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THEORETICAL AND PRACTICAL ANALYSIS OF THE IMPROVEMENT OF THE WORKING PARTS OF THE EXCAVATOR BUCKET

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Abstract

This article analyzes from a theoretical and practical point of view that steel cable shovels in the mining industry improve the working bodies of the bucket, and the decrease in productivity is due to the negative consequences of factors arising as a result of weight, friction and reaction forces acting on the excavator bucket during operation and as a result of the installation of the bushing, the service life of the bucket ring increases, and during operation the working body of the excavator comes into contact with rocks, the optimal position of the bucket, depending on the angle of concavity in the mining area of 60 degrees, the influence of forces and the angle between the steel cable lifting the bucket and the horizontal plane 60 degrees or more, it is found that the cooling distance decreases at higher degrees.

Key words: ladle, ring, bushing, concavity angle, steel rope, cooling path, zulfin.

Introduction

The rapid development of the mining industry and the daily growth of the development of the mining industry require the improvement of the quality of mining machinery and equipment, modernization, technical re-equipment, their improvement and repair work in the extraction of minerals and rocks. The technical parameters of mining equipment depend on integrated approaches to technological processes while improving their designs, effective use of new structural materials and control automation systems [6,7].

The factors influencing the technical condition of the buckets of mining excavators are the organization of access to mining operations, the control of the excavator, attention to the technical condition of the excavator, climate, mining and geological conditions, the mass of the mine and the quality of the mining site are the foundations (Fig. 1).

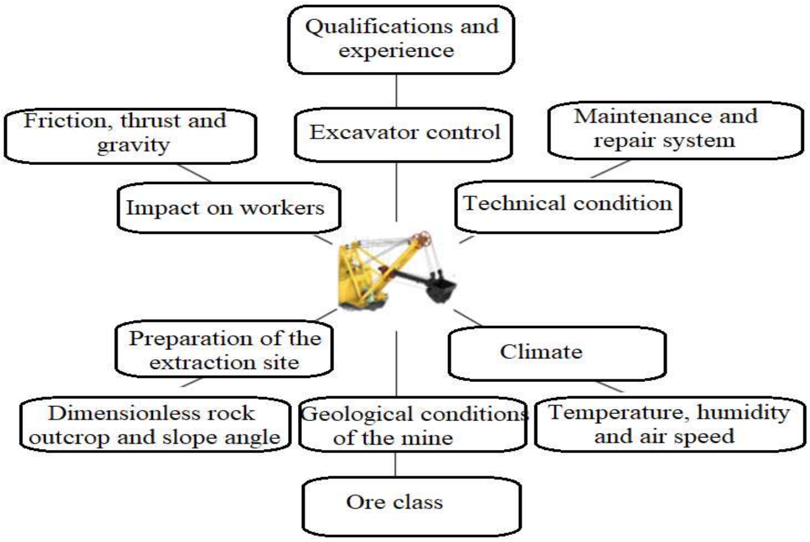


Figure 1. Factors affecting the technical condition of the bucket of mining excavators

Material and methods. We determine the friction force that affects the opening and closing of the bottom of the bucket, loosening the rock in the inclined position of the excavator bucket and the weight of the stone in the bucket, the weight of the bottom of the bucket, the distance from the center of the zero point to the center of the mass of the stone, the distance from the center of the zero point to the center of the bottom of the bucket, the distance from the center of point 0 to the place where the sulfin passes is inversely proportional (Fig. 2).

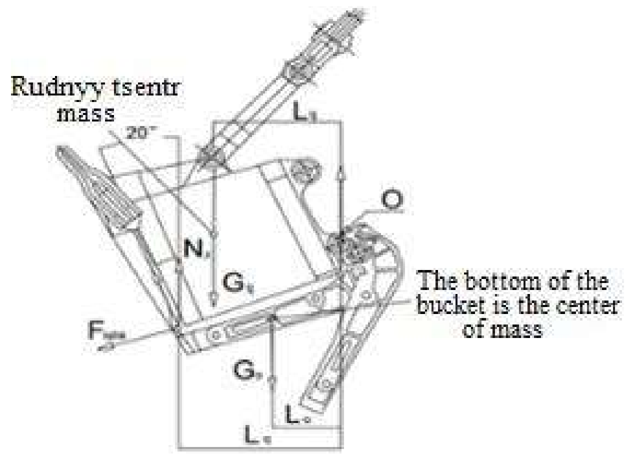


Figure 2. Bucket in inclined position

When the sum of the moments at point 0 is zero, the following formula is obtained: $\sum M_0 = 0$

