ГЕОТЕХНОЛОГИЯ. ГОРНЫЕ МАШИНЫ

DOI: 10.21440/0536-1028-2024-4-8-16

Applying periodic hopper-reloaders when driving traffic tunnels by the heading method

Aleksei S. Nosenko[1], **Aleksei A. Domnitskii**[1], **Viktoriia V. Nosenko**[1], **Mariia S. Altunina**[1]*, **Viktor V. Zubov**[1]
[1] Shakhty Automobile and Road Construction Institute (branch) of Platov South-Russian State Polytechnic University (NPI), Shakhty, Russia
e-mail: mariyaltunina@mail.ru

Abstract

Research relevance. *Heading technology with automobile long haul transport has become widespread in traffic tunnels construction. An analysis of scientific and technical information sources that consider work in a tunnel face revealed a number of problems and limitations that decrease productivity.*
Research objective *is to develop methods and ways of coordinating the operation of drifting equipment to reduce the drifting cycle time and increase the pace of construction.*
Methods of research. *It is proposed to include periodic hopper-reloaders with high unloading capacity in the "heading machine-dump truck" process flow in order to ensure continuous operation of a heading machine and a dump truck and thereby improve production efficiency.*
Results. *To quantify the effectiveness of a hopper-reloader, the coefficient of a cycle time (duration) reduction was introduced. A mathematical model has been developed to determine the drifting cycle duration under different conditions of driving a mine working.*
Calculation ***results analysis*** *showed that by reducing the time of the hopper-reloader unloading in half compared to the time of loading, it is possible to reduce the drifting cycle duration by 25%. A qualitative assessment of the developed model for the drifting cycle time formation shows that the main factor leading to time reduction is the improved capacity of hopper-reloaders during unloading.*
Conclusions. *As a result of the research, ways have been outlined to improve the efficiency of mine development using the heading method of driving a working for a traffic tunnel by reducing the duration of the drifting cycle. It is proposed to use a periodic hopper-reloader to coordinate the operation of a heading machine and a dump truck with a capacity significantly higher than that of the heading machine.*

Keywords: *heading method; traffic tunnels; heading machine; hopper-reloader; drifting cycle.*

Introduction. Heading technology with automobile long haul transport has become widespread in traffic tunnels construction [1–11].

The country has experience in driving mine workings for transport tunnels using KP-21, KP-25, KP-200T heading machines by JSC Kopeysk Machine-Building Plant [12]. Broken rock, in this case, was hauled away by MoAZ or KamAZ series dump trucks.

An analysis of scientific and technical information sources that consider work in a tunnel face revealed a number of problems and limitations that decrease productivity. First of all, these include forced downtime of equipment due to uncoordinated operation. The studies and results presented are aimed at eliminating them.

Research objective is to develop methods and ways of coordinating the operation of drifting equipment to reduce the drifting cycle time and increase the pace of construction.

Methods of research. It has been established that transport handling operations in the case under study are cyclical, that is, the cargo moves periodically along the excavation, but not in a continuous flow. Firstly, from the face to the vehicle through the heading machine, after that it is hauled by a dump truck along the mine workings to the dumping site. Thereby, the heading machine is in a state of forced downtime waiting for the haulage vehicle to be loaded. The obvious solution to this problem is to use several dump trucks. However, this is not always technically possible and economically profitable.

One way of solving the problem in question is to use the PNB mining machines (side-grip continuous loaders), scraper reloaders, and hopper-reloaders, which coordinate the operation of a heading machine and a haulage vehicle, as part of drifting equipment. In particular, BP-15, BPS-22, PP-15, etc. hopper-reloaders are used.

The use of the above-mentioned intermediate transport facilities has a number of disadvantages. They provide for simultaneous work with a heading machine and a dump truck being loaded, which means that while waiting for a long-haul transport their work is greatly impeded. Moreover, the time it takes to load a dump truck with a reloader is comparable to the time it takes to load it directly from a heading machine, which means that the production rate remains practically the same.

