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Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
АКАДЕМИИ НАУК РЕСПУБЛИКИ
КАЗАХСТАН»
ЧФ «Халық»

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В 2016 году для развития и улучшения качества жизни казахстанцев был создан частный Благотворительный фонд «Халык». За годы своей деятельности на реализацию благотворительных проектов в областях образования и науки, социальной защиты, культуры, здравоохранения и спорта, Фонд выделил более 45 миллиардов тенге.

Особое внимание Благотворительный фонд «Халык» уделяет образовательным программам, считая это направление одним из ключевых в своей деятельности. Оказывая поддержку отечественному образованию, Фонд вносит свой посильный вклад в развитие качественного образования в Казахстане. Тем самым способствуя росту числа людей, способных менять жизнь в стране к лучшему – профессионалов в различных сферах, потенциальных лидеров и «великих умов». Одной из значимых инициатив фонда «Халык» в образовательной сфере стал проект *Ozgeris powered by Halyk Fund* – первый в стране бизнес-инкубатор для учащихся 9-11 классов, который помогает развивать необходимые в современном мире предпринимательские навыки. Так, на содействие малому бизнесу школьников было выделено более 200 грантов. Для поддержки талантливых и мотивированных детей Фонд неоднократно выделял гранты на обучение в Международной школе «Мирас» и в *Astana IT University*, а также помог казахстанским школьникам принять участие в престижном конкурсе «*USTEM Robotics*» в США. Авторские работы в рамках проекта «Тәлімгер», которому Фонд оказал поддержку, легли в основу учебной программы, учебников и учебно-методических книг по предмету «Основы предпринимательства и бизнеса», преподаваемого в 10-11 классах казахстанских школ и колледжей.

Помимо помощи школьникам, учащимся колледжей и студентам Фонд считает важным внести свой вклад в повышение квалификации педагогов, совершенствование их знаний и навыков, поскольку именно они являются проводниками знаний будущих поколений казахстанцев. При поддержке Фонда «Халык» в южной столице был организован ежегодный городской конкурс педагогов «*Almaty Digital Ustaz*».

Важной инициативой стал реализуемый проект по обучению основам финансовой грамотности преподавателей из восьми областей Казахстана, что должно оказать существенное влияние на воспитание финансовой грамотности и предпринимательского мышления у нового поколения граждан страны.

Необходимую помощь Фонд «Халык» оказывает и тем, кто особенно остро в ней нуждается. В рамках социальной защиты населения активно проводится работа по поддержке детей, оставшихся без родителей, детей и взрослых из социально уязвимых слоев населения, людей с ограниченными

возможностями, а также обеспечению нуждающихся социальным жильем, строительству социально важных объектов, таких как детские сады, детские площадки и физкультурно-оздоровительные комплексы.

В копилку добрых дел Фонда «Халык» можно добавить оказание помощи детскому спорту, куда относится поддержка в развитии детского футбола и карате в нашей стране. Жизненно важную помощь Благотворительный фонд «Халык» оказал нашим соотечественникам во время недавней пандемии COVID-19. Тогда, в разгар тяжелой борьбы с коронавирусной инфекцией Фонд выделил свыше 11 миллиардов тенге на приобретение необходимого медицинского оборудования и дорогостоящих медицинских препаратов, автомобилей скорой медицинской помощи и средств защиты, адресную материальную помощь социально уязвимым слоям населения и денежные выплаты медицинским работникам.

В 2023 году наряду с другими проектами, нацеленными на повышение благосостояния казахстанских граждан Фонд решил уделить особое внимание науке, поскольку она является частью общественной культуры, а уровень ее развития определяет уровень развития государства.

Поддержка Фондом выпуска журналов Национальной Академии наук Республики Казахстан, которые входят в международные фонды Scopus и Wos и в которых публикуются статьи отечественных ученых, докторантов и магистрантов, а также научных сотрудников высших учебных заведений и научно-исследовательских институтов нашей страны является не менее значимым вкладом Фонда в развитие казахстанского общества.

С уважением, Благотворительный Фонд «Халык»!

NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

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. Web of 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.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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MONITORING THE CONDITION OF MINE HAUL ROADS USING DIGITAL SYSTEMS

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Abstract. The article presents the original practical results of experimental data of monitoring the conditions of mining haul roads using the on-board digital monitoring system installed on mining dump trucks. The efficiency of mining vehicles largely depends on the quality and operability of mining roads. Therefore, control of road conditions is an important opportunity in improving the efficiency of open-pit mining of mineral deposits. According to the results of the earlier studies, it was established that appropriate construction and maintenance of mining haul roads, allow to reduce total cost of road transport for individual cost items by 10–50 %. Possibility of improving efficiency of mining transport by timely detection of hidden defects of mining haul roads is considered in the study. The tasks were executed by setting up experimental studies, using GPS digital data, processing the results of experimental studies using methods of mathematical statistics, regression analysis and probability theory. The carried-out researches and the developed on their basis intellectual method of monitoring the condition of mining roads permit to detect degree of influence of operational factors of mining haul roads on efficiency of use of open pit mining dump trucks by means of information of on-board automated systems of dump trucks. The novelty of the work it consists in establishing the influence of the quality of mining haul roads on the level

of dynamic loading of metal structures of dump trucks in the form of frame twisting, longitudinal or transverse bending, excessive fuel consumption, reduced speed, service life of tires, productivity, increase of maintenance and repair costs. Practical significance of the work it consists of use of the results of monitoring the condition of mining roads as pre-design materials and an informational base for development of reconstruction, overhaul, ongoing repair and maintenance projects for operated roads in the established manner.

Keywords: monitoring, mining haul roads, on-board digital system, experimental research, mining dump trucks

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ЦИФРЛЫҚ ЖҮЙЕЛЕРДІ ПАЙДАЛАНЫП ТАУ КЕН ТЕХНОЛОГИЯЛЫҚ ЖОЛДАРЫНЫҢ ШАРТТАРЫН БАҚЫЛАУ

Аннотация. Мақалада тау-кен автосамосвалдарында орнатылған сандық борттық автоматты бақылау жүйесінің көмегімен тау-кен жолдарының жай-күйін бақылау бойынша тәжірибелік деректердің бастапқы практикалық нәтижелері берілген. Ашық тау-кендегі көліктердің тиімділігі көп жағдайда ашық жолдардың сапасы мен өнімділігіне байланысты. Сондықтан жол жағдайын бақылау пайдалы қазбалар кен орнын ашық әдіспен өндірудің тиімділігін арттырудың маңызды резерві болып табылады. Алдыңғы жүргізілген зерттеулердің нәтижелері бойынша ашық жолдарды ұқыпты салуды және күтіп ұстауды бақылауды қамтамасыз ету арқылы жекелеген баптар бойынша автомобиль көлігінің жалпы құнын 10–50 %-ға төмендетуге болатыны анықталды. Тау-кен жолдарының қатты жабындарының құрылымындағы жасырын ақауларды дер кезінде анықтау арқылы карьерлік автомобиль көлігінің тиімділігін арттыру мүмкіндігін белгілеу қарастырылды. Тапсырмаларды шешу натуралық және эксперименттік зерттеулерді орнату, сандық GPS деректерін пайдалану, математикалық статистика, регрессиялық талдау және ықтималдықтар теориясы әдістерін қолдану арқылы эксперименттік зерттеулердің нәтижелерін өңдеу арқылы жүзеге асырылды. Жүргізілген зерттеулер және олардың негізінде әзірленген тау кен жолдардың жай-күйін бақылаудың интеллектуалды әдісі карьерлік жолдардың эксплуатациялық факторларының тау-кен автосамосвалдарын пайдалану тиімділігіне әсер ету дәрежесін анықтауға мүмкіндік береді. самосвалдардың борттық автоматтандырылған жүйелері. Жұмыстың жаңалығы тау-кен жолдар

сапасының раманың бұралуы, бойлық немесе көлденең бұрмалануы, шамадан тыс жанармай шығыны, отын шығынының төмендеуі түріндегі самосвалдардың металл құрылымдарының динамикалық жүктелу деңгейіне әсерін анықтауда. самосвалдардың жылдамдығы, шиналардың қызмет ету мерзімі, өнімділігі, техникалық қызмет көрсету мен жөндеу шығындарының өсуі. Жұмыстың практикалық маңыздылығы тау-кен жолдардың жай-күйін бақылау нәтижелерін жоба алдындағы материалдар және қолданыстағы тау-кен қайта құру, күрделі жөндеу, күтіп ұстау және күтіп ұстау жобаларын белгіленген тәртіппен әзірлеу үшін ақпараттық база ретінде пайдалануында. жолдар.

