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Satbayev University

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

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РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

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ELECTROMAGNETIC VEHICLE WITH AUTOMATED CONTROL SYSTEM FOR SURFACE MINING OPERATIONS

Abstract. The modern development of the mining industry is aimed at expanding the development of mineral deposits by surface mining.

Along with the increase in the number of surface mining enterprises, a further increase in the extraction of minerals is associated with the development of deeper horizons. At the same time, the cost of transporting rock mass and its cost increase.

The growing depth of mining operations places new demands on mining and transportation equipment. The effectiveness of traditional types of open-cut transport – sharply reduced at a depth of more than 150-200 m.

The purpose of this research is to develop an electromagnetic vehicle with an automated control system for the delivery of rock mass in large pieces from the lower horizons of the open pit to the surface.

The main focus of research is the design and technical capabilities of the locomotive-free conveyor train engine and the development of a combined electromagnetic drive on the basis of electromagnetic motors with a moving magnetic wire and linear asynchronous motors.

In order to develop a technical proposal for the creation of a locomotive-free automated vehicle, existing designs and control systems for conveyor trains and electromagnetic motors were studied, as a result of which the positive qualities of solenoid type electromagnets and linear asynchronous motors were established, while it was noted that when they are used together as a combined drive, their drawbacks are almost mutually compensated.

The basic idea is to use a hybrid system with electromagnetic drives to move the conveyor train on an inclined track and anelectric unit to control and monitor the interaction of combined electromagnetic drives with the vehicle.

Key words: mining industry, open-pit transport, conveyor train, electromagnetic motor, linear asynchronous motor, automated control system.

Introduction. The entry and consolidation of Kazakhstan in the world mineral raw materials market in the conditions of increasing competition depends on the competitiveness of the products offered, which in turn depends on the quality, quantity and cost of the ores extracted.

The modern development of the mining industry is aimed at expanding the development of mineral deposits by the open method [1,2].

Along with the increase in the number of surface mining enterprises, a further increase in the extraction of minerals is associated with the development of deeper horizons. Over the past 15-20 years, the depth of open pits from the surface of 250-300 meters has already been reached, the project provides for deepening of open pits up to 500-600 m, and in some cases up to 900 m [1]. At the same time, the cost of transporting rock mass and its cost increase. The share of costs for open pit transport in the total cost of mineral extraction is currently almost 60%, and with an increase in the depth of open pits to 500-600 m. they will increase by at least 3 times [2, 3].

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The growing depth of mining operations places new demands on mining and transportation equipment. The use of traditional types of open-pit transport – railway and automobile in the development of deep horizons is associated with an increase in the open pit field, an increase in overburden work during the passage of exits, and in the case of using motor vehicles – and with the creation of an additional ventilation system for cleaning the atmosphere from toxic components of the exhaust gases of the internal combustion engine. The use of conveyor transport is associated with the need for crushing rock mass and a limited angle of transportation. The efficiency of using these types of transport is sharply reduced at a depth of more than 150-200 m.

An analysis of the structure of the cost of one ton of rock mass extracted under these conditions shows that transport costs have the greatest share in this cost. Thus, the share of costs for intra-barrier transport in the total cost of a ton of minerals is almost 50%, reaching about 70% in deep open pits. In this connection, the problem of reducing the cost of transporting rock mass with an increase in the depth of field development and, accordingly, reducing the cost of minerals is important.

The reduction of mineral reserves and their non-renewability are important factors in the development of a strategy for the development of mining production and, in particular, the delivery of rock mass from deep open pits.

Materials and methods. A promising technical solution is the use of steeply inclined lifts formed on the basis of locomotive-free (conveyor) trains with electromagnetic drives, distributed and contactless acting on a vehicle made in the form of a flexible system of running trolleys with a load-bearing surface adapted to loading large-bulk materials, and moving continuously between loading and unloading points [4-6]. One of the advantages of conveyor trains is that, thanks to the distribution of traction drives along the transportation path and continuous interaction with the magnetic field of the engines, it is possible to carry out steeply inclined delivery of rock mass, like a traction rope. In addition, given that open-cut transport is the main environmental polluter in the mining industry, the transition to electric energy will improve the environmental situation in the surrounding open-pit environment.

Currently, electromagnetic motors operating on direct current (solenoid type electromagnets with a moving magnetic wire [5]) and alternating current (linear asynchronous motors [6-10]) are used as consumers of electrical energy in conveyor trains (CT).

