SUBSTANTIATION OF THE EFFICIENCY OF CONTAINER TECHNOLOGIES APPLICATION FOR THE TRANSPORTATION OF ROCK IN DEEP PITS

Kuzmin Sergey, Turbit Andrey, Salko Oksana

Rudny Industrial Institute, 111500 Rudny, Republic of Kazakhstan; info@rii.kz

ABSTRACT. In the article a new technology of container carriage of rocks without construction of transport communications in an open-pit mine and with technological and energy-saving advantages is proposed. These advantages are: simultaneous excavation of rocks, transportation of rocks by the shortest distance, small mass of a container and mobility of a complex of hoists which will reduce energy expenses and the cost of transportation of the mined rock. One of the principal advantages of the developed technology is decrease in environmental emissions into the atmosphere of the open-pit mine thanks to the reduction of the vehicle fleet. This technology will enable significant improvement of the environmental situation in the area of mining operations. The main feature of the proposed technology is that all types of equipment for container transportation are simple to manufacture and can be created directly in the conditions of mining sites.

Keywords: pit, container, transport, economic and environmental efficiency

ОБОСНОВАНИЕ ЭФФЕКТИВНОСТИ ПРИМЕНЕНИЯ НА ГЛУБОКИХ КАРЬЕРАХ КОНТЕЙНЕРНОЙ ТЕХНОЛОГИИ ТРАНСПОРТИРОВАНИЯ ГОРНОЙ МАССЫ

Кузьмин Сергей, Тюрбит Андрей, Салько Оксана

Рудненский индустриальный институт, 111500 Рудный, Республика Казахстан

РЕЗЮМЕ. В статье предллагается новая технология контейнерной перевозки горных пород без строительства транспортных коммуникаций в карьере и обладающей технологическими и энергесберегающими преимуществами. Этими преимуществами являются: одновременная выемка горных пород, транспортировка горных пород на кратчайшие расстояния, небольшая масса контейнера и подвижность комплекса подъемников, что позволит снизить энергозатраты и стоимость транспортировки добываемой породы. Одним из основных преимуществ разработанной технологии является снижение выбросов в атмосферу карьера, благодаря сокращению парка транспортных средств. Данная технология позволит значительно улучшить экологическую ситуацию в районе добычи полезных ископаемых. Главная особенность предлагаемой технологии заключается в том, что все виды оборудования для контейнерных перевозок просты в производстве и могут быть созданы непосредственно в условиях горных предприятий.

Ключевые слова: карьер, контейнер, транспорт, экономическая и экологическая эффективность

Introduction

In the modern conditions the need for efficient and environmentally safe development and management of subsurface resources is becoming ever more relevant. As a result of the scientific and technological revolution the adverse effect on the environment has increased many times. The opencast mining – one of the principal sources of the environment pollution – plays a leading role in this.

In terms of power, conveyance of the mined rock along the edge of the open-pit mine by motor transport increases the rate of fuel consumption 2–3 times. Accordingly, harmful emissions into the atmosphere of the open-pit mine increase as well. Significant costs of conveying the rocks by motor transport limit the cost-efficient height of mine dumps, which leads to the increase of their occupied area and additional environmental losses.

The environmental issues of the use of motor transport at open-pit mines have several directions:

- First of all, pollution of the atmosphere of the open-pit mines as a result of diesel engine emissions. It was found that the biggest rate of fuel consumption takes place during conveyance of the mined rock from the open-pit mines. Excavating-motor transport hubs have one fundamental disadvantage in the form of additional inefficient diesel fuel consumption during the down time in the process of loading a dump truck;
- Secondly, dust emission in the process of blow-off from the surface of the mined rock in the truck body and from the wheel-road surface interaction. The high level of the dust blow-off from the dump truck surface results from a significant area of the rock surface, which is related to the geometric parameters of the truck body. During interaction of the wheels with the road surface the level of dust emission depends on the speed of dump trucks and road surface. Additional road irrigation and surface improvement costs are required in order to fight dust emission;
- Third, dust emission from the surface of external mine dumps of waste rock. As mentioned above, the external motor dumping sites are characterised by a large area of dump operations and a long-term running order. This results in a high level of dust blow-off from the surface of mine dumps and environmental damage for the surrounding land;
- Fourthly, increase of the land area of external mine dumps and withdrawal of these areas from agriculture for long terms. The area of external mine dumps depends on their height, which in turn is determined by the cost-efficient height of rock hoisting by motor transport. High unit cost of motor transportation limits the height of mine dumps (usually up to 20–40 metres) and increases its area.