Түйін сөздер: мониторинг, тау-кен жолдары, сандық борттық жүйесі, тәжірибелік зерттеулер, тау-кен самосвалдары

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МОНИТОРИНГ СОСТОЯНИЯ КАРЬЕРНЫХ ТЕХНОЛОГИЧЕСКИХ ДОРОГ С ИСПОЛЬЗОВАНИЕМ ЦИФРОВЫХ СИСТЕМ

Аннотация. В статье представлены оригинальные практические результаты экспериментальных данных мониторинга состояния карьерных автомобильных дорог с использованием информационной цифровой бортовой системы автоматического мониторинга, установленной на карьерных автосамосвалах. Эффективность работы карьерного автотранспорта во многом зависит от качества и работоспособности карьерных автомобильных дорог. Поэтому контроль дорожных условий, важный резерв в повышении эффективности открытых разработок месторождения полезных ископаемых. По результатам ранее выполненных исследований установлено, что за счет обеспечения тщательного строительства и контроля содержания карьерных дорог возможно снизить общие затраты на автомобильный транспорт по отдельным статьям на 10–50 %. Рассмотрено установление возможности повышения эффективности карьерного автотранспорта путем своевременного выявления скрытых дефектов структуры жестких покрытий карьерных дорог. Решение поставленных задач проводилось постановкой натуральных и экспериментальных исследований, использованием цифровых данных GPS, обработкой результатов экспериментальных исследований методами математической статистики, регрессионного анализа и теории вероятностей. Проведенные исследования и разработанный на их основе интеллектуальный метод мониторинга состояния карьерных автомобильных дорог позволяют выявить степень влияния эксплуатационных факторов карьерных дорог на эффективность использования карьерных автосамосвалов, посредством информации с бортовых автоматизированных систем автосамосвалов. Новизна

работы заключается в установлении влияний качества карьерных дорог на уровень динамической нагруженности металлоконструкций автосамосвалов в виде скручивания рамы, продольном или поперечном перекосах, завышенного расхода топлива, снижения скорости движения самосвалов, срока службы шин, производительности, увеличения расходов на техническое обслуживание и ремонт. Практическая значимость работы заключается в использовании результатов мониторинга состояния карьерных дорог как предпроектных материалов и информационной базы для разработки в установленном порядке проектов реконструкции, капитального ремонта, текущего ремонта и содержания эксплуатируемых карьерных дорог.

Ключевые слова: мониторинг, карьерные автомобильные дороги, цифровая бортовая система, экспериментальные исследования, карьерный автосамосвал

Introduction

At the present stage of mining development, moving of rock mass was the most time-consuming, energy-intensive and expensive process. To date, automobile transport is the main type of mining transport used in open works, cost of mining material transportation reaches almost 80 % (Khazin et al., 2018). In this case, the effectiveness of this work depends directly on the quality and durability of mining roads. It was established that improving the quality of the road surface reduces the cost of transporting mining material by 15–35 %. The most noteworthy property of mining roads is evenness of the surface, determined by strength of the surface, the technology of construction and condition control, determining rolling resistance, speed and capacity of mining dump trucks, and also, safety and comfort of operator. Introduction of modern systems for monitoring the condition of mining roads would help to solve the problem of providing effective operation of a mining road system (Aleksandrov et al., 2019).

In the mining industry, the movement of the mine material takes the labor input of 40–70 % of the total mining cost in an open mining process. It is an integral part of the technological process. The growth of open-cast mining is inextricably connected with the improvement and efficiency of mining transport, the performance of which largely depends on the technical - operational qualities of mining roads. Load stress (the amount of cargo considering all types of movement in tons at a section of road per unit of time) is the main feature characterizing the design and parameters of the road. Considering increase in the depth of the mines and the condition of the roadway, the operational conditions of mining and transport equipment become more complicated, in particular, the loads on the load-bearing metal structures of the dump trucks increase, productivity and mechanical availability ratio decrease (Gorshkov et al., 2008).

The analysis of the current energy efficiency of transport systems at mining enterprises still states that the speed modes of movement of mining dump trucks and the rolling resistance to run of dump truck on mining haul roads, which depend on the condition of the road surface are the main parameters determining the energy features of transportation. Rolling resistance and speed are directly related to the spent power for transportation of the mining material and, accordingly, to the set power of the engine of

the dump truck, the value of which depends on the specific energy consumption (diesel fuel) in a set speed mode of movement of the auto dump truck.

In practice, it has been established that an increase in rolling resistance during the movement of the dump truck by 5 % reduces its productivity by 10%. Figure 1 (Juan et al., 2021).

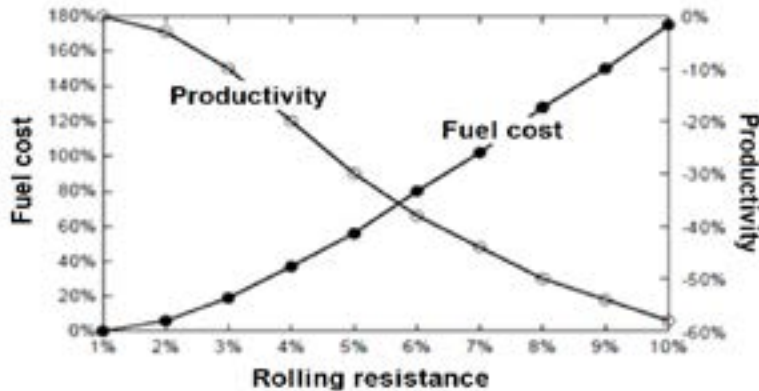


Fig. 1. Productivity of mining dump truck and fuel costs depending on rolling resistance.

