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On the parameters of an industrial motor vehicle designed to transport sized coal out of the face of an open pit

Mulenkova A. O.[1], Demchenko I. I.[1]
[1] Siberian Federal University
(79, Svobodny Prosp., Krasnoiarsk, Russia)

Abstract

Introduction. *Sized coal production in the face of an open pit allows to reduce its prime cost by reducing transfers and backhauls. At that, the maintenance of the quantitative and qualitative characteristics of the produced coal is highly significant. For this purpose it is suggested that the coal's transfer from the face to the daylight surface ought to be carried out in specialized containers installed on an industrial motor vehicle being the initial link in the resource-saving and ecological technology of sized coal transportation out of the face of an open pit.*

The research aims *to determine and substantiate the parameters of an industrial motor vehicle for sized coal transportation in specialized containers out of the face to the daylight surface.*

Methodology. *An industrial motor vehicle parameters determining mathematical model have been worked out, which allows to determine the rational values of its carrying capacity and structural parameters. Research methods include mathematical modeling and analysis, computer calculation software tools, and physical modeling.*

Results. *The present work has determined the range of parameters and the alternatives of structural variants of an industrial motor vehicle adapted for the specialized containers with sized coal transportation out of the face of an open pit. Interdependences between its basic parameters among themselves and between its basic parameters and external factors have been examined. The dependences between the carrying capacity and the productivity of processing equipment, time of sized coal loading into the containers, and the dimensions of a freight platform.*

Conclusions. *Dependences derived in the present work allow to determine rational values of industrial motor vehicle parameters and come into the substantiation of excavating and loading equipment and processing equipment for co-operation in the process chain of coal production in the face of an open pit.*

Key words: *sized coal; stoping face; industrial motor vehicle; parameters; carrying capacity.*

Introduction. Coal producers' competitive growth is an important development objective of the industry [1–3]. The growth in coal production output leads to the increasing demand for sized coal. Sized coal production in the face of an open pit allows to reduce its prime cost by reducing transfers and backhauls. The maintenance of the quantitative and qualitative characteristics is provided by technological use of the specialized containers (SCC) for sized coal delivery to the consumer. The delivery of SCC from out of the face to the daylight surface is carried out by an industrial motor vehicle (IMV).

Consequently, there appeared the need to substantiate the parameters of an industrial motor vehicle being the initial link in the resource-saving and ecological technology of sized coal transportation out of the face of an open pit.

Methodology. Research methods include mathematical modeling and analysis, computer calculation software tools, and physical modeling.

Research results and analysis. Under cyclic technology of coal mining it is offered to organize sized coal production in the face [4] and then load the produced sized coal in SCC installed on an industrial motor vehicle for its transportation out of the face to the daylight surface [5].

IMV represents an open pit automobile with removable load-carrying vessels in the form of specialized coal containers installed in a platform. IMV parameters must provide the fulfillment of the following requirements:

– structural adaptation to the conditions of exploitation – moving on open pit roads with complex and changeable cross section and a large number of sharp turns [6];

– operation in confined spaces – numerous manoeuvres including manipulations at the territory which is limited across the width of a working site [7];

– structural suitability for specialized containers transportation – the availability of the equipped load platform;

– carrying capacity correlating with the productivity of processing equipment.

The range of IMV parameters has been determined on the basis of the initial data analysis – the main conditions of its operation, namely: mining technical conditions, productivity of mining transportation equipment and SCC parameters being a removable load carrying element of IMV. The basic parameters are the nominal carrying capacity of a vehicle $q_{т.с}$, t; dimensions of a freight platform (length $a_п$, m; width $b_п$, m; height $h_п$, m); dimensions of IMV (length $a_{т.с}$, m; width $b_{т.с}$, m; height $h_{т.с}$, m); minimum swing radius R, m; motor power N, kW; the coordinates of a loaded vehicle centre of gravity ensuring its longitudinal and transverse stability.

