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Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

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ИЗВЕСТИЯ

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ГЕОЛОГИЯ ЖӘНЕ ТЕХНИКАЛЫҚ ҒЫЛЫМДАР СЕРИЯСЫ

♦

СЕРИЯ ГЕОЛОГИИ И ТЕХНИЧЕСКИХ НАУК

♦

SERIES OF GEOLOGY AND TECHNICAL SCIENCES

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A. D. Mekhtiyev[1], A. V. Yurchenko[1], F. N. Bulatbayev[2], Y. G. Neshina[1], A. D. Alkina[1]

[1]Tomsk polytechnic university, Tomsk, Russia,
[2]Karaganda state technical university, Karaganda, Kazakhstan.
E-mail: barton.kz@mail.ru, niipp@inbox.ru, felix4965@mail.ru, 1_neg@mail.ru, alika_1308@mail.ru

THEORETICAL BASES OF INCREASE OF EFFICIENCY OF RESTORATION OF THE WORN OUT HINGED JOINTS OF MINE HOISTING MACHINE

Abstract. In this article, the work was carried out to find the optimal conveyor schemes which are necessary to successfully solve the pipelining problem when transporting rock cargo to the deep quarry. Analysis of ways to increase the conveyor length by varying independent variables has shown that the construction of the pipeline scheme is characterized only by those ways of increasing the length of the conveyors that determine the mechanical structure of their traction body and, consequently, the behavior of the latter under static and dynamic loads. The optimal algorithm was established for constructing the structural diagrams of the traction organ of the main conveyors. Theoretical grounds are given for the creation of new means of continuous transport, which ensure the continuous conveyance of technological chains for the extraction of minerals, the issuance and laying of overburden in the dump. Analysis and synthesis of structural schemes of "uninterrupted" conveyors was held. Synthesis of the structural schemes of these conveyors is carried out by a mathematical operation - the operation of adding the strength indicators of the traction organs used. Two classes of pipelines, fundamentally different from each other, were considered: a BC with parallel autonomous circuits and a BMC. The introduction of vertical and steeply sloped conveyors as a trench transport is a promising direction in the field of conveyorization of the mining industry and a reduction in the cost of mining.

Key words: magistral conveyer, optimization of structural schemes, conveyers' classification, autonomic pulling part, multi-drive conveyer.

Introduction. In the development of coal seams by underground method, it is impossible to do without shafts equipped with cable lifting facilities, on the basis of which the overall technical and economic parameters of the mining enterprise depend both on its overall performance and on its individual structural divisions. The service life of the mine hoisting machine (MHM) is 25-50 years and is almost equal to the life of the mine [1-4]. Now in the Karaganda coal basin 69 MHM are operated, launched in the 1960-1990 of the last century. UD of JSC "Arcelor Mittal Temirtau" on whose balance sheet this equipment is located performs all necessary maintenance work for keeping in good condition. It is planned to modernize the park of MHM in operation with their gradual replacement of the park, out of 69 MHM, in the period from 2010 to 2016 7 new MHMs were put into operation but this is not enough to break the situation with a morally and physically outdated technique [5-8]. A complete replacement of this equipment in the short term is not foreseen, since it requires a huge amount of funds. Accordingly, the solution of the problem of increasing the technical level of the MHM as a whole, as well as the wear resistance and reliability of its individual structural parts, will increase the service life of the shipboard.

MHM is equipped with a mechanical braking device with pneumatic or hydraulic drive of the kinematic part. Strict requirements for reliability of the operation of the brake device of MHM, during the entire period of its operation, is dictated by the regulatory requirements of safety in the mining industry. The efficiency of operation of the mechanism of the brake device of mine hoisting machines depends on the reliability of the operation of its main elements, in particular, hinged joints. When the lifting machine is used intensively in the elements of the lever-hinge mechanism, there are damages due to the appearance of gaps due to wear on the contact surfaces of the bushings [9, 10]. This leads to a change in the operating parameters of the braking device and, as a consequence, to an increase in the time of its operation.