Due to their high mobility and ability to overcome significant rises, mining dump trucks are widely used in open mining around the world. At the same time, there are problems with transportation costs and high fuel consumption. Driving style refers to the relatively stable and familiar internal trends formed by an operator in the process of driving, which in general can be divided into aggressive, normal and mild types.

Earlier studies showed that the difference in energy consumption between "mild" and radical drivers is about 30 % when using the same route and type of vehicle (Yarmuch et al., 2019; Dowd et al., 1992).

Understanding the energy efficiency of a dump truck is not limited to analyzing the parameters of a vehicle, so mining companies can benefit by expanding the analysis to include other factors affecting dump truck energy consumption, such as parameters of road conditions (Tannant Dwayne et al., 2001; Nuric et al., 2019).

There is several effective parameters of road conditions that affect the energy required by dump trucks, which must be considered simultaneously to optimize fuel consumption. Fuel consumption depends on many factors, including road slope, rolling resistance, payload (useful load), speed and features of dump truck engine (Burdett et al., 2015). It has been found that by reducing the resistance to movement of the dump truck encountered during the transport cycle, it is possible to increase the general fuel efficiency without affecting the cycle or performance parameters (Nuric et al., 2016; Goodyear, 2010)

It is advisable to produce the optimal profile of the in-pit mining roads using CAD Design program, as well as mathematical modeling, to achieve the optimal economic effect between such parameters as overburden ratio, dump truck maintenance costs and fuel consumption (Nuric et al. 2012).

At the conditions of mining enterprise in Antofagasta province (Chile), the design showed a 43 % reduction in cost as compared to the manual design of an experienced engineer (Ding-Bang et al., 2014; Nurić et al., 2019), using mathematical modelling of capital and in-pit mining roads, considering the volume of stripping roads.

Repairs and maintenance of in-pit mining haul roads require certain costs. The use of on-board digital monitoring and information processing systems installed on modern mining dump trucks, can lead to significant savings of operational costs and increased productivity of dump trucks, along with reduced emergency downtime is one of the possible types of quality assessment of in-pit mining haul roads.

Thus, for in-pit mining haul roads, it is important to improve the indicators of conditions of the road surface by use of modern on-board digital information processing systems installed on modern dump trucks.

Caterpillar mining dump trucks are equipped with one of the technologies for the analysis of dynamic loads on elements of a dump trucks, depending on the conditions of the road surface. Vital Information Management System (VIMS) is a system of processing basic digital information, it is a tool of machine management that allows operators and maintenance staff to receive information about whole number of basic functions of a machine.

The function of recording data of performance and energy efficiency is foreseen in VIMS system at dump trucks. Data are recorded from various sensors of the dump truck operation cycle, including load duration, travel time, unloading time, empty run time, and waiting time. All this information is used for reporting and scheduling. Such reports provide the basis for in-depth analysis and optimal solutions to improve efficiency and reduce the cost per ton of produced material.

The concept of improving the condition of in-pit mining haul roads confirms the fact that the technical condition of dump trucks is directly related both to the condition of the haul road and to the loading of machines. Improving both suggests:

- Reduction of production costs by increasing service life of components of dump trucks;
- Increasing productivity (based on increased average speed and reducing cycle time);
- Decrease of fuel consumption based on reduction of rolling resistance;
- Improving driver safety (by reducing efforts and fatigue).

Earlier studies note the importance of the correct construction of transport roads at the development of the deposit by open method and their impact on the total cost of mining. The profile of roads, access roads and the selection of material with certain characteristics and properties in layers of road construction were considered by (Soofastaei et al., 2016; Alexandrov et al., 2019; Soofastaei et al., 2017).

This article presents the results of an experiment conducted at the "Altyntau-Kokshetau" gold deposit mined in the Republic of Kazakhstan and analysis of data obtained from on-board systems of Caterpillar dump trucks. Data are presented about the impact of road conditions on the operation of dump trucks, fuel consumption, as well as changes of productivity.

Setting of researches tasks. It consists in identifying sections of mining roads that do not meet the regulatory requirements for their transport — operational condition by systematic monitoring using on-board VIMS systems.

Research Objectives:

1. Determine the degree of influence of the factors of the condition of mining haul roads on transport - operational indicators of the operation of dump trucks;
2. Establish actual values of mining haul road parameters as an object for monitoring of their condition;
3. Develop and verification of an intellectual method of monitoring mining roads, which ensures the consideration of the regularities of the influence of the factors of the condition of mining haul roads on the transport-operational.

