening angle of the groove walls of 50 instead of 40-45 according to OST 24-191-01.

Tests and practice have shown that the amount of rotation of the rope around its axis depends on the opening angle of the groove. The larger the angle, the less the rope will twist. But many companies make pulleys with -30, 35 and 45 angles, taking into account the requirements of different standards.

Purpose of the problem

The purpose of the scientific research is to improve the methodology for determining the durability of the rope by taking into account new factors that significantly affect the operation of the rope.

Presentation of the main material

B. Kovalsky [1] proposed a new method for calculating crane hoisting ropes for durability, which takes into account the influence of the multiplicity of the chain hoist and the dimensions of the drum on the lifting mechanism. One of the main wear parameters is the radial pressure of the rope on the block, which is proportional to the rope tension T. The radial pressure determines the stressed state of the wire at the points of contact with each other and the groove of the winding body.

B. Kovalsky recommended such a dependence to determine the block diameter

$$\mathrm{D} = \mathrm{ABC}\left(\mathrm{d} + \mathrm{abc}\frac{\mathrm{T}}{\mathrm{d}}\right). \quad (1)$$

Where $\boldsymbol{\alpha}$ is a coefficient that depends on the material of the block (steel - 1.1; cast iron - 1.0; duralumin - 0.8; capron - 0.6); b is a coefficient that shows the influence of the rounding radius of the stream r and depends on the tension of the rope and the direction of the lay. With a safety margin, the values $m = 5 \div 6$ bare induced in Table 2.

Table 2 – Values of coefficient b

r/d	Lay	
	cross-over	one-sided lay
0,53	1	1
0,56	1,04	1,02
0,60	1,10	1,05
∞	1,30	1,20

c is a coefficient that takes into account the metal filling of the rope section. For six-strand ropes of the TK type c = 0.21, LK c = 0.20, for eight-strand ropes c = 0.23.

A is a coefficient that establishes a relationship between the value $\frac{D}{d}$ and the number of cycles N. On the basis of research on running cars, such a relationship can be established

$$A=\frac{C'}{1+\frac{C''}{N}}. \quad (2)$$

Based on the experiments of Scoble [11], Wernl [12] and others $C' = 14{,}5, C'' = 56000$
Within $N = 30000 \div 300000, A = 0{,}2\sqrt[3]{N}$
B is a coefficient that takes into account the influence of the rope structure. At the ultimate strength of the wire $\sigma = 1600 \div 1800$MPa, its value is given in Table 3.

Table 3 – The value of the coefficient B

Design	Twisting lay	
	lay cross	one-sided lay
6x19+ОС ТК	1,15	0,95
6x19+ОС ЛК-Р	1,00	0,90
6x37+ОС ТК	1,20	1,10
6x37+ОС ТЛК-О	1,06	0,95

C is a coefficient that takes into account the influence of the wire size on the endurance limit at pulsating contact stresses; its values are given in Table 4.

Table 4 – The value of the coefficient C design

Design of rope	D				
6x37+o.c.	0,96	1	1,04	1,06	1,08
6x19+o.c.	0,94	1	1,06	1,10	1,13

D is the block diameter;
d is the diameter of the rope.
Consider an example, T=31123Н, d_k=17,5 мм, rope LK-3 6x25, 4m. We choose the diameter of the block and the drum according to the normative data

$$D=ed_k=25\cdot 175=437{,}5\ . \quad (4)$$

According to the Kowalski formula:

$$D=ABC\left(d_k+0{,}25\frac{S}{d_k}\right) = 10\cdot 1\cdot 1$$

$$\left(17{,}5+0{,}25\frac{31123}{9{,}81\cdot 17{,}5}\right)=628\text{мм} \quad (5)$$

where C when $\frac{r}{d}=\frac{10}{17{,}5}$=0,57 according to the graphs we take 1. A=10 for $N = 15000$ cycles.
As you can see, the standard value of the diameter of the block and the drum differs from that recommended by B. Kovalsky by 30 %.
Let us determine the durability of the rope with this block diameter

$$A=\frac{D}{BC\left(d_k+0{,}25\frac{S}{d_k}\right)}=$$

$$=\frac{437{,}5}{1\cdot 1\left(17{,}5+0{,}25\frac{31123}{9{,}81\cdot 17{,}5}\right)}=6{,}97. \quad (6)$$

This value of A corresponds to a durability of 50,000 cycles.

As we can see from the calculation, the durability of the rope selected according to the normative data decreases by 3 times.

Let's consider another case. Let's take a rope TK 6x18 cross lay, which has a force of 28495N with a diameter of 17mm. For this rope, we will have a block diameter

$$D=25\cdot 17=425\ \text{мм}. \quad (7)$$

Determine the durability for this block diameter

$$A=\frac{425}{1{,}1\cdot 1{,}1\left(17+0{,}25\frac{28495}{9{,}81\cdot 17}\right)}=\ 5{,}96 \quad (8)$$

This A value corresponds to a durability of 25,000 cycles.
According to the Kovalsky formula for A=10

$$D=1{,}1\cdot 1{,}1\cdot 10\left(17+0{,}25\frac{28495}{9{,}81\cdot 17}\right)=\ 712{,}7\ \text{мм}. \quad (9)$$

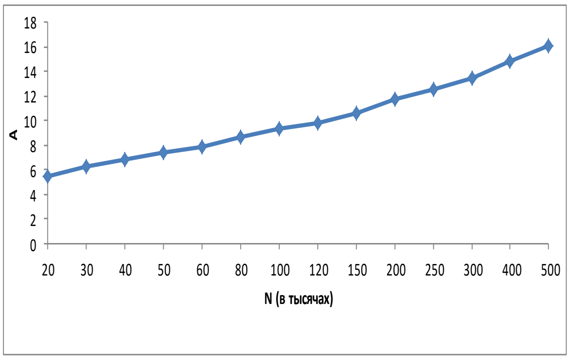


Fig. 1. Dependence of the coefficient A of the influence of rope kinks on the blocks during operation

From graph 1 we get N=150000 cycles. As you can see, with an increase in the block diameter by 68 %, we get a 6-fold increase in durability.