Meanwhile, the possibility of increasing the reliability of articulated joints by increasing the area of the contact surfaces, changing lubrication regimes, applying strong protective coatings on the metal surfaces of the hubs, which reduces their wear during operation, is not used. Proceeding from the foregoing, the establishment of rational design parameters for the elements of hinged joints and the development of methods to increase the reliability of their work is an urgent task.

Based on the analysis of operation of mine hoisting machines [11], it can be concluded that in most cases the failure of the braking device mechanism is due to the wear of its hinged joints. Deterioration, jamming and jamming of hinges leads to an unacceptable change in the braking parameters and the destruction of individual structural elements. The decrease in reliability and design life of the hinges of the brake device of mine hoisting machines can be the result of design features, quality, manufacturing technology, material properties, operating conditions, operating modes and other conditions. To prevent premature failures in the braking device, at the design stage, it is necessary to take full account of all the factors affecting the wear and shorten the durability of the hinges.

An important contribution to solving the problems of increasing the resource, reliability and efficiency of mine hoisting machines was made by various scientific schools of mining mechanics, which reflect the concept that a shaft hoisting installation must be represented as a single set of interrelated elements [12-13]. Research in this area should be carried out from the position of a systems approach and only in this case the results obtained will have completeness and reliability.

Grounds for conducting research and setting the problem. The lack of research in the field of ensuring the reliability of the operation of joints and their wear and tear during their operation was revealed. There is a need for additional studies on this direction, to determine the factors that affect the reduction in reliability and wear resistance of the hinges of the brake device of MHM during their operation. The solution of this applied problem is to develop methods for ensuring the reliability of the hinged joints of the mechanism of the brake device of mine hoisting machines using diagnostic and simulation tools, which will allow us to determine the wear and stress dependencies on the structural parameters of the hinge joint elements. The change in the physico-mechanical properties of the bushings and their geometric parameters will significantly reduce their wear and increase their working life.

Analytical study of the object. he object of the study are the swivel joints of the brake mechanism of mine hoisting machines 2Ts-4x2,3; 2Ts–5x2,3; 2Ts-5x2,4; 2Ts-6x2,4at the mines of the Karaganda coal basin and the city of Ekibastuz at various operational loads [14-16].

Studies and practical observations have shown that the main factors for the failure of the sleeve-finger pair are the following factors: increased gaps due to wear of the sleeve, contact stresses during loading, insufficient lubrication of surfaces. For the manufacture of the bushing, cast iron is used (CI), and for the finger - high-carbon steel marks CI45X18H2M. This pair has a low wear resistance, but it is possible to reuse the worn out bush several times during several overhauls. It is necessary to develop a method that allows to reduce material costs and shorten the time for repair and restoration work of the mechanism of the brake device of a mine hoisting machine.

The expected technical result is an increase in the efficiency of repair, durability and wear resistance of the hinged joints of the brake mechanism of mine hoisting machines. This method is simple, prolongs the safe life of the mine hoisting system and provides the required reliability.

Restoration of the hinge sleeve is carried out without a complete analysis of the mechanism of the brake device of the mine hoisting machine. The technology provides for boring a cylindrical bore of the bushing in place of its installation, a mobile milling device that is fixed on the surfaces of the elements of the brake device, where it is necessary to perform the restoration of the bushing. The essence of the method consists in boring the hole of the bushing along its geometrical axis with a cylindrical and conical milling cutter.

The conical part is 0.35 of the total length of the sleeve. A finger of the corresponding configuration is inserted into the bore of the bushing. It is economically feasible to use the bush, in two repair periods, without dismantling it and disassembling the whole mechanism. At repeated restoration, the conical part is bored by 0.7 of the total length of the bushing. The conical shape allows the self-alignment of the friction

Figure 1 – Hinges with structural differences

surfaces to be realized and the radial misalignment of the finger assembly is avoided, and the end movement of the finger in the sleeve during operation is limited. The articulation consists of a sleeve made of cast iron with an inner hole diameter of 18 to 260 mm, exceeding the permissible clearance from 0.3 to 0.9 mm. The connecting pin has a configuration similar to the inner surface of the sleeve.