Researches materials and methods

A questionnaire was created to assess the current procedures of designing and construction of mining haul roads used in Kazakhstan, which was sent to 8 deposits, dated May 2019. Answers from all deposits were received within 6 months. The questionnaire contained the following questions:

- List of equipment used – dump trucks, excavators, auxiliary equipment;
- Method of construction and maintenance of mining haul roads — geometry of haul roads, structure, materials used at building, reasons for road repairs;
- Equipment maintenance processes and procedures, intervals of mining equipment breakdowns, monitoring of breakdowns, basic reasons.

A study to identify the most important factors of unsatisfactory condition of mining roads was attended by 56 employees of various mining enterprises, of which 26 % worked in the field of mining road design; 44 %-in the field of technical maintenance of auto dump truck, 21 %-in the field of operation and repair of mining roads and 9 %-in the field of mining planning.

Based on the analysis of the results of the questionnaires processing, the main factors affecting the state of the road pavement of mining technological roads, were established, which are shown in Figure 2.

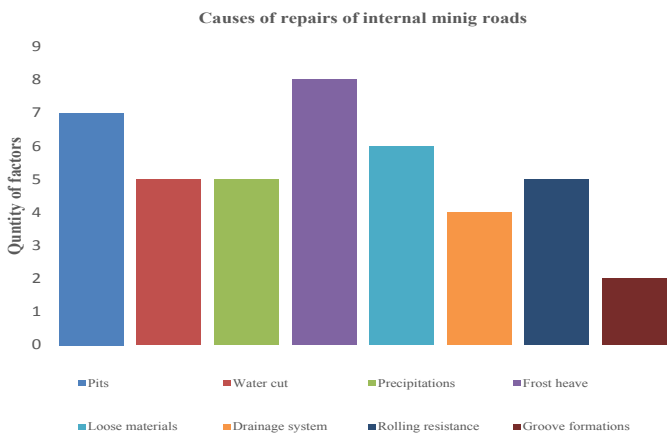


Fig. 2. Distribution of factors identified in the period of operation of mining haul roads.

As can be seen from the diagram (Figure 2) at most Kazakhstan deposits, the main problems were: frosty bulging, pits, watering and loose road surface.



Fig. 3. Open pit mining diagram and selected sections of road.

In view of the above mentioned an improved method of monitoring the condition of the mining road surface using on-board systems of control has been tested at the "Altyntau-Kokshetau" gold deposit in central Kazakhstan. The diagram of the deposit, as well as selected sections of roads indicated using modern GPS equipment is shown in Figure 3. At the time of experimental researches, work in the mining was carried out at a depth of 800 meters. The total length of the hauling ways of the route № 1 and № 2 was 2.3 and 2.1 km, respectively.

At the selected sections 1 and 2 (figure 3) measurements were made before the road was repaired using the VIMS program installed on the Caterpillar 785C dump truck. The loaded dump truck passed through these sections 12 cycles, after which readings were recorded from the on-board computer to a portable computer with the output of the resulted diagrams on the screen. Figure 4.

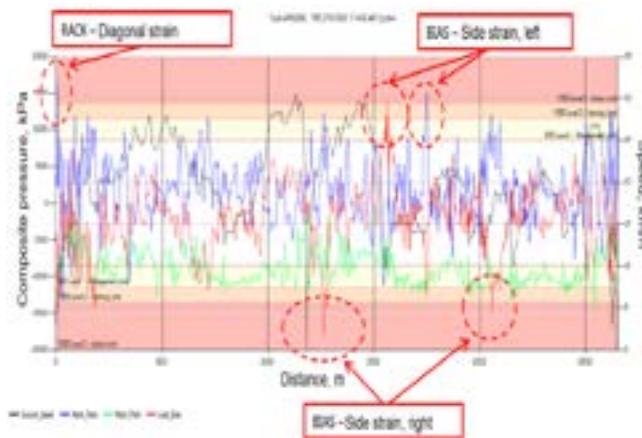


Fig. 4. Readings of VIMS before repair of haul road.

The results of experimental studies. The results obtained in the form of a diagram shown in Figure 4, which shows BIAS curves (red curve), how loading into a dump truck was carried out either at center or at sides. Also, the diagram shows the presence of dynamic loads during the passage of steep turns or turns at high speed with insufficient sharp turn.

