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ГЕОЛОГИЯ ЖӘНЕ ТЕХНИКАЛЫҚ ҒЫЛЫМДАР СЕРИЯСЫ

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СЕРИЯ ГЕОЛОГИИ И ТЕХНИЧЕСКИХ НАУК

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Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

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WAYS TO INCREASE OPERATIONAL EFFICIENCY OF BUSHINGS OF LEVER-HINGED MECHANISM OF MINING MACHINES

Abstract. In this article, ways to increase operational efficiency of bushings of lever-hinged mechanism of mining machines. Reliable operation of braking device of mine elevating machines, throughout the service life, is dictated by regulatory safety requirements. The research task is to determine the presence of significant changes on the surface of the mating parts of the hinged joints under different conditions. The friction surfaces of the hinge and their physical-mechanical and tribological characteristics are compared. Using a special measuring system basic regularities of interaction elements articulation parameters for establishing the wear in the contact surfaces were studied. Research changes of the friction coefficient and wear quantity in mating parts was conducted. Research carried out for various materials and various designs Bush-finger pairs of articulation. The experimental study of stress-strain states of the various designs of hinges possible to determine the parameters of the bore inner surface of the bush with the lowest voltage in the contact zone of the sleeve and the pin. The best tribotechnical characteristics are hinges with bronze bushes. Steel bushes with a bronze coating have wear of greater than 10% compared to bronze ones. Increasing the contact area of the bush with the pin due to the conical boring reduces the wear of the hinge, allows increasing the resistance to physical wear.

Key words: mine hoisting machines, hinged mechanism, friction machine, coefficient of friction, bushing.

Introduction. Rope mine elevating machines are the most important element in transport chain of mineral resources movement from the lower horizons of mine to the surface, and also provide transportation of personnel and equipment. Service life of mine elevating machine, generally, is equal to the service life of the mining enterprise. At the present time, in the mining industry elevating machines are used, mostly commissioned in the 60-80s of the last century. Complete replacement of this equipment does not provided. Braking device, which performs control and protection functions, is one of the most responsible elements of mine elevating machines [1-3].

Reliable operation of braking device of mine elevating machines, throughout the service life, is dictated by regulatory safety requirements.

Operational efficiency of braking device mechanism of mine hoisting machines depends from work reliable of its main elements, particularly hinged joints. During the intensive use of elevating machine there are damages in elements of lever-hinged mechanism, which associated with the appearance of gaps due to wear of the contact surfaces of bushings [4-7]. It leads to changing of operating parameters of braking device and consequently to increasing the time of its operation.

Meanwhile, does not use possibilities of increasing hinged joints reliability due increasing the area of contact surfaces, changes in lubrication conditions, deposition on the metal surfaces of the bushes of the most durable protective coatings, which reduce their wear during operation. Based on the foregoing, establishing rational design parameters of elements hinged joints and the development of methods to increase the reliability of their work is an urgent task.

Definition of the research task. Design parameters of the different variants of the research object are established (figure 1). We perform initial diameter measurement d_1; d_2; d_3 of lengths L_2 in order to establish the parameters of conic bore. Bore depth of the inner conical surface of the sleeve is selected as a part of the total length L_3, the remainder of the length L_4 is bent to a cylindrical shape, provided that the inner diameter of the new hole d_7 is increased to the value $d_2 + 2\Delta_{in}$ (Δ_{in} is the amount of radial wear of the inner diameter of the sleeve) at a length L_4, while the outer diameter of the bushing d_1 remains unchanged. Finger Length Ratio: L_8 is equal to L_2, length L_5 is the difference between L_2 and L_{11}; diameter of the larger base of the resulting truncated cone d_5 is d_8; diameter of the hole and smaller base of the truncated cone d_7 is equal to diameter of the finger of new repair size d_4 with the condition $d_2 + 2\Delta_{rel}$.

