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Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

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DESIGN OF CUTTING ELEMENTS OF REUSABLE MOTOR GRADERS IN MINING

Abstract. Motor graders are used in mining for construction, repair, maintenance of quarry roads, on dumps, during the development of placer places-births, construction of pipelines, etc.

The polygonal shape of auto grader knife leads to the fact that ground is cut by three faces-the main one forming common blade of the dump, two side ones adjacent to main face, producing oblique cutting.

It was established that wear of dump's blade occurs unevenly along length - peripheral parts of blade wear more intensively than central ones. Moreover, in dumps of different length, blade sections located at same distances from the center wear similarly, i.e. doesn't depend on the dumping total length.

The following requirements for design of dumps cutting part have been developed on basis of established patterns of blades wear of motor grader dumps:

- standard knives have maximum two blades. Therefore, single knife can be used to form an unencumbered dump blade only twice - by detaching it, turning and fixing it on the dump. It is then restored or rejected.

- since the dump's blade wears unevenly along the length, it is advisable to replace it with the unworn one not entirely, as is done, but along the sections. The square knives adopted as a basis for development allow to increase the number of blade shifts to four, which increases the knives' life and productivity compared to standard knives.

Key words: Auto grader, Dump, Knife, Cutting face, Cutting.

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ТАУ-КЕН ӨНДІРІСІНДЕ АВТОГРЕЙДЕРЛЕРДІҢ КӨП РЕТ ҚОЛДАНЫЛАТЫН КЕСКІШ ЭЛЕМЕНТТЕРІНІҢ КОНСТРУКЦИЯСЫ

Аннотация. Тау-кен жұмыстарында пайдаланылатын автогрейдерлер карьерлік автомобиль жолдарын салу, жөндеу және күтіп ұстау үшін, қайырмаларда, шашылған кен орындарын игеру кезінде, құбырлар салу кезінде және т.б. қолданылады.

Автогрейдер пышағының көпбұрышты пішіні тау жынысын кесу бірден үш бетпен жүзеге асырылады – қайырма күректің жалпы жүзін құрайтын негізгі және негізгі бетке іргелес жатқан және қиғаш кесу жасайтын екі бүйірі. Қайырманың пышағының тозуы оның ұзындығы бойынша біркелкі жүрмейтіні анықталды – перифериялық бөліктері орталыққа қарағанда қарқынды түрде тозады. Сонымен қатар, әртүрлі ұзындықтағы қайырма күректерде ортасынан бірдей қашықтықта орналасқан пышақтың бөліктері бірдей тозады, яғни тозу қайырма күректің жалпы ұзындығына байланысты болмайды.

Автогрейдерлер қайырма күрек пышақтарының тозуының белгіленген заңдылықтары негізінде олардың кесу бөлігінің конструкциясына мынадай талаптар әзірленді:

- стандартты пышақтарда ең көбі екі пышақ болады. Сондықтан, қайырма күректен босату, бұру және бекіту арқылы бір пышақты қайырма күректің жүзін келтіру үшін тек екі рет қолдануға болады. Содан кейін ол қалпына келтіріледі немесе қайта қолданылмайды.

- қайырма күректің жүзі ұзындығы бойынша біркелкі болмағандықтан тозады, оны толығымен тозбаған пышақпен емес, учаскелерменауыстырған жөн. Әзірлеу үшін негіз ретінде қабылданған шаршы пышақтар жүзінің өзгеру санын төртке дейін арттыруға мүмкіндік береді, бұл стандартты пышақтармен салыстырғанда ресурсы мен өнімділігін арттырады. Демек, пышақтарға қойылатын негізгі талап –қайта пайдалануға жарауы керек, яғни төрт бұрыштан кем емес, тұрақты көп бұрышты пішінді болуы керек.

Түйін сөздер: Автогрейдер, қайырма күрек, пышақ, кесу беті, кесу.

