ANNOTATION

Dissertations for the degree of doctor of philosophy (PhD) in the specialty 6D070700 – «Mining»

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JUSTIFICATION OF A RATIONAL TRANSPORT SYSTEM BASED ON ENERGY CAREER CRITERION

Assessment of the current state of the solved scientific or technical problem

Mining as one of the most energy-intensive industries occupies a significant part of the energy balance of Kazakhstan.

The energy intensity of the open-pit mining method is largely (50-90%) determined by the energy costs of transporting the rock mass, which tend to increase with the depth of development.

The modern period of development of the open method of development of deposits of solid minerals is characterized by the growing importance of energy consumption for transport, a buttress of rock, which in the cost structure of mining masses constitute nearly half of all operating costs.

The increase in energy intensity with the simultaneous intensive growth of energy prices becomes one of the main factors limiting the development of mining production, and makes it necessary to introduce highly efficient energy-saving technologies for accounting and reducing the consumption of diesel fuel and electricity by technological quarry transport.

Research in the field of quarry transport conducted by scientists from the CIS countries and the experience of many years of operation have shown that the most effective for quarry conditions is electric traction, which has a number of traction and operational advantages over other types of traction.

The energy advantages of rail transport over road transport are explained by lower values of the coefficient of resistance to the movement of a loaded train (8-10 times) and the coefficient of packaging. The tare ratio of modern dump cars is 0.41-0.50 and domestic dump trucks 0.70-0.84. However, the implementation of these advantages when working on the rise of the mountain mass is limited to a relatively small slope of the railway tracks (40-60%) and a significant coefficient of their development to (1.5-1.8). Therefore, the aim of the thesis is to establish the laws of the influence of the magnitude of the guiding slope of the congresses on the level of energy consumption when lifting the rock mass from deep quarries.

Energy efficiency and minimized operating costs are key factors in selecting the most suitable mining technologies. The global application of semi-stationary (mobile) and mobile (self-propelled) crushing plants leads to a significant reduction in the number of large-capacity trucks used. In addition to cost savings, continuous mining equipment has a huge potential to reduce CO2 emissions from mining operations, thus providing a more environmentally friendly environment.

The basis and raw data for the development of the theme.

The basis for the development of the theme of the dissertation work is to reduce the consumption of various types of energy when moving rock mass in deep quarries by rail, road, conveyor and container modes of transport at the Aktogay and Bozymchak quarries.

As the initial data for the development of the research topic, it is accepted to establish the specific value of energy consumption by different types of quarry transport, which is a quantitative measure characterizing the properties of the development object and the parameters of the associated technological processes.

Modern open pit mining and ore processing facilities are characterized by large scale and capacity of the equipment used. In the conditions of growing shortage of energy, material, labor and other types of resources, the time factor for the implementation of technological processes remains important.

It is established that the criteria of energy efficiency-specific energy intensity and specific action-can be used as criteria for optimization of transport processes of open pit mining.

The main indicators of any production process that should be managed and controlled are the amount of production-conditioned product and the amount of energy consumed during the production process. In this regard, we can conclude about the universality of these indicators, which in principle does not contradict either the physical or the philosophical understanding of energy as a form of movement and work, as a measure of the mechanical interaction of physical bodies.

In the energy assessment of deep pit transport systems, two key issues need to be addressed.

The first is connected with bringing the thermal energy of diesel fuel consumed by motor transport and electric energy consumed by conveyor and rail transport into a comparable form.

In another approach, which has become quite widespread in practice, the consumption of electricity is reduced to the consumption of diesel fuel by multiplying by a factor characterizing the specific fuel consumption for the production of 1 kWh of electricity at diesel power plants (230-250 kg/kWh). Here we clearly overestimate the energy intensity of electrified modes of transport, since the bulk of the electricity mining enterprises receive from power plants running on natural gas, coal and fuel oil. The difference in the estimates of the specific energy intensity of individual modes of transport of deep pits using these methods is 3.0-3.5 times.

In our opinion, the most objective comparison is by reducing the consumption of electricity and diesel fuel to the consumption of primary energy resources, i.e. to "conditional fuel" (C. t.), taking into account the corresponding energy costs for their production, processing and transportation. A similar approach has spread abroad.

The second question is related to the choice and justification of the criterion for assessing the energy efficiency of transport systems of deep pits and individual modes of transport. The criterion for assessing the energy efficiency of transport systems is the main factor that should determine the reliability of the results of the transport of deep pits and the effectiveness of the decision.