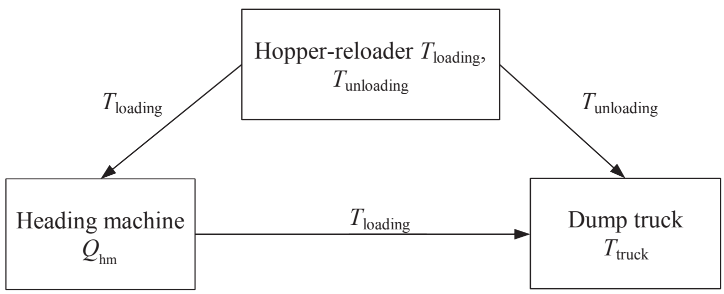

Figure 1. A block diagram of the studied sets of heading equipment
Рисунок 1. Структурная схема исследуемых комплектов горнопроходческого оборудования

From the point of view of environmental safety, the fact that traffic tunnels are usually built within residential areas and public roads imposes certain limitations on the technologies used. This applies to equipment that hauls broken rock outside residential areas over significant distances along public roads. The restriction refers primarily to using specialized LHD (load, haul, dump) machines adapted to work with heading machines in terms of design, as long-haul transport. This also confirms the relevance of developing and justifying the technology of loading standard vehicles, which are allowed access to public roads, directly in the face.

It is proposed to include periodic hopper-reloaders in the "heading machine – dump truck" process flow and therefore ensure continuous operation of the heading machine and improve production efficiency. Periodic hopper-reloaders possess high unloading capacity; during the dump truck operation, they will accumulate rock mass coming from the heading machine and reload it into the dump truck.

Let us consider a mathematical model of how a set of drifting equipment under study operates. Its block diagram is presented in Figure 1 (Q_{hm} is the technical capacity of the heading machine, m^3/min; T_{loading} is the loading time of the hopper-reloader, min; $T_{\text{unloading}}$ is the time of unloading the hopper-reloader into the dump truck, min; T_{truck} is the time of the dump truck haul cycle to the dumping area and back, min).

The main characteristic of a heading cycle is its duration. When developing the hopper-reloader design, we will assume that the dump truck is loaded at one stop, i.e. the volume of the hopper-reloader $V_{\text{hopper-reloader}}$, m^3, is greater than or equal to the volume of the dump truck body V_{truck}:

$$V_{\text{hopper-reloader}} \geq V_{\text{truck}}.$$

The moment the dump truck arrives for loading is taken as the beginning of the cycle. Then, without a hopper-reloader in the process flow scheme, the cycle duration is determined by the following expression:

$$T' = T_{\text{loading}} + T_{\text{truck}}.$$

With is a hopper-reloader, the cycle duration is determined depending on the $T_{\text{truck}} / T_{\text{loading}}$ ratio:

– if $T_{\text{truck}} / T_{\text{loading}} \geq 1$, then

$$T = T_{\text{unloading}} + T_{\text{truck}};$$

– if $T_{\text{truck}} / T_{\text{loading}} < 1$, then

$$T = T_{\text{unloading}} + \left(T_{\text{loading}} - T_{\text{truck}}\right) + T_{\text{truck}} = T_{\text{unloading}} + T_{\text{loading}}.$$

It can be said that the use of an intermediate hopper-reloader is most effective when T_{truck} and T_{loading} values are equal, since this means that a heading machine and a dump truck endure downtime only during the hopper-reloader unloading. A downward change in the $T_{\text{truck}} / T_{\text{loading}}$ ratio will lead to increased drifting cycle time due to longer forced