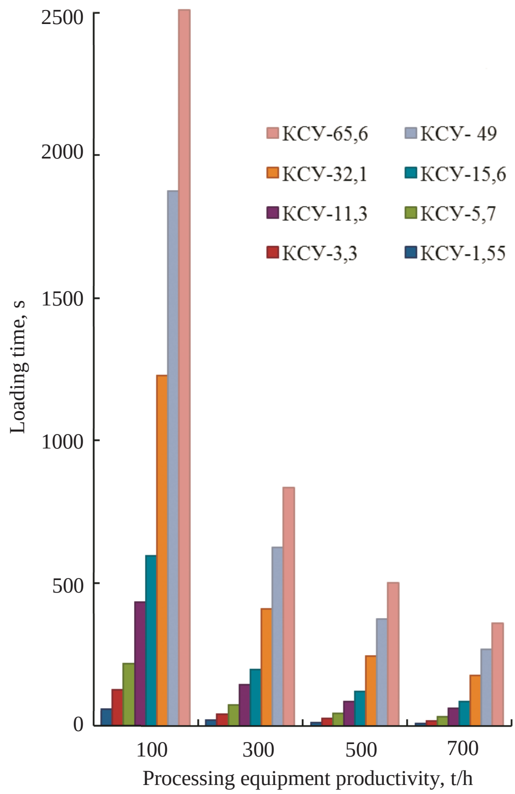

Fig. 1. The dependence between the time of sized coal loading into the specialized containers and processing equipment productivity

Рис. 1. Зависимость времени погрузки сортового угля в специализированные контейнеры от производительности перерабатывающего оборудования

Carrying capacity is one of the crucial factors to determine the structural variant, dimensions and power of IMV engine. Carrying capacity of IMV must correlate with the productivity of the processing equipment complex installed in the face in order to prevent failures in winning, processing and transporting components of open pit technological process. For that reason the given parameter takes priority in its value determination and substantiation.

Actual carrying capacity of IMV $q'_{т.с}$, t, is determined by the parameters of the complex of processing equipment and by the loading technology:

$$q'_{т.с} = \frac{Q_{об} K_{п} \eta t'_{п}}{\gamma},$$

where $Q_{об}$ is the productivity of the processing equipment complex, m^3/h; $K_{п}$ is a correction factor taking into account a fraction of sized coal output from the processing equipment; $t'_{п}$ is IMV loading time, h; η is a coefficient of vehicles' uneven arrivals at the loading point; γ is IMV carrying capacity operation factor [8].

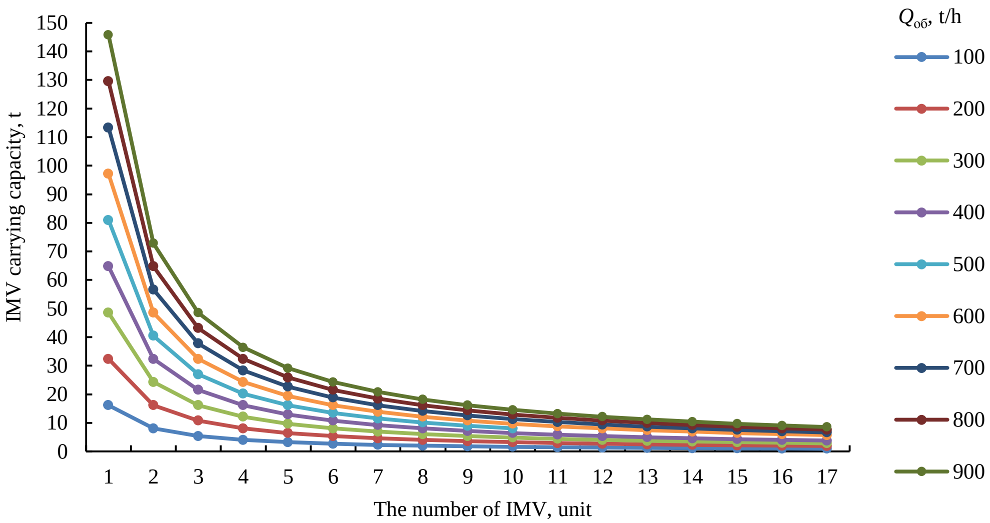

Fig. 2. Dependence between IMV nominal carrying capacity and the number of vehicles in use
Рис. 2. Зависимость номинальной грузоподъемности ТАТС от количества используемых автомобилей

IMV loading time $t'_{п}$ is the time to load sized coal into all the SCC installed on the freight platform; the number of SCC should meet two basic conditions:

1) the total gross weight of the specialized containers $m_{бр}$, t, installed on the freight platform converges to nominal carrying capacity of IMV and is equal to actual carrying capacity of IMV:

$$\sum_{i}^{1} m_{брi} n_i = q'_{т.с} \leq q_{т.с},$$

where i is a nominal scale value which classifies the specialized containers according to the form factor; $m_{брi}$ is the gross weight of a container with i form factor, t; $q'_{т.с}$ is IMV actual carrying capacity, t; n_i is the number of containers with i form factor;