The principle of operation of conveyor trains (KT) with solenoid-type electromagnetic motors with a movable magnetic circuit [5] is based on the interaction of the magnetic field created by the inductor when an electric current flows through its winding with a magnetic circuit magnetized in this field connected to a running trolley. As a result of this interaction, the running trolley is set in motion. This happens until the magnetic circuit approaching the inductor reaches the next pole. At this moment, the inductor winding is disconnected from the power source. With the help of induction sensors, the following electromagnetic motor is switched on. The inductor windings are powered from a three-phase network with a line voltage of 380 V and a frequency of 50 Hz through a three-phase bridge rectifier. The switching of inductors is controlled by means of thyristor switches with the use of magnetic energy quenching circuits.

The control of electromagnetic motors using thyristor switches is quite simple and provides their switching mode. However, such control cannot take into account changes in the terrain of the route, as well as when approaching the next engine with this inclusion, the traction force is maximum, which leads to a jerk and heavy load on the car couplings.

When creating high-speed passenger transport and conveyor trains, linear asynchronous motors (LAM) with a traveling magnetic field are widely used [8,9], which work well in a horizontal motion, but with an increase in the angle of transportation, the traveling magnetic field reduces its efficiency. The operation of the LAM is significantly affected by the edge effect due to the open-end magnetic circuits, which worsen such parameters as traction force, power factor, and efficiency.

A linear asynchronous electric drive [11] containing two autonomous voltage inverters (frequency converters) and a linear asynchronous electric motor. A linear asynchronous motor consists of two opposite inductors with working windings and a non-magnetic secondary element. In this electric drive, two voltage inverters are connected to a transformer, and their resulting voltage supplies the windings of a linear asynchronous motor. The disadvantage of controlling frequency converters in relation to high-speed electric drives is low efficiency, due to the fact that the start is carried out not at maximum current and maximum traction force, but at the moment when the traction force exceeds the force of starting the moving part. With a limited length of the moving part, this means that part of its length will not be used immediately with switching on at full current and at maximum power.

The use of frequency converters to control linear motors is widely used but has low informational efficiency, in particular, there is no possibility to control the movement and speed of the vehicle and motor operation.

Using the positive qualities of the above engines, namely, the ability of solenoid engines to develop a large tractive effort to ensure a normal start, and linear asynchronous motors carry out a relatively uniform movement of the train along the track, provides prerequisites when using them in combination to create a steeply inclined lift.

Results. To control the combination of electromagnetic motors, an automated control system was developed at the D.A. Kunaev Institute of Mining.

The technical proposal for the creation of a locomotive-free magnetic transport system consists in combining two principles of magnetic traction, namely, the principle of power electromagnetic traction and the principle of a running magnetic wave.

An experimental sample of a locomotive-free transport, is a trolley that moves along the guide tracks, where electromagnetic motors are installed along the way of the movement. The power electromagnetic traction is implemented using two solenoid electromagnetic motors with a movable magnetic circuit, one of which accelerates the trolley at the beginning of movement, and the other slows it down at the end of movement. The booster engine is installed at the beginning of the track and provides the starting traffic. A linear asynchronous electromagnetic motor (LAEM), containing 12 electromagnets of a running magnetic field, provides traction of the trolley along the course of movement. At the end of the track, an electromagnetic motor is installed to brake the trolley. Figure 1 shows a diagram of the installation of electromagnetic motors of a locomotive-free magnetic transport system.

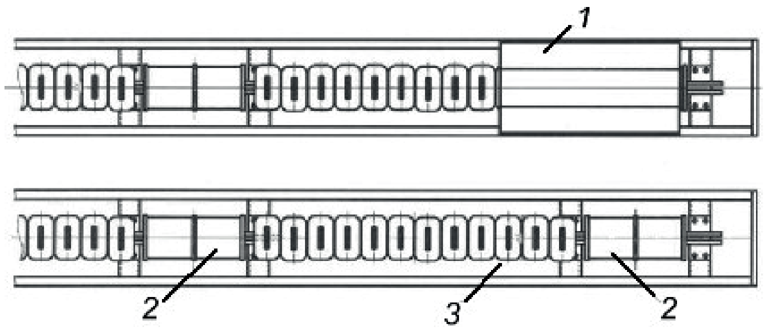

Fig. 1-Diagram of the installation a fragment of a combined electromagnetic motor of a locomotive-free magnetic transport system. (View from above). 1-Trolley, 2-Solenoid type electromagnetic motor, 3-Linear induction electromagnetic motor.