The investigated hinges, shown in figure 1, have the following structural differences in the geometric shape of the bushing and the finger:

a) cylindrical, typical construction (position 1);

b) with a different partial conical boring of the inner cylindrical surface by 0.35 of its length, the first boring in the repair,

c) with a partial conical boring of the inner cylindrical surface by 0.7 of its length (position 2);

c) a full conical boring of the inner cylindrical surface for the entire length, the second boring in the repair (position 3).

To carry out the experiments, experimental samples of the above-listed variants of bushings and connecting fingers.

The design parameters of various variants of the research object are established. We perform the initial measurement of diameters d_1; d_2; d_3 lengths; L_2 in order to establish the parameters of the conical boring (Figure 2)We perform the boring of the bush by 0.35 of its length L_1.The depth of boring of the inner conical surface of the sleeve L_5 (Figure 2) is selected as a part of the total length L_3, the remaining part of the length L_4, is bent to a cylindrical shape, provided that the inner diameter of the new hole d_7 will be increased to the value $d_2 + 2\Delta_{wear}$ (Δ_{wear} – the amount of radial wear of the inner diameter of the bushing)at length L_4, thus the external diameter of the sleeve d_1 remains unchanged. The ratio of finger lengths: L_8 is equal to L_2; length L_5 is the difference between L_2 and L_{11}; the diameter of the larger base of the resulting truncated cone d_5 is d_8; the diameter of the hole and smaller base of the truncated cone d_7 is equal to the diameter of the finger of the new repair size d_4 with the condition $d_2 + 2\Delta_{rel}$.

1) Using a mathematical tool to accurately determine the optimal parameters of the boring of the bushing and the manufacture of repair fingers for repairs No. 1 and No. 2.

2) angle of boring:

$$\mathbf{tg\varphi_1 = \delta / L_5}, \tag{1}$$

where φ_1 – angle of boring, ^{0}; δ – the value of the increment to the diameter d_7 for boring, мм; L_5 – the depth of boring of the inner conical surface of the bushing isXL_3, mm; X – ratio of the length of the bored part to the total length of the bushing.