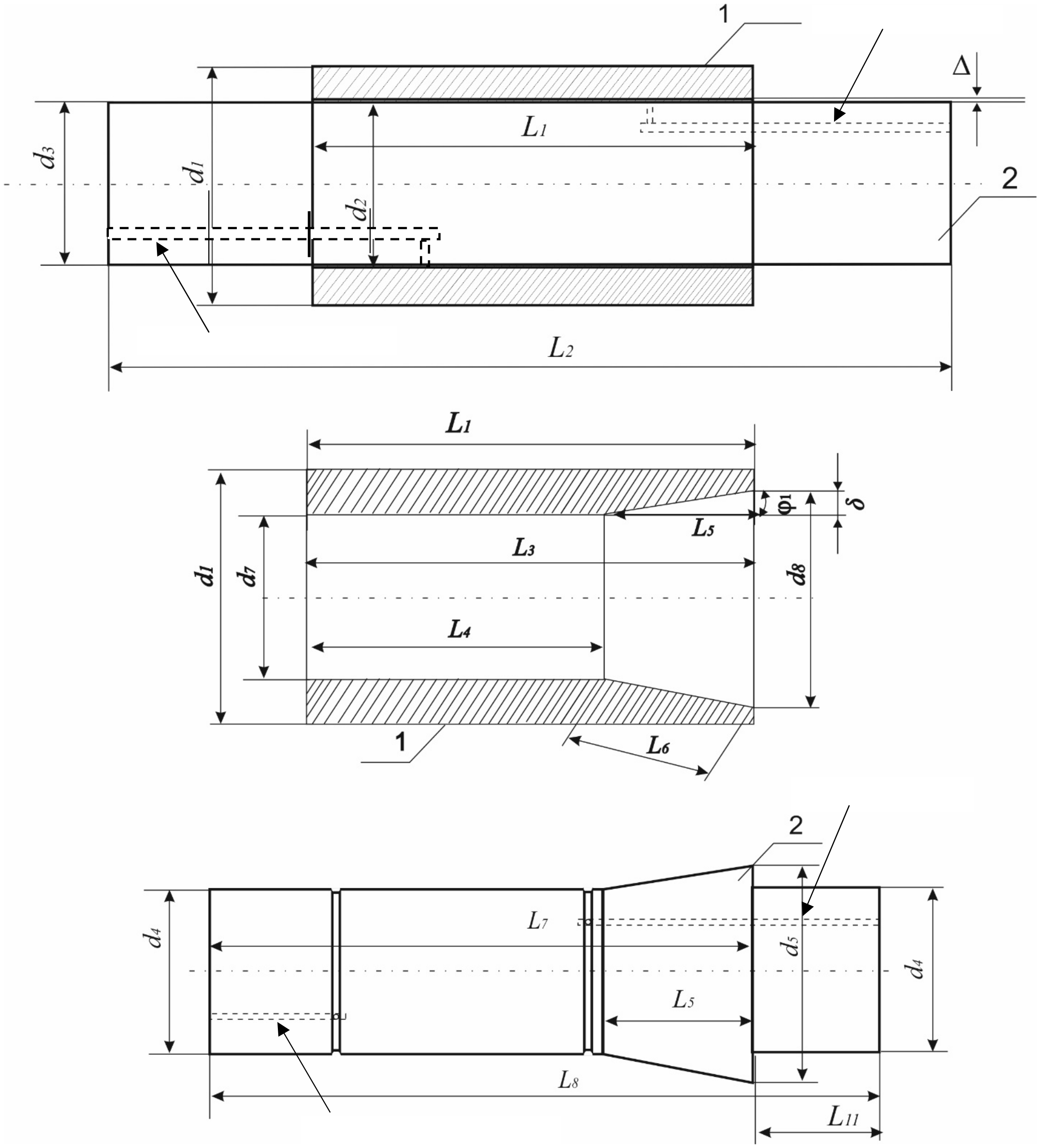

Figure 1 – Settlement scheme of the hinge

1) boring angle:

$$tg\varphi_1 = \delta / L_5, \quad (1)$$

where φ_1 – bore angle:, ^{0}; δ – value of increment to diameter d_7 at bore, mm; L_5 – the depth of the bore inner conical surface of the sleeve is HL_3, mm; X – ratio of the length of the bored part to the total length of the bushing.