Justification of the need for this research work.

The tendency of constant increase of load-carrying capacity of motor transport leads to expansion of area of its effective application. At the same time, the increase in the depth of quarries complicates the operating conditions of vehicles and makes increased demands on its reliability, determined, in particular, by the energy efficiency of production.

The need for this research work is dictated by the demand for improving the energy efficiency of quarry transport, by criterion evaluation of the energy efficiency of various types and types of transport equipment of quarries and establishing patterns of change in the specific consumption of diesel fuel and electric energy by quarry transport during operation in deep quarries, determining ways to reduce energy consumption during transportation of rock mass.

In connection with the above, studies aimed at improving the energy efficiency of transport systems of deep pits and their justification by energy criteria are necessary for research work.

Information about the planned scientific and technical level of development, patent research and conclusions from them are determined by the completeness of the review of the patent search on the problem of methods for establishing the energy efficiency of various types of quarry transport, aimed at improving the performance of quarry transport systems, reducing the consumption of diesel fuel and electricity. It is revealed that the existing methods do not adequately reflect the issues of energy efficiency of quarry transport and there are no methods, techniques and recommendations aimed at streamlining the organization, accounting and control of energy consumption.

Previously performed in patents and works in the career choice of parameters of technological transport are not taken into account energy costs for transportation of rock mass, is not sufficiently justified criteria base the assessment of the energy efficiency of various types of transportation equipment, proper attention is not paid to the patterns of change in specific consumption of diesel fuel and electric energy mining transport when operating in deep pits are not developed and complex technology programs and ways to reduce energy consumption for transportation of rock mass. Therefore, there was a need to fill these gaps.

Information on metrological support of the dissertation.

The thesis is based on experimental and industrial works at Aktogay and Bozymchak mines. The analysis of the research results was carried out on the basis of the laboratory of Aktogay quarry (PAB-Plant Administration Building) and Bozymchak quarry, where devices and installations that have passed the state metrological verification during their operation are used. In tabular and graphical data units of measurement corresponding to metrological rules and norms Of the international system of SI units are used.

Relevance of the topic.

The issues of saving energy resources have faced society at all times. With the increase in the level of development of civilization, this urgent problem is becoming increasingly acute, developing into a crisis of the entire economy.

To successfully solve this problem, it is necessary to establish a system of control and accounting of heat and electricity: the development and implementation of effective technological solutions to reduce the total and specific energy costs, a comprehensive analysis of enterprises on energy conservation; the introduction of alternative, more economical sources of energy production and transmission.

Analysis of the structure of energy consumption in quarries shows that the most energy-intensive process is the transportation of rock mass. The increase in energy intensity with the simultaneous intensive growth of energy prices becomes one of the main factors limiting the development of mining production, and makes it necessary to introduce highly efficient energy-saving technologies for accounting and reducing the consumption of diesel fuel and electricity by technological quarry transport.

The novelty of the topic lies in the substantiation of the principle of energy assessment of technological processes of transport systems of deep pits taking into account the universal criterion of specific energy intensity (specific energy consumption per unit of production) in the conditions of growing shortage of energy resources.

The following new scientific results are obtained:

- a method of energy assessment of different types of quarry transport, based on the established dependencies of specific energy consumption on the rise of the rock mass from the parameters of intra-quarry routes, allowing to form energy efficient transport systems of deep quarries;
- developed methods for establishing rational slopes of quarry tracks on the criterion of minimizing energy consumption for the rise of the mountain mass;
- dependences of energy efficiency of transport systems of a quarry on depth of input of the main transport and the organization of transportations according to the scheme "from top to down" are established.

Connection of work with other research works

The work was carried out in the framework of the lot of the program" energy Saving-2020 "(hereinafter-the Program). The basis for the development of sub-Paragraph 6) of paragraph 2 of the Protocol of the meeting with the participation of the President of the Republic of Kazakhstan dated January 23, 2013 No. 01-7. 1. The state body responsible for the development and implementation of the program is the Ministry of industry and new technologies of the Republic of Kazakhstan (hereinafter MINT).

The aim of the research is to develop a method of energy assessment and practical recommendations to reduce the energy intensity of transport systems in quarries.

The object of the study is the transport systems of deep quarries.

The subject of the study is the energy performance of various types of quarry transport.

Research objectives, their place in the performance of research work in General:

In accordance with the goal in the thesis formulated and solved the following tasks:

1. The analysis of conditions of development of deep pits, technical, economic and energy indicators of operation of various types of quarry transport in the quarries of Kazakhstan is carried out.