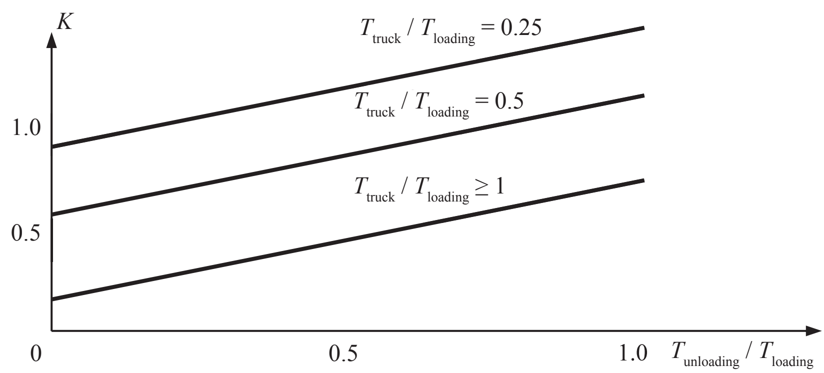

Figure 2. A dependency graph of the cycle time reduction factor

Рисунок 2. Графическая интерпретация зависимости коэффициента снижения времени цикла

downtime of the dump truck. An upward change in the $T_{\text{truck}} / T_{\text{loading}}$ ratio indicates that the cycle duration is maintained, however, the forced downtime of the heading machine will increase.

To quantitatively assess the effectiveness of a hopper-reloader, let us introduce the concept of the cycle time (duration) reduction factor K:

$$K = \frac{T}{T'} = \frac{\left(T_{\text{unloading}} + T_{\text{truck}}\right)}{\left(T_{\text{loading}} + T_{\text{truck}}\right)}.$$

If the hopper-reloader loading time $T_{loading}$ and the dump truck haul cycle T_{truck} are equal, and the $T_{truck} / T_{loading} \geq 1$ inequality is satisfied, then:

$$K = \frac{1}{2}\left(\frac{T_{unloading}}{T_{loading}} + 1\right).$$

It can be seen that the hopper-reloader unloading time reduction compared to the loading time by half, makes it possible to reduce the drifting cycle duration by 25%.

Under $T_{truck} / T_{loading} < 1$ the K factor formula takes the form:

$$K = 1 + \frac{T_{unloading}}{T_{loading}} \Bigg/ 1 + \frac{T_{truck}}{T_{loading}}.$$

Research results. A dependency graph of the cycle time reduction factor is presented in Figure 2. It should be noted that the minimum value of the K factor tends to 0.5 indicating that the maximum possible reduction in the drifting cycle time due to the hopper-reloader presence in the process flow does not exceed 50%.

A linear graph of work organization by the studied heading method when driving a working for a traffic tunnel is presented in Figure 3.

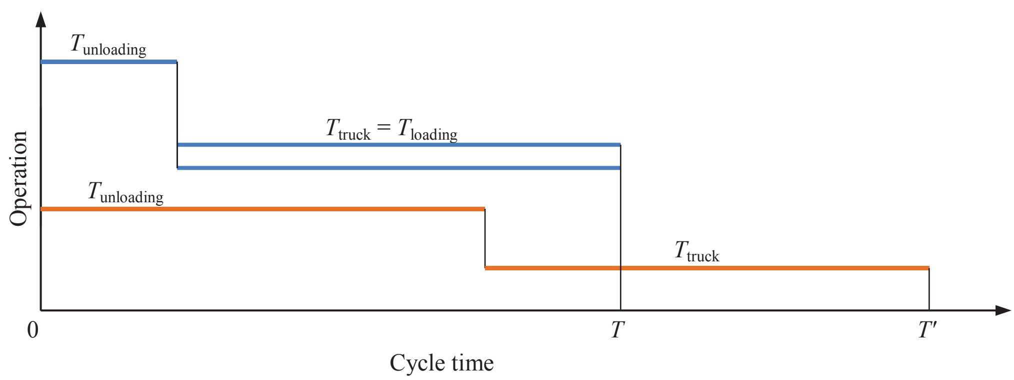

Figure 3. A linear graph of work organization by the heading method
Рисунок 3. Линейный график организации работ с применением комбайновой технологии

A qualitative assessment of the developed model for the drifting cycle time formation shows that the main factor leading to time reduction is the hopper-reloader capacity improvement during unloading.