2) length of the lateral line of the cone:

$$L_6^2 = L_5^2 + \left(\frac{d_8 - d_7}{2}\right)^2, \quad (2)$$

where L_6 – length of the lateral line of the cone, mm; d_8 – larger inner diameter of the bushing after boring, mm; d_7 – inner diameter of the bushing, mm.

3) contact surface area:

$$S_k = \pi L_6 + \left(\frac{d_8 + d_7}{2}\right)^2 + \pi d_7 L_4, \quad (3)$$

where S_k – contact surface area, mm; L_4 – length of the lateral line of the cylinder of the non-doped part of the inner surface of the sleeve, mm.

The maximum angle of conical bore of the bushing is limited by its outer diameter and the collapsing condition. The minimum angle of conical bore is limited in accordance with GOST 8593-81 [8], GOST 25557-82 [9]. At angles of bore less than 70, grasping of the mating surfaces and jamming of the hinge may appear, since the coefficient of friction in this case may be more than one.

The research task is to determine the presence of significant changes on the surface of the mating parts of the hinged joints under different conditions. The friction surfaces of the hinge and their physical-mechanical and tribological characteristics are compared [10, 11].

Using a special measuring system (figure 2) basic regularities of interaction elements articulation parameters for establishing the wear in the contact surfaces were studied.

Research changes of the friction coefficient and wear quantity in mating parts was conducted. Research carried out for various materials and various designs Bush-finger pairs of articulation. Various lubricants and different lubrication regimes were used (GOST 9490-75) [12].

Tests were carried out on a SMC-2 friction machine with hinges of various design versions. The analysis of obtained results for further realization in the actuating mechanisms of brake device of mine hoisting machines is carried out [11].

The friction machine SMC-2 (owned by Ugleservis of JSC ArcelorMittal Temirtau) is designed for testing materials for friction and wear during rolling, rolling with slip and sliding. Tests can be carried out on three different contact patterns of samples that simulate work of parts in friction units. The samples are loaded by a spring mechanism, and the carriage is balanced by a counterweight, which makes it possible to carry out tests with loads on a pair of friction.

Figure 2 – The friction machine

Figure 2 – The friction machine consists of:
- three-phase asynchronous AC motor;
- worm reducer;
- crank-slider mechanism with interchangeable eccentrics;
- friction unit with mandrels for samples of different types and sizes;
- removable bath for testing in a liquid medium;
- two tensor beam, installed in the friction unit of the stand and outside it (standard);
- a block for recording the analog output signal from the strain gages, consisting of a power supply, a digital oscilloscope PCS-500 and a computer [13].

Technical characteristics of the friction machine are presented in table.

Technical characteristics of the friction machine

Technical characteristics	Value
Power of the electric motor of the drive, kW	2.2
Rotational speed of the lower sample, s^{-1}	5; 8.3; 16.7
Slippage of samples, %	0, 10, 15, 20, 100
Maximum load on a friction pair P, MPa	5

The object of research is a hinge, which consists of a bush and pin. Gray cast iron and bronze are used for making bushings. Bronze bushes are limited in use because of their high cost, an alternative variant is a bush made of steel with an antifriction coating. The pin is made of steel CT45 X18N. An important condition for testing is the correct choice of the value of the load on the friction pair, since its values directly affect wear.

An important factor in the wear of contact surfaces of bushes is the area of mating contact surfaces. The lubrication mode depends on type of lubricant and design of the bush-pin pair. The studies were carried out at an ambient temperature of + 22 ° C [14-20].

Conducting experiments. A set of experiments was performed, which made it possible to identify groups of friction pairs with minimum values for the coefficients of friction, wear, relative roughness, etc.

Further, dependencies connecting the coefficient of friction and wear value were constructed and analyzed with factors such as the relative slip velocity and pressure for the most widely represented material used for manufacturing friction pairs. The experimental data were processed by a statistically determined method of constructing models using a computer.

Determination of the friction coefficient as a function of slip speed when testing hub bushes made of different materials.