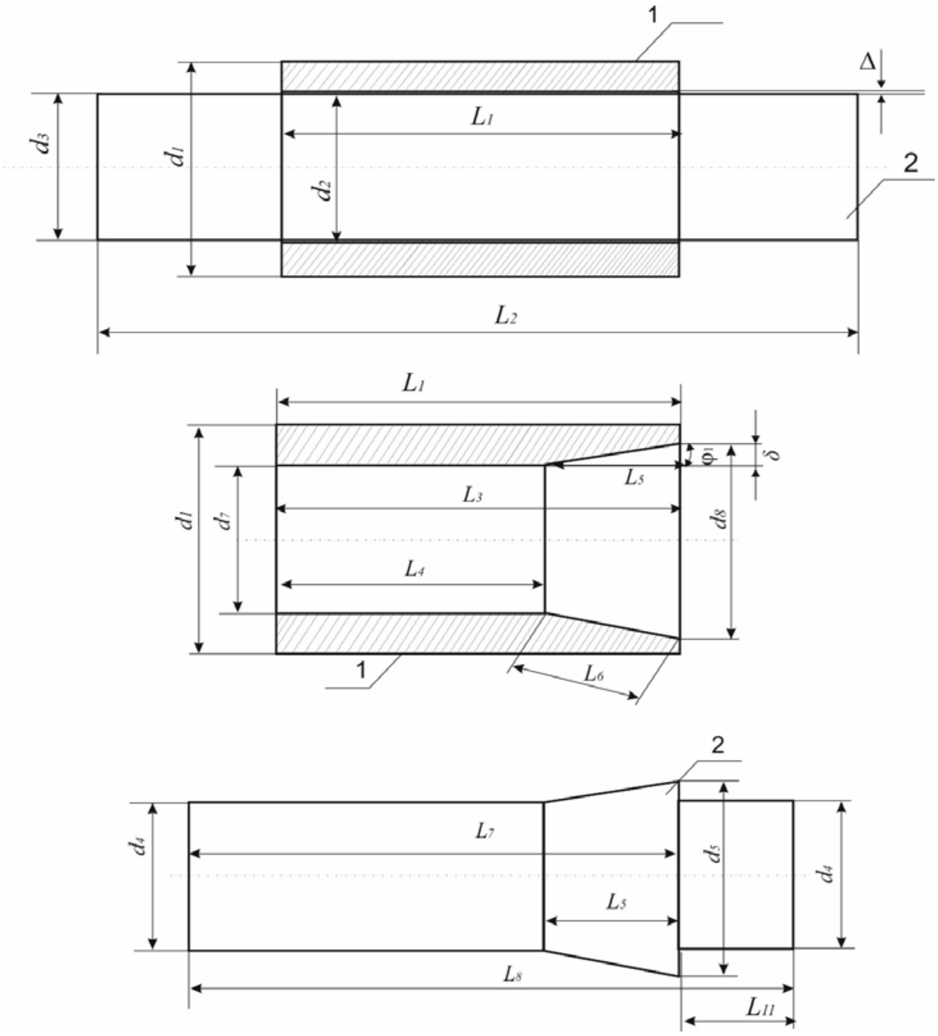

Figure 2.
1 – sleeve; 2 – finger

1) the length of the lateral line of the cone:

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

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

2) contact surface area:

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

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 boring of the bushing is limited by its outer diameter and the collapsing condition. The minimum angle of conical boring is limited in accordance with State standard [17-19]. At corners of boring less than 7^0, 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.

We define the equation of the relationship between the lengths of the cylindrical part of the sleeve and the angle of boring of the sleeve, and their relationship to the total length of the bushing, the diameter of the bored part and the diameter of the cylindrical part of the bushing (figure 4).