$$N_q \cdot l_q - G_{tj} \cdot l_{tj} - G_o \cdot l_0 = 0 .$$

The reaction force connecting the Zulfin and the lower part of the bucket is determined by the following formula:

$$N_q = \frac{G_{tj} \cdot l_{tj} + G_o \cdot l_0}{l_q} .$$

The friction force on zulfin is determined by the following formula:

$$F_{ishq} = \mu \cdot N_q \cdot \cos\alpha; \qquad F_{ishq} = \mu \cdot \frac{G_{tj} \cdot l_{tj} + G_o \cdot l_0}{l_q} \cdot \cos\alpha \text{, кN.}$$

here G_{tj} – rock weight, kN;

G_0 – bucket bottom weight, kN;

l_{tj} – distance from the center of point 0 to the center of the rock mass, mm;

l_0 – distance from the center of point 0 to the center of the bottom of the bath, mm;

l_q – Distance from the center of point 0 to the place of passage of the sulfin, mm;

μ – coefficient of friction.

When filling the bucket with rock, the friction force acting on the sulfin is determined by the following formula (Fig. 3).

$$F_{ishq} = \mu \cdot \frac{G_{tj} \cdot l_{tj} + G_o \cdot l_0}{l_q}, \text{ кN.}$$

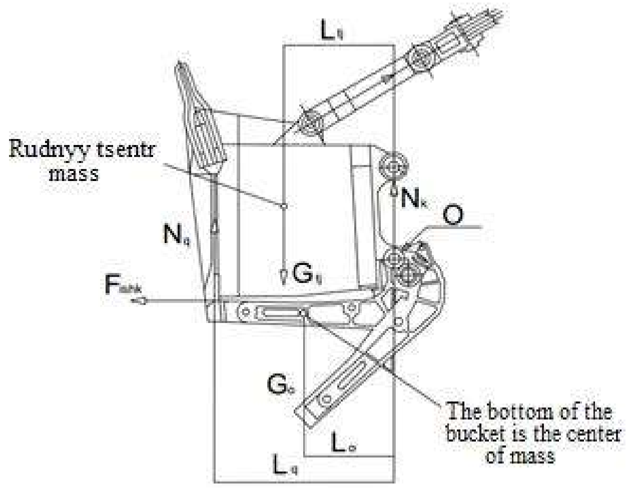
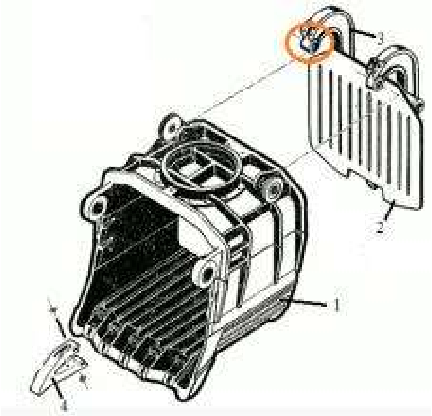


Figure 2. The scheme is hollow and flat

Comparing the friction forces obtained for the schemes in figures 2 and 3, pulling the zulfin with a bucket in an inclined position, the relative resistance force and friction force in a horizontal position are greater. When using the excavator bucket in a horizontal position, the body of the dump truck should be compatible with the excavator bucket, the power consumption of the electric drive when opening the bottom of the bucket can be efficiently used, and the zulfin should not break, break, and break the steel cable.