The first stage of the experiment consists in investigating the coefficient of friction of the "bushing-finger" pair, with different slip velocities in the interval from 0.1 to 0.6 m/s. The object of investigation in this experiment is the hinge, which consists of a bushing and a connecting pin.

The purpose of this experiment is to establish tribotechnical parameters of three variants of bushings with different physical and mechanical properties.

The first version of the hinge, when the bushing is made of cast iron; the second variant, when the bushing is made of steel with a coating of the inner working surface of the bushing with a bushing; the third option, when the bushing is made of bronze. Inside the sleeve, a finger is made of hardened steel grade ST45H18N2M, which is used in all experiments with three variants of bushings. The condition for carrying out this experiment is a predetermined slip speed interval from 0.1 to 0.6 m/s.

The construction of the investigated bushings is shown in figure 3. The graphs of the dependences constructed from the experimental results are shown in figure 4.

Figure 3 – Construction of the bushes

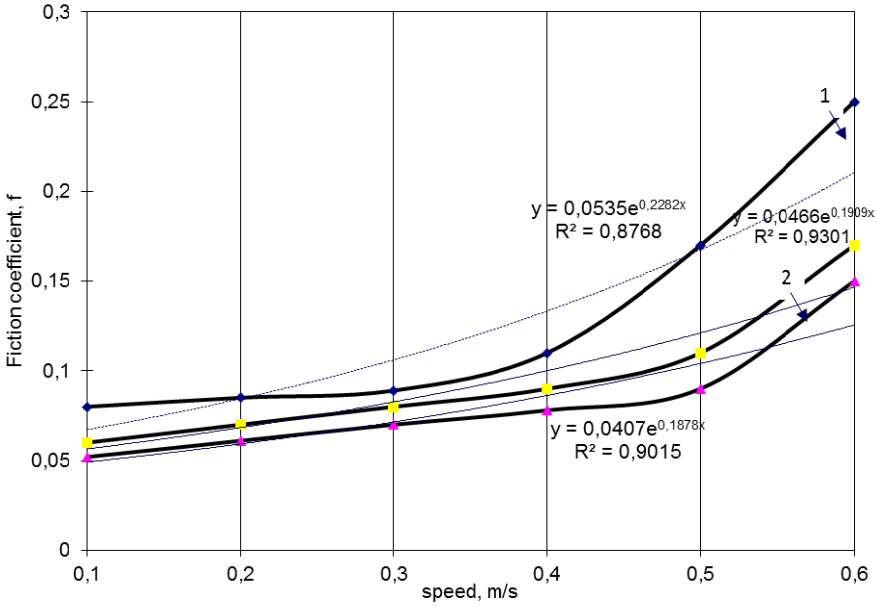

Figure 4 – Graphs of friction coefficient variation as a function of slip speed
when testing hub bushings made of different materials:
1 – for the cast iron bushing; 2 – for a steel bush with a bronze coating; 3 – for the bronze bush

Determination of the wear of the inner surface of the bushes as a function of the load when testing the hub bushings made of various materials. We will determine the wear value of three different versions of hinge bushes made of different materials, depending on the applied pressure. The object of investigation in this experiment is a hinge bush with a connecting pin. Inside the bushing, a pin is installed, which is made of hardened steel grade ST45H18N2M. We will establish the value of wear, provided that the specified range of the pressure value lies in the range from 1 to 5 MPa. The graphs of the dependencies constructed from the results of the experiment are shown in figure 5.

Analysis of the dependencies in figures 4 and 5 shows that the hinges with bronze bushings have the best tribotechnical characteristics.