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КОНСТРУКЦИЯ РЕЖУЩИХ ЭЛЕМЕНТОВ АВТОГРЕЙДЕРОВ МНОГОРАЗОВОГО ИСПОЛЬЗОВАНИЯ В ГОРНОМ ПРОИЗВОДСТВЕ

Аннотация. Используемые на горных работах автогрейдеры применяются для строительства, ремонта и содержания карьерных *автомобильных дорог*, на отвалах, при разработке *россыпных месторождений*, при строительстве *трубопроводов* и др.

Многоугольная форма ножа автогрейдера приводит к тому, что резание грунта осуществляется сразу тремя гранями – основной, формирующей общее лезвие отвала, и двумя боковыми, прилегающей к основной грани и производящими косое резание.

Установлено, что износ лезвия отвала происходит неравномерно по его длине - периферийные части лезвия изнашиваются интенсивнее центральных. Причем в отвалах разной длины участки лезвия расположенные на одинаковых расстояниях от центра изнашиваются аналогично, т.е. износ не зависит от общей длины отвала.

На основании установленных закономерностей износа ножей отвалов автогрейдеров разработаны следующие требования к конструкции режущей части отвалов:

- стандартные ножи имеют максимум два лезвия. Следовательно, один нож может использоваться для формирования незатупленного лезвия отвала лишь дважды - путем его откреплення, поворота и закрепления на отвале. Затем он подвергается реставрации или отбраковке.

- так как лезвие отвала изнашивается по длине неравномерно, то целесообразно заменять его на неизношенное не целиком, как это делается, а по участкам. Принятые за основу для разработки квадратные ножи позволяют увеличить число смен лезвия до четырех, что повышает ресурс ножей и их производительные показатели по сравнению со стандартными ножами. Отсюда основное требование к ножам - они должны быть многоразового использования, т.е. иметь форму правильного многогранника с числом граней более четырех.

Ключевые слова: Автогрейдер, Отвал, Нож, Режущий грань, Резания.

Introduction. Today, the country has achieved the highest total volume of mining and displaced mountain masses in the world in open mining. Works of creative teams of a number of research, design and development and training institutes of the country contribute to the rapid development of technology for open mining (Docenko, 2012: 688, Sharma, 2019: 6, Volkov, 2012: 448).

The creation of the material and technical base of the country focused on ensuring the full growth of labor productivity in all sectors of public production, for the mining industry, which was one of the labor-intensive industries, increasing labor productivity was most relevant. In this regard, an extensive programme of technical re-equipment and production equipment is currently being implemented in open-pit mining. The basis for increasing labor productivity in open developments is the mechanization and automation of all basic and auxiliary works, the growth of single capacities of mining and transport machines, the transition from the creation and implementation of individual tires to the development and implementation of machine systems that completely cover the entire technological process. Complex mechanization creates the necessary conditions for the transition to the most advanced organization of production - automation, in which the work on machine control is transferred to control devices (Galitskov, 2020: 4, Ilge, 2021: 8, Korytov, 2019: 10, Meshcheryakov, 2018: 12, Sherbakov, 2019 a: 6, Yanhua, 2012: 6, Zhao, 2011: 7), while the person remains the creative phase of activity - planning and monitoring the action of these devices.

In mining, motor graders are used for the construction, repair and maintenance of quarry roads, on dumps, during the development of placer deposits, during the construction of pipelines, etc. The construction of earth structures is a complex production process in which a wide variety of construction machines and mechanisms, workers of various specialties of different qualifications, engineering and technical workers are involved. At the same time, various space-planning and structural solutions of objects, diagrams and methods of work execution are used.

The implementation of such large volumes of work makes it relevant and effective to raise the production indicators of motor graders, which are widely used for the construction, repair and maintenance of quarry motor roads, on dumps, during the development of placer deposits, during the construction of pipelines, etc.

The process of operation of the motor grader consists of successive passages, during which the rock is cut, moved, leveled and the surface of the structure is planned. The performance of all functions of the auto grader is carried out using a special working tool - a dump with a knife, which is mounted on the frame of the machine. It can be lifted, lowered, rotated in a horizontal and vertical plane.