The mechanism that serves to hold and open the lower part of the bucket is a ring, and the place where the pin is attached to the shell of the bucket (Fig. 4a) wears out during operation after 18-22 months, the reasons for this are friction, the ingress of small sharp stones through dust, large tension. due to rapid failure, the 100 mm finger area (fig. 4b) increases to 125-130 mm in diameter, and the fingers get stuck in this place (fig. 4c), as a result of which the ring breaks or the bottom of the bowl hangs down and won't close properly. As a result, part of the rock will become dusty due to spillage, which will lead to reduced productivity and costly and time-consuming repairs.



a.

b.

c.

1 – bucket; 2 – bucket bottom; 3 – the loop; 4 – bucket tooth

Figure 4. The ring of the mechanism that holds the bottom of the bucket and serves to open it.

Taking into account the location of the pin connecting the bottom of the bucket and its lower part for elimination, a bushing with an inner diameter of 101 mm (Fig. 5a) and an oil transfer system tube (Fig. 5b) were placed on it, the life of the ring has increased from 60 to 72 months, and the opening and closing of the lower part of the basin has become easier. On fig. 5c shows a cross-section of the lapping of internal grooves with oil during bushing lubrication.

a. b. c.

a – sleeve, б – oil transfer tube, в – bushing lubrication section,

Figure 5 Parts Needed to Extend Ring Life

The reaction forces acting on the hinge connecting the bucket and its bottom are shown in fig. 6 and are considered theoretically.

The reaction forces acting on the hinge are defined as:

$$R_A = \sqrt{X_A^2 + Y_A^2}, \text{ кN.}$$

here X_A – reaction force along the abscissa, kN;

Y_A – reaction force along the ordinate axis, kN;

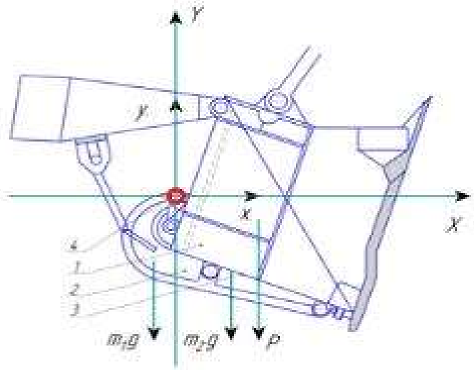
When forces are projected with respect to a point, it happens in the following way.

$$\sum F_X = X_A; \qquad \sum F_Y = m_1 g + m_2 g + P;$$

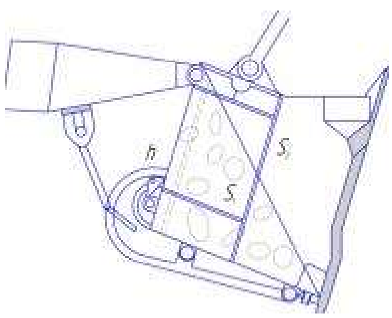
here $m_1 = 2{,}2 -$ bucket bottom mass t;

$m_2 = 0{,}357 -$ mass of the ring (loop) holding the bottom of the bucket,t;

P – weight of the load falling into the bucket, kN;



a.



б.

1 – bucket; 2 – a loop holding the bottom of the bucket;
3 – bucket bottom; 4 – hinge

Figure 6. Reaction forces acting on the ring (loop) connecting the bucket and its lower part

The weight of the load falling into the bucket is determined by the following formula:

$$P = m_{tog`} \cdot g = 22 \cdot 9{,}81 = 215{,}82 \text{ кN.}$$

The cross-sectional area of the bucket bottom $S_{um} = 8{,}794$ is $m_{tog`} = 22$ tons of bucket rock in m^2 full condition.