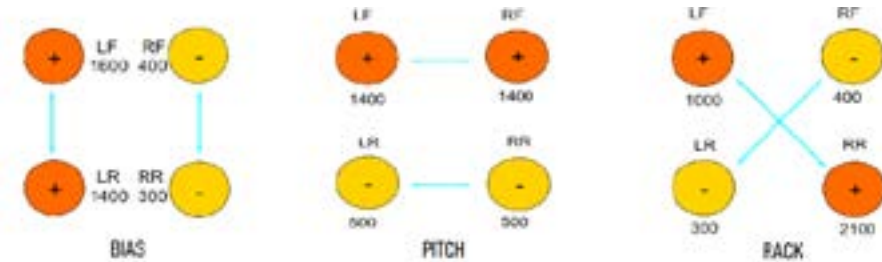
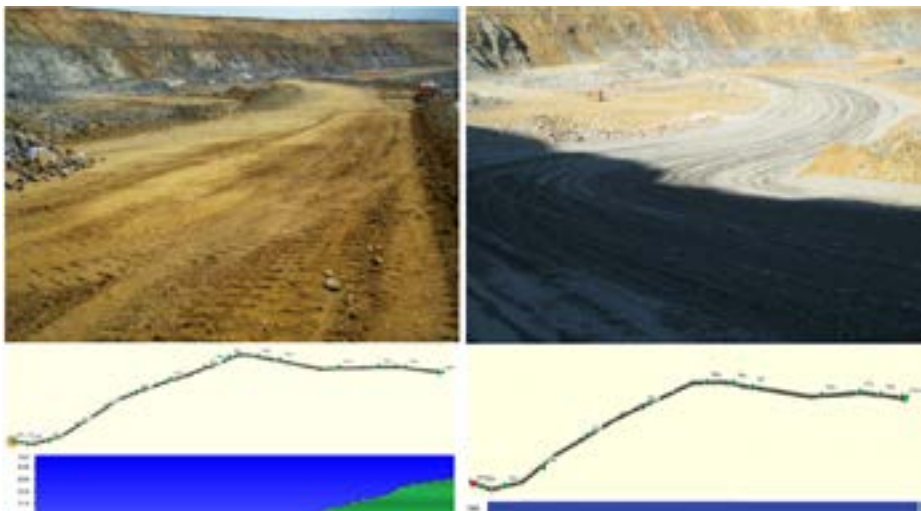


Fig.5. Decryption of symbols BIAS, PITCH, RACK - the main cumulative loads on dump truck suspensions, which are tested when moving in the loaded state with exceeding their permissible fatigue range along the main routes 1 and 2.

(BIAS) — Loads arising at side pressure on the suspensions, i.e. — at turns, at incorrect distribution of the load in the body. (PITCH) - Loads arising at side pressure on the suspensions, i.e., at unsmooth places on the road, at a wavy road or at a sharply changing slope. (RACK) — Loads arising at diagonal pressure on the suspension, the dump truck frame experiences torsion loads - due to uneven places on the road.

BIAS data in Figure 5 shows the difference between the pressure on suspension and the total pressure on each side of the dump truck $(LF + LR) - (RF + RR)$. PITCH values indicate the difference between the longitudinal pressure on the suspension of the front and rear parts of the dump truck $(LF + RF) - (LR + RR)$. The RACK data indicate the difference between the diagonal pressure on the suspension passing through the center of the dump truck $(LF + RR) - (RF + LR)$, which twists the frame and dump truck blocks during movement.

According to the obtained results, Figure 5 shows at which section of the road there are loads on the dump truck in the form of frame twisting, longitudinal or transverse distortions.



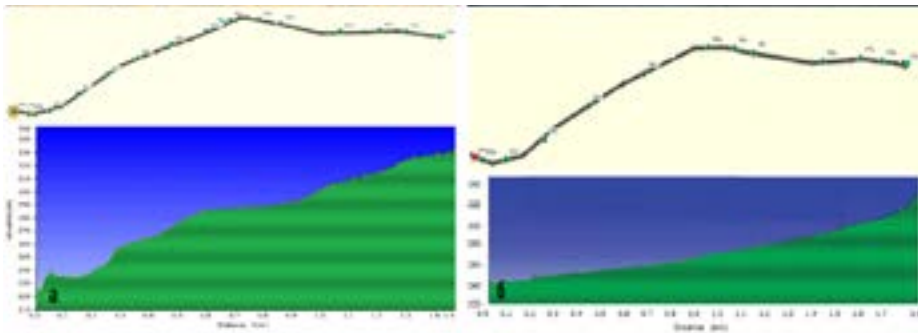


Fig. 6. Plan and profile of haul road.

A – plan and profile of the road before repair, b – plan and profile of the road after repair.

At the two sections of the road, where the measurements described above were carried out, the road pavement was repaired, the road was widened, all uneven places were smoothed, the radius of sharp turns was increased, the filling and the final compaction were made. The road pavement was leveled with crushed stone of fraction 30–40 mm with filling of fine fraction 0–25 mm. (Figure 6.)