2. The method of energy assessment of transport systems of deep pits, based on the minimum energy costs when increasing the slopes of transport communications.

3. A simulation-statistical model of the functioning of different types of quarry transport at different slopes of quarry tracks has been developed.

4. The technique of automated calculation of dependence of energy efficiency of transport systems of a quarry on depth of input of the main transport and the organization of transportations according to the scheme "from top to down"is developed.

The thesis uses a set of scientific research methods, including:

• scientific generalization and technical and economic analysis of the experience of development of deep pits and operation of transport systems;

• energy analysis of open pit mining processes;

• geoinformation and economic-mathematical modeling, multivariate regression analysis, methods of differential calculus.

Methodological base of scientific research

Among the main methods of research and analysis used in the performance of dissertation work are:

- regression and correlation analysis method;
- statistical analysis of operational data;
- building graphical dependencies in Microsoft excel and ANSYS:
- research of influence of mining factors, the scheme of track development, reliability of elements of transport system, capacity of warehouses and bunkers and other technological parameters on productivity of motor-conveyor transport.

Provisions for protection:

- Development of a strategy for the formation of energy efficient transport systems of deep pits, provided with the use as the main criterion of the minimum cost of primary energy resources (conventional fuel) to lift the rock mass, and as an additional-the minimum specific action, linking energy costs with the performance and organization of the transport system.

- Increasing the energy efficiency of transport systems of deep pits is achieved by increasing the slopes of transport communications. For each type of transport, rational slopes of intra-barrier routes are established, providing minimum energy consumption for the rise of the mountain mass.

- Established linkage of energy efficiency of transport systems of open pits to the depth input of the main types of transport (railway tunnels, cell complexes) and the transportation scheme "top down", allow to choose rational parameters of transport systems and provides increased energy efficiency by 17-20 %.

The practical significance of the work lies in the development of a method for establishing rational slopes of quarry routes according to the criterion of energy consumption for the rise of the mountain mass, in particular for dump trucks with Electromechanical transmission, the optimal guiding slope is determined by the quality of the road surface and is: for roads with asphalt concrete coating 80-100, for crushed stone roads 90-110, for roads without coating on a rocky base 100-120‰; for electrified railway and conveyor transport, the optimum slope (angle of inclination of the conveyor lift) is: when operating traction units 40-50, electric traction 30-40, belt conveyors of high performance, their angle of inclination is 170-19°, and for conveyors with a pressure belt 400-600.

Recommendations for the establishment of rational longitudinal slopes of the routes of individual modes of transport on the energy criterion, which should be considered as a private optimum and the lower limit of the slope adopted in the design of transport systems. The final decision on the guiding bias should be taken from the global optimum-the specific energy intensity of the entire transport system and economic indicators. Typically in deep open pit mines, the value of the optimal slope of the main modes of transport, established the energy consumption of the transport system, 10 - 25% higher values for the energy of a particular mode of transport.

Publications and approbation of the work. Publications include 3 articles in journals included in the Scopus database (Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, Ukraine) ISBN 2071-2227 IF 0.20; 3 articles in journals recommended by the Committee for control in the field of education and science of the Ministry of education of the Republic of Kazakhstan; 12 reports at international scientific conferences, two of them in the far abroad (Poland).

The main provisions and results of research on the thesis were reported and approved at international scientific and practical conferences: "VII international Symposium of young searchers" transport problems Katowice, Poland 2017; "IX international conference" transport problems Katowice, Poland 2017. International scientific and practical conference "Rational use of mineral and technogenic raw materials in the conditions of industry 4.0", Kazakhstan, Almaty, 2019;

Scope and structure of work. The dissertation consists of an introduction, four sections, conclusion, list of used sources and appendices. The volume of the dissertation is 102 pages of typewritten text, 6 tables, 30 figures, a list of references, including 108 titles and 4 appendices.

The main content of the work

In recent years, the energy method of evaluation of transport systems of open pit mining has received the greatest development in the works of many scientists. In any technological process, there are three energy components:

1. Theoretical energy intensity of the process - the calculated specific amount of energy required for a given change in the physical state and spatial position of the object.

2. Specific energy consumption - the total amount of energy consumed in a given process per unit of production.

3. Specific energy intensity of the process - the physical specific amount of energy consumed in a real technological process to change the physical state and spatial position of a unit of mass or volume of rocks.

Under the specific energy intensity, we will understand the total amount of energy consumed in a given process per unit of production, i.e. the same as the specific energy consumption.