The surface acting on the bottom of the bucket is defined as follows:

$$S_1 = \frac{h \cdot l}{2} = \frac{2{,}364 \cdot 3{,}72}{2} = 4{,}39 \text{ м}^2$$

The weight of rock falling to the bottom of the bucket is determined as follows:

$$m_{ost} = \frac{m_t \cdot S_1}{S_{um}} = \frac{22 \cdot 4{,}39}{8{,}794} = 10{,}9 \text{ t.}$$

Forces acting on the ring:

$$\begin{Bmatrix} X_A = 0 \\ Y_A = (m_1 + m_2) \cdot g + m_{ost} \cdot g \end{Bmatrix}$$

$$Y_A = (m_1 + m_2) \cdot g + m_{ost} \cdot g = (2{,}2 + 0{,}714) \cdot 9{,}81 + 10{,}98 \cdot 9{,}81 = 136{,}3 \text{ кN.}$$

The reaction forces acting on the ring are determined by the following expression:

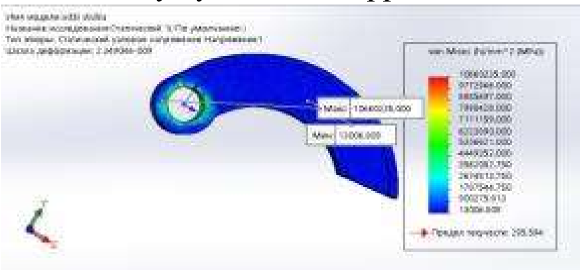
$$R_A = \sqrt{X_A^2 + Y_A^2} = \sqrt{0^2 + 136{,}3^2} = 136{,}3$$

Since there are 2 rings and they are symmetrical to each other, the forces acting on each are distributed:

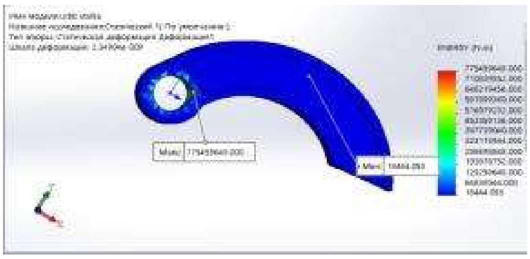
$$R_B = \frac{R_A}{2} = \frac{136{,}3}{2} = 68{,}15 \text{ kN force applied.}$$

Results. The forces acting on the cross-sectional surface of the bucket ring and on the annular sleeve were determined using ANSYS software models. To do this, the bucket ring is connected to the bucket itself with a pin. The result of snap ring connection and full gravity is shown in fig. 7a, which proves that due to the large stress applied to the ring, it can increase, resulting in destruction. The deformation state is shown in fig. 7, and here it proves that the erosion of the ring was due to forces.

Comparing the results for a bushing ring with and without a bushing (figs. 7 and 8), it can be seen that the bushing absorbs the full forces and therefore does not transfer force to the ring. This leads to an increase in the service life of the ring. In the second variant, the applied force was checked only by the forces applied to the base of the ring without a bushing and with a bushing.



a.

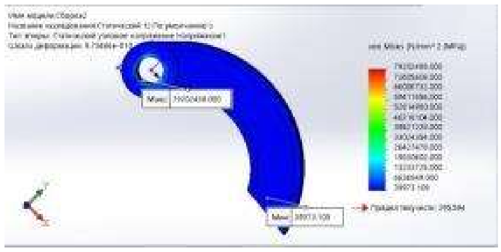
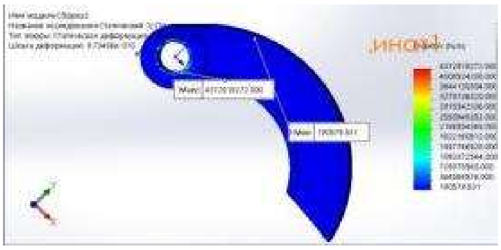


б.

a-tension; b-deformation

Figure 7. Results of the bucket ring model

To eliminate the load on the ring, a bushing with an inner diameter of 101 mm is placed, as a result, the load on the ring is prevented and the service life of the ring is increased (Fig. 8a,b).

а.  б. 

a-tension; b-deformation

Figure 8. Results of the bucket ring model

Applying the forces calculated above to a ring without a sleeve (Fig. 9a), it could be seen that the result is a color gloss marked in red and one-sided shrinkage or expansion of the ring, i.e. one-sided shrinkage of the ring in production is confirmed. On fig. 9b, when the sleeve was placed inside the same ring, the result showed that the sleeve absorbed the base of all forces acting on it, and did not transfer them to the base of the ring.

