ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ
Satbayev University

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ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
Satbayev University

SERIES
OF GEOLOGY AND TECHNICAL SCIENCES

6 (450)

NOVEMBER – DECEMBER 2021

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

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«ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).

Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ39VPY00025420** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Тақырыптық бағыты: геология, мұнай және газды өңдеудің химиялық технологиялары, мұнай химиясы, металдарды алу және олардың қосындыларының технологиясы.

Мерзімділігі: жылына 6 рет.

Тиражы: 300 дана.

Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19
http://www.geolog-technical.kz/index.php/en/

Типографияның мекен-жайы: «Аруна» ЖК, Алматы қ., Мұратбаев көш., 75.

«Известия НАН РК. Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ39VPY00025420,** выданное 29.07.2020 г.

Тематическая направленность: геология, химические технологии переработки нефти и газа, нефтехимия, технологии извлечения металлов и их соеденений.

Периодичность: 6 раз в год.

Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19

http://www.geolog-technical.kz/index.php/en/

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).

The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ39VPY00025420,** issued 29.07.2020.

Thematic scope: geology, chemical technologies for oil and gas processing, petrochemistry, technologies for extracting metals and their connections.

Periodicity: 6 times a year.

Circulation: 300 copies.

Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19

http://www.geolog-technical.kz/index.php/en/

Address of printing house: ST «Aruna», 75, Muratbayev str, Almaty.

NEWS
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 6, Number 450 (2021), 30-36 https://doi.org/10.32014/2021.2518-170X.116

UDC 629.3.03

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RESEARCH ON THE OPERATIONAL QUALITIES OF A MINING MACHINE FOR THE DEVELOPMENT OF MINERAL DEPOSITS

Abstract. Mining machines of different types and designs with different technical characteristics have been created for geological exploration. The fleet of mining and transport vehicles engaged in mining production is constantly growing. However, the quantitative growth of the park alone is not enough for a rapid increase in labor productivity. Qualitative changes are needed due to the creation and introduction of fundamentally new means of labor that surpass the best domestic and foreign models of equipment in their technical and economic indicators.

The modern development of mining machines is characterized by an increase in their power, traction qualities, cross-country ability, increased reliability and others. These trends in the development of machines can be solved by creating new models of machines or upgrading existing designs of individual components and aggregates of machines. The modernization of mining machines is due to an increase in the energy saturation of the power plant, which leads to an increase in the mass of the mining machines, without significant improvements in the design of the running system. This leads to a more intense impact of the movers of the machines on the ground, to the destruction of its structure.

Therefore, it is necessary to improve the performance of the running systems of the machines, which characterize the interaction of the propulsion with the support base. To do this, it is necessary to conduct a study of the influence of the design parameters of the machine on its operational qualities.

Experimental studies of the influence of the design parameters of a mining machine on its operational qualities require large expenditures of resources, time and money.

In order to reduce the material, time and resource costs of conducting experimental studies and obtaining data for mathematical modeling of the interaction of the propulsor with the ground, physical modeling methods are used.

Testing on models makes it possible, as well as on real machines, to identify the qualitative side of even such complex processes as the interaction of propellers with the support surface. A number of general patterns can be established on the model more strictly than on a real machine, since it is easier to exclude the influence of random factors here.

The results of the conducted research make it possible to reduce the cost of time and material resources in the creation and operation of running systems of mining machines.

Key words: mining machines, mineral deposits, undercarriage system, physical modeling, ground, operational properties, model of a undercarriage of a vehicle, traction and drag properties.

Introduction. Mining machines of various types and designs with different technical characteristics have been created for operation in various conditions. The type and purpose of the machine determine the design of its undercarriage system. Tractive and transportation vehicles are widely used in agriculture, in the construction of highways and railways, in the laying of gas and oil pipelines, in the mining industry and in the exploration of minerals [1, 2, 3].

As part of the research work, a team of authors has developed designs for the undercarriage systems of tractive and transportation vehicles, the peculiarity of which is that they are equipped with rubber-reinforced tracks [4].

In the paper [5], a mathematical model of the interaction of a rubber track with a support base was developed. To obtain confirmation of the results of theoretical studies, experimental studies were carried out.

