New hopper-cars with one-sided self-unloading

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S u m m a r y . The prospects of use of the modernized hopper-cars with one-sided self-unloading were considered. The basic parameters of structure of the car body were determined. The investigations of loading and unloading process of bulk freight of the hopper-car were conducted. The study allowed to determine the loads upon external and internal rails for the purpose to provide the stability of the car.

K e y w o r d s : hopper-car, structure, traffic safety, modeling.

INTRODUCTION

In the modern world the important direction of development of transport in the industry is modernization and re-equipment of the rolling stock for the purpose of providing the minimum expenses for transportation of freights, reductions of time on loading - unloading operations, ensuring reliability and convenience in operation of the rolling stock, decrease in prime cost of the finished products delivered to consumers.

The metallurgical and mining branches of production with the open cast or closed way of mining with removal of rock into spoil bank occupy the special role in the industry. The questions of development and perfection of the quarry transport and metallurgical industry transport are the most important as these branches are one of the most profitable [20].

Transport of the enterprises in the coal-mining industry represents difficult system of the interconnected transport links located both inside the enterprise, and out of it. The uninterrupted work of all links of technological process of the enterprise depends on the accurate organization of transport process. In this connection not only reliability of transport and efficiency of its use but also expenses on the equipment, materials and resources are of great importance in operation of transport. The purpose of transport in mining industry is to provide delivery of all volume of coal output from the extraction place to the destination point, removing the rock into a dump and transportation of materials with the maximum speed, with the minimum expenses and with taking into account the traffic safety. And the problem of decrease in expenses for transportation of dead rock to a mine dump is very actual in a mining industry [16, 18, 21].

So, in metallurgical industry the problem demanding its direct solution is reduction of transport expenses in transit of mass bulk freights, idle time shortening under loading-unloading operations, rational use of transport vehicles and loading factor of a rolling stock.

MATERIALS AND METHODS

In recent years the intensive searches of new most acceptable ways of development of transport of coal-mining and metallurgical industry for transportation of mass bulk freights are carried out. The modern vehicle is to be convenient in operation, powerful and economic. Therefore in modern conditions the industrial railway transport continues to remain one of main types of technological transport at the large industrial enterprises. Long-term economic experience confirms efficiency of use of the electrified railway transport not only at the enterprises which are producing the finished goods, but also in deep open pits.

The analysis of scientific-technical and design solutions allows to claim that the electrified railway transport will remain one of basic technological transport in the long term perspective both on operating, and on newly developed coal-mining deposits [1, 4, 12, 16]. The main advantages of the electrified railway transport are the following:

•high average operational efficiency,

•profitability (rather low prime cost of transportation of mining mass) and reliability in operation,

•possibility of a considerable overload of electric locomotives,

•simplicity of control, maintenance and repair of transport [4, 16].

All these advantages are a consequence of the centralized power supply of electric locomotives It should be noted, however, that the centralized power supply requires the creation of quite large infrastructure (traction substations, a contact network, etc.) that along with the high cost of locomotives and considerable volumes of a rating of boards of pits for placement of communications causes a high capital intensity of railway transport.

The essential advantages of the electrified railway transport are also the economy of not filled liquid fuel, almost total absence of a gas contamination of the territory by exhaust gases, insignificant dependence on climatic conditions. Along with it there is the problem of modernization of carriage yard, improvement of structures of cars for the purpose of reduction of metal consumption, reduction of time for their processing and feeding the cars in cargo fronts for loading and unloading. The worn-out and outdated park of cars demands new rationalization solutions which will improve technical and economic indicators of transportation of freights at the enterprises [2, 5, 13, 22].

Dump trucks, dump cars play a huge role in the organization of transportations of mass bulk freights in the industry [17]. However use of this rolling stock is not effectively in connection with its high metal consumption, considerable wear of all its parts, complexity of a structure of the car and the mechanism of overturning of a body, big efforts for self-loading.

Thus, the purpose of this study is modernization of carriage yard for transportation of bulk mass freights in industry.

The special role in the solution of this problem is assigned to creation of new structures of specialized cars for transportation of bulk freights. The problem of perfection of methods a choice of rational parameters of cars of this type is extremely becoming important at creation of specialized hopper-cars of new generation for transportation of bulk freights (the mining, mass, crushed rock, granulated slag, etc.). It will allow to reveal the perspective options of structures of cars and their separate functional units at early stages of their designing too [6, 19].