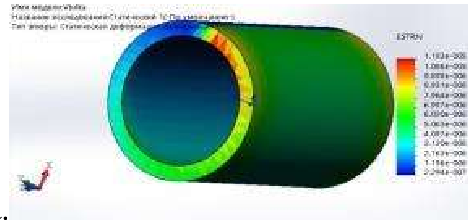
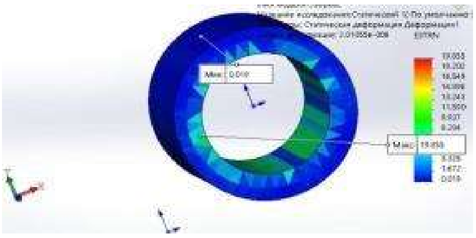
а.  б. 

Figure 9. Deformation of the ring model with and without a sleeve

As a result of the expansion of the ring, defects appear in the opening and closing of the bottom of the bucket, and a certain part of the rock that enters the bucket spills out, becomes dusty, productivity decreases and the cost of repairing the failed part increases..

Figure 10 shows that, according to the manufacturer's instructions, the with the tank is 110 mm. As a result of chronometric studies, it was found that the service life of the ring under production conditions lasted up to 18-22 months, and the wear of the ring was 125-128 mm. metal decomposition smoothing of ring without sleeve during use duration of use of the ring without a sleeve according to the factory instructions bushing ring wear during operation

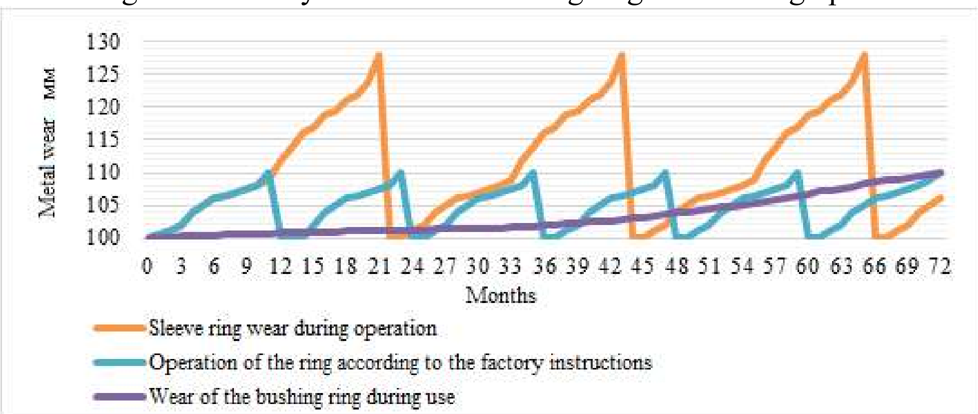


Figure 10. Graph of wear of the metal of the bucket ring depending on time

Thus, it was possible to determine that the service life of the ring reaches 60-72 months, when the uniform and smooth wear of the metal reaches 110 mm during operation with a bushing and a lubrication system installed on the ring.

In addition, the steel cable that raises and lowers the bucket passing through the head block of the excavator support arm (arrow) causes a number of negative factors to exit the excavator bucket from the guide channel of the head block pulley as a result of shaking under the action of certain forces. Such factors include: steel cable breakage, main block axis distortion, bucket loss of balance, stress formation in the hoist gear bearing, etc. These factors lead to delays in repairs, wire rope breakage, reduced productivity and rapid failure of parts.

A diagram of a bucket filled with rock at the mining site with the arm extended to the maximum is shown in Fig. 11 [1-3].