Materials and research methods. Experimental studies of the influence of the design parameters of a mining machine on its performance require a lot of resources, time and money [6, 7]. Therefore, in order to reduce material, time and resource costs for conducting experimental research and obtaining data for mathematical modeling of the interaction of a tracked propulsive device with the ground, it is proposed to use physical modeling methods [8, 9]. In physical modeling, the soil remains natural, while the machine is vehicle with a model that simulates the effect of a full-scale vehicle on the soil. In this case, a change in scale occurs, however the nature of the phenomenon remains unchanged. Qualitative and quantitative connections of such phenomena are established in the form of criterial relationships.

To carry out experimental studies, the method of speed-up and coasting of the undercarriage system model on a horizontal surface was used, which provides comparative data for hard and soft soils [10]. This method provides the accuracy of measurements and the ability to compare different versions of the models in the same parameters of mass and base.

To carry out experiments at the Department of Transport Equipment and Logistics of Toraighyrov University NJSC, a stand was designed and made for studying various types of undercarriage systems on a universal non-self-propelled model of the undercarriage system of a tractive and transportation vehicle.

The essence of the method lies in conveying a precisely defined amount of energy to the model, that ensures the acceleration of the model to speed *v*. Then this speed gets put out due to losses in the propulsion device during coasting (run-out).

In practice, the creation of a certain amount of energy can be carried out using the potential energy of the lifted load. The scheme of the experiment is shown in Figure 1.

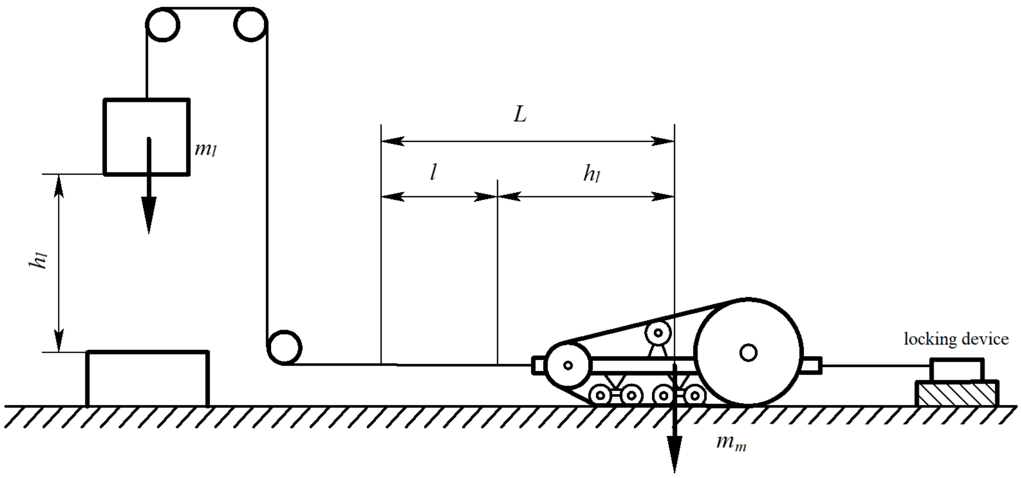

Figure 1 – The scheme of the experiment by the speed-up and coasting method.

Load of the mass m_1 is raised to the height $h_1$and gets connected by a cable through a system of blocks with the model that is held in its original position by a locking device. When the model is unlocked under the action of the load m_1 it is accelerated in a section corresponding to the drop height h_1 of the load followed by a run-out to the length *l*.

Potential energy $m_1 \cdot h_1$ of the load m_1 gets spent on:

a) overcoming the forces of resistance to movement on the section h_1;

b) acceleration of the model to speed *v*;

c) acceleration of the load to speed *v*;

d) losses in the blocks.

$$m_1 \cdot h_1 \cdot \eta_b = F_f \cdot h_1 + E_m + E_l, \quad (1)$$

where η_b is the block system efficiency, η_b=0.98;

F_f is the rolling resistance force;

E_m is the kinetic energy of the model;

E_l is the kinetic energy of the load.