To assess the impact of the resulted changes on the operation of dump trucks, it is necessary to repeat the measurements using the VIMS system in practice.

At the repaired sections 1 and 2 of the road data were again read after repairing the road using the VIMS program installed on the Caterpillar 785C dump truck. The loaded dump truck passed through these sections 10 cycles, after this, readings from the on-board computer were transmitted to the portable computer with the output of the received data on the display.

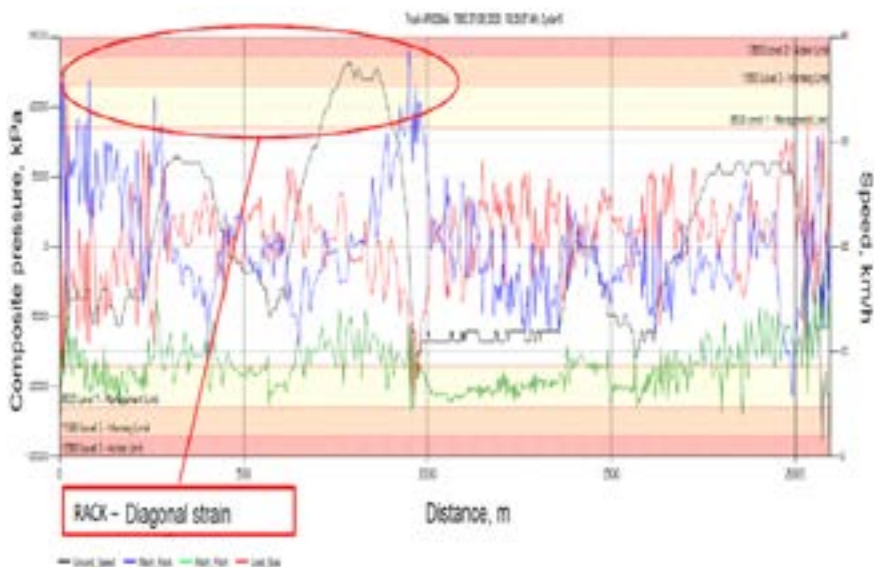


Fig. 7. Readings of VIMS after repair of road pavement.

After interpreting the experimental data, diagrams were obtained that showed a change in curves for the positive direction (Figure 7), so the diagram shows that the side and transverse loads of BIAS and PITCH disappeared, which indicates the presence of an even road without steep climbs and pits.

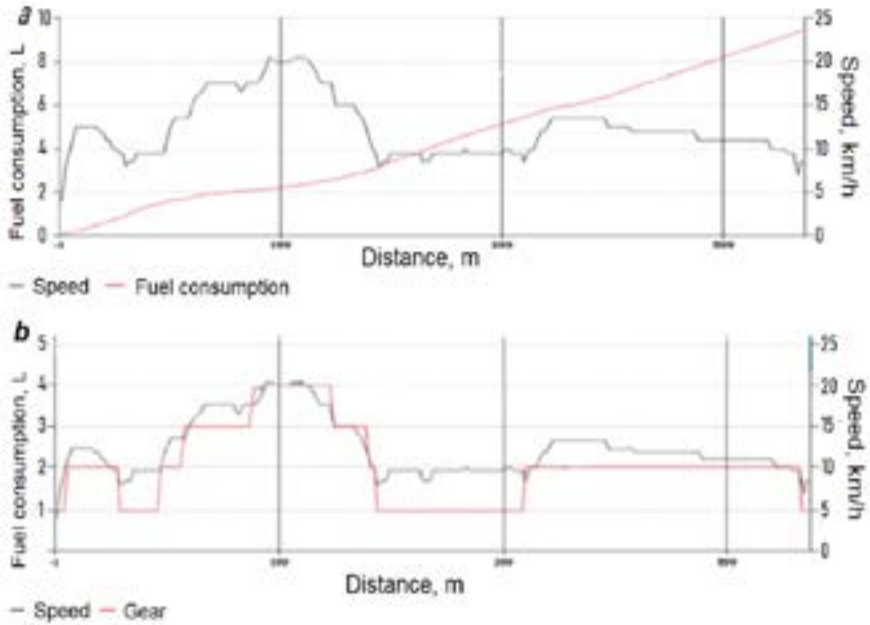


Fig. 8. VIMS readings before repair of haul road.

a - diagram of fuel consumption rate, b – diagram of transmission switch.