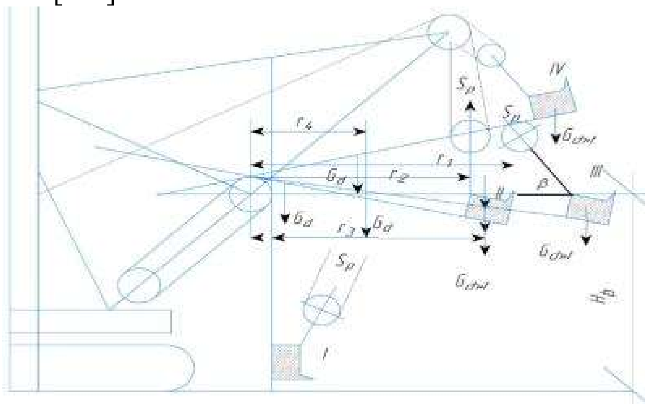


Figure 11. Scheme for determining the tension forces of the excavator bucket

The force acting on the lever bucket, the lifting force S_n is found by constructing the equation of moments relative to the bucket tension:

$$S_n = \frac{P_1 \cdot r_1 + G_{ch+t} \cdot r_2 \cdot \cos\alpha + G_r \cdot r_3 \cdot \cos\alpha}{r_4 \cdot \sin\beta}, \text{ кN.}$$

r_1; r_2; r_3; r_4 – power shoulders (when forces are applied relative to the stress axis located in the middle of the support), m;

G_{ch+t} – Bucket weight with rock, t;

G_r – handle weight, t;

S_n and S_z – lifting force and tension force, kN;

P_1 and P_2 – active and normal component of earthwork resistance, kN;

α – angle between handle and horizontal line, degrees;

β – angle between lifting steel cable and lever, deg.

The digging resistance component is found by the following formula:

$$P_1 = \frac{V \cdot K_q}{H_z \cdot K_m}, \text{ кN.}$$

here V – bucket volume, m^3;

K_q – relative digging resistance, MPa;

H_z – tension shaft height, m;

K_m – reduction factor.

The weight of the bucket with the rock is determined by the following expression:

$$G_{ch+t} = \left(M_{ch} + \frac{V \cdot \gamma}{K_m} \right) \cdot 9{,}81, \text{ кN.}$$

here M_{ch} – Bucket weight, t.

The mass of the lever is determined by the following expression:

$$G_r = M_{ch} \cdot g \ , \ \text{кN}.$$

The tensile strength of the steel rope is determined by the tension of the steel rope, given that two ropes pass through the tension block that drives the lever on the excavator.

$$S_u = \frac{4{,}0 \cdot S_n}{a_d \cdot n_k \cdot i_n} \ , \text{кN}.$$

here a_d – number of drives in the mechanism;

n_k – number of steel ropes;

i_n – number of chain hoists.

For this tensile strength, a steel rope of grade 52.0 G-V-O-N-160 is adopted, with a 15% discount, the breaking load of the steel rope is kN. The calculation of the tension mechanism of both steel ropes passing through the main block is carried out according to the same calculation scheme [10-12]. All forces are found by projecting them onto the horizontal axis:

$$S_z = S_n \cdot \cos\beta + P_2, \text{кN}.$$

here $P_2 = 0{,}1 \cdot P_1$ – horizontal component of digging resistance, kN.

Excavators allow you to calculate the forces acting on rocks during operation and determine the stress state of each part.

The force acting by the bucket on the steel rope in the process of applying pressure to the excavation site is calculated.

Since the working body of the excavator is in a state of equilibrium, the equilibrium equation is formulated for the problem:

$$\sum F_x = S_z - P_2 - S_n \cdot \cos\beta = 0 ,$$

$$\sum F_y = S_n \cdot 2g\sin\beta - G_r - G_{ch+t} + P_1 = 0;$$

$$S_n \cdot \cos\beta = S_z - P_2,$$

$$S_{n1} \cdot 2g\sin\beta = G_r + G_{ch+t} - P_1 = 0;$$

S_{n1} is determined from the equations:

$$S_{n1} = \frac{G_r + G_{ch+t} - P_1}{2g\sin\beta}, \text{кN}.$$

When the bucket is released from pressure in the mining area, the force acting on the steel rope is taken into account. In this case, the balance equation is also created:

$$\sum F_x = S_n \cdot \cos\beta = 0,$$

$$\sum F_y = S_n \cdot 2g\sin\beta - G_r - G_{ch+t} = 0;$$

$$S_n \cdot \cos\beta = 0,$$

$$S_{n2} \cdot 2g\sin\beta \ = G_r + G_{ch+t} = 0;$$

S_{n2} is determined from the equations:

$$S_{n2} = \frac{G_r + G_{ch+t}}{2g \cdot \sin\beta} \ , \text{кN}.$$

The tension of the steel rope is determined by the following expression:

$$\Delta x = \frac{P_1}{k \cdot 2g \sin\beta} = \frac{P_1 \cdot l}{ES \cdot 2g \sin\beta} = \frac{P_1 \cdot l \cdot 4}{E\pi D^2 \cdot 2g \sin\beta}, \text{ м.}$$