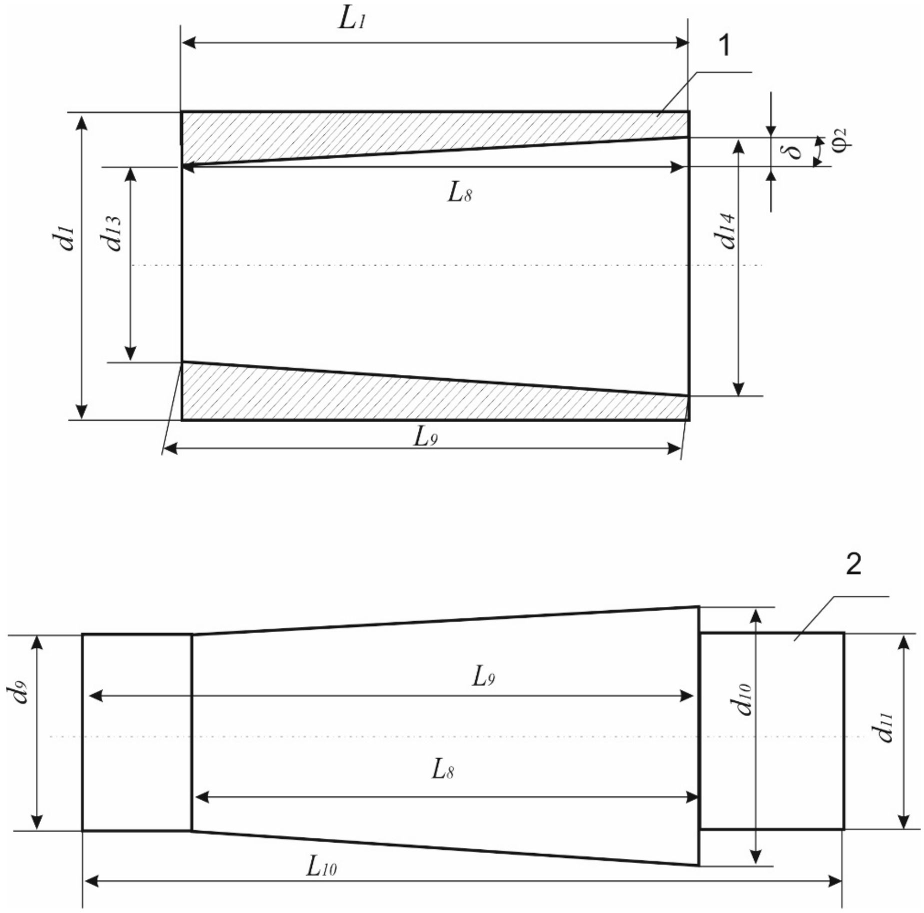

Figure 3.
1 – sleeve; 2 – finger

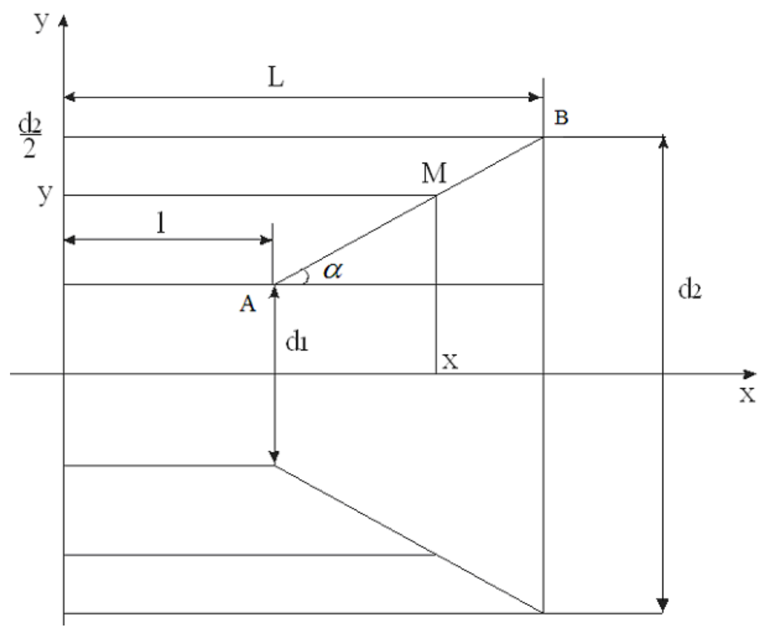

Figure 4 – Determination of the relationship
between the length of the cylindrical part of the bushing l and the boring angle of the bushing α

Initial conditions:

$$y(L)=\frac{d_2}{2}, \qquad tg\alpha_1=\frac{2(d_2-d_1)}{L} \tag{4}$$

where L – total length of the sleeve, mm; d_1 –diameter of the bored part of the bush, mm; d_2 – diameter of the cylindrical part of the sleeve, mm; α_1 – boring angle,^{0}.

In determining the optimum internal dimensions, the bushings were based on the fact that: dimensions L, d_1, d_2 are unchanged; boring angle α varies from the minimum angle α_1 to the maximum angle α_2, as $\alpha_1 \le \alpha \le \alpha_2$.

It was necessary to establish the relationship between the values of the length of the cylindrical part of the sleeve l and the boring angle of the bushing α, to connect them to the present specific values of the total length of the sleeve L, the diameter of the bored portion of the sleeve d_1, diameter of the cylindrical part of the bushing d_2.

The equation of the line AB is written in the form:

$$y=kx+b. \tag{5}$$

In this equation, the angular coefficient of the line AB will be considered variable, since it directly depends on the values of the angle α.

The boundary condition $y(L)=\frac{d_2}{2}$.

Solving equation (3), we obtained a linear equation of the first order:

$$y'-\frac{y}{x}=-\frac{b}{x}. \tag{6}$$

We solve it by the Bernoulli method:

$$y=uv, \tag{7}$$

$$y'=u'v+uv',$$

$$u'v+uv'-\frac{uv}{x}=-\frac{b}{x}, \tag{8}$$

$$\begin{cases} u(\frac{dv}{dx}-\frac{v}{x})=0 & (9)\\ u'v=-\frac{b}{x} & (10)\end{cases}$$

From the equation (9) we got:

$$\frac{dv}{dx}-\frac{v}{x}=0, \quad \int\frac{dv}{v}=\int\frac{dx}{x}, \quad \ln|v|=\ln|x| \Rightarrow v=x$$

We went on to equation (10):

$$u'x=-\frac{b}{x}, \int du=-b\int\frac{dx}{x^2}, \; u=\frac{b}{x}+c \text{ then we got}$$

$$y=uv=(\frac{b}{x}+c)x=b+cx. \tag{11}$$

We found b and c, using the boundary condition:

$$\mathbf{y(L)=\frac{d_2}{2}},\quad \mathbf{\frac{d_2}{2}=b+cL}$$

It was necessary to compile another equation connecting the ratio of the diameter d1 to the length l of the cylindrical part of the sleeve.