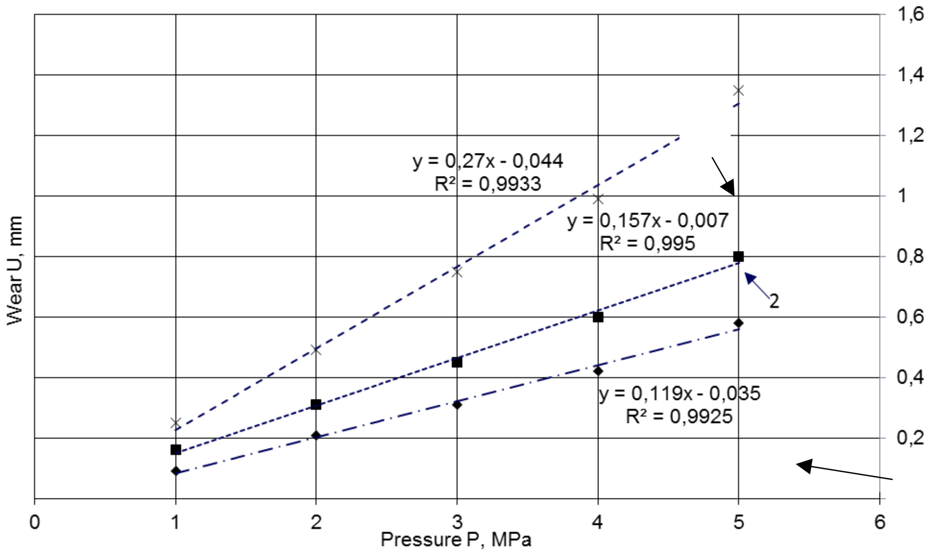

Figure 5 – Graphs of changes in wear of the inner surface of bushings depending
on the load when testing hinge sleeves made of different materials:
1 – for the cast iron bushing; 2 – for a steel bush with a bronze coating; 3 – for the bronze bush

The proposed steel bushings with a bronze coating have excellent wear characteristics of about 10% compared to bronze ones, but considering the economic aspects of their production, we can talk about the advisability of using them.

The following single-factor dependencies are obtained with the condition that the output parameter is wear of the bush (U), and the input parameter is the pressure (P), depending on the applied pressure from 1 to 5 MPa, for the investigated bushings 1 - for the cast iron bush; 2 - for a steel bush with a bronze coating; 3 - for the bronze bush.

Determining the wear of hinge bushes with different geometric parameters depending on the load

At the second stage of the experiment, the wear values of hinge bushes with different geometric parameters are determined depending on the loading value. The object of investigation in this experiment is a hinge bush with a connecting finger. Inside the bushes, a finger is installed, which is made of hardened steel grade ST45H18N2M.

Wear values are established provided that the specified pressure range is in the range of 1 to 5 MPa. The graphs of the dependencies constructed from the results of the experiment are shown in figure 6.

The following single-factor dependencies with the condition that the output parameter is the wear of the sleeve (U), and the input parameter is the pressure (P), from 1 to 5 MPa are obtained.

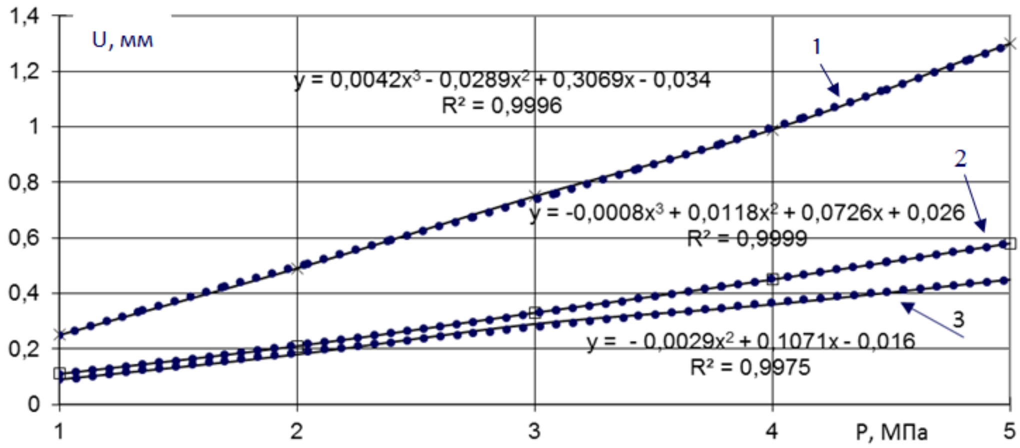

Figure 6 – Graphs of changes in the wear of the inner surface of the bushes as a function of the load when testing the hinge with different bushings:
1 – a cylindrical bush; 2 – bush with a partial conical boring of the inner cylindrical surface by 0.35 length;
3 – bush with a partial conical boring of the inner cylindrical surface by 0.7 of its length

According to the geometric shape of the inner surface of the cast iron bush: cylindrical; with a partial conical boring of the inner cylindrical surface by 0.35 of its length; with a partial conical boring of the inner cylindrical surface by 0.7 of its length.