Here l – length of steel rope, m;
E – Jung's modulus of steel rope, N/m^2
S – cross-sectional area of steel cable m^2.

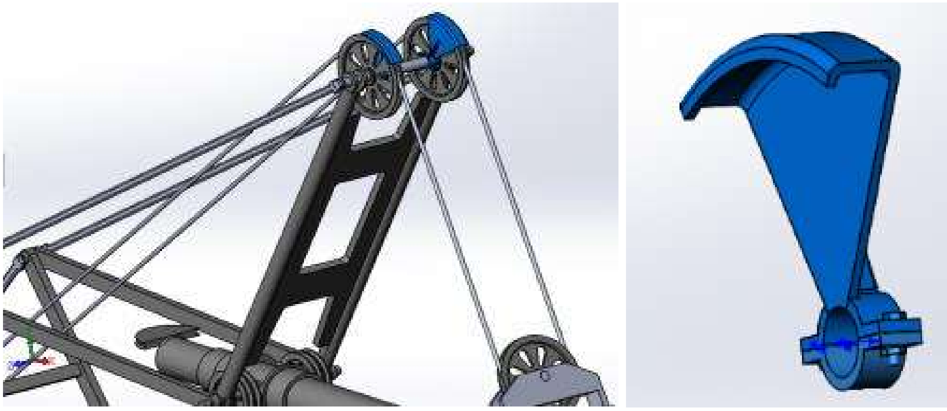


Figure 12. View of an excavator head pulley with a metal cover fitted to prevent the steel cable from being pulled out

It has been determined that the optimal limiting angle between the steel cable and the excavator bucket lift lever is 60 degrees. In cases of lack of skills and experience of the machinists, as well as encounters of large-sized rocks in the rock, vibrations may appear in the bucket, and as a solution to this problem, a metal cover is installed on the head unit (Fig. 12)..

Due to the installation of this metal casing, a break in the steel cable, bending of the shaft of the main unit, imbalance of the bucket, tension in the bearing of the lifting gear and other factors will be excluded. . On fig. 13 shows a graph of the angle of inclination of the front strand of the steel cable lifting the bucket relative to the horizontal plane and the inclination of the front strand of the steel cable. From this graph, it can be determined that when the angle between the lifting steel cable and the horizontal plane is 60 degrees or more, the steel cable's coolability will decrease..