When $\mathbf{x=l}$, $\mathbf{y=\frac{d_1}{2}}$, and $\mathbf{y(l)=\frac{d_1}{2}}$.

We got:

$$\begin{cases} \mathbf{\dfrac{d_2}{2}=b+cL} \\ \mathbf{\dfrac{d_1}{2}=b+cl} \end{cases} \tag{12}$$

Taking away from the upper equation the lower one, we get:

$$\mathbf{\frac{d_2-d_1}{2}=c(L-l)}, \tag{13}$$

$$\mathbf{c=\frac{d_2-d_1}{2(L-l)}} \tag{14}$$

Then it follows from (12):

$$\mathbf{b=\frac{d_2}{2}-cL=\frac{d_2}{2}-\frac{d_2-d_1}{2(L-l)}L}. \tag{15}$$

Then the solution (11) of the differential equation (6) has the form:

$$\mathbf{y=\frac{d_2-d_1}{2(L-l)}x+\frac{d_2}{2}-\frac{d_2-d_1}{2(L-l)}L} \quad \text{или} \quad \mathbf{y=\frac{d_2-d_1}{2(L-l)}(x-L)+\frac{d_2}{2}}$$

After the transformations, a relationship could be established between the variable lengths and boring angle α, depending on each other:

$$\mathbf{l=L-\frac{d_2-d_1}{2}ctg\alpha}. \tag{16}$$

From (16), always, taking into account condition $\alpha_1 \le \alpha \le \alpha_2$, it is possible to determine the dimensions of the length l of the cylindrical and correspondingly the length of the bored portion of the sleeve. Due to the use of a conical surface, the contact area of the surfaces of the sleeve and the finger increases, as a result of which contact stresses decrease under operational loads, and wear of contact surfaces of the sleeve decreases. It is necessary to note the economic feasibility of reuse of the bushing, for two repair periods, without its dismantling and disassembly of the whole mechanism. Studies of the imitation model of the "bushing-finger" pair using a computer have shown that applying external loads will change the distribution of stresses in the zone subject to wear. This is due to the increase in contact surfaces, as wear depends functionally on the area of contact and when it increases, it decreases. Stresses in the contact area of the bushing and the finger also functionally depend on the area of contact and when it increases, they decrease. The analysis of the obtained dependence of stresses on the contact surface of the bushing against the depth of boring (figure 5) allows to determine the field of full-scale experiment on physical models. This area lies within the depth of boring 0.35 ... 0.7 of the length of the bushing.

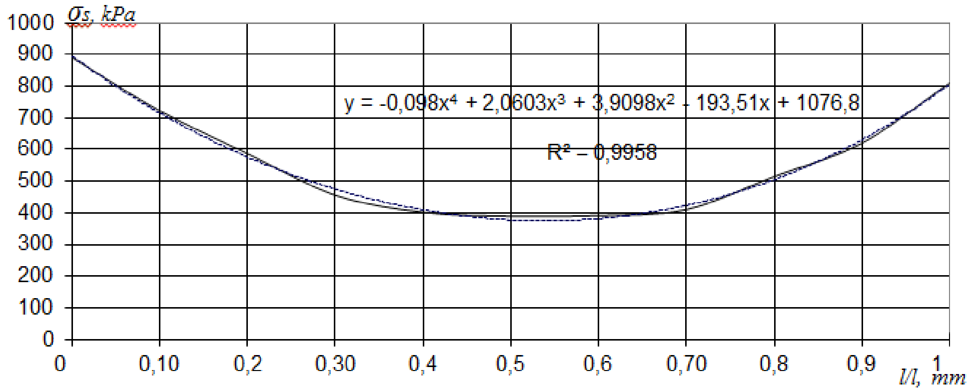

Figure 5 – Dependence of stresses on the contact surface of the bushing against the depth of boring in relation to its total length

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.