Analysis and discussion. Belt, scraper, and apron feeders, hopper-loaders and reloaders with wedge transport elements or with changing geometry of the transport element, driven by power hydraulic cylinders, can act as devices coordinating the operation of a heading machine and a vehicle [13].

However, they cannot effectively reduce the duration of the drifting cycle, comparable with due to slow unloading relative to the heading machine capacity.

Studies have shown that it is important to implement technical solutions for hopper-reloaders with high unloading capacity. For this purpose, schematic structural diagrams of heading hopper-loaders with the required properties were developed at the Shakhty Automobile and Road Construction Institute (branch) of Platov South-Russian State Polytechnic University (NPI); the designs are protected by invention patents of Russian Federation [14].

Any design option incorporates the principles of unloading bulk material due to the translational motion of a pushing plate or a moving bottom together with the horizontal unloading. The mentioned elements are driven by translational power hydraulic cylinders.

Figure 4 shows a schematic diagram and a prototype of a hopper-reloader with the majority of the mentioned unique features implemented. The hopper-reloader consists of a hopper, a draw-out pushing plate, sections in motion with respect to each other, and power hydraulic cylinders. After the dump truck has arrived, the material is unloaded by simultaneously drawing out the pushing plate and shifting the moving section, which ensures a twofold increase in the hopper-reloader capacity. The main distinctive property of the proposed designs, which is achieving high capacity values, is ensured by the simultaneous flow of material across the entire cross-section of the hopper and the simultaneous process steps of unloading it.

a *b*

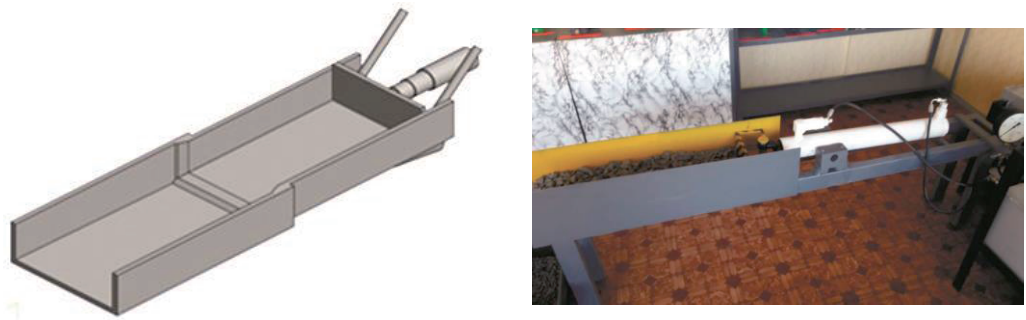

Figure 4. A hopper-reloader with a pusher plate and a sectional moving bottom: *a* – schematic diagram; *b* – prototype

Рисунок 4. Бункер-перегружатель с толкателем и секционным подвижным днищем: *a* – принципиальная схема; *b* – экспериментальный образец

Mathematical modeling of hopper-reloader operation and its parameters justification [15] made it possible to find relationship between the height of the pushing plate, the granulometric composition of the loaded material and the permissible length of the reloader:

$$L \leq \left(1 + \left(d_{\text{av}} / H_{\text{layer}}\right)^2\right) H_{\text{layer}} / \mu_{\text{friction}},$$

where L is the permissible length of the reloader, m; d_{av} is the average diameter of the loaded piece, m; H_{layer} is the height of a layer of the material moved (assumed equal to the height of the pushing element), m; μ_{friction} is the coefficient of material friction along the hopper.

The width of the hopper-reloader B_{hm} is linked to the parameters of the heading machine and dump truck. The speed of linear movement of the power elements of the drive V_{hm}, according to recommendations [15], does not exceed 0.1 m/s. The estimated capacity of a 2 m wide hopper-reloader with a 1 m high pusher plate during unloading will be 10–12 m^3/min.