Delivery of mined rock to mine dumps or bunkers of concentrating factories accounts for the principal share of energy consumption in mining. The issue of transport support of the bottom levels of deep open-pit mines has no ultimate technological solution, while the principal share of transport costs falls on the cycle of hoisting the mined rock.

Enterprises developing deposits in the unconsolidated and water-flooded rock face significant transportation problems. A low load bearing capacity of rock, complicated road conditions lead to the fact that the prime cost of transportation works is double compared to the average values in other open-pit mines. Given the combination of the identified rock and technological issues in the conditions of critically increased man-caused pressure on the environment and intense competition in the external market, creation of an energy-saving and environmentally safe technology of opencast mining becomes very relevant.

The selection of technological equipment of open-pit mines is the most complicated issue in the technology of the existing open-pit mines. This shows that they have a range of contradictions requiring new solutions. With the lowering of mining in open-pit mines the distance of motor transportation increases therefore higher capacity dump trucks are required. Increase of the capacity of dump trucks disrupts the optimal ratio of the capacity of a shovel size of a face shovel to the dump truck's body capacity. In order to decrease the down time of expensive dump trucks it is required to increase the shovel power and standard dimensions of a face shovel. The increased dimensions of dump trucks require the extension of highways, manoeuvring platforms, etc., which significantly decreases the volumes of ore mining. This facilitates the increase in a number of internal open-pit mine loading points used in combined transportation.

Technology Improvement

It is proposed to introduce a container technology of mined rock transportation in the opencast mining, which will allow increasing the opencast mining indicators in the area of saving energy resources and environment conservation at a totally new level.

It will include:

– One-off rock fragmentation in the process of loading a container, which reduces energy consumption;

– Delivery of mined rock by transportation of a container's assembly to the place of hoisting is performed at minimum horizontal road distances, which leads to reducing the required vehicle fleet, the rate of consumption of fuel, tires and emissions of harmful gases;

– The coefficient of dead load of a transport container (0.25–0.30) is significantly lower than the coefficient of a truck body (0.70–0.80) or of railway transport (0.80–0.82) therefore, the unit cost of energy for transportation of the rock mass in a container is reduced 1.4 times;

– The container hoisting hub is mobile, which allows moving to a new place during blasting operations or another bench in an open-pit mine with subsequent mining of the open-pit mines. Opportunities for regulation and maintenance of the optimum mining regime increase;

– The need for additional energy-intensive fragmentation of the mined rock is eliminated as opposed to the process schemes with the use of conveyer lifts;

– Container delivery of the overburden rock with the use of an open-pit mine hoist during liquidation of the open-pit mine will reduce the required land and form a compact height with minimum rock hoisting.

The key aspect of the proposed technology is in the fact that the entire equipment for container carriage is not difficult to produce and can be produced at mining enterprises. Walking mining excavators may be used as hoists.

In accordance with the basic process scheme of the open-pit mine hoisting containers are installed on the benches of the open-pit mine for hoisting containers from the lower benches up (according to Fig. 1). On the intermediate platforms loaded and empty containers are cleared up. Following hoisting to benches, where the railway transport operates, containers are loaded directly into carriages.