RESEARCH OBJECT

In this work creation of the rolling stock of new generation for transportation of bulk freights - the modernized hopper-car with unilateral self-unloading (on one side of a railway track) is offered [7, 8, 9].

The main feature of hopper-cars is their ability to self-unloading. This feature also determines the conceptual constructive scheme of the unloading device and the hopper-car body. The choice of rational parameters of hopper-car unloading system determines one of the major commercial indicators for cars of this type, namely, idle time on final operations.

The hopper-car of open type of model 20-40-15 for transportation of hot pellets and agglomerate [14] is enough known. The structure of the car provides the mechanized loading through an open body and the automated unloading on two sides from a railway track through two lateral hatches. The car is equipped with the unloading mechanism with the pneumatic drive and the automatic blocking, providing reliable locking of covers of hatches and automation of unloading process. The open hopper-car has the remote automated system of unloading of freight on both sides of the railway track, controlled by means of the compressed air fed from the power plant of the locomotive. Essential lack of the hopper-car is incomplete self-unloading of bulk freights which demands additional manual unloading,as well as impossibility of the mechanized formation of one-sided flat dump of bulk freights at unloading.

Researches of scientists of V. Dahl East-Ukrainian National University (EUNU) [6, 8, 9, 10] showed that it is possible to provide full unloading of bulk freight on the right side of a railway track concerning car movement by modernization of the known hopper-car of model 20-471 with a loading capacity of 65 t thanks to constructive changes of the shape of the body and the self-unloading mechanism (Fig. 1, Fig. 2) [7, 8, 9].