For comparison, the capacity of the KP-21 heading machine, depending on the strength of the host rocks, is 0.3–2.0 m^3/min. So, under $T_{\text{truck}} / T_{\text{loading}} \geq 1$, the hopper-reloader will reduce the duration of the drifting cycle by 40%.

Conclusions. As a result of the research, ways have been outlined to improve the efficiency of mine development using the heading method of driving a mine working for a traffic tunnel by reducing the duration of the drifting cycle. It is proposed to use a periodic hopper-reloader to coordinate the operation of a heading machine and a dump truck with a capacity significantly higher than that of the heading machine.

REFERENCES

1. Zhabin A. B., Poliakov A. V., Averin E. A. A brief analysis of problems and solutions when ensuring the mining enterprise with modern equipment. *Ugol = Coal*. 2018; 1: 27–30. (In Russ.) Available from: doi: 10.18796/0041-5790-2018-1-13-16

2. Khazanovich G. Sh. Current trends in scientific research mining equipment. *Gornoe oborudovanie i elektromekhanika = Mining Equipment and Electromechanics*. 2018; 2: 41–45. (In Russ.)

3. Iudin A. V., Popov A. G., Shestakov V. S. Bunker systems of combined open-pit transport complexes. *Izvestiya vysshikh uchebnykh zavedenii. Gornyi zhurnal = News of the Higher Institutions. Mining Journal*. 2019; 2: 128–139. (In Russ.) Available from: doi: 10.21440/0536-1028-2019-2-128-139

4. Linnik Y. N., Linnik V. Y., Zhabin A. B., Polyakov A. V. Theoretical framework for the efficiency evaluation of coal mining machines. *Eurasian Mining*. 2020; 1: 61–64. Available from: doi: 10.17580/em.2020.01.12

5. Burt C. N., Caccetta L. Erratum to: Equipment selection for mining: With case studies. In: *Equipment Selection for Mining: With Case Studies. Studies in Systems*. Springer, Cham; 2018. Available from: doi: 10.1007/978-3-319-76255-5-11

6. Li Y., Mu X., Fan R. Multi-objective optimization and simulation of novel working mechanism for face-shovel excavator. *International Journal of Intelligent Robotics and Applications*. 2021; 5(1): 1–9. Available from: doi: 10.1007/s41315-020-00160-1

7. Suryo S. H., Bayuseno A. P., Jamari J., Wahyudi I. A. Analysis of rake angle effect to stress distribution on excavator bucket teeth using finite element method. *Civil Engineering Journal*. 2017; 3(12): 1222–1234. Available from: doi: 10.28991/cej-030952

8. Deng D. P., Li L., Zhao L. H. Limit equilibrium method (LEM) of slope stability and calculation of comprehensive factor of safety with double strength-reduction technique. *Journal of Mountain Science*. 2017; 14(11): 2311–2324. Available from: doi: 10.1007/s11629-017-4537-2

9. Wang X., Sun H., Feng M., Ren Z., Liu J. Dynamic analysis of working device of excavator under limit digging force. *Journal of the Institution of Engineers*. 2021; 102(5): 1137–1144. Available from: doi: 10.1007/s40032-021-00725-4

10. Afonina N. B., Khazanovich G. Sh., Otrokov A. V. Comparative analysis of continuous loading units of roadheaders and loaders. *Gornoe oborudovanie i elektromekhanika = Mining Equipment and Electromechanics*. 2023; 2: 41–48. (In Russ.) Available from: doi: 10.26730/1816-4528-2023-2-41-48

11. Linnik Y. N., Linnik V. Y., Zhabin A. B., Polyakov A. V. Theoretical framework for the efficiency evaluation of coal mining machines. *Eurasian Mining*. 2020; 1: 61–64. Available from: doi: 10.17580/em.2020.01.12

12. Kalashnikov S. A., Malkin O. A., Levchenko A. N. Main directions in heading equipment development. *Gornoe oborudovanie i elektromekhanika = Mining Equipment and Electromechanics*. 2008; 8: 27–33. (In Russ.)