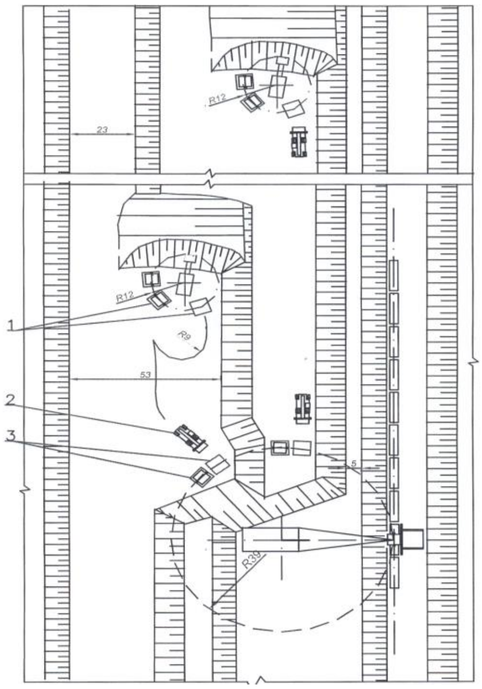

Fig. 1. Plan of energy-saving container technology in opencast mining. 1 – containers under loading, 2 – container carriers; 3 – containers on the platform at the hoist

One hoist serves two benches during the hoisting. The hoist is located at the platform of the lower bench beyond the possible caving area. The container is delivered by a container carrier to the bottom edge of the lower bench, the hoist moves the container to the upper bench platform from where a container is delivered to the next hoist through the interchange point.

The new technology may be applied within the existing combined transportation patterns, for example, within a motor-railway transportation pattern as an interagent – a hoisting-reloading point.

The container hoisting hub may become an alternative solution for a major problem of modern open-pit mines in tapping of new horizons, though it may be used at any mining stage in the open-pit mine.

Abandoning the hoisting of mined rock by motor transport provides an opportunity to increase the grade limit of ramps, as they will be used for traffic of empty cars only. A possible transition from the grades 8 % to the grades 15 % will reduce the area for positioning of ramps in the open-pit mine.

The efficiency of the new technology is expressed in reducing, in terms of cost savings, of the specific energy consumption for transportation of the mined rock compared to the most common technology with the use of motor-railway transport with reloading at the internal open-pit mine warehouses: for hoisting the mined rock by an electric drive hoist in containers with the minimum dead load coefficient; from reducing the coefficient of overburden removal by reducing the area of the reloading point, which organisation in this case loses its meaning.

The hoist capacity is justified by the required productivity of the open-pit mine. The productivity of the hoist Q_{year}, thous. t/year will be determined depending on the time of its operating cycle T_c according to the equitation:

$$Q_{year} = \frac{3600 \cdot T_C \cdot K_{eu} \cdot Q_{cont} \cdot K_{cu}}{T_{cycle}}, \quad (1)$$

where

T_c Calendar annual fund of time, T_c = 8760 hours;
K_{eu} Coefficient of equipment use, K_{eu} = 0.75;
Q_{cont} Container capacity, t;
K_{cu} Coefficient of the capacity use, K_{cu} = 0.95;
T_{cycle} Time of cycle, sec.

We shall assess the impact of the container's capacity complex on the productivity, accepting the time of cycle according to the passport speed of hoisting of a walking excavator 1 m/s. The time of hoisting to the height of 80 m will be 80 seconds and taking the coupling into account the total time of the hoist's cycle is 220 seconds.

During movement of a dump truck the ascent time to the height of H = 80 metres under the grade of i = 80 $^0/_{00}$ and average speed V = 15 km/h will be:

$$t = H/(1000 \cdot i \cdot V) = 80/(0.08 \cdot 15 \cdot 1000) = 0.067 \text{ hours.}$$

Consequently, during movement of a dump truck, only the time of the truck ascent will be 240 seconds.

The impact of the container capacity (G) on the productivity of hoisting devices (Q) is given in Fig. 2.

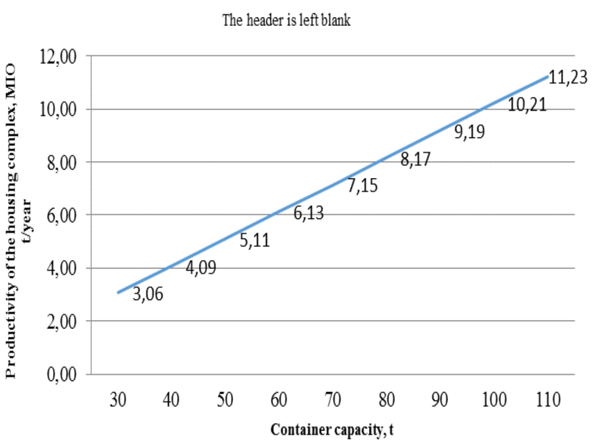

Fig. 2. Impact of the container capacity on the productivity of the hoisting complex

By analysing the graph it can be seen that one complex of hoisting devices with containers with the carrying capacity of 80 tons may secure productivity around 9 million tons/year but if higher productivity is required, it is necessary to increase the number of hoisting complexes.