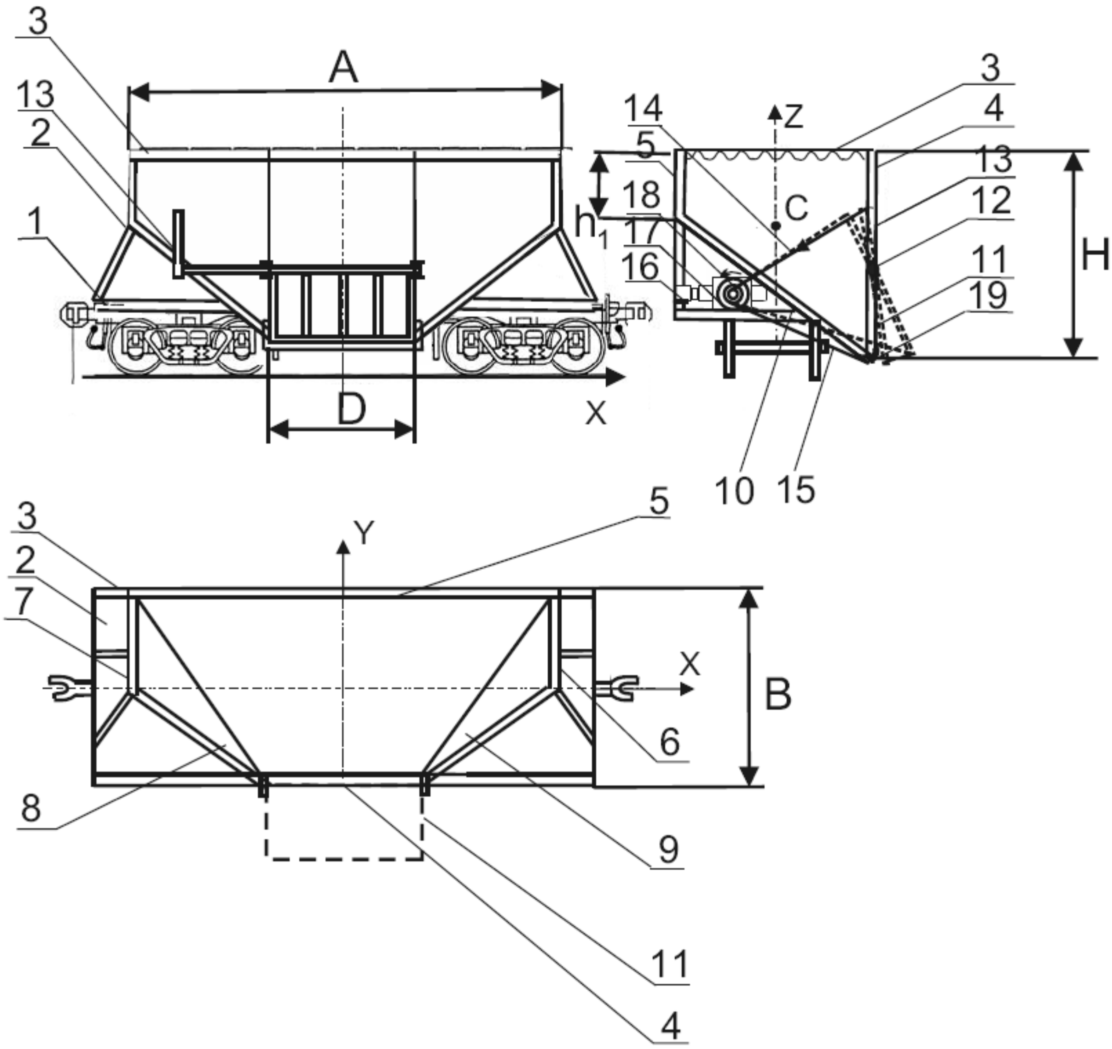


Fig. 1. The hopper-car with one-sided self-unloading

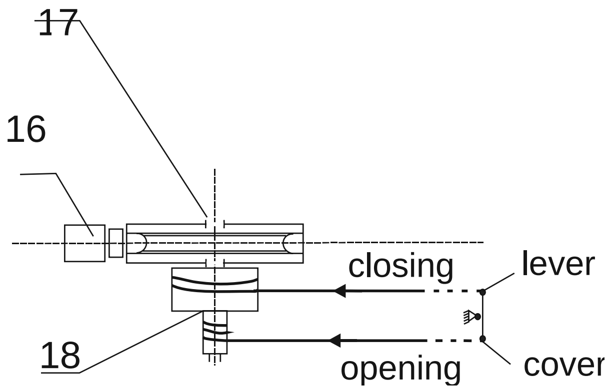


Fig. 2. Scheme of equipment for unloading of the hopper-car

The structure of the hopper-car is shown in Fig. 1. (three-view arrangement: front view, top view and side view). The hopper-car consists of a frame 1, a framework 2, the all-metal body 3 consisting of lateral walls 4 and 5, end face walls 6 and 7, transitional walls 8, 9. The part of a lateral wall 5 is transformed to an inclined floor 10 of the body 3.

The equipment for unloading is presented by rope system for opening, closing and fixing of a cover 11 of an unloading hatch, attached in hinges 12 to a lateral wall 4. The rope system consists of the lever 13 attached to a cover 11of the unloading hatch, ropes 14 and 15, the electric motor 16, a worm reduction gear17, the step drum 18 and locks 19.

The transitional walls 8, 9 provide increase in net volume of the body 3 and improvement of indexes of loading of the hopper-car through the open body 3.

In the hopper-car one unloading hatch is kept with the cover 11 suspended in hinges on a forward vertical lateral wall 4 from the unloading side, all other walls are executed obliquely.

In the place of formation of the dump through the electric motor 16, the torque is transferred by the worm reducer 17 to the step drum 18 (Fig. 2), then the tension of ropes 14 and 15 is carried out, position of the lever attached to the unloading hatch cover changes, the unloading cover of the hopper-car is opened and self-unloading of the hopper-car is executed on one side from railway track (on the right concerning movement). The ropes 14 and 15 which are reeled up on different steps of the drum 18, and the worm reducer 17 (Fig. 2) provide fixing of the cover of the hatch. The locks 19 are provided for reliable fixing of the cover 11 of the unloading hatch in a closed position that is especially important for transportation process [8, 9].

In the place of formation of the dump, the hopper-car unloading hatch cover, suspended in hinges to the lateral wall, is opened by means of the lever mechanism with driving pneumatic cylinders and self-unloading is carried out under the action of own freight weight through the hopper-car hatch on one side of railway track (on the right side concerning movement).

In operating conditions of railway transport, for example, in a mining industry, providing stability and reliability of the rolling stock as well as of traffic safety] is especially important [2, 5]. The offered asymmetrical body of the hopper-car developed by scientists of V. Dahl EUNU [6, 7, 8, 9] conforms to such requirements. It provides an arrangement of the center C of masses (Fig. 1) on the central vertical CZ axis at full loading of bulk freight. It is provided by the structure of the body and creates conditions for identical loads from the static forces on all eight wheels and, as result, promotes improvement of technical data (specifications) during movement and self-unloading.