As the load stops, its energy is spent on impact, and the model moves further due to the kinetic energy it has acquired.

Taking into account that at equal speeds the energy is proportional to the masses, we get

$$\frac{E_m}{E_l} = \frac{m_m}{m_l}, \quad (2)$$

where m_m is the mass of the model.

At the moment the load touches m_l the base surface, the kinetic energy of the load – model system, on the one hand, is equal to the sum of the kinetic energy of the model and the load, and on the other hand, the difference between the potential energy of the load and the work spent on overcoming the rolling resistance of the model in the section h_l

$$E = E_m + E_l; \quad (3)$$

$$E = m_l \cdot h_l \cdot \eta_b - F_f \cdot h_l \cdot \quad (4)$$

From equations (2) and (3) we infer

$$E_m = E \cdot \frac{m_m}{m_l + m_m} \cdot \quad (5)$$

By putting E from equation (4) in equation (5) we obtain

$$E_m = (m_l \cdot h_l \cdot \eta_b - F_f \cdot h_l) \cdot \frac{m_m}{m_l + m_m} \cdot \quad (6)$$

The kinetic energy of the model is spent on overcoming the rolling resistance forces of the model F_f in the run-out section l

$$E_m = F_f \cdot l \cdot \quad (7)$$

By putting E_m from equation (7) in equation (6) we obtain

$$F_f \cdot l = (m_l \cdot h_l \cdot \eta_b - F_f \cdot h_l) \cdot \frac{m_m}{m_l + m_m} \cdot$$

Therefore

$$F_f = \frac{m_l \cdot h_l \cdot \eta_b}{h_l + \frac{m_l + m_m}{m_m} \cdot l} \cdot \quad (8)$$

In this formula, the value $m_l \cdot \eta_b$ corresponds to the pulling force F_p. Replacing the ratio $\frac{m_l + m_m}{m_m}$ with k, where k is the run-out coefficient, we obtain the formula which is convenient for experimental calculations

$$F_f = \frac{m_l \cdot h_l \cdot \eta_b}{h_l + k \cdot l} \cdot \quad (9)$$

The value F_f represents the average rolling resistance of the model.

The speed at the end of the acceleration can be determined from the equality of the energy acquired by the model during the acceleration period and its consumption for run-out

$$F_f \cdot l = \frac{m_l \cdot v^2}{2g},$$

therefore

$$v = \sqrt{\frac{2g \cdot F_f \cdot l}{m_l}} \cdot \quad (10)$$

Calculation formula (10) is valid at constant force F_f. With variable force, the results obtained are sufficient for comparative experiments.

The purity of the experiments is achieved by conducting experiments on soil with uniform physical and mechanical properties in its depth.

Results and discussion. The study was carried out on a universal non-self-propelled model of the undercarriage system of a tracked vehicle with an elastic balanced suspension. The longitudinal base of the model is 380 mm. The experiments were carried out on sand, wet loam and flat concrete.

The main characteristics of soils:

a) sand – volume weight 16 kN/m^3, humidity 5%, density 1.6 g/m^3, structural composition: 2.0 mm sized particles 4%; 1.0 mm sized particles 6%; 0.5 mm sized particles 17%; 0.25 mm sized particles 73%.

b) loam – volume weight 20 kN/m^3, humidity 15%, density 1.5 g/m^3. Loam is clay with a significant admixture of sand and dust particles. Structural composition: clay 15%, sand 35%, dust particles 50%.

c) concrete track – straight platform without any slope. During the experiments, cement concrete with a density of 2.0 g/m^3 was used.

In order to determine the effect of the mass of the vehicle on its traction and drag properties, models with weights of 48 kg, 64 kg and 80 kg were made, which, in terms of a natural vehicles corresponds to weights of 30 kN, 40 kN and 50 kN. In addition, each model was loaded with ballast weights, thereby providing intermediate values of the model mass.

The change in the mass of the model was carried out with constant parameters of the undercarriage system, therefore, it was accompanied by a corresponding change in the specific pressure.

Experimental data on the effect of the mass of the vehicle on its traction and drag properties have shown that, with constant parameters of the undercarriage system, each type of soil has its own certain value of the optimal mass.