Results

The efficiency of container hoisting in the container technology of the opencast mining is in the reduction of energy and economic losses due to the down time of vehicles under loading and in the productivity increase of an excavator. The cycle path of a container carrier does not include down time during loading as opposed to dump trucks and railway trains.

The process scheme with the use of hoisting devices of the open-pit mine is sufficiently reliable, flexible and diverse. This allows gradual increasing of the height of hoist, positioning the systems of hoisting devices on the open pit benches, distributing or combining the cargo traffic according to the types of mined rock.

In this case the means for increasing the efficiency of the transport system will be the application of container equipment in the motor transport working area based on the increase of capacity of container carriers with the help of traction engines with an electric drive. If the hoisting height by one hoisting mechanism is insufficient, two- or three-stage hoisting is possible. This will allow reducing or excluding the container conveyance by container carriers, which deliver loaded containers from excavators to the hoisting locations. In the container technology the mined rock according to Fig. 1 is loaded to containers by excavators. Two-three containers are set up in the area of excavator's operations. The exchange of loaded containers to empty ones is performed by automatic loaders – container carriers. They deliver loaded containers to short distances on the container platform in the area of works of the next hoisting device. Container carriers also perform descent of empty containers into the open-pit mine.

In the container technology within the opencast mining the mined rock is loaded by face shovels into containers, which are delivered by hoisting-transport vehicles to the reloading point. Then containers are hoisted to surface by hoists and are delivered to concentrating factories or mine dumps by container carriers. There, a hoist carries out its automatic reloading by gripping it (Fig. 3).

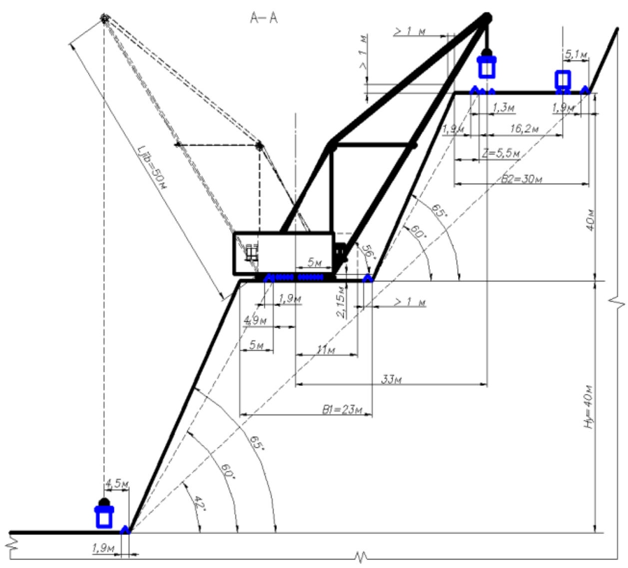

Fig. 3. Passport of setting up a hoist on a bench

Based on the analysis of existing containers that are used in the industry for the transportation of goods, it was found that none of the container designs suits us. Basically, containers are used to transport loose fine goods, and for the transportation of lumpy abrasive rock, the patent search conducted has not given positive results. For transportation of rocks in a deep quarry, a container was designed that has no analogues (Fig. 4). The design of the container is protected by the patent of the Republic of Kazakhstan No. 33091.