The photo of a fragment of a combined electromagnetic motor of a locomotive-free magnetic transport system is shown in Figure 2.

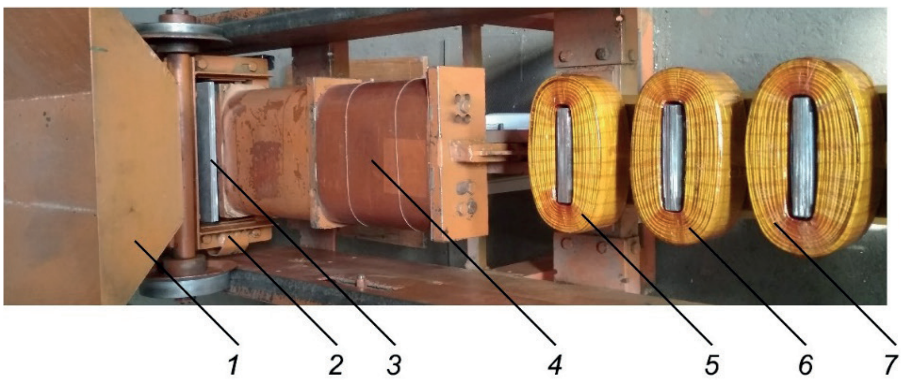

Fig. 2-The photo of a fragment of a combined electromagnetic motor of a locomotive-free magnetic transport system. (View from above).

The principle of operation of a combined electromagnetic motor is based on the interaction of a magnetic field created by a solenoid-type electromagnetic motor (4) and three coils of a running magnetic field (5, 6, 7) with a moving magnetic circuit (2) and an aluminum inductor (3) mounted on the undercarriage (1) when electric current flows. As a result of the magnetic-inductive interaction, the running trolley is set in motion.

Power electromagnetic motors are connected to the industrial network through three-phase rectifiers controlled by an electronic unit based on signals from inductive sensors of the trolley position. Induction coils of a linear asynchronous motor are connected to the industrial network through a switching unit controlled by signals from inductive sensors of the trolley position. The electrical circuit of an automated control system for a combined electromagnetic motor of a locomotive-free magnetic transport system is shown in Figure 3.

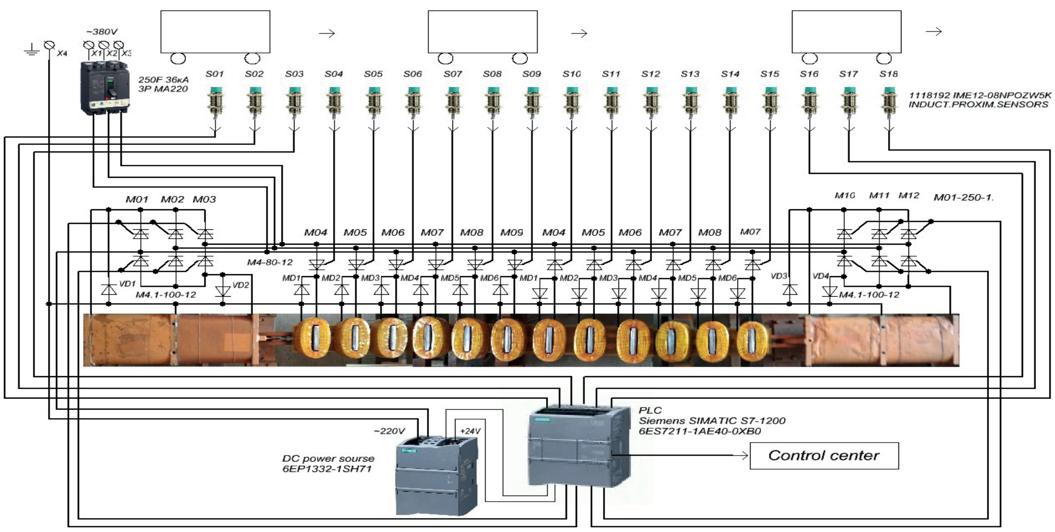

Fig.3 - The electrical circuit of an automated control system for a combined electromagnetic motor of a locomotive-free magnetic transport system.

The windings of the solenoids and induction coils of the excitation of linear motors are powered from a three-phase network with a line voltage of 380 V and a frequency of 50 Hz through three-phase half-bridge rectifiers and single-phase rectifiers implemented on opto-thyristor modules M01-250-12.