Determination of the change in the friction coefficient as a function of slip speed when testing hinges with different lubrication regimes. The third stage of the experiment is the establishment of the friction coefficient of the pair, depending on the sliding speed, under different lubrication regimes. Different lubrication regimes can be obtained by applying different design versions of the grease nipples of the swivel joint. The object of investigation in this experiment is a sleeve made of cast iron and fingers with different arrangement of channels for lubrication of the hinge (figure 1). For the first variant, a typical cylindrical pin with one lubrication channel; for the second variant, the finger is cylindrical with two through lubrication channels. The first option is typical and is performed at the factory, we made changes to the lubrication system and equipped the pin with an additional lubrication channel (figure 1).

Determining the wear of hinge sleeves with different lubrication regimes depending on the load. The object of investigation in this experiment is a sleeve made of cast iron and pins made of hardened steel grade ST45H18N2M with different arrangement of channels for greasing the hinge (figure 1).

The condition for this experiment is a predetermined slip speed interval from 0.1 to 0.5 m/s. The loading is constant and is 1 MPa. The graphs of dependencies constructed from the results of the experiment are shown in figure 7.

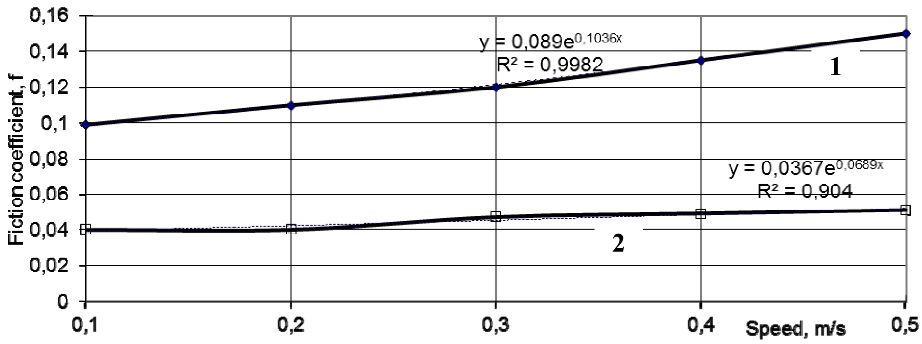

Figure 7 – Graph of the change in the coefficient of friction as a function of sliding speed
when testing hinges with different lubrication regimes:
1 – cylindrical pin, single-channel lubricant; 2 – cylindrical pin, two-channel lubricant

Analyzing the graph of the dependencies shown in figure 7, we can draw the following conclusion: the proposed design changes of lubricating channels allow about more than three times, depending on the speed, to reduce the coefficient of friction of the conjugate surfaces, and thereby significantly increase the tribotechnical performance of the hinges.

Conclusions. The experimental study of stress-strain states of the various designs of hinges possible to determine the parameters of the bore inner surface of the bush with the lowest voltage in the contact zone of the sleeve and the pin. The spacing of the bushing is 0.35 to 0.7 times its length. The best tribotechnical characteristics are hinges with bronze bushes. Steel bushes with a bronze coating have wear of greater than 10% compared to bronze ones. But, given the economic aspects, we can talk about the advisability of using them. Increasing the contact area of the bush with the pin due to the conical boring reduces the wear of the hinge, allows increasing the resistance to physical wear, and also opens the possibility of reusing the bush due to its boring. Design changes lubricating channels improve joint lubrication regime and use of additional lubrication channel can significantly reduce wear and reduce the coefficient of friction of the mating surfaces 3 times.