RESULTS OF RESEARCH

1. Input data for research

The determination of loads to external and internal rails is very important in investigation of process of loading and unloading of the asymmetrical body of the hopper-car. We will note that loading is carried out with tthe bucket excavator 1 through an open body of the car. But unloading is executed through the unloading hatch 2 (Fig. 3).

The input data for research are:

- portion of loaded freight, m_1, t,
- weight of the empty car, t,
- height of falling h of freight on an inclined surface of the body floor, m,
- α – an inclination angle of a surface of a floor of the hopper-car body.

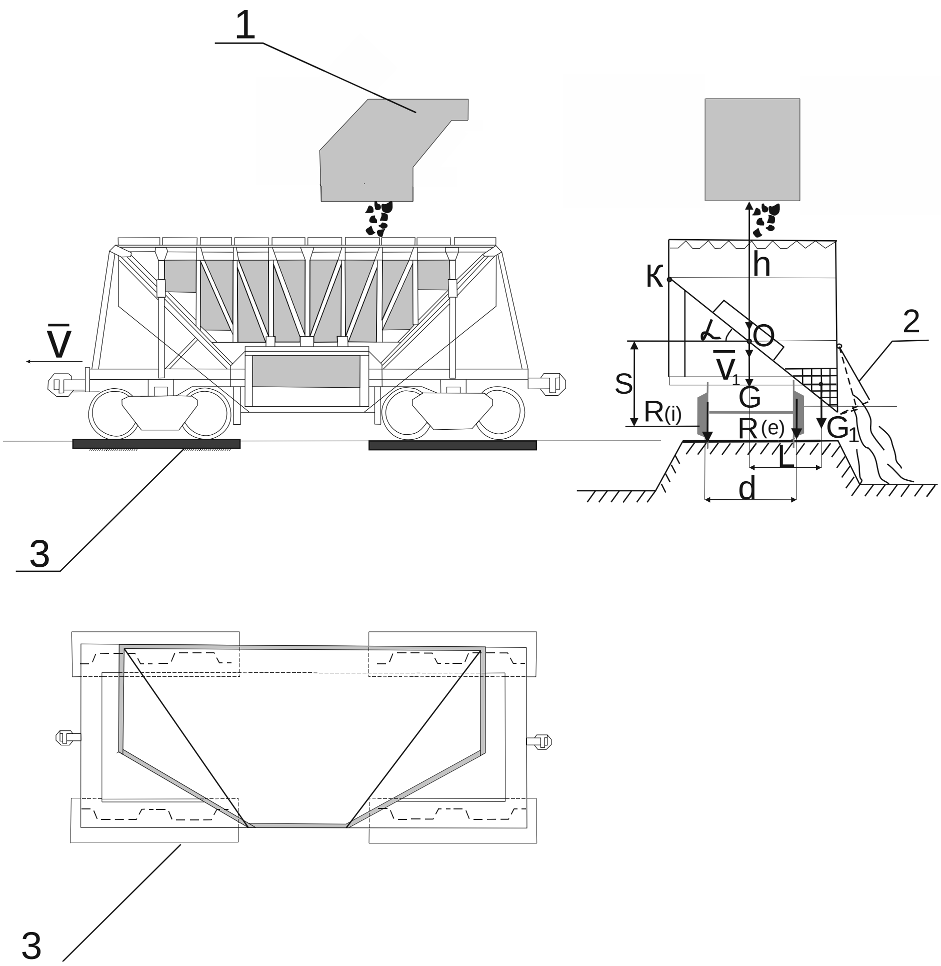


Fig. 3. Loading and unloading of the hopper-car:
1 – loading bunker (hopper), 2 – cover of the unloading hatch, 3 – scales

For calculations we take the hopper-car design with the following parameters [6]: body width B = 3154 mm, the hopper-car body length A = 9300 mm, height of one lateral wall according to vehicle gauge H = 3100 mm, width of the unloading hatch D = 3500 mm. Weight of the empty car G = 23 t.

At these parameters (width of the unloading hatch of the hopper-car D = 3500 mm) the height of the second lateral wall h_1, an inclination angle of the body floor of the hopper-car α are determined (Fig. 1) from relationships (Eg. 1) and (Eg. 2) [3, 12]:

$$h_1 = H\frac{(A+7D)}{(9A-D)}, \quad (1)$$

$$tg\alpha = \frac{H-h_1}{B}. \quad (2)$$

They will be respectively equal h_1=1300 mm, $\alpha = 30^0$.