It is generally accepted that excessive blunting of the working elements (WE) of the motor grader does not only affect the production performance of the machines, but also their technical condition, since it requires increased power consumption and, accordingly, increased stresses in their units and parts. In this aspect, rational the cutting elements (CE) development modes involving timely replacement of blunted blades are of great importance. Method for determining the limit size of the value taken as the blunting criterion (Korchagin, 2018: 10, Kozbagarov, 2020 a: 8, 2021 b: 8, 2021 c: 8, 2021 d: 8, Sherbakov, 2021 b: 6, *Shevchenko*, 2020: 8, Sukharev, 2021: 7).

An analysis of work related to the WE of motor graders showed that they were mainly aimed at identifying the effectiveness of oblique cutting, but did not take into account the features of combined cutting, did not show the effect of blade wear on the efficiency of work, did not study the patterns of blade wear and did not give information about the criteria for working out knives and its limit value. As a result, the currently used motor grader dumps are characterized by high metal consumption and cost, as well as a small resource of work.

The width of the knife and its faces primarily affect the ability to adjust the pro-process of working out the blade of the dump, in particular, the process of its wear. Production observations were made that showed uneven wear of the blade of the dump along the length. The method of sequential change of the most worn blade sections is proposed. The width of the knives should ensure the most optimal division of the blade into such areas. At the same time, the criterion is the cost of working out knives. It has been established that the optimal number of trays on the dump corresponds to 20... 25. Accordingly, the width of the knife face must be within 120... 150 mm, and the ratio of the width of the main working face and the width of the grip of the side working face of the knife $B_к/B_п$ = 0.4 ... 0.6 (Kozbagarov, 2020 a: 8, 2021 b: 8, Polyarus, 2016: 7, Rakhmanov, 2019: 10).

During operation, the cutting elements (CE) of auto graders, as parts in direct contact with the abrasive medium, undergo significant wear. The optimal geometric shapes and dimensions of CE, established by many years of theoretical and experimental studies, change significantly due to abrasive wear, leading to an increase in the cost of energy, material and labor resources.

In practice, wear and tear of CE motor graders causes an increase in the cutting force by 3 ... 4 times, the energy intensity of the cutting process by 1.4 ... 3 times, the cost of developing grunts by 8 ... 15% with a decrease in productivity by 10 ... 30%. This increases the stress state of the entire machine and reduces its operational reliability. Excessive wear of the CE leads to economic impracticality or practical impossibility of further operation of the machines.

Soil resistance to cutting increases significantly as a result of blade wear and

the appearance of additional surfaces contacting the soil during its destruction. Hence the importance of studying the nature and patterns of wear and tear.

Materials and methods. The theoretical and experimental studies described in the works (Kozbagarov, 2021 b: 8) made it possible to determine the optimal values of the parameters dictating the requirements for the design of knives and the cutting part of the motor grader dump, as well as for the technology of their development.

Thus, a knife in the form of a hexagonal plate (Figure 1) was adopted as the basis for the design of the cutting part of the autograder dump. And "K" -shaped knives are proposed as side knives for equipping dumps that perform work in an inclined position.

To create a continuous line of the blade of the dump, which allows the planning work to be carried out, the knives 2 are arranged on the dump 1 in two rows (Kozbagarov, 2021 b: 8). The knives of the second row are displaced relative to the first row and overlap the gaps between the cutting faces of the knives of the first row with their cutting faces. All knives are 2 of the same type. Therefore, the design has a high degree of unification.

The knives are attached to the dump by means of bolts 4. Holes of knife and dump are made at points of intersection of bisector of equilateral triangles constituting hexagonal plate of knife. Therefore, when the knife is rotated by 60^0, 120^0, 180^0, 240^0, 300^0 и 360^0, its holes always coincide with the holes of the dump.

When the blade of the dump is worn, it is customary to replace it entirely. In this case, in the disclosed structure, all hexagonal knives are simultaneously rotated by 60^0 and the continuously-worn cutting edges of adjacent faces form a common unworn dump blade. When replacing only the individual, most worn-out sections of the blade of the dump, not all knives turn, but only those that form said sections of the blade.