The analysis of the research results shown in Figure 2 demonstrated that on a concrete slab the rolling resistance coefficient is almost constant and slightly increases only with a minimum weight of the vehicle. This is due to an increase in losses in the tracked propulsive device, which depend little on the mass.

On sand, rolling resistance decreases as the mass of the tractive and transportation vehicle increases. This is due to the fact that the bulk of the resistance is made up of forces that are little dependent on mass. On sand, these are the friction forces in the details of the tracked propulsive device.

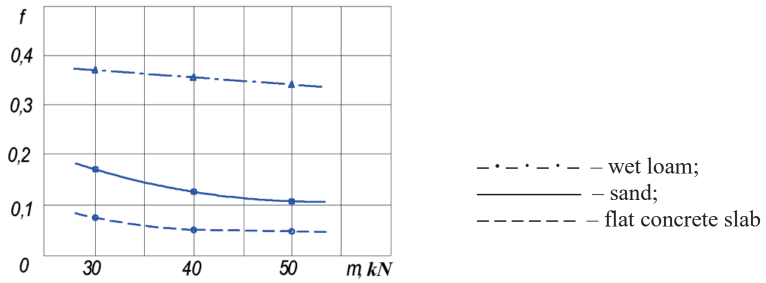

Figure 2 – The dependence of the rolling resistance on the mass of the vehicle.

On wet loam, the rolling resistance coefficient decreases smoothly, in proportion to the increase in the weight of the vehicle. This is due to the fact that the loss due to pressing of the support base depends little on the mass.

Also, studies were carried out on the effect of the mass of the vehicle on the rolling resistance at various values of the speed of movement, which showed that with an increase in the speed of movement, the nature of the dependence of the coefficient of rolling resistance on the weight of the machine practically does not change.

On cohesive soil, wet loam in particular, the adhesion coefficient increases with a decrease in mass according to a law close to hyperbolic, which corresponds to the presence of a component of the adhesion force that does not depend on the mass

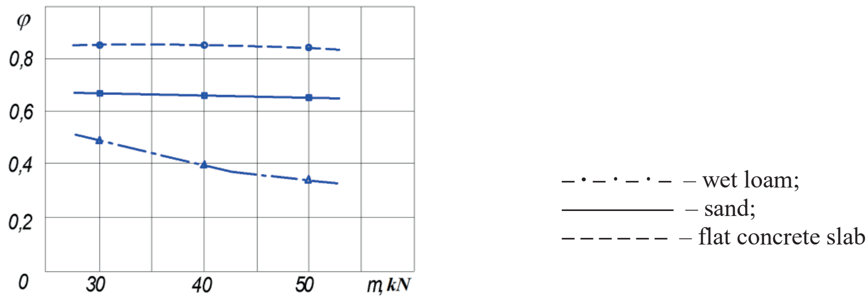

Figure 3 – The dependence of the coefficient of adhesion on the mass of the vehicle.

Studies have been carried out on the effect of the mass of the vehicle on the coefficient of adhesion at different values of the coefficient of slipping, which showed that with an increase in the mass of the vehicle, the value of the coefficient of adhesion decreases. At the same time, the mass of the tractive and transportation vehicle does not affect the slipping.

From the graph shown in Figure 4, it can be seen that on sand, the efficiency of the undercarriage system decreases with an increase in the mass of the vehicle, which is explained by an increase in power losses for soil deformation due to an increase in pressure on it.

On a flat concrete surface, the efficiency of the undercarriage increases with increasing mass of the vehicle. This is due to the fact that soil deformation losses are small.

On wet loam, the highest efficiency of the undercarriage occurs with a machine weight of 40 kN. A decrease in mass leads to a decrease in efficiency due to an increase in the rolling resistance coefficient, and an increase in mass reduces efficiency due to an increase in rolling resistance and slipping due to soil deformation.