Thus, the total volume of the hopper-car body will make V_1 = 49,48 m^3 [6]. For the hopper-car this volume is considerable in comparison, for example, with the hopper-car of model 20-471 with a loading capacity of 65t. It is used for transportation of hot pellets and agglomerate and has the total volume of 42 m^3. The center of gravity is located on the central vertical axis that is provided with a structure of the car body.

The design of offered modernized hopper-car provides the mechanized loading through an open body with the bucket excavator or the conveyor. Besides the hopper-car also executes the automated unloading on one side from a railway track through the lateral unloading hatch.

2. Mathematical simulation of static weighing process of portion loading of the hopper-car asymmetrical body

Mathematical simulation of loading operation of the hopper-car asymmetrical body is carried out in the following order and to some stages:

2.1. Determination of force of action upon the left and right rail at the top loading.

The loads upon the external $R_{(e)}$ and the internal rail $R_{(i)}$ in the moment of freight blow about a surface are determined from relations (Eg. 3) and (Eg. 4) [3, 12]:

$$R_{(e)} = \sqrt{\frac{m_1 * g * h * c}{8}}(\cos^2\alpha - \frac{S}{d}\sin 2\alpha) + \frac{G}{2}, \quad (3)$$

$$R_{(i)} = \sqrt{\frac{m_1 * g * h * c}{8}}(\cos^2\alpha + \frac{S}{d}\sin 2\alpha) + \frac{G}{2}, \quad (4)$$

where: S – height from a rail head to the middle of an inclined surface, m,

m_1 – the mass of a portion of freight, t,

h – the height of falling of freight on an inclined surface of a body floor, m,

c - rigidity, N/m,

α – an inclination angle of a surface of the car body floor, ^{0},

d – the width of wheel pair, m,

G – the weight of the empty car, kg.

Investigating the loading process of the hopper-car we obtain the dependences of loads upon the external $R_{(e)}$ and internal rail $R_{(i)}$ in the moment of freight blow about an inclined body floor on the mass of falling freight and to give to recommendation on loading of hopper-car in initial moment of time.

On the basis of the conducted research it is possible to draw a conclusion that stability of the car from overturning will be provided due to positive values of loads, however it is possible to make the recommendations to carry out loading process by small portions at the initial moment of loading of the car.

2.2. Determination of redistribution of loads $R_{(i)}$ and $R_{(e)}$ upon the sides of wheel pairs.

We will consider the freight displacement under the action of gravity G_1 and potential energy of springs (Fig. 3) to the unloading hatch on distance L from the central axis.

This movement leads to redistribution of loads on the sides of wheel pairs. The loads are determined from relations (Eg. 5) and (Eg. 6) [3, 12]:

$$R^*_{(e)} = \frac{G}{2} + G_1(\frac{1}{2} + \frac{L}{d}), \quad (5)$$

$$R^*_{(i)} = \frac{G}{2} + G_1(\frac{1}{2} - \frac{L}{d}), \quad (6)$$

where: L – distance of the center of a triangle of freight from the central vertical axis, m.

2.3. Determination of force of action upon the left and right rail at the loading to a point O.

At the third stage the loads upon rails $R^*_{(i)}$ and $R^*_{(e)}$ are determined at the moment of filling of the hopper-car body with freight up to a point O (Fig. 3).

After that a half of freight portion which is loaded into the hopper-car body, falls on the inclined surface, the second part – on a horizontal surface, thus the loads upon rails at the moment of blow decrease almost twice that provides stability of the car.

2.4. Determination of force of action upon the left and right rail at the loading to a point K.

At the fourth stage, taking into account the features of the construction of the car hopper body, we determine the calculated loads upon rails when filling body to a point K (Fig. 3).

2.5. Determination of force of action upon the left and right rail at full filling of the hopper-car body.

At the fifth stage we define the calculated loads upon rails at full filling of the hopper-car body.

Dependences of loads upon the external $R^*_{(e)}$ and internal $R^*_{(i)}$ rails on the mass of loaded freight are shown in Fig. 4.