2) the total area of the foundation $S_{осн}$, m^3, of the installed containers converges to IMV freight platform effective area $S_{пл}$, m^3:

$$\sum_{n}^{1} S_{оснi} n_i \leq S_{пл}.$$

Loading time $t'_{\text{п}}$ is directly proportional to the mass of sized coal stored in a container with a definite form factor and to the number of containers on a freight platform; and it is inverse to the productivity of the complex of equipment:

$$t'_{\text{п}} = \sum_{i=1}^{8} \left(n_i \frac{V_{\text{в}i} \gamma_0 K_{\text{н}}}{Q_{\text{об}}} \right),$$

where $V_{\text{в}i}$ is the internal volume of a specialized container with i form factor, m^3; γ_0 is the dimensional weight of coal, t/m^3; $K_{\text{н}}$ is a coefficient of container filling; for small pieces $K_{\text{н}} = 1.0–1.1$; for average – 0.7–0.8; for large 0.3–0.6.

The formula $(V_{\text{в}i}\gamma_0 K_{\text{н}})/Q_{\text{об}}$ is the loading time for one specialized container with i form factor $t_{\text{к}}$, h.

Fig. 1 represents a graph of the dependence between the time of sized coal loading into the specialized containers $t_{\text{к}}$, s, and processing equipment with the productivity $Q_{\text{об}}$, t/h.

Thus, the actual loading time for IMV $t'_{\text{п}}$ equipped with SCC with various form factors depends on their total number installed on the freight platform with the account of the number of containers of each form factor and the loading time $t_{\text{к}}$ for each container.

The dependence between the actual carrying capacity of IMV $q'_{\text{т.с}}$ and the parameters of mining transportation equipment will become:

$$q'_{\text{т.с}} = Q_{\text{об}} K_{\text{п}} \eta \sum_{i=1}^{8} \left(n_i \frac{V_{\text{в}i} \gamma_0 K_{\text{н}}}{Q_{\text{об}} K_{\text{п}}} \right).$$

Nominal carrying capacity of IMV $q_{\text{т.с}}$, which determines the largest quantity of cargo which can be transported by a vehicle at the same time, is relevant to the number of IMV operating in the line of sized coal bulk transportation:

$$q_{\text{т.с}} = \frac{QK_{\text{п}} \eta \left(\sum_{i=1}^{8} \left(n_i \frac{V_{\text{в}i} \gamma_0 K_{\text{н}}}{Q_{\text{об}} K_{\text{п}}} \right) + 2\frac{L}{v} + n_i t_{\text{р}} \right)}{A\gamma},$$

where A is the number of IMV operating in the complex of equipment, unit; L is the distance between the face and the warehouse of temporary storage, km; v is the speed of IMV movement, km/h; $t_{\text{р}}$ is the time to unload one SCC from IMV freight platform.

Dependence between the carrying capacity $q_{\text{т.с}}$ and the number of vehicles A in use when producing sized coal using the equipment with productivity Q is presented at fig. 2.

In order to determine dependence between IMV actual carrying capacity and freight platform dimensions (length $a_{\text{п}}$, m, width $b_{\text{п}}$, m) under different variants of specialized containers arrangement on the IMV platform, the Institute of Mining, Geology and Geotechnology of Siberian Federal University has written a computer program [9]. The developed computer program allows to consider the variants of IMV platform arrangement with various SCC form factors and their combination and determine the dependence between IMV carrying capacity and its platform dimensions. The values of IMV actual carrying capacity under given values of platform length and width are graphically represented at fig. 3. The values of width ($b_{\text{п}}$, m) are the following: 2.44 is the maximum width of a specialized container out of all granted for use, which determines the minimum width of IMV platform ensuring the arrangement of specialized containers of any form factor out of the suggested ones; 3.86 – the width of BelAZ-7540 dump truck with carrying capacity 30 t [10]; 4.24 – the width of BelAZ-7545 dump truck with carrying capacity 45 t [11]; 4.74 – the width of BelAZ-7555 dump truck with carrying capacity 55 t [12]. Freight platform length values correspond to maximum lengths of SCC. Open pit vehicle taken as a base is plotted on the horizontal axis. Platform dimensions are plotted on the vertical axis; for each IMV, 4 combinations of platform length and width are presented. Highlighted are the variants of platform length and width combination corresponding or close to the nominal carrying capacities of open pit vehicle on the basis of which it is made.