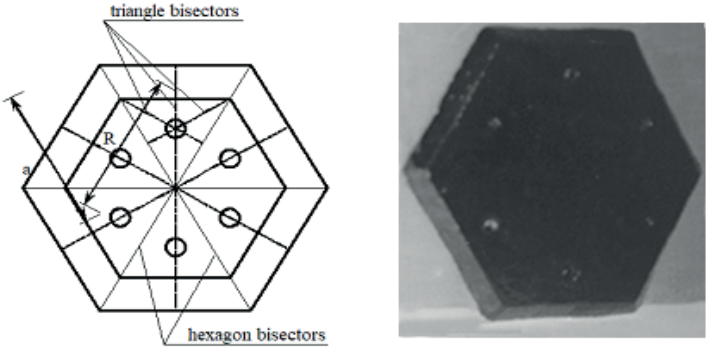

Figure 1. Plate of autograder knife: a) - the diagram of the knife; b) – a general view

Thus, six cutting faces of the knife are used, instead of two - in standard knives, or four - in square ones.

Such a design can be recommended for planning work, since it is not possible to tilt the dump.

In order to expand the field of application of the structure by adding types of works requiring tilting of the dump, a second version of the design of the cutting part of the dump is developed, in which the middle part is made of hexagonal knives arranged in two rows, and reversible "K" -shaped knives with two cutting edges forming the dump blade and with a side face perpendicular to the blade are proposed as side faces. This design can be used for all types of auto grader work.

Both described designs have another, common drawback: the arrangement of hexagonal knives in two rows requires a significant number of them. The desire to reduce the metal consumption of the cutting part of the dump led to the development of a third design option. Here, hexagonal knives are arranged in one row, side knives are made "K" -shaped, and smaller triangular knives with three cutting edges are placed in the gaps between cutting faces of hexagonal knives along the blade of the dump.

Comparative tests of dumps, the cutting part of which was equipped with standard knives and promising reusable knives, were carried out at the road construction facilities of JSC "Kazakhstan Zholdary".

Three designs of the cutting part of the dumps were studied:

1. Standard, equipped with two medium knives of type ПС02 and two side knives of type КР02 (Figure 2, a). All knives with two cutting faces. The worn blade of the dump (when the peripheral part reaches wear S = 15 mm) was replaced completely by turning all the knives by 180^0.

2. Equipped with seventeen quadrangular knives 178x 200 mm with four cutting faces (Figure 2, b).

3. Equipped with the above-described twenty-three hexagonal knives with six cutting faces 132 mm long (Figure 2, c).

The unevenness of the wear intensity of the blade is most noticeably manifested on its periphery [7], and in the middle part, about 2000 mm long, it is weakly manifested. Therefore, when using the second and third structures of the cutting part of the dump, a method for sequentially replacing worn out portions of the dump blade starting from peripheral ones has been investigated.

The structure and dimensions of the knives caused a conditional division of the dump blade into zones with different wear intensity. For tetrahedral, three zones turned out to be: peripheral, formed by two extreme tetrahedral knives (ETK), 178 mm long on both sides of the blade, intermediate (ITK), formed by four knives and medium, about 1970 mm long, formed by eleven medium

tetrahedral knives (MTK). For hexagonal knives, four zones were obtained: peripheral, 132 mm long, formed by two extreme hexagonal knives (EHK), two intermediate - the first (HIZK), adjacent to the peripheral and formed by two knives, the second or internal, formed by four knives (HIZK/) and the middle, 1980 mm long, formed by fifteen knives (HMK).