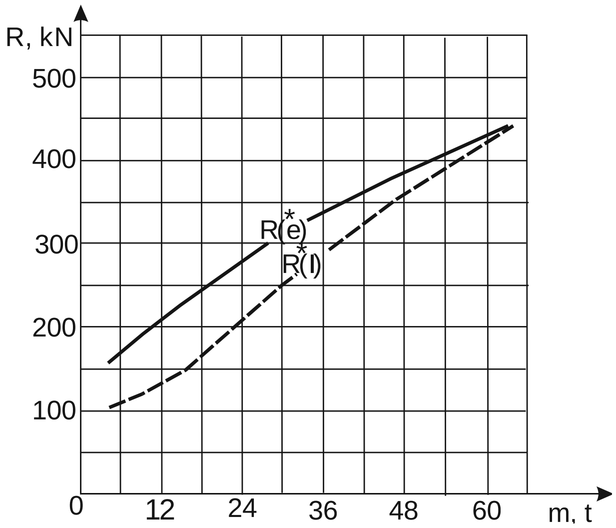


Fig. 4. Dependence of loads upon the external $R^*_{(e)}$ and internal $R^*_{(i)}$ rails on the mass of loaded freight *m*

The analysis of the dependences given on fig. 4 shows that at a full loading of the hopper-car the loads upon external $R^*_{(e)}$ and internal $R^*_{(i)}$ rails will be equal.

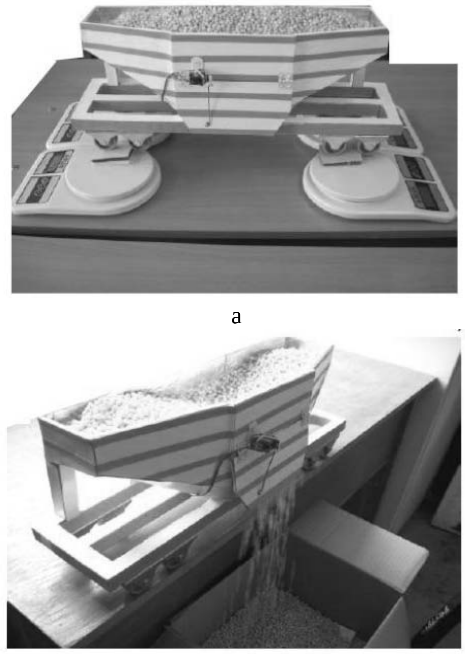
3. Experimental studies and their results

In the experimental study the physical modeling of loading and unloading process of the car hopper was applied to determine the relations of loads upon the external and internal rails. The plastic balls with a diameter of 5-6 mm were used as a bulk material. The hopper-car was manufactured from wood (timber) on the scale of 1:20. The coefficient of friction accepted on indications of friction gauge (tribometer) is equal to f = 0,48.

Model installation is presented in Fig. 5, a and 5b. Two operations respectively had been carried out at the model installation: Fig. 5, a – car loading and determination of the loads upon rails by means of scales, Fig. 5, b – car self-unloading through the unloading hatch.

The loads upon the internal $R^*_{(i)}$ and external $R^*_{(e)}$ rails were determined by the indications of scales (Fig. 3, Fig. 5, b) which were installed under each wheel of the car.

Dependence of the loads upon the external $R^*_{(e)}$ and internal $R^*_{(i)}$ rails on the portions of loaded freight is shown in Fig. 6.



a

b

Fig. 5. Loading and unloading of thehopper-car:
a– car loading and determination of the loads upon rails by means of scales,
b – car self-unloading through the unloading hatch

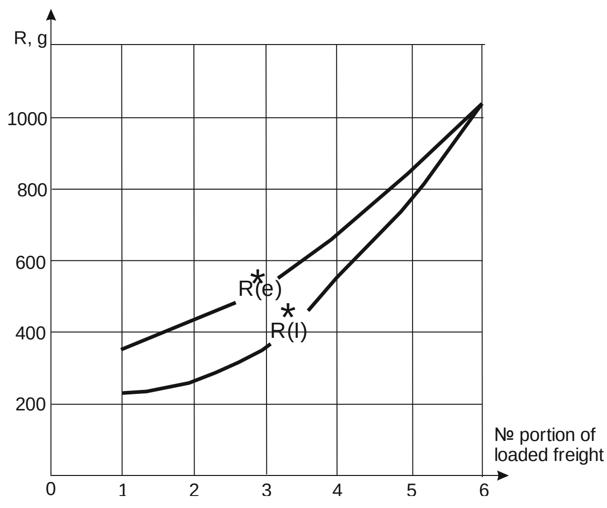


Fig. 6. Dependence of the loads upon the external and internal rails on the portion of loaded freight

The loads upon the external and internal rails will be equal at a full loading of the hopper-car. Thus, use of this car is expedient for transportations at various distances and at various trajectory of the route.