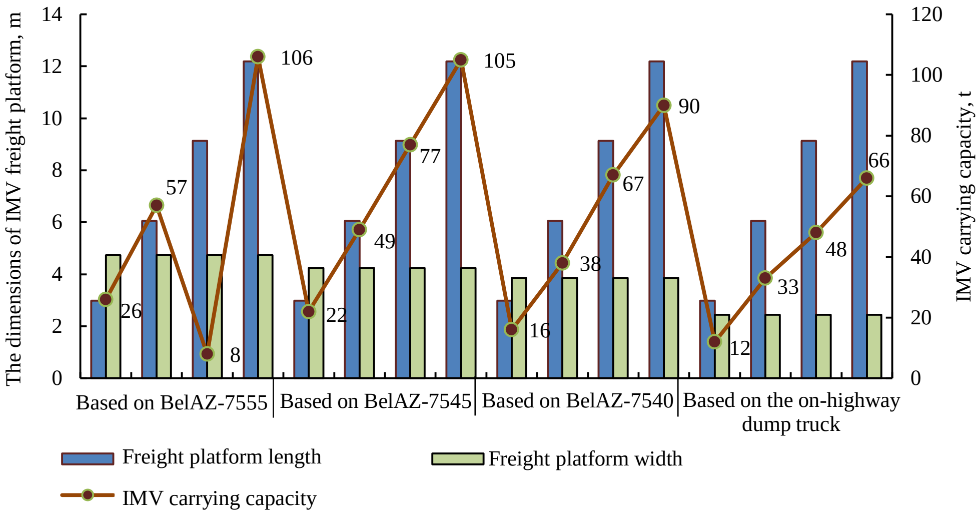

Fig. 3. The dependence between IMV actual carrying capacity and platform dimensions
Рис. 3. Зависимость фактической грузоподъемности от габаритных размеров платформы ТАТС

For example, for IMV made on the basis of BelAZ-7555 optimum platform dimensions will be the length of 6.06 and the width of 4.74 m, at which maximum possible nominal carrying capacity will make 57 t.

IMV loading height $h_п$, m, which determines IMV suitability for loading operations, is an important parameter. Under specialized containers top load, the following condition should be met:

$$h_{сб} \geq h_п + h_к,$$

where $h_{сб}$ is the height of coal discharge from screener loading conveyor, m; $h_к$ is the maximum height of a specialized container installed on a platform, m; $h_п$ is IMV loading height, m.

The dimensions of the platform considered above are the components of the IMV dimensions. Besides, IMV dimensions depend on the structure: a single unit vehicle, semi-trailer road train or trailer type road train [13]. The structural variant, apart from its influence on IMV length, affects the minimum swing radius *R*, which determines the possibility of manoeuvring. IMV minimum swing radius *R* depends on IMV wheelbase *L*, maximum wheel turning angle, and structural variant. A single unit IMV with hinged-articulated frame has the minimum swing radius. External swing radius depending of IMV dimensions determines the possibility of IMV manoeuvring at the face working site territory.

Longitudinal cross section of open pit roads represents the sequence of rises and descents of various gradient and length. In complex conditions of operation, longitudinal road slopes can reach 10–12 % and more at certain short road sections [4], at that, cross slope can reach 6 %. That is why it is necessary to pay special attention to IMV parameters which determine the stability and all-terrain capability in the specified conditions. The checking calculations of IMV longitudinal stability have shown that in case of the centre's of gravity maximum shift towards the back axle, vehicle roll-over will happen if the elevation of its centre of gravity h_a will be 9.8 m. The given value corresponds to the elevation critical height of a loaded IMV centre of gravity. Calculation values of h_a, m, are presented at fig. 4.