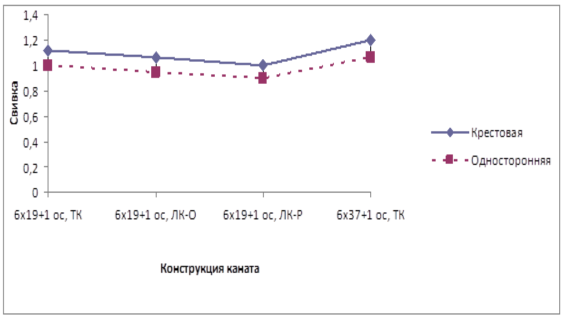


Fig. 2. Coefficient B, taking into account the influence of the rope structure

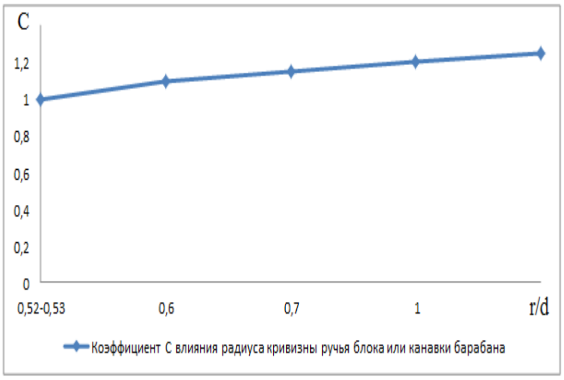


Fig 3. Coefficient C takes into account the influence of the radius of curvature of the groove of the block or the groove of the drum

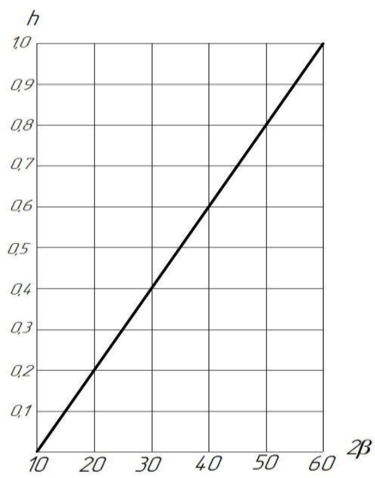


Fig. 4. Dependence of the coefficient h on the angle β

As mentioned above, the opening angle of the groove of the rope block greatly affects the durability of the rope, but it was not taken into account in the formula of B. Kovalsky. We carried out experimental studies, on the basis of which a formula was derived to determine the effect of the opening angle of the groove to the block on the durability of the rope

$$h = 0{,}2(0{,}2\beta - 1). \quad (10)$$

The graph of the dependence of the coefficient h on the opening angle of the groove block is shown in fig. 4

Then formula (1) takes the form

$$D = \frac{ABC}{h}\left(d + abc\frac{T}{d}\right) \quad (11)$$

Conclusions

The analysis of the obtained solutions showed that in addition to the main factors that are included in the method of calculating the ropes for the service life of B. Kovalsky, there are a number of other indicators that have a significant impact and taking into account which will help to significantly increase the durability of crane ropes.

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Визначення впливу геометричних параметрів канатних блоків на довговічність канату

Анотація. Проблема. *Довговічність кранових канатів має дуже важливе значення, оскільки забезпечує не тільки основні витрати на експлуатацію вантажопідйомної машини, але й безпеку навантажувально-розвантажувальних операцій. Умови експлуатації канату дуже суттєво впливають на термін його використання, але не завжди вони враховуються.* ***Мета.*** *Методика розрахунку канату, відтворена в стандарті, не враховує умови роботи канату, тому спрогнозувати точно його довговічність дуже складно. У сучасній навчальній і довідниковій літературі вплив розмірів і геометрії канатних блоків на довговічність підйомних канатів недооцінена.* ***Методика.*** *Основним критерієм, що врахований у виборі канату за наявними методиками, є сила розтягнення канату, хоча, як показують дослідження багатьох відомих учених, дротинки канату розриваються саме внаслідок згинання на блоках і барабані. Діаметр блоку обирається залежно від діаметра канату й режиму роботи механізму підйому. Матеріал блоку та його геометрія зовсім не враховується під час вибору типу канату і його діаметра, тоді як зношення поверхонь канату й блоку дуже впливає на довговічність цих елементів механізму підйому. Визначення факторів, що впливають на зношення канату й зменшення його довговічності, є досить важливим завданням і потребує не тільки теоретичних, але й експериментальних досліджень.* ***Результати.*** *У роботі розглядалися канати різної конструкції та діаметра. Це дало змогу оцінити вплив різних елементів канату й блоку на прогнозовану довговічність канату.* ***Оригінальність.*** *Проведені дослідження дали змогу вдосконалити формулу Б. Ковальського, яку вчений запропонував для вибору діаметра канату за терміном служби. Отримано залежність впливу кута розкриття рівчака блока, який визначається з умови зменшення кручення канату в разі його девіації, на довговічність канату.* ***Практична цінність.*** *Для отримання більш реальної картини навантаження канату, що згинається на блоці та барабані, удосконалено розрахункову схему й збільшено кількість факторів, які мають суттєвий вплив на довговічність канату. Результати дослідження значно наближають умови навантаження канату під час згину його на блоці та барабані до реальних значень.*

Ключові слова: *канат, механізм підйому, канатний блок, довговічність канату, кут відхилення канату.*

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