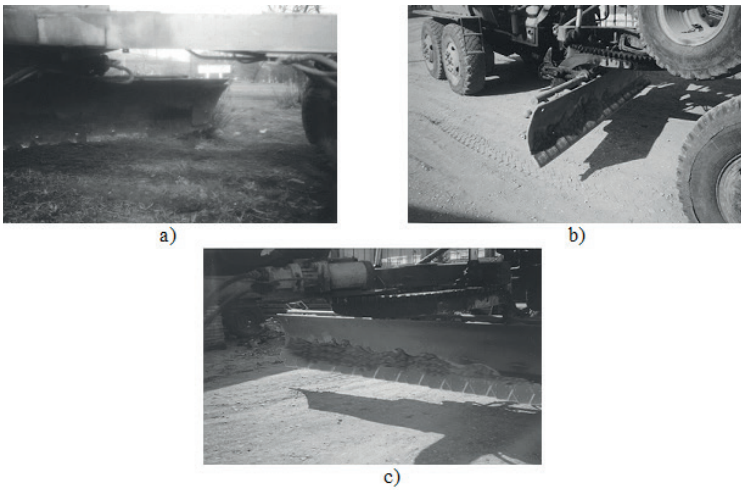

Figure 2. Auto grader when working with different types of cutting part design: a) dump with standard knives; b) dump with tetrahedral knives; c) dump with hexagonal knives

For these designs of the cutting part of the dump, two methods of replacing a worn blade were investigated: standard (parallel) - when the entire blade is replaced when critical wear is reached S = 15 mm on the extreme knives, and sequential - by sequentially replacing blade sections along the dump zones.

The studies consisted of 4 series of 4 experiences in the series for each design of the cutting part of the dump. Experience refers to the cutting of soil by the dump of an auto grader to the volume of operating time of 4 thousand m^3 per dump. At the same time, the reduced wear size S.

Results. The obtained data correspond to the regression equations given in Table 1.

From the equations of Table 1 it can be seen that the knives of the extreme zones wear most intensively. When in the dumps of the 2nd and 3rd types of structures these knives reach the ultimate wear, the knives of the remaining zones remain quite sharp, and, therefore, they have a reserve of development, and they are not replaced, but continue to be operated. Thus, at the moment of changing the knives of the extreme zone, the working out of the cutting part of the dump will be not 100%, as in dumps of the 1st type, but less. To characterize

the development of dumps of the types studied, we introduce the development factor K_o:

$$K_o = \frac{\sum S©{\cdot}n}{\sum n} = \frac{S©_k{\cdot}n_k + S©_n{\cdot}n_n + S©_c{\cdot}n_c}{n_k + n_n + n_c} = \frac{\frac{S_k}{S_k}\cdot n_k + \frac{S_n}{S_k}\cdot n_n + \frac{S_c}{S_k}\cdot n_c}{n_k + n_n + n_c},$$

where S_k, S_n, S_c - relative wear of knives, respectively, of extreme, intermediate and middle zones during the period when the knives reach the extreme zone of ultimate wear;

n_k, n_n, n_c is the number of knives, respectively, in the extreme, intermediate and middle zones.

Using the equations of Table 1, we obtain:

- for the structure of the dump of the second type: $K_o = 0{,}637 \approx 0{,}64$;
- for the structure of the dump of the third type: $K_o = 0{,}587 \approx 0{,}59$.

Table 1. Regression equations for calculation of reduced wear and tear

Type of knife	Conditional designation	Reduced wear size S, mm
Standard	SK	$S_к = 1{,}875{\cdot}V$
Extreme tetrahedral	ETK	
Extreme hexagonal	EHK	
Intermediate zone tetrahedral knife	ITK	$S_п = 1{,}562{\cdot}V$
Hexagonal knives of intermediate zones	HIZK	$S_{пш} = 1{,}393{\cdot}V$
	HIZK/	$S_{пв} = 1{,}187{\cdot}V$
Middle zone tetrahedral knife	MTK	$S_c = 0{,}937{\cdot}V$
Hexagonal knife of middle zone	HMK	

Thus, 100% of knives are worked out for the same volume of soil production by the dump of the first type (standard), the second type (with tetrahedral knives) - 64%, and the third type (with hexagonal knives) - 59%. That is, the third type of dump has the largest number of sufficiently sharp knives, which should also affect the performance of the auto grader.

According to the data of Table 1, taking wear S = 15 mm as the criterion for the development of the blade zone, we determine the volume of soil operating time until the maximum blunting is reached for each type of knives. For each type of knives under investigation, a nomogram (Kozbagarov, 2020 a: 8, 2021 b: 8) is built, showing the change of the value of blunting of knives along the dump zones at sequential change of knives and corresponding change of efficiency of the motor grader.