The SIMATIC S7-1200 programmable logic controller 6ES7211-1AE40-0XB0 performs general control of an experimental model of a locomotive-free vehicle. The position of the trolley is controlled by eighteen inductive sensors, through which the operator also receives information about the speed of movement, information about the technical condition of the engines (current value, heating of the inductor, etc.). An experimental sample of a locomotive-free vehicle is connected to a three-phase network via an automatic switch LV525439 3P AUTH. OFF. CVS250F 36KA MA220. Protection of opto-thyristor modules from EMF self-induction of induction coils is performed by diode-diode modules M4-80-12, and power electromagnets by diode modules M4.1-100-12.

The diagram of the operation of an automated control system for a combined electromagnetic motor of a locomotive-free magnetic transport system is shown in Figure 4.

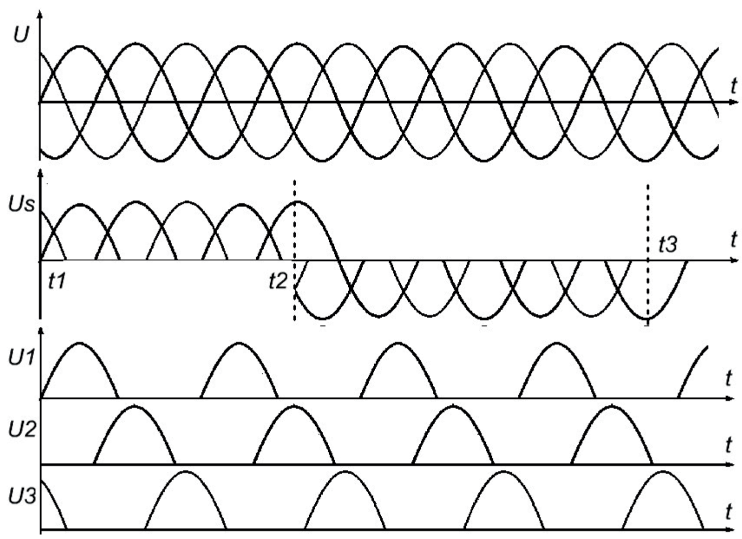

Fig.4 - The diagram of the operation of an automated control system for a combined electromagnetic motor of a locomotive-free magnetic transport system.

The three-phase mains voltage U according to the signal from the sensor S1 at the time moment t1 is converted into a rectified positive voltage Us, which supplies the first half of the solenoid. According to the signal from the sensor S3 at time t3, the second half of the solenoid is de-energized and the trolley approaches the coils of the traveling magnetic field. According to the signals of the sensors S4, S5 and S6, three coils are connected to different phases of the positive voltage U1, U2 and U3, respectively.

Discussion. The solution of the problem of the open-cut transport is associated with the creation of a steep-slope transport installed on the non-working side of the open pit side using combined traction drives based on solenoid-type electromagnets and linear asynchronous motors with an automated control system and control over the operation of transport. The photoof a locomotive-free magnetic transport system is shown in Figure 5.

Fig.5 - The photoof a locomotive-free magnetic transport system.(Front view).

A linear asynchronous motor contains twelve electromagnetic coils in a three-phase connection mode, three coils as they move.

The presence of a programmable logic controller in the automated control system will allow you to control the operation and manage transport through a centralized control system, as well as change the algorithm for switching on the solenoids and investigate the dynamic characteristics of the trolley movement, in order to find out the optimal control mode.

Conclusion. The main results are the development of a technical proposal for a locomotive-free open-pit transport with hybrid electromagnetic drives and a unique automated control unit for the transport complex.

The scientific and practical significance lies in the use of combined electromagnetic motors for the semi-steep hoist, moving along the railroad tracks, installed on the non-working side of the pit, in the development and creation of an automated control system for the reliable operation of the hoist.

The practical significance of the research results is associated with the continuation of work in this direction with the creation of steep-slope transport, which reduces the cost of transportation and improves the environmental situation at the open pit by replacing dump trucks.

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АШЫҚ ТАУ-КЕН ЖҰМЫСТАРЫНА АРНАЛҒАН АВТОМАТТАНДЫРЫЛҒАН БАСҚАРУ ЖҮЙЕСІ БАР ЭЛЕКТРОМАГНИТТІ КӨЛІК

Аннотация. Кен өндіру өнеркәсібінің қазіргі заманғы дамуы пайдалы қазбалардың кен орындарын ашық тәсілмен игеруді кеңейтуге бағытталған.