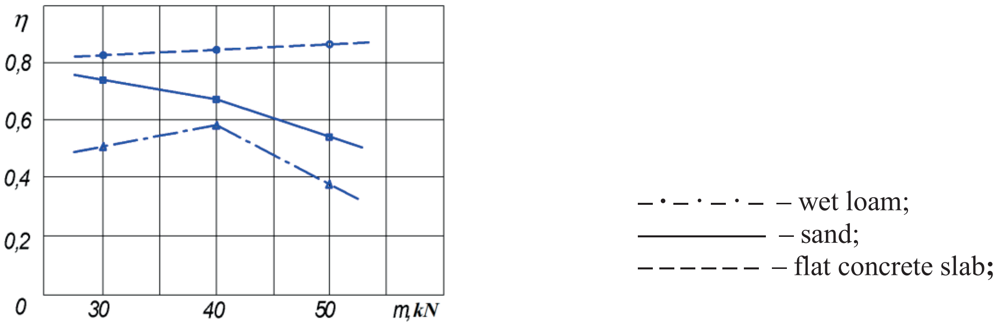

Figure 4 – Dependence of the efficiency of the undercarriage system on the mass of the vehicle.

Conclusions. The considered experimental results showed that each type of soil corresponds to its own value of the optimal weight of the machine. In this regard, it is rational to set the mass of the tractive and transportation vehicle according to those soil conditions that require its minimum value, and to load the vehicle with additional ballast weight on other soils.

Financing. The research was carried out within the framework of grant funding for fundamental and applied scientific research on scientific and technical projects for 2021-2023 under the IRN AP09258862 project "Development and research of a multipurpose vehicle", funded by the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan.

Acknowledgments. *The authors are grateful to M. Kairova, G. Itybayeva, A. Baltabekova and V. Yessaulkov [11, 12] for preparing and collecting materials for this publication.*

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ПАЙДАЛЫ ҚАЗБАЛАР КЕН ОРЫНДАРЫН ИГЕРУГЕ АРНАЛҒАН ТАУ-КЕН МАШИНАСЫНЫҢ ПАЙДАЛАНУЛУ ҚАСИЕТТЕРІН ЗЕРТТЕУ

Аннотация. Геологиялық барлау жұмыстарын жүргізу үшін әртүрлі техникалық сипаттамалары бар әртүрлі типтегі және құрылымдағы тау-кен машиналары жасалды. Тау-кен өндірісі саласында жұмыс істейтін тау-кен және көлік машиналары паркі үнемі өсіп келеді. Алайда, еңбек өнімділігін тез арттыру үшін парктың сандық өсуі жеткіліксіз. Өздерінің техникалық-экономикалық көрсеткіштері бойынша техниканың үздік отандық және шетелдік үлгілерінен асып түсетін мүлде жаңа еңбек құралдарын жасау және енгізу есебінен сапалы өзгерістер қажет.

Тау-кен машиналарының қазіргі заманғы дамуы олардың қуаттылығының, тарту-ұстасу қасиеттерінің, өткіштігінің, сенімділігінің артуымен және басқаларымен сипатталады. Машиналардың дамуының көрсетілген тенденцияларын машиналардың жаңа үлгілерін жасау немесе машиналардың жеке түйіндері мен агрегаттарының қолданыстағы құрылыстарын жаңарту арқылы шешуге болады. Шынжыр табанды машиналарды жаңғырту қуат қондырғысының энергиямен қанықтылығын арттыру арқылы жүзеге асырылады. Жүріс бөлігінің құрылысын айтарлықтай жетілдірусіз тау-кен машинасының массасының ұлғаюына әкеледі. Бұл машина қозғалтқыштарының топырыққа қарқынды әсер етуіне, оның құрылымының бұзылуына әкеледі.

Сондықтан қозғалтқыштың тірек бетімен өзара әрекеттесуін сипаттайтын машиналардың жүріс жүйелерінің көрсеткіштерін жақсарту қажет. Ол үшін машинаның құрылымдық параметрлерінің оның пайдалану сапасына әсерін зерттеу қажет. Тарту-көлік машинасының құрылымдық параметрлерінің оның пайдалану сапасына әсерін эксперименттік зерттеу ресурстардың, уақыт пен қаражаттың үлкен шығындарын талап етеді.