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ТАУ-КЕН МАШИНАЛАРЫНЫҢ ТЕЖЕГІШ-ШАРНИРЛІ МЕХАНИЗМДЕРІНІҢ ТИІМДІЛІГІН АРТТЫРУ ЖОЛДАРЫ

Аннотация. Берілген мақалада иінтіректік-топсалы механизмдегі төлкенің жұмыс істеу тиімділігін арттыру жолдарын қарастырады. Шахтылы көтергіш машинаның тежегіш құрылғасының сенімді қолданылуы жұмыс істеу барысы нормативтік қауіпсіздік талаптарына сай бағынады. Зерттеудің мақсаты әр түрлі шарттарда топсалы қосылыстардың бетіндегі жанасатын бөлшектердің маңызды өзгерістерін анықтау. Топсаның үйкеліс беттерін салыстыру және олардың физика-механикалық және трибологиялық сипаттамаларын зерттеу жүргізіледі. Арнайы өлшеу кешенінің арқасында байланыс беттерінің аймағындағы тозу параметрлерін белгілеу үшін топсаның элементтері арасындағы өзара әрекеттесу үрдісінің негізгі заңдылықтары зерттелді. Үйкеліс коэффициентінің өзгеруін және жұпар бөліктеріндегі тозу мөлшерін зерттеу жүргізілді. Зерттеу әртүрлі материалдар мен хаб-түйіспелі жұптас жұптың түрлі жобалық нұсқалары үшін жүргізілді. Әр түрлі топсалы конструкциялардың стресс-штамм күйін өткізген эксперименталдық зерттеулер төлке. пен саусақты байланыстыру аймағындағы ең төменгі кернеулі төлкенің ішкі бетінің бұрғылау параметрлерін анықтауға мүмкіндік берді. Үздік триботехникалық сипаттамалары қола бұталары бар ілмектер. Қола жабындысы бар болат жеңдер қоламен салыстырғанда 10% артық тозуға ие. Тұтқаны конустық бұрғылаумен байланысты саусағымен байланыстыру аймағының жоғарылауы топсаның тозуын азайтады, физикалық тозуға төзімділікті арттырады.

Түйін сөздер: шахталық көтергіш машиналар, топсалы механизм, үйкеліс машинасы, үйкеліс коэффициенті, төлке.

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ПУТИ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ ЭКСПЛУАТАЦИИ ВТУЛОК РЫЧАЖНО-ШАРНИРНОГО МЕХАНИЗМА ГОРНЫХ МАШИН

Аннотация. В статье рассматриваются пути повышения эффективности эксплуатации втулок рычажно-шарнирного механизма. Надежная эксплуатация тормозного устройства шахтных подъемных машин, на протяжении всего срока эксплуатации, диктуется нормативными требованиями безопасности. Задача исследования состоит в определении наличия значимых изменений на поверхности сопрягаемых деталей шарнирных соединений при различных условиях. Проведено сравнение поверхностей трения шарнира и изучения их физико-механических и трибологических характеристик. С помощью специального измерительного комплекса проведено исследование основных закономерностей процесса взаимодействия элементов шарнирного соединения для установления параметров износа в области контактных поверхностей. Было проведено исследование изменения коэффициента трения и величины износа в сопрягаемых деталях. Исследование проводились для различных материалов и различных конструктивных исполнений втулочно-пальцевой пары шарнирного соединения. Проведенные экспериментальные исследования напряженно-деформированного состояния различных конструкций шарниров позволили определить параметры расточки внутренней поверхности втулки с наименьшим напряжением в зоне контакта втулки и пальца. Наилучшими триботехническими характеристиками обладают шарниры с бронзовыми втулками. Стальные втулки с бронзовым покрытием имеют износ больший на 10% по сравнению с бронзовыми. Увеличение площади контакта втулки с пальцем за счет конической расточки уменьшает износ шарнира, позволяют повысить сопротивление физическому износу.

Ключевые слова: шахтные подъемные машины, шарнирный механизм, машина трения, коэффициент трения, втулка.

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