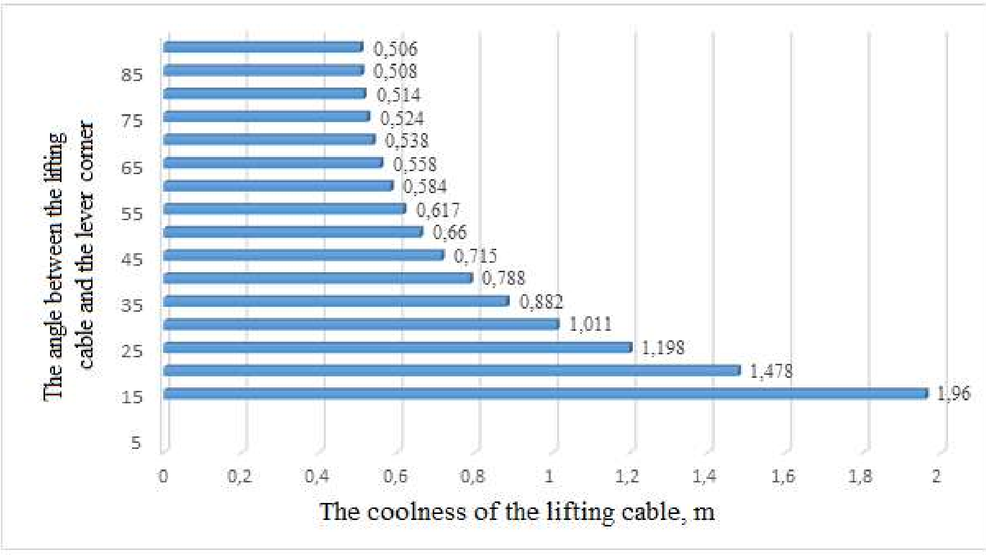


Figure 13. Graph of the angle of inclination of the leading strand of the steel rope relative to the horizontal plane, the inclination of the leading strand of the steel rope for lifting the bucket

On fig. 14 shows a graph of the dependence of the tension force on the place of extraction, the angle of impact of the teeth on the place of extraction. This picture shows how to tilt a mining bucket with a bucket.

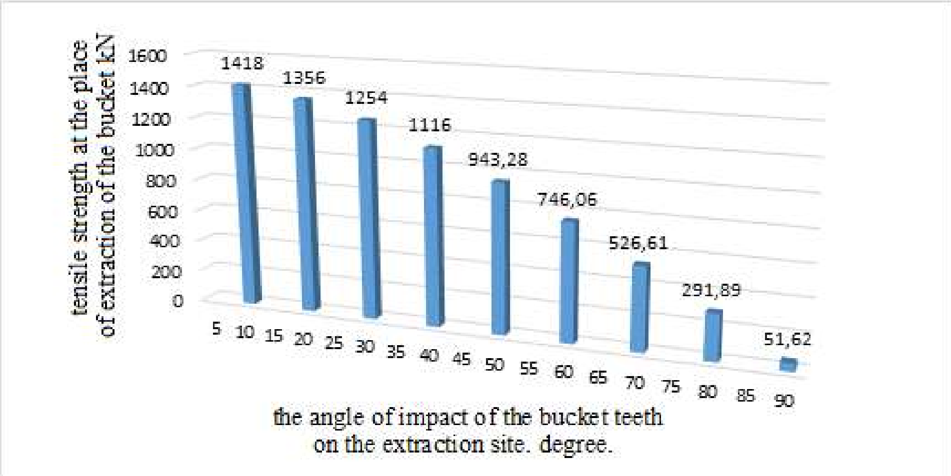


Figure 14. Graph of the dependence of the pulling force on the digging area of the bucket from the angle of impact of the bucket teeth on the digging area

Conclusions. Under the influence of the negative consequences of the impact of weight, friction, reaction forces on the excavator bucket during operation, the service life of the bushing and bucket ring was increased using repair and maintenance methods, and when used by the working body of the excavator, its impact on rocks, it was found that the optimal position of the bucket depending on the angle of concavity in the mining area is 60 degrees and the angle between the steel cable lifting the bucket and the horizontal. the plane is reduced by 60 degrees or more.

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МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ ОПРЕДЕЛЕНИЯ ПРОИЗВОДИТЕЛЬНОСТИ ЭКСКАВАТОРА ПРИ ОТРАБОТКЕ НАКЛОННЫХ СЪЕЗДНЫХ УСТУПОВ УГОЛЬНЫХ РАЗРЕЗОВ ПРИ РАБОТЕ С МОБИЛЬНЫМИ КОМПЛЕКСАМИ

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Аннотация

В данном статье приведена методика определения времени отработки и производительности экскаватора при разработке наклонного съездного уступа угольных разрезов. Произведен расчет времени отработки съездного уступа и определен среднюю эксплуатационную производительность экскаватора в условиях Ангренского угольного разреза. Рассмотрено технологическая схема отработки уступов продольными заходками мобильной экскаваторно-дробильной комплексом при боковом расположении забойного конвейера и наличии мобильного межуступного перегружателя с последовательным ведением добычных работ на двух горизонтах. По данной технологической схемы рекомендован методика определения полного рабочего цикла комплекса. Разработана