Эксперименттік зерттеулер жүргізуге және деректер алуға арналған материалдық, уақыттық және ресурстық шығындарды азайту мақсатында қозғалтқыштың топырақпен өзара әрекетін математикалық модельдеу үшін физикалық модельдеу әдістері қолданылады.

Модельдердегі сынауды жүргізу нақты машиналардағы сияқты, қозғалтқыштардың тірек бетімен әрекеттесуі сияқты күрделі процестердің сапалы жағын анықтауға мүмкіндік береді. Модельде бірқатар жалпы заңдылықтарды нақты машинаға қарағанда қатаң түрде орнатуға болады, өйткені кездейсоқ факторлардың әсерін жою оңайырақ.

Жүргізілген зерттеулердің нәтижелері тау-кен машиналарының жүріс жүйелерін жасау және пайдалану кезінде уақыт пен материалдық құралдар шығындарын қысқартуға мүмкіндік береді.

Түйінді сөздер: тау-кен машиналар, пайдалы қазбалар кен орындары, жүріс жүйесі, физикалық модельдеу, грунт, пайдалану қасиеттері, машина жүріс бөлігінің моделі, тарту-ұстасу қасиеттері.

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ИССЛЕДОВАНИЕ ЭКСПЛУАТАЦИОННЫХ КАЧЕСТВ ГОРНОЙ МАШИНЫ ДЛЯ РАЗРАБОТКИ МЕСТОРОЖДЕНИЙ ПОЛЕЗНЫХ ИСКОПАЕМЫХ

Аннотация. Для проведения геологоразведочных работ созданы горные машины разных типов и конструкций с различными техническими характеристиками. Парк горных и транспортных машин, занятых в сфере горного производства, постоянно растет. Однако только количественного роста парка недостаточно для быстрого повышения производительности труда. Необходимы качественные изменения за счет создания и внедрения принципиально новых средств труда, превосходящих по своим технико-экономическим показателям лучшие отечественные и зарубежные образцы техники.

Современное развитие горных машин характеризуется повышением их мощности, тягово-сцепных качеств, проходимости, повышением надежности и другими. Указанные тенденции развития машин могут быть решены путем создания новых образцов машин или модернизации существующих конструкций отдельных узлов и агрегатов машин. Модернизация гусеничных машин идет за счет увеличения энергонасыщенности силовой установки, что приводит к увеличению массы горной машины, без существенных усовершенствований конструкции ходовой системы. Это приводит к более интенсивному воздействию движителей машин на грунт, к разрушению ее структуры.

Поэтому требуется улучшить показатели работы ходовых систем машин, которые характеризуют взаимодействие движителя с опорным основанием. Для этого необходимо провести исследование влияния конструктивных параметров машины на его эксплуатационные качества.

Экспериментальные исследования влияния конструктивных параметров горной машины на ее эксплуатационные качества требуют больших затрат ресурсов, времени и средств.

С целью снижения материальных, временных и ресурсных затрат на проведение экспериментальных исследований и получения данных для математического моделирования взаимодействия движителя с грунтом используются методы физического моделирования.

Испытание на моделях позволяют так же, как и на реальных машинах, выявить качественную сторону даже столь сложных процессов, как взаимодействие движителей с опорной поверхностью. Ряд общих закономерностей может быть установлен на модели более строго, чем на реальной машине, поскольку здесь проще исключить влияние случайных факторов.

Результаты проведенных исследований позволяют сократить затраты времени и материальных средств при создании и эксплуатации ходовых систем горных машин.

Ключевые слова: горные машины, месторождения полезных ископаемых, ходовая система, физическое моделирование, грунт, эксплуатационные свойства, модель ходовой части машины, тягово-сцепные качества.

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ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Редакторы: *М.С. Ахметова, А. Ботанқызы, Д.С. Аленов, Р.Ж. Мрзабаева*
Верстка на компьютере *Г.Д.Жадыранова*

Подписано в печать 15.12.2021.
Формат 60х881/8. Бумага офсетная. Печать – ризограф.
4,6 п.л. Тираж 300. Заказ 6.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-19