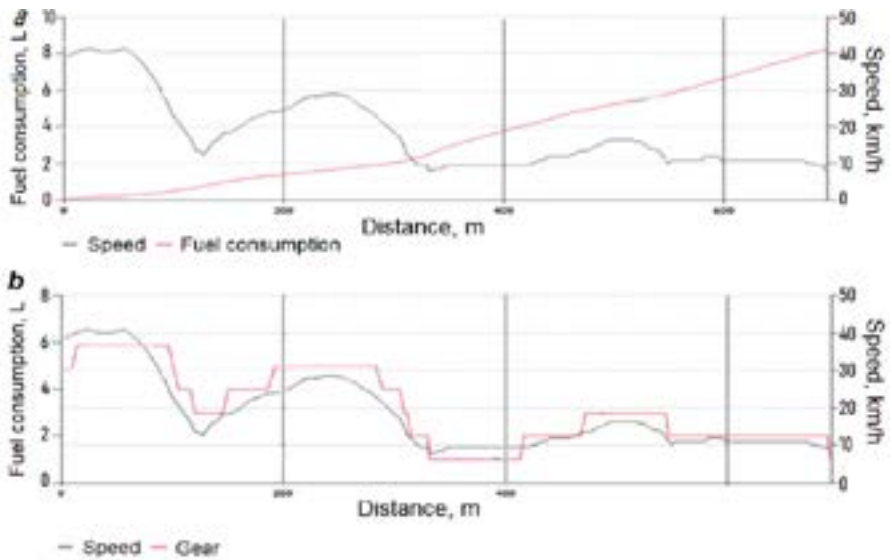


Fig.9. VIMS readings after repair of road pavement.

a - diagram of fuel consumption rate, b – diagram of transmission switch.

The Figures 8 and 9 shows interval in which transmission switched on before and after road repair. As it can be seen in the diagrams, after the repair of the road, the maximal speed of the dump truck increased from 22 km/h, Figure 8 (b), to 29 km/h Figure 9 (b). After repair gear shift changed for the better, movement of the first gear decreased, movement in the 5th gear appeared.

Figure 8 (a) shows the schedule of fuel consumption, where the average fuel consumption was 9.1 liters at the selected the area, and figure 9 (a) shows that the total fuel consumption was 8.2 liters at the same section after repair.

Discussion

A comparison of the results of the studies carried out using the VIMS system installed on dump trucks before and after repair of the mining road showed that a decrease in dynamic loads and energy consumption of the dump truck is achieved by the need to maintain the acceptable haul road conditions, which helps to reduce fuel consumption, move dump trucks with increased transmission, increase the number of cycles per shift with an increase in productivity.

The measurements established the possibility of achieving economic benefit, so that the cumulative fuel consumption after repairing the mining road decreased by 1 liter in the allocated section. On average, the Caterpillar 785C dump truck performed 1,340 cycles per month at the deposit. $1,340 \text{ cycles/month} \times 0.9 \text{ liter /cycle} = 1,206 \text{ liter/month}$ is monthly fuel saving per one dump truck. $1,206 \text{ liter /month} \times 12 \text{ months} = 14,472 \text{ liter / year}$ is annual fuel saving per on one dump truck after road repair. The annual fuel saving per dump truck park of 22 units was 318,384 liters.

Monitoring of haul road conditions will help to achieve improvement of indicators in increasing the service life of tires, reducing stress loads on the load-bearing structure of dump trucks, reducing costs on fuel - lubricants and repairing the haul road.

Conclusion

The studies made it possible to draw the following conclusions:

1. Based on the results of the review of scientific publications and the analysis of questionnaires, the need and possibility of developing an intellectual method of monitoring of the conditions of mining haul roads are identified. It will provide the reduction of labor costs for controlling the condition of mining haul roads by 8–10 times, increase in speed of transportation by 24 %, decrease in annual fuel consumption, respectively, of fuel by 14 tons and an increase in productivity by 60 tons per year per dump truck at specific conditions of operation;

2. It was established that a developed intellectual method of monitoring the condition of mining haul roads can be the opportunity for improving the energy efficiency of mining vehicles by identifying not only the current state, but also by the ability to predict the capability of mining roads with enough accuracy;

3. The method of intellectual monitoring of mining haul roads at conditions of real operation has been developed based on identification of regularities of influence of factors on transport – operational indicators of dump trucks performance;

4. Acceptable values of dynamic loads on the structural elements of dump trucks during regular work, recommended by the manufacturer, can be taken as a criterion of the effective operation of mining roads;

5. The coefficient of allowable transport - operational state of mining roads can be presented as a function of the current fuel consumption rate of the dump truck during the cycle;

6. To establish the optimal speed of movement of loaded and empty dump trucks at each section of the mining haul road, in future studies. It is necessary to evaluate the relationship of the life of mining roads with the frequency and amplitude of existing loads from dump trucks based on their registration and analysis.

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