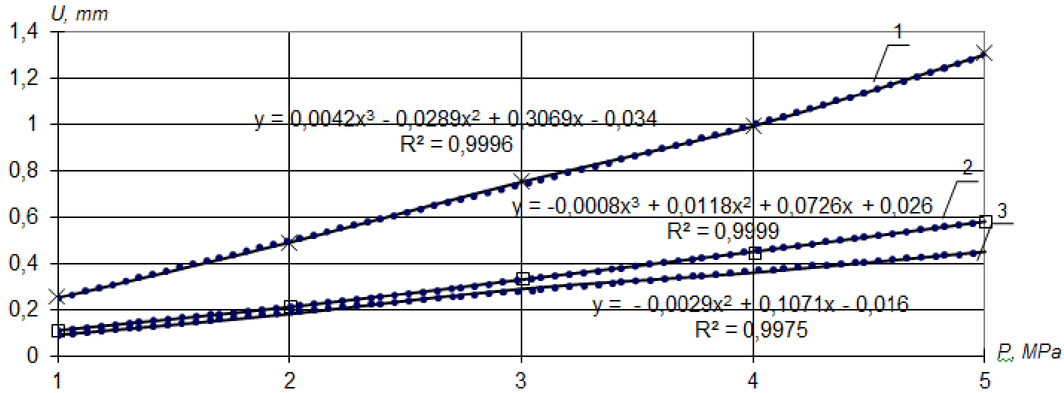

Figure 6 – Charts U=f($S_к$) changes in the wear of the inner surface of the bushings depending on the load when testing the hinge with different geometric parameters.
1 – the bushing is cylindrical; 2 – sleeve with a partial conical boring of the inner cylindrical surface by 0.35 length; 3 – sleeve with a partial conical boring of the inner cylindrical surface by 0.7 of its length

The conical shape makes it possible to realize the property of self-setting of the friction surfaces and to eliminate the radial misalignment during the mounting of the finger, and also to limit the end movement of the finger in the sleeve during operation.

Figure 7 – Implementation of the method of repair and restoration of the hinged connection of the mechanism of the brake device of a mine hoisting machine

Conclusions. Taking into account the above, it can be argued about the increase in durability and service life of the hinge joint of the mechanism of the brake device of mine hoisting machines. The results of the research were used in the repair of the hinges of mine hoisting machines of the type NKMZ 2Ts-4x2,3; 2Ts-5x2,4; 2Ts-6x2,4 (UD of Arcelor Mittal). The method for restoring the inner cylindrical surface of the hinge joint of the brake mechanism of a mine hoisting machine is set forth in [20].

Development and implementation of author's scientific methods for performing repair using the developed recommendations will expand the technological capabilities of repair and increase the resource and technical level of the joints of the brake device of a mine hoisting machine that is in long-term operation.

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А. Д. Мехтиев[1], А. В. Юрченко[1], Ф. Н. Булатбаев[2], Е. Г. Нешина[1], А. Д. Алькина[1]

[1]Томск политехникалық университеті, Томск, Ресей,
[2]Қарағанды мемлекеттіктехникалықуниверситеті, Қарағанды, Қазақстан