13. Kargin R. V., Khazanovich G. Sh., Nosenko A. S. *Reloaders for tough bulk materials: monograph*. Novocherkassk: Platov South-Russian State Polytechnic University (NPI) Publishing; 2005. (In Russ.)

14. Nosenko A. S., Domnitskii A. A., Isakov V. S., Zubov V. V. Designing loading-and-transport systems for tunneling assemblies. *Gornyi informatsionno-analiticheskii biulleten (nauchno-tekhnicheskii zhurnal) = Mining Informational and Analytical Bulletin (scientific and technical journal)*. 2018; 4: 189–196. (In Russ.)

15. Nosenko A. S., Domnitskii A. A., Altunina M. S., Zubov V. V. Theoretical and experimental research findings on batch-operation bin loader with hydraulically driven conveying element. *Gornyi informatsionno-analiticheskii biulleten (nauchno-tekhnicheskii zhurnal) = Mining Informational and Analytical Bulletin (scientific and technical journal)*. 2019; 11: 119–130. (In Russ.)

Received 24 October 2023

Information about the authors:

Aleksei S. Nosenko – DSc (Engineering), Professor, Head of the Department of Mechanization and Automation of the Road Building Complex, Shakhty Automobile and Road Construction Institute (branch) of Platov South-Russian State Polytechnic University (NPI). E-mail: asnosenko@mail.ru; https://orcid.org/0000-0002-9345-7709

Aleksei A. Domnitskii – DSc (Engineering), Associate Professor, professor of the Department of Mechanization and Automation of the Road Building Complex, Shakhty Automobile and Road Construction Institute (branch) of Platov South-Russian State Polytechnic University (NPI). E-mail: dom-a-a@mail.ru; https://orcid.org/0000-0001-9400-3365

Viktoriia V. Nosenko – PhD (Engineering), Associate Professor, associate professor of the Department of Mechanization and Automation of the Road Building Complex, Shakhty Automobile and Road Construction Institute (branch) of Platov South-Russian State Polytechnic University (NPI). E-mail: vvnosenko@mail.ru; https://orcid.org/0000-0003-3003-8440

Mariia S. Altunina – PhD (Engineering), Associate Professor, associate professor of the Department of Mechanization and Automation of the Road Building Complex, Shakhty Automobile and Road Construction Institute (branch) of Platov South-Russian State Polytechnic University (NPI). E-mail: mariyaltunina@mail.ru; https://orcid.org/0000-0001-5598-2564

Viktor V. Zubov – PhD (Engineering), associate professor of the Department of Mechanization and Automation of the Road Building Complex, Shakhty Automobile and Road Construction Institute (branch) of Platov South-Russian State Polytechnic University (NPI). E-mail: zubovv.v@mail.ru; https://orcid.org/0000-0002-3629-8545

УДК 622.619 DOI: 10.21440/0536-1028-2024-4-8-16

Применение бункер-перегружателей периодического действия при проходке транспортных тоннелей комбайновым способом

Носенко А. С.[1], Домницкий А. А.[1], Носенко В. В.[1], Алтунина М. С.[1], Зубов В. В.[1]

[1] Шахтинский автодорожный институт (филиал) ЮРГПУ (НПИ) им. М. И. Платова, Шахты, Россия.