Since Tables 1 and 2 are based on test data, the nomogram can still be built

taking into account the change in the performance of the auto grader depending on the blunting of the knives. This dependence can be recorded directly in comparative tests, and can, as in this case, be known from previous studies.

Table 2. Soil operating time for different types of knives

Type of knife	Conditional designation	Soil operating time V, thousand m^3
Standard	SK	8,00
Extreme tetrahedral	ETK	
Extreme hexagonal	EHK	
Intermediate zone tetrahedral knife	ITK	9,60
Hexagonal knives of intermediate zones	HIZK	10,77
	HIZK/	12,64
Middle zone tetrahedral knife	MTK	16,00
Hexagonal knife of middle zone	HMK	

The method of carrying out comparative tests using a nomogram proposed by us is convenient in that it does not require the complete development of all the knives of the dump, and, therefore, is based on a reduced amount of soil production. This technique can also be applied to WE of other 3M if they allow a sequential change of CE over several wear zones.

The technique is as follows. The blade of the dump is worked out until the knives reach the extreme zone of ultimate blunting. Wear of all blade areas is fixed. Such experiments are repeated as many times as necessary to obtain statistically valid wear values. If there is no representative performance data depending on the wear, the performance indicators are recorded in the mentioned experiments.

Discussion. Based on the obtained data, a nomogram is constructed. Its upper part is a graph in which along the ordinate axis the value of operating time is deposited on the dump V, and along the abscissa axis - the reduced wear size of the blade S. When the faces of the knives of the edge of the zone wear to the limit value S (in this case, up to S = 15 mm), the point of intersection of ordinate V with abscissa S = 15 mm is connected by a horizontal line with axis V. This line (in this case she corresponds to V = 8 thousand m^3) means change of edges of knives of an extreme zone - their turn. Points corresponding to blunting of knives of other zones at the same operating time are marked on this line. These points are connected to the origin of coordinates by straight lines, which are continued until intersection with the vertical line drawn through the point corresponding to the limit value of wear S. Points of intersection of graphs with the vertical line are connected to the axis V by horizontal sections,

which show the value of operating time on the knives of these zones before the next replacement of their cutting faces. After changing the cutting faces (turning the knives), the graph corresponding to their operating time starts from the V axis (at S = 0) from the previous horizontal line. Thus, cycles are repeated until the knives of all zones are completely worn out.

The lower part of nomogram is a graph of productivity change at change of value of reduced wear. In this case, the scale of the abscissa - S axis must correspond to the upper part of the nomogram. The vertical projections of the crossing points of the graphs of the upper part of the nomogram with horizontal straight lines on the graphs of the lower part show the productivity provided by the knives of a particular dump area at a certain operating time and wear.

Using the obtained nomogram, it is possible to establish the average wear of knives at a certain volume of worked soil, the average productivity and operating time on knives of a particular zone, as well as the entire dump as a whole, i.e. all the main indicators for comparing the structures of CE and WE machines.

To compare the wear and productivity of dumps of the 2nd and 3rd types, when sequentially changing knives and dumps of the 1st type (with standard knives), using a nomogram, the values of these indicators were determined.

Dependencies of average reduced dampening size S and capacity P on the number of working edge shifts.

From the given graphs in operation (Kozbagarov, 2020 a: 8, 2021 b: 8)] you can see the following:

1. The average wear of knives is less, and the average productivity is higher for dumps of the 3rd type, which is confirmed by the minimum value of the test coefficient K_o, derived earlier.

2. This type of dump is also characterized by the most optimal development indicators when changing the working edge: during five shifts, the average dampening value and productivity remain almost constant, moreover, the dampening value is minimal, and the productivity is maximum, while in a dump of type 2, these parameters change hopefully, reaching significant differences in values.

Three designs of the cutting part of the dumps were studied - with standard knives, with tetrahedral knives and with hexagonal knives located in two rows.

For these designs of the cutting part of the dump, two methods of replacing a worn blade were investigated: standard (parallel) - when the entire blade is replaced, and sequential - by sequential replacement of blade sections along dump zones.