МАГИСТРАЛДЫ КОНВЕЙЕРЛАРДЫҢ ТАРТЫМ ҚҰРАЛЫ ҚҰРЫЛЫМДЫҚ СҰЛБАСЫНЫҢ ОҢТАЙЛАНДЫРУЫ

Аннотация. Осы мақалада тау жыныстарын терең карьерге тасымалдау кезінде конвейерлеу мәселесін табысты шешуге қажетті оңтайлы конвейерлік сызбаларды табу бойынша жұмыс жүргізілді. Конвейер ұзындығын тәуелсіз айнымалылардың көмегімен ұлғайту жолымен талдау көрсеткендей, құбыр схемасының құрылысы тек өздерінің тартқыш денесінің механикалық құрылымын анықтайтын конвейерлердің ұзақтығын ұлғайту жолымен және, тиісінше, статикалық және динамикалық жүктемелердің мінез-құлқымен сипатталады. Магистральды конвейерлердің тартқыш органының құрылымдық сызбаларын құру үшін оңтайлы алгоритм құрылды. Тау-кен жұмыстарының технологиялық тізбектерін үздіксіз конвейерлеуді, төгінділерді шығаруды және төгуді қамтамасыз ететін үздіксіз көліктің жаңа құралдарын құрудың теориялық негіздері келтірілген. «Үздіксіз» конвейерлердің құрылымдық сызбаларын талдау және синтездеу жүргізілді. Осы құбырлар құрылымдық схемаларын синтездеу математикалық операциямен жүзеге асырылады - қолданылатын тартқыш органдардың күш көрсеткіштерін қосу операциясы. Құбырлардың бір-бірінен түбегейлі ерекшеленетін құбырларының екі классы қарастырылған: параллель автономдық схемалары бар БК және ВМС. Траншеялық көлік ретінде тік және тегіс көлбеу транспортерлерді енгізу тау-кен өнеркәсібі құбырлары саласында перспективалық бағыт болып табылады және тау-кен жұмыстарының құнын төмендету болып табылады.

Түйін сөздер: магистралды конвейер, құрылымдық сызбаларды оңтайландыру, конвейерлерді жіктеу, автономды тартушы орган, көпжетекті конвейер.

А. Д. Мехтиев[1], А. В. Юрченко[1], Ф. Н. Булатбаев[2], Е. Г. Нешина[1], А. Д. Алькина[1]

[1]Томский политехнический университет, Томск, Россия.
[2]Карагандинский государственный технический университет, Караганда, Казахстан

ОПТИМИЗАЦИЯ СТРУКТУРНЫХ СХЕМ ТЯГОВОГО ОРГАНА МАГИСТРАЛЬНЫХ КОНВЕЙЕРОВ

Аннотация. В статье проведена работа по поиску оптимальных схем конвейера, необходимых для успешного решения проблемы конвейеризации при транспортировании скальных грузов на борт глубокого карьера. Анализ способов увеличения длины конвейера вариацией независимых переменных величин показал, что построение схемы конвейеров характеризуется только теми способами увеличения длины конвейеров, которые определяют механическое строение их тягового органа и, следовательно, поведением последних при статических и динамических нагружениях. Установлен оптимальный алгоритм для построения структурных схем тягового органа магистральных конвейеров. Даны теоретические основания для создания новых средств непрерывного транспорта, обеспечивающих сплошную конвейеризацию технологических цепочек добычи полезных ископаемых, выдачи и укладки вскрышных пород в отвал. Проведен анализ и синтез структурных схем «бесперегрузочных» конвейеров. Синтез структурных схем данных конвейеров осуществляется математической операцией – операцией сложения прочностных показателей используемых тяговых органов. Рассматривались два класса конвейеров, принципиально отличающихся друг от друга: БК с параллельными автономными контурами и БМК. Внедрение в качестве траншейного транспорта вертикальных и крутонаклонных конвейеров является перспективным направлением в области конвейеризации горнодобывающей промышленности и ведет к снижению себестоимости добычи полезных ископаемых.

Ключевые слова: магистральный конвейер, оптимизация структурных схем, классификация конвейеров, автономный тяговый орган, многоприводный конвейер.

Information about authors:

Mekhtiyev Ali – Candidate of Technical Sciences, Junior Researcher, Tomsk Polytechnic University; doi 0000-0002-2633-3976

Yurchenko Alexey, Doctor of Technical Sciences, Professor, Tomsk Polytechnic University; doi 0000-0002-7854-5495

Bulatbayev Felix, Candidate of Technical Sciences, Dean of the Faculty of Energy, Automation and Telecommunications, Karaganda State Technical University; felix4965@mail.ru; doi 0000-0002-3574-1189

Neshina Yelena, master of engineering and technology, postgraduate student of Tomsk Polytechnic University; doi 0000-0002-8973-2958

Alkina Aliya, master of engineering and technology, postgraduate student of Tomsk Polytechnic University; doi 0000-0003-4879-0593

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