4. Investigation of the process of freight unloading from the hopper-car

As it was already noted in [6] time of unloading is in inverse proportionality to width D of the unloading hatch.

Proceeding from the accepted values of size of the unloading hatch of 3500 mm and the taken inclination angle of the main rolling-down surface 30^0, we investigate change of time of unloading of the car depending on an angle of opening of the hatch cover (on the hopper-car which has been executed on the scale of 1:20). Possibility of opening of the hatch cover in several provisions gives the chance of freight weighing in the course of unloading. Experimentally we obtain dependences of time of freight unloading on an angle of opening of the hatch cover (Fig. 7). We investigate the process of freight unloading in four positions: of completely filled body, filled for 50%, 30% and 25%. The results of research depend on type of the freight which is in the car, on its physical and chemical properties and density.

The dependence of unloading time of the hopper-car on an angle of opening of the unloading hatch cove, investigated on the model installation, is shown in Fig. 7.

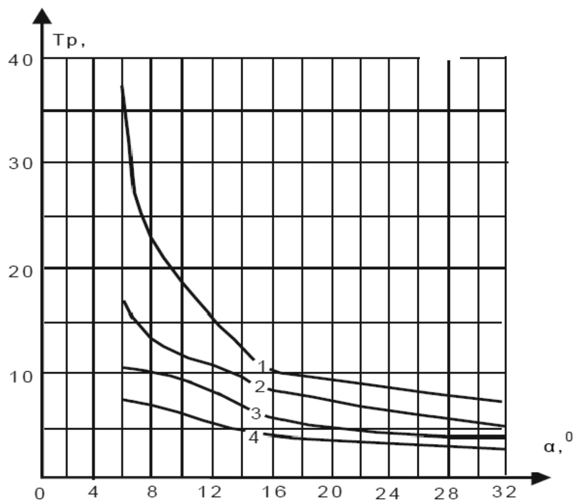


Fig. 7. Dependence of unloading time of the hopper-car on an angle of opening of the unloading hatch cover: 1 – 100% filling, 2 – 50%, 3 – 30%, 4 – 25%

CONCLUSIONS

1. Full unloading of freight on the right side of railway track concerning car movement is provided thanks to constructive changes in the shapes of the body and the mechanism of self-unloading of the hopper-car. Modernization of the hopper-car body is executed so that its net volume in comparison with initial variant (model 20-471 with a loading capacity of 65 t) should not be decreased.

2. The loading-unloading process of the hopper-car was investigated and the important calculated and experimental values were obtained. Thus, it is possible to draw a conclusion that stability of the hopper-car in the course of loading-unloading and transportation will be provided.

3. The use of the modernized hopper-car with the changed asymmetrical structure of the body and the mechanism of self-unloading is expedient for transportation of mass bulk freights in various branches of industry.

REFERENCES

1. **Anistratov K.Yu., 2011.:** Justification of structure of park of dump trucks of a class of the loading capacity of 40-100 tons. Open mining operations in the XXI eyelid / Collection of materials of the international scientific and practical conference. Krasnoyarsk. MVDTs "Siberia", 105-111. (in Russian).
2. **Basov G., Kireev A., Lysak D., 2010.:** Improvement of testiong operations during diagnosing of wheelpair tires of railway vehicles. TEKA Commission of Motorization and Power Industry in Agriculture. XC, 12-18.
3. **Vilke V.G., 2003.:** Theoretical mechanics. Moscow State University publishing house. (in Russian).
4. **Golubenko A.L., Gubacheva L.A., Andreyev A.A., 2010.:** Prospects of creation and use of narrow-gage traction units//Visnyk V.Dahl EUNU. Scientific Journal №10 [152], Part 1, 32-39. (in Russian).
5. **Gorbunov N., Kostyukevich A., Kravchenko K., Kovtanets M., 2011.:** Influence of operatonal factors on redistribution of wheel pairs vertical loads upon rails. TEKA Commission of Motorization and Power Industry in Agriculture. XIA, 30-32.
6. **Gubacheva L.O., Andreev O.O., Leonova S.O., 2012.:** The hopper-car with one-sided self-unloading. Visnyk V.Dahl EUNU. Scientific Journal № 4 [175], 69-74. (in Russian).
7. **Gubacheva L.O., Andreev O.O., Leonova S.O., 2012.:** The hopper-car for transportation of bulk