Conclusions. Based on the study of the change in the cost of rock development depending on blade wear, it was established that the maximum

permissible wear should be considered the wear value S = 15 mm, allowing in some cases an increase in values to 20 mm.

The established optimal value of the parameters of the blades of the taps of auto graders, the laws of their wear and tear and the nature of work in the soil determined the requirements for their

structure and structure of cutting part of dumps. With these in mind, six-carbon knives with six cutting faces have been developed.

On the basis of a hexagonal knife, three designs of the cutting part of the motor grader dump have been developed for various working conditions and technology for their development.

Comparative tests were carried out on dumps with a cutting part of three configurations - with standard knives, with tetrahedral knives and with hexagonal knives located in two rows. The obtained results showed the advantage of a cutting part with hexagonal knives, developed according to the proposed method of sequential replacement of worn knives: its average life is 4 times more than the life of a standard cutting part and 1,5 times more than the life of a cutting part with tetrahedral knives, developed in the same way.

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REFERENCES

Docenko A.I., Karasev G.N., Kustarev G.V., Shestopalov K.K. (2012) Machines for earthworks [Mashiny dlja zemljanyh rabot]. Moscow: Bastet, Russia. ISBN: 978-5-903178-28-5 (in Russ.).

Galitskov K.S., Nazarov M.A., Lukyanov A.S. (2020) Studying the dynamics of the automatic control system for the elevation position of a motor grader blade with an alternative position sensor. *IOP Conference Series: Materials Science and Engineering*, *International Scientific Conference Interstroymeh (ISM 2020) 17th-18th December, Samara, Russia*, *1103*:1-5. DOI:*10.1088/1757-899X/1103/1/012021* (in Eng.).

Ilge I. (2021). Method of selecting automatic control system of a motor grader [Sposob vybora sistemy avtomaticheskogo upravlenija avtogrejderom]. Vehicle and Electronics. Innovative Technologies, 20:37–44. DOI: *https://doi.org/10.30977/VEIT.2021.20.0.04* (in Ukrainian).

Korchagin P.A., Letopolskiy A.B., Teterina I.A. (2018) Research results of the efficiency of the motor grader side working equipment [Rezul'taty issledovanija rabotosposobnosti bokovogo rabochego oborudovanija avtogrejdera]. The Russian Automobile and Highway Industry Journal, 15(4):492-501. DOI: *https://doi.org/10.26518/2071-7296-2018-4-492-501* (in Russ.).

Korytov M.S., Shcherbakov V.S., Titenko V.V., Ots D.A. (2019) Simulation model for the determination of energy losses during vibrations of the working equipment of a earth-moving machine in the transport mode. *Journal of Physics: Conference Series*, *vol. 1260(11*):1-10. DOI:*10.1088/1742-6596/1260/11/112015* (in Eng.).

Kozbagarov R.A., Zhussupov K.A., Kaliyev E.B., Yessengaliyev M.N., Kochetkov A.V., N.C. Kamzanov. (2020) Development of control suspension of attachment of a bulldozer. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 4(442):166-174. DOI: *https://doi.org/10.32014/2020.2518-170X.97* (in Eng.).

Kozbagarov R.A., Taran M.V., Zhussupov K.A., Kanazhanov A.E., Kamzanov N.C., Kochetkov A.V. (2021) Increasing the efficiency of motor graders work on the basis of working elements perfection. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 1(445):98-105. DOI: *https://doi.org/10.32014/2021.2518-170X.14 (in Eng.)*.

Kozbagarov R.A., Kamzanov N.S., Akhmetova Sh.D., Zhussupov K.A., Dainova Zh.Kh. (2021) Improving the methods of milling gauge on highways. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 3(447):87-93. DOI: *https://doi.org/10.32014/2021.2518-170X.67* (in Eng.).

Kozbagarov R.A., Zhussupov K.A., Kaliyev Y.B., Yessengaliyev M.N., Kochetkov A.V. (2021) Determination of energy consumption of high-speed rock digging. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 6(450):85-92. DOI: *10.32014/2021.2518-170X.123* (in Eng.).