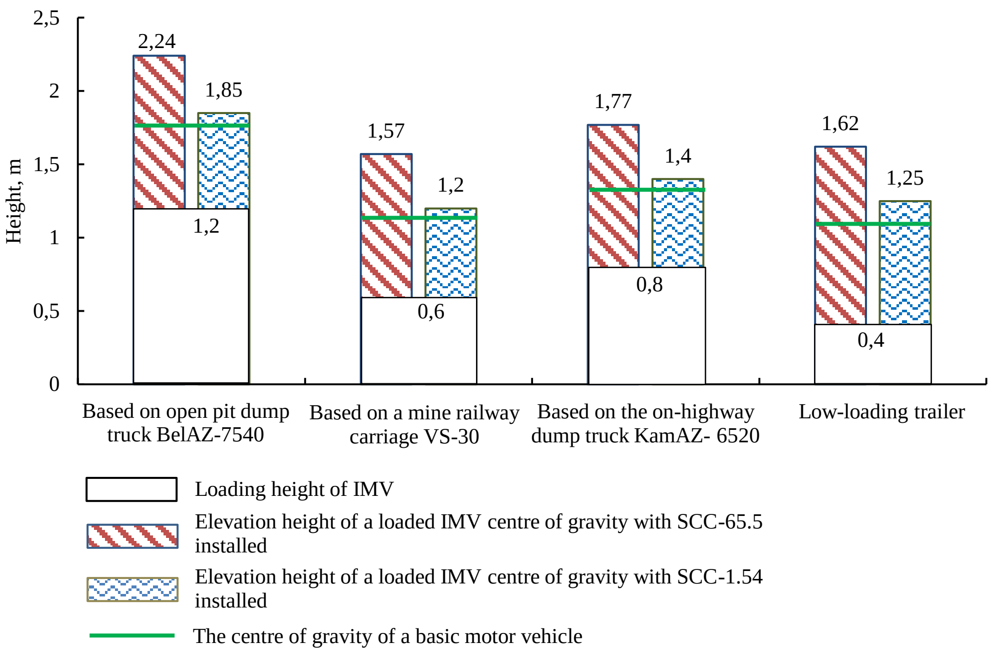

Fig. 4. Calculation values of elevation height of a loaded IMV centre of gravity to overcome a longitudinal slope of 120 ‰ when transporting rock mass with the dimensional weight of 1 kg/m

Рис. 4. Расчетные значения высоты центра тяжести груженого ТАТС для преодоления продольного уклона 120 ‰ при перевозке горной массы объемным весом 1 кг/м

As can be seen at fig. 4, actual maximum arrangement of the centre of gravity is 2.24 m for the IMV variant based on BelAZ-7540. That is why IMV longitudinal stability is reached in any structural variant.

Conclusions. The present work has determined the range of the basic IMV parameters depending on the features of mining technology and mining technological conditions of mining. Dependences between the nominal carrying capacity and dimensions of a platform derived in the present work allow to determine rational values of an industrial motor vehicle structural parameters being the initial link in the resource-saving and ecological technology of sized coal transportation out of the face of an open pit.

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Information about authors:

Anastasiia O. Mulenkova – assistant lecturer at the Department of Mining Machines and Complexes, Siberian Federal University. E-mail: 15anastasiya@mail.ru
Igor I. Demchenko – Doctor of Engineering Science, Associate Professor, professor of the Department of Mining Machines and Complexes, Siberian Federal University. E-mail: demtchenkoii@yandex.ru

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О параметрах технологического автотранспортного средства, предназначенного для вывозки сортового угля из забоя разреза

Муленкова А. О.[1], Демченко И. И.[1]
[1] Сибирский федеральный университет, Красноярск, Россия.

Реферат
Введение. *Получение сортового угля в забое разреза позволяет снизить его себестоимость за счет сокращения перевалок и встречных перевозок. При этом большое значение имеет сохранение качественных и количественных характеристик полученного угля. Для этого предлагается осуществлять его перевозку из забоя на дневную поверхность в специализированных контейнерах, установленных на технологическом автотранспортном средстве, служащем начальным звеном ресурсосберегающей и экологически чистой технологии доставки сортового угля из забоя разреза.*
Цель. *Определить и обосновать параметры технологического автотранспортного средства для вывоза сортового угля в специализированных контейнерах из забоя разреза на дневную поверхность.*
Методология. *Разработана математическая модель определения параметров технологического автотранспортного средства, которая позволяет определить рациональные значения его грузоподъемности и конструктивных параметров. Методы исследования включают математическое моделирование и анализ, программные средства расчетов на ЭВМ, физическое моделирование.*
Результаты. *В работе определены номенклатура параметров и варианты конструктивного исполнения технологического автотранспортного средства, адаптированного для транспортировки специализированных контейнеров с сортовым углем из забоя разреза. Рассмотрены взаимозависимости основных его параметров друг с другом и внешними факторами. Определены зависимости грузоподъемности от производительности перерабатывающего оборудования, времени погрузки сортового угля в контейнеры и размеров погрузочной платформы.*
Выводы. *Выведенные в работе зависимости позволяют определить рациональные значения параметров технологического автотранспортного средства и выйти на согласование параметров выемочно-погрузочного и перерабатывающего оборудования для совместной работы в технологической цепочке получения сортового угля в забое разреза.*

Ключевые слова: *сортовой уголь; добычной забой; технологическое автотранспортное средство; параметры; грузоподъемность.*

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Сведения об авторах:

Муленкова Анастасия Олеговна – ассистент кафедры горных машин и комплексов Сибирского федерального университета. E-mail: 15anastasiya@mail.ru
Демченко Игорь Иванович – доктор технических наук, доцент, профессор кафедры горных машин и комплексов Сибирского федерального университета. E-mail: demtchenkoii@yandex.ru

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