freights. Patent of Ukraine № 75199, B61D 7/02, issued 26.11., Bull № 22. (in Ukrainian).
8. **Gubacheva L.O., Andreev O.O., Leonova S.O., Mokrousov S.D., Scherbakov V.P., 2013.:** The hopper-car. Patent of Ukraine № 83182, B61D 7/02, issued 27.08., Bull № 16. (in Ukrainian).
9. **Gubacheva L.O., Andreev O.O., Leonova S.O., Kutnyakhov S.V., 2013.:** The hopper-car for transportation of bulk freights. Patent of Ukraine № 82575, B61D 7/02, issued 12.08., Bull № 15. (in Ukrainian).
10. **Gubacheva L.O., Leonova S.O., 2013.:** Assessment of economic efficiency of use of the modernized hopper-cars with the electric equipment for self-unloading. Visnyk V.Dahl EUNU. Scientific Journal №9 [198], Part 1, 36-40. (in Russian).
11. **Debeliy B., Debeliy L., Melnikov S., 2006.:** The main trends of mine locomotive transportation. Coal of Ukraine. Scientific Journal №6, 30-31. (in Russian).
12. **Dobronravov V.V., Nikitin N.N., 1971.:** Course of theoretical mechanics, p.1 and 2. M., the Higher school. (in Russian).
13. **Kulichkin P.S., Konopelko S.A., Biryukov A.N., 2011.:** Operating experience of TEREX TRI 00 dump trucks of Kuzbass. Mining industry. № 4 (98), 30-34. (in Russian).
14. **Kuzmich L.D, 1978.:** Cars.: M, "Mechanical engineering", 204-207. (in Russian).
15. **Melnikov N.N., Reshetnyak S.P., 1994.:** Prospects of solving scientific issues at working off powerful deep pits. Mining: IGD SO RAS. – Yakutsk, 14–23. (in Russian).
16. **Parunakyan V.E., 1966.:** To a question of improvement of railway transport//Equipment and technology of development of minerals: works / NIIOGR. – M, – V. 5. (in Russian).
17. **Parunakyan V.E., Yasyuchenya V.V., 1960.:** Operating experience motorized dump cars on Korkinsky coal pits.// Mining industry. Scientific Journal № 11, 157-162. (in Russian).
18. **Popov M.S., Kaplunov V.Y., 2010.:** The problem of environmental and economic decision-making on the use of of dumps and heaps in the coal industry in Russia. Mining informational-analytical bulletin. №7, 241-254. (in Russian).
19. **Savushkin R.A., 2003.:** Improving the design of self-unloading hopper cars for the transportation of bulk cargo: the dissertation of the candidate of technical sciences: 05.22.07.- St. Petersburg, 100-134. (in Russian).
20. **Yakovlev V.L., Bahturin Y.A., Stolyarov V.F., 2002.:** Some promising research areas in the field of quarry transportation. Proceedings of the International Scientific and Technical Conference on Quarry Transport. – Yekaterinburg, 15–20. (in Russian).
21. **Yakovlev V.L., Vitiazev O.V., 2004.:** Guidelines on Energy Conservation on the quarry railway transport //Mining Journal. № 10, 66–68. (in Russian).
22. **Yakovlev V.L., Popov V.Y., Kotyashev A.A., Kosnarev E.S., 2002.:** Improving safety and operational efficiency of rail transport in open cast mining / / Problems of pit transport: International Scientific Technical Conf. - Yekaterinburg: RAS., 94–97. (in Russian).

НОВЫЕ ВАГОНЫ-ХОППЕРЫ С ОДНОСТОРОННЕЙ САМОРАЗГРУЗКОЙ

Лариса Губачева, Александр Андреев, Леонова Светлана

Аннотация. Рассмотрены перспективы использования модернизированных вагонов-хопперов с односторонней саморазгрузкой. Определены основные параметры кузова вагона. Проведены исследования процесса погрузки и выгрузки сыпучего груза из вагона-хоппера, которые позволили определить нагрузки на наружный и внутренний рельсы и обеспечить устойчивость вагона.

Ключевые слова. Вагон-хоппер, конструкция, безопасность, моделирование.