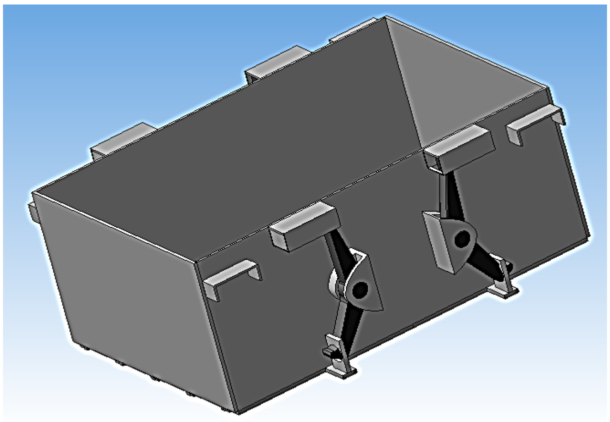

Fig. 4. General view of the container

Structurally, the container is welded, with a drop-down bottom. The opening of the bottom is controlled by the operator of the lifting machine due to the system of mechanical levers. All container assembly elements are tested for mechanical strength using computer simulation methods. The bottom section is attached to the walls on five hinges. When loading, the container is installed on the ground, and the bottom sections are fixed with a locking element – a knee. The container is lifted by the side fittings located on the side walls. In this case, the stops of the load gripping device come into contact with the fittings and keep the container in the closed state. During the unloading process, the stops are released from contact with the fittings, and due to their own weight, the rock is poured out of the container. The bottom closure occurs when the container is installed on the stand, which causes the bottom sections to move upwards until they are completely in contact with the knee. The bottom of the container is one of the most loaded parts and directly perceives the load of the weight of the transported rock, as well as the dynamic load from lifting, transporting and lowering to the surface. In addition, this part of the container perceives the main load from the impact of the loaded rock mass. For the manufacture of the bottom of the container, steel St60 is used. The most labour-intensive operations in the production of loading and unloading operations with large cargoes are their slinging and detaching. Performing these operations manually requires large expenditures of inefficient and unsafe labour of loaders and prevents the introduction of complex mechanised and automated technological processes for loading and unloading. In our case, the usual lifting device is not suitable and, therefore, it is advisable to use a spreader. The following requirements are imposed on the designed spreader: high reliability coefficient and reliability, economical operation, which allows increasing the service life and largely avoiding container deformation, automating container pickup, the possibility of unloading the container and the simplicity of the design. Known constructions of spreaders do not meet the requirements of open pit mining; therefore, the design of the spreader was developed to lift containers in a quarry (in accordance with Fig. 5).

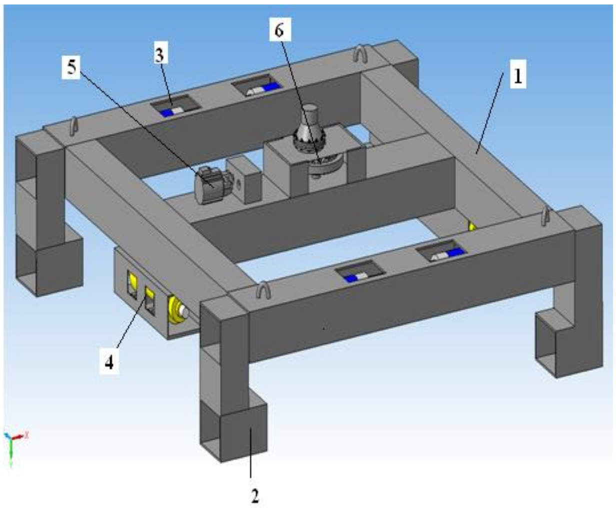

Fig. 5. General view of the gripping device

When transporting containers, the pickup device consists of a supporting beam 1, which is equipped with rectangular grippers 2. The length of the beam increases, and both sides are extended with the help of hydraulic cylinders 3. The grippers move to clamp the container. The beam is equipped with hydraulic cylinders 4, providing unloading of the container. The control hydraulic station 5 is located on the support beam and includes: engine, pumps and control valves. A gear that is rotated by a hydraulic motor located on the spreader 6 is used to centre the container. The beam of the traverse is made of steel grade 10HSND. The material of the bracket for unloading on the container is steel St10. The calculation of the hydraulic system of the unloading device was carried out. The hydraulic drive uses standard assembly items and parts. Hydraulic oil VMGZ (TU 101479-74) is used as a working fluid. The container with the spreader is shown in Fig. 6.