Реферат

Актуальность. *При строительстве транспортных тоннелей широкое распространение получила комбайновая технология с применением автомобильного магистрального транспорта. Анализ научно-технических источников в области организации работ в тоннельном забое выявил ряд проблем и недостатков, ограничивающих темпы проведения работ.*

Цель исследований *– разработка методов и способов согласования работы проходческого оборудования для снижения времени проходческого цикла и повышения темпов строительства.*

Методика проведения исследований. *Обеспечить непрерывность работы проходческого комбайна и автосамосвала и за счет этого повысить эффективность производства предлагается включением в технологическую цепочку «проходческий комбайн–автосамосвал» бункер-перегружателей периодического действия, обладающих высокой разгрузочной производительностью.*

Результаты. *Для количественной оценки эффективности применения бункер-перегружателя введено понятие коэффициента снижения времени (продолжительности) цикла. Разработана математическая модель для определения продолжительности проходческого цикла в разных условиях проведения выработки.*

Анализ результатов *расчетов показал, что снижение времени разгрузки бункер-перегружателя по сравнению со временем его загрузки в два раза позволяет уменьшить продолжительность проходческого цикла на 25 %. Качественная оценка разработанной модели формирования продолжительности проходческого цикла показывает, что основным фактором, ведущим к его снижению, является повышение производительности бункер-перегружателей при его разгрузке.*

Выводы. *В результате выполненных исследований намечены пути повышения эффективности горнопроходческих работ при комбайновом способе проведения выработок под транспортные тоннели за счет снижения продолжительности проходческого цикла. Предложено использовать бункер-перегружатель периодического*

действия для согласования работы проходческого комбайна и автотранспортного средства, обладающего высокой производительностью, значительно превышающей производительность проходческого комбайна.
Ключевые слова: *комбайновый способ; транспортные тоннели; проходческий комбайн; бункер-перегружатель; проходческий цикл.*

БИБЛИОГРАФИЧЕСКИЙ СПИСОК

1. Жабин А. Б., Поляков А. В., Аверин Е. А. Краткий анализ проблем и путей решения при обеспечении горнодобывающего предприятия современными техническими средствами ведения горных работ // Уголь. 2018. № 1. С. 27–30. DOI: 10.18796/0041-5790-2018-1-13-16

2. Хазанович Г. Ш. Актуальные направления научных исследований горнопроходческого оборудования // Горное оборудование и электромеханика. 2018. № 2. С. 41–45.

3. Юдин А. В., Попов А. Г., Шестаков В. С. Бункерные системы комплексов комбинированного транспорта в карьерах // Известия вузов. Горный журнал. 2019. № 2. С. 128–139. DOI: 10.21440/0536-1028-2019-2-128-139

4. Linnik Y. N., Linnik V. Y., Zhabin A. B., Polyakov A. V. Theoretical framework for the efficiency evaluation of coal mining machines // Eurasian Mining. 2020. No. 1. P. 61–64. DOI: 10.17580/em.2020.01.12

5. Burt C. N., Caccetta L. Erratum to: Equipment selection for mining: With case studies. In: Equipment Selection for Mining: With Case Studies. Studies in Systems. Springer, Cham; 2018. DOI: 10.1007/978-3-319-76255-5-11

6. Li Y., Mu X., Fan R. Multi-objective optimization and simulation of novel working mechanism for face-shovel excavator // International Journal of Intelligent Robotics and Applications. 2021. Vol. 5. No. 1. P. 1–9. DOI: 10.1007/s41315-020-00160-1

7. Suryo S. H., Bayuseno A. P., Jamari J., Wahyudi I. A. Analysis of rake angle effect to stress distribution on excavator bucket teeth using finite element method // Civil Engineering Journal. 2017. Vol. 3. No. 12. P. 1222–1234. DOI: 10.28991/cej-030952

8. Deng D. P., Li L., Zhao L. H. Limit equilibrium method (LEM) of slope stability and calculation of comprehensive factor of safety with double strength-reduction technique // Journal of Mountain Science. 2017. Vol. 14(11). P. 2311–2324. DOI: 10.1007/s11629-017-4537-2

9. Wang X., Sun H., Feng M., Ren Z., Liu J. Dynamic analysis of working device of excavator under limit digging force // Journal of the Institution of Engineers. 2021. Vol. 102. No. 5. P. 1137–1144. DOI: 10.1007/s40032-021-00725-4