Ашықтау – кен өндірісі бар тау-кен кәсіпорындары санының өсуі мен қатар пайдалы қазбаларды өндірудің одан әрі артуы терең горизонттардың дамуы мен байланысты. Бұл реттетау – кен массасын тасымалдауға жұмсалатын шығындар және оның өзіндік құны өседі.

Тау-кен жұмыстарының тереңдігінің өсуі тау-кен көлік жабдықтарына жаңа талаптар қояды. Карьер көлігінің дәстүрлі түрлерін қолданудың тиімділігі – 150 – 200 м-ден астам тереңдікте күрт төмендейді.

Осы зерттеулердің мақсаты карьердің төменгі горизонттарынан жер бетіне ірі кесекті тау-кен массасын жеткізу үшін автоматтандырылған басқару жүйесі бар электромагниттік көлікті әзірлеу болып табылады.

Зерттеудің негізгі бағыты – локомотивсіз конвейерлік пойыздың құрылымдық және техникалық мүмкіндіктері және жылжымалы магниттік тізбегі және сызықты асинхронды қозғалтқыштары бар электромагниттік қозғалтқыштар негізінде құрама электромагниттік жетекті дамыту.

Локомотивсіз автоматтандырылған көлік құралын құру туралы техникалық ұсынысты әзірлеу үшін қолданыстағы конструкциялар мен конвейерлік пойыздарды басқару жүйелері мен электромагниттік қозғалтқыштар зерттелді, нәтижесінде сол еноидты электромагниттердің және сызықты асинхрондық озғалт қыштардың оң қасиеттері анықталды, оларды біріктірілген жетек ретінде пайдалану кезінде олардың кемшіліктері іс жүзінде өз ара өтеледі.

Негізгі идея – конвейер пойызын көлбеу жолмен жүргізу үшін және сандық басқару блогы мен және аралас электромагниттік жетектердің көлік құралы мен өзара әрекеттесуін бақылау үшін электромагниттік жетегі баргибридті жүйені қолдану.

Түйінді сөздер: тау-кенөндірісі, карьерлік көлік, конвейерлік пойыз, электромагниттік қозғалтқыш, сызықты асинхронды қозғалтқыш, автоматтандырылған басқару жүйесі.

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ЭЛЕКТРОМАГНИТНЫЙ ТРАНСПОРТ С АВТОМАТИЗИРОВАННОЙ СИСТЕМОЙ УПРАВЛЕНИЯ ДЛЯ ОТКРЫТЫХ ГОРНЫХ РАБОТ

Аннотация. Современное развитие горнодобывающей промышленности направлено на расширение разработок месторождений полезных ископаемых открытым способом.

Наряду с ростом числа горных предприятий с открытым способом добычи дальнейшее повышение извлечения полезных ископаемых связано с разработкой более глубоких горизонтов. При этом растут затраты на транспортирование горной массы и ее себестоимость.

Рост глубины горных работ предъявляет новые требования к горно - транспортному оборудованию. Эффективность применения традиционных видов карьерного транспорта –резко снижаются при глубине разработке более 150-200 м.

Целью настоящих исследований является разработать электромагнитный транспорт с автоматизированной системой управления для доставки крупнокусковой горной массы с нижних горизонтов карьера на поверхность.

Основными направлениями исследований являются конструктивные и технические возможности безлокомотивного конвейерного поезда и разработка комбинированного электромагнитного привода на базе электромагнитных двигателей с подвижным магнитопроводом и линейными асинхронными двигателями.

Для разработки технического предложения по созданию безлокомотивного автоматизированного транспортного средства были изучены существующие конструкции и системы управления конвейерными поездами и электромагнитные двигатели, в результате чего были установлены положительные качества электромагнитов соленоидного типа и линейных асинхронных двигателей, при этом было отмечено, что при их совместном использовании в качестве комбинированного привода их недостатки практически взаимно компенсируются.

Основная идея заключается в применении гибридной системы с электромагнитными приводами для перемещения конвейерного поезда по наклонному пути и цифрового блока управления и контроля за взаимодействием комбинированных электромагнитных приводов с транспортным средством.

Ключевые слова: горнодобывающая отрасль, карьерный транспорт, конвейерный поезд,

электромагнитный двигатель, линейный асинхронный двигатель, автоматизированная система управления.

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