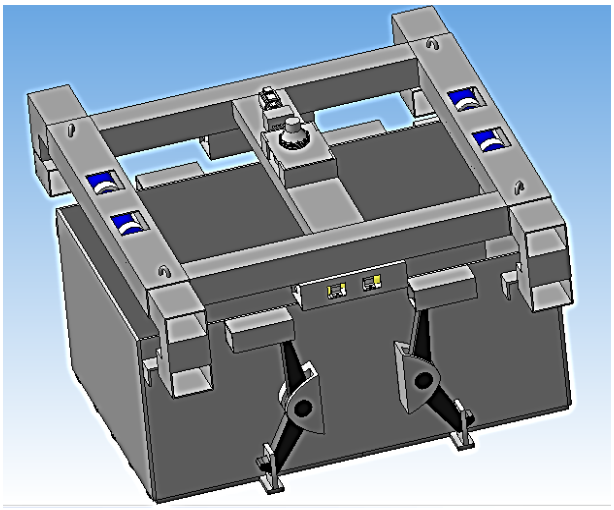

Fig. 6. View of the container with the spreader

The efficiency of the new technology will be reflected in the reduction of the specific energy consumption for transportation of the rock mass compared to the most common technology using road and rail transport with overloading into intra-warehouse warehouses due to cost savings: to lift the rock mass due to lifting it with electric powered hoppers in containers having minimum tare coefficient; from reducing the overburden by reducing the area of the transshipment point, the device of which in this case loses its significance.

Discussion

Calculations of the use of container technologies in deep open-pit mines showed that compared to traditional options of transportation of the mined rock by motor transport or combined motor-railway transport, the energy efficiency of the new technology is obvious and the level of its advantage increases with the increasing hoisting height of the mined rock.

The graph of growth of the economic efficiency of the container technology depending on the depth of an open-pit mine is presented in Fig. 7.

Having analysed the graph it can be concluded that the economic efficiency from the introduction of a container hoisting in the open-pit mine increases with the growing depth of mining. It happens due to the reducing of operating costs, such as diesel fuel consumption, amortised values and decreasing the costs for equipment repairs and reducing the down time of the equipment due to environmental damages.

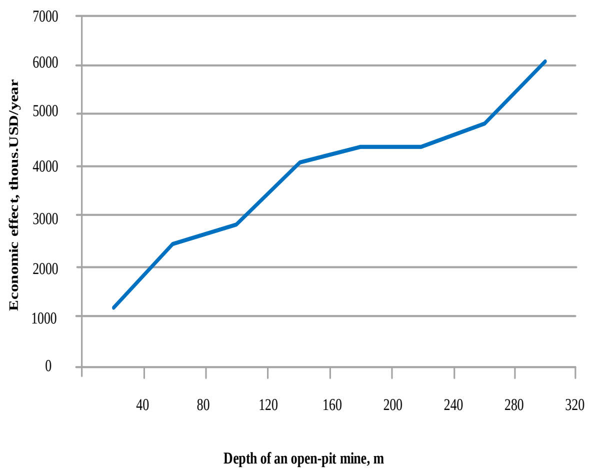

Fig. 7. Dependence of the economic efficiency of the introduction of the container technology on the depth of an open-pit mine

Conclusions

The container technology allows solving the entire set of objectives of the principal technological processes of the opencast mining – from the extracting of rock in the front to loading into vehicles at the reloading warehouse. The use of exchangeable containers in the fronts will significantly change the organisational principles of the excavation-transport hubs, will increase their productivity and a coefficient of the use of excavators within principal operations. Replacement of the obsolete extraction-and-loading equipment with the advanced one and increase of the transport provision of the fronts will increase the level of used area of mining and productive capacity of the open-pit mine.

The major advantage of the container technology is an automation outlook of a range of operations of the transport process in the open-pit mine and on the daylight area. The performed assessment of the economic indicators of the container technology shows its economic advantages over the current methods of mined rock delivery. In the process of technical and economic justification of the introduction of the container technology a detailed comparison of the two technologies of deep horizon development was carried out – with the help of the motor transport and containers. As a result, at all depths of the open-pit mine the economic effect within the range from 1 to 6 million dollars a year was obtained.

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