10. Афонина Н. Б., Хазанович Г. Ш., Отроков А. В. Сравнительный анализ погрузочных органов непрерывного действия проходческих комбайнов и погрузочных машин // Горное оборудование и электромеханика. 2023. № 2. С. 41–48. DOI: 10.26730/1816-4528-2023-2-41-48

11. Linnik Y. N., Linnik V. Y., Zhabin A. B., Polyakov A. V. Theoretical framework for the efficiency evaluation of coal mining machines // Eurasian Mining. 2020. No. 1. P. 61–64. DOI: 10.17580/em.2020.01.12

12. Калашников С. А., Малкин О. А., Левченко А. Н. Основные направления совершенствования горнопроходческой техники // Горное оборудование и электромеханика. 2008. № 8. С. 27–33.

13. Каргин Р. В., Хазанович Г. Ш., Носенко А. С. Перегружатели для крепких сыпучих материалов: монография. Новочеркасск: ЮРГТУ (НПИ), 2005. 127 с.

14. Носенко А. С., Домницкий А. А., Исаков В. С., Зубов В. В. Разработка погрузочно-транспортных модулей в составе тоннелепроходческого оборудования // ГИАБ. 2018. № 4. С. 189–196.

15. Носенко А. С., Домницкий А. А., Алтунина М. С., Зубов В. В. Результаты теоретических и экспериментальных исследований бункер-перегружателя с гидравлическим приводом транспортирующего элемента периодического действия // ГИАБ. 2019. № 11. С. 119–130.

Поступила в редакцию 24 октября 2023 года

Сведения об авторах:

Носенко Алексей Станиславович – доктор технических наук, профессор, заведующий кафедрой механизации и автоматизации автодорожной отрасли Шахтинского автодорожного института (филиал) ЮРГПУ(НПИ) им. М. И. Платова. E-mail: asnosenko@mail.ru; https://orcid.org/0000-0002-9345-7709

Домницкий Алексей Александрович – доктор технических наук, доцент, профессор кафедры механизации и автоматизации автодорожной отрасли Шахтинского автодорожного института (филиал) ЮРГПУ(НПИ) им. М. И. Платова. E-mail: dom-a-a@mail.ru; https://orcid.org/0000-0001-9400-3365

Носенко Виктория Владимировна – кандидат технических наук, доцент, доцент кафедры механизации и автоматизации автодорожной отрасли Шахтинского автодорожного института (филиал) ЮРГПУ(НПИ) им. М. И. Платова. E-mail: vvnosenko@mail.ru; https://orcid.org/0000-0003-3003-8440

Алтунина Мария Сергеевна – кандидат технических наук, доцент, доцент кафедры механизации и автоматизации автодорожной отрасли Шахтинского автодорожного института (филиал) ЮРГПУ(НПИ) им. М. И. Платова. E-mail: mariyaltunina@mail.ru; https://orcid.org/0000-0001-5598-2564
Зубов Виктор Владимирович – кандидат технических наук, доцент кафедры механизации и автоматизации автодорожной отрасли Шахтинского автодорожного института (филиал) ЮРГПУ(НПИ) им. М. И. Платова. E-mail: zubovv.v@mail.ru; https://orcid.org/0000-0002-3629-8545

Для цитирования: Носенко А. С., Домницкий А. А., Носенко В. В., Алтунина М. С., Зубов В. В. Применение бункер-перегружателей периодического действия при проходке транспортных тоннелей комбайновым способом // Известия вузов. Горный журнал. 2024. № 4. С. 8–16 (In Eng.). DOI: 10.21440/0536-1028-2024-4-8-16
For citation: Nosenko A. S., Domnitskii A. A., Nosenko V. V., Altunina M. S., Zubov V. V. Applying periodic hopper-reloaders when driving traffic tunnels by the heading method. *Izvestiya vysshikh uchebnykh zavedenii. Gornyi zhurnal = Minerals and Mining Engineering*. 2024; 4: 8–16. DOI: 10.21440/0536-1028-2024-4-8-16