Meshcheryakov V.A., Weber V.V. (2018) Setpoint optimization for the control system of the motor grader in heavyload mode [Optimizacija zadajushhego vozdejstvija dlja sistemy upravlenija tjagovym rezhimom avtogrejdera] The Russian Automobile and Highway Industry Journal, 15(4): 502-513. DOI: *https://doi.org/10.26518/2071-7296-2018-4-502-513* (in Russ.).

Polyarus A., Paschenko R., Poliakov E., Lebedinskyi A. (2016). Analysis of motor-grader loading on the basis of fractal dimension. *Automobile Transport*, 39:47-53. DOI: *https://doi.org/10.30977/AT.2219-8342.2016.39.0.47* (in Eng.).

Rakhmanov M.L., Saveliev A.G., Mikhailovskaya V.A., Kosov M.A. (2019) The method of synthesis of new structural schemes of additional working equipment of the motor grader with the use of graphs and matrices. *IOP Conference Series: Materials Science and Engineering*. *International Scientific Conference Interstroymeh (ISM 2019) 12th-13th September, Kazan, Russian* Federation, 786(1):1-10. DOI:10.1088/1757-899X/786/1/012041 (in Eng.).

Sharma D., Barakat N. Evolutionary Bi-objective Optimization for Bulldozer and Its Blade in Soil Cutting. Journal of The Institution of Engineers (India) (2019): Series C, 100(2):295-310. DOI: *https://doi.org/10.1007/s40032-017-0437-z* (in Eng.).

Sherbakov V.S., Ionova Yu.E. (2017) Improving the hydraulic drive of the motor grader [Covershenstvovanie gidroprivoda rulevogo upravlenija avtogrejdera]. The Russian Automobile and Highway Industry Journal, 4-5(56-57):8-13. DOI: *https://doi.org/10.26518/2071-7296-2017-4-5(56-57)-8-13*(in Russ.).

Sherbakov A.P., Pushkarev A.E., Maksimov S.E. (2021) Replacement working body material as a way to increase reliability of road construction machines [Zamena materiala rabochego organa kak put' povyshenija nadezhnosti dorozhno-stroitel'nyh mashin] The Russian Automobile and Highway Industry Journal, 18(6):646-661. DOI: *https://doi.org/10.26518/2071-7296-2021-18-6-646-661* (in Russ.).

Shevchenko V. (2020) Determination of indexes of the motor grader course stability on the basis of studying its analytical model of movement [Opredelenie pokazatelej kursovoj ustojchivosti avtogrejdera na osnove issledovanija ego analiticheskoj modeli dvizhenija] December, *Bulletin of Kharkov National Automobile and Highway University*, 2(88):43-50. DOI:*10.30977/BUL.2219-5548.2020.88.2.43* (in Ukrainian).

Sukharev R.Yu. (2021) Trajectory Plotting Algorithm for a Self-Driving Road Grader. Published under licence by IOP Publishing Ltd *Journal of Physics: Conference Series*, *International Conference on Automatics and Energy (ICAE 2021), Vladivostok, Russia*, *2096*:1-7. DOI:10.1088/1742-6596/2096/1/012181 (in Eng.).

Volkov D.P., Krikun V.Ja., Totolin P.E., Gaevskaja K.S., Nikulin P.I. (2012) Machines for earthworks [Mashiny dlja zemljanyh rabot]. Moscow "Mashinostroenie", Russia. ISBN: 5-217-01973-5 (in Russ.).

Yanhua S., Taohua Z., Chun J. (2012). Simulation based analysis of articulated steer grader with six motor-driven wheels. *Advanced Materials Research*, 455-456:1090-1095. DOI:*10.4028/www.scientific.net/AMR.455-456.1090* (in Eng.).

Zhao *Rui Ying*, *Wang* Xin. (2011) Research on Power Adaptive Control Method for Hydraulic Motor Grader Based on Simulink/AMESim. *Applied Mechanics and Materials*, 135-136:793-799. DOI:*10.4028/www.scientific.net/AMM.135-136.793* (in Eng.).

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