All experience of researches supported by the analysis of technical literature, testify that this criterion is really universal and can be applied in the most various spheres of material production. This approach has become the most widespread in the practice of open pit mining.

If mining operations in a quarry are carried out according to several transport schemes, the total specific energy intensity is determined from the expression

$$w_k = \sum_{j=i-1}^{m} \frac{w_{mcj} \cdot V_j}{\sum_{k=i-1}^{m} V_k} , \qquad (1)$$

w_{mcj} - specific energy intensity of the j-th transport scheme of transport works, kJ / t;

m – number of transport schemes;

V_j - the volume of excavation and transportation of rock mass according to the j-th technological scheme, t / year;

$\sum_{k=i-1}^{m} V_k = \Pi_k$ – quarry productivity by rock mass, t / year.

As an additional criterion for comparing the energy intensity of various technological processes, the value of the specific action, which is the product of the amount of energy consumed by this technological process, and the time required to perform this process, can be adopted.

$$d_m = \sum_{j=i-1}^{n} w_{mcj} \cdot t_j, \qquad (2)$$

w_{mcj} - specific energy intensity, kJ / t;

t_j - time to perform the i-th technological process, s.

Thus, specific energy consumption is a quantitative measure characterizing the properties of the development object and the parameters of the associated technological processes.

Based on the transport functions of deep pits, as the main criterion for assessing energy efficiency, the value of specific costs for lifting 1 ton of rock mass from the quarry, reduced to primary energy resources – conventional fuel (C.t.) can be taken.

Then the energy efficiency is determined from the expression:

$$\eta=(P_T/P_\Phi)\cdot 100\% \quad , \qquad (3)$$

where P_T – is the theoretically necessary amount of energy consumption for lifting 1 ton of rock mass to a height of 1m (RT=9.81 kJ / t·m);

P_Φ – actual energy consumption by this mode of transport, kJ / TM.

Reduction of actual energy costs to the consumption of primary energy resources is recommended for the following expressions:

$$P_{ф.а} = qk_{пер}k_{т}k_{д}; \quad P_{ф.к.(ж)} = wk_{э}k_{пот}k_{m},$$

where $P_{ф.а}$, $P_{ф.к.(ж)}$ - specific fuel consumption for lifting the mountain mass, respectively, by road and conveyor (rail) transport,

q, w-respectively, the specific consumption of diesel fuel (kg / TM) and electricity (kWh/TM) conveyor (rail) transport;

$k_{д}, k_{пер}$ - coefficients that take into account energy costs for the extraction and transportation of fuel ($k_{д} = 1{,}04 \div 1{,}10$) and for obtaining diesel fuel from oil ($k_{пер} = 1{,}18 \div 120$);

$k_{т}$ - coefficient that takes into account the difference in specific heat of combustion of diesel and conventional fuel ($k_{т}$=1.5);

$k_{э}$ – factor that takes into account the cost of conventional fuel to obtain 1 kWh of electricity ($k_{э} = 0{,}31 \div 0{,}33$ кг/кВт·ч);

$k_{пот}$ - coefficient that takes into account the loss of electricity in transmission and distribution ($k_{пот} = 1{,}09$).

Then the formula (1) can be represented as:

$$\eta = \frac{P_{т}}{F \quad \cdot Q_{y.m}} \cdot 100\%.$$

where $Q_{y.m}$ - specific heat of combustion of conventional fuel, kJ/g ($Q_{y.m} = 29{,}3$ кДж/г).

With equal or similar indicators of specific energy intensity, individual models of vehicles, modes of transport or transport systems, it is necessary to use an additional criterion – the specific action [j•s] is a physical quantity, which is the product of the amount of energy consumed to move the object and the time of its movement. Then the specific action will be written as follows

$$D = P_{\text{о}} \cdot t_n; \quad D_{\text{к(ж)}} = P_{\text{к(ж)}} \cdot t_{\text{к(ж)}} \ ,$$

where $D, D_{к(жс)}$ - specific action, respectively, road and conveyor (railway) transport, kg. u. t. s / TM;

$t_n, t_{к(жс)}$ – average time of lifting of mountain weight, respectively, automobile and conveyor (railway) transport, with.

The presented methodological approach allows to evaluate the energy efficiency of transport systems and individual modes of transport using different types of energy.

In General, the consumption of diesel fuel dump truck for the transport cycle $Q_{\text{ц}}$, l is defined as:

$$Q_{\text{ц}} = Q_1 + Q_{\text{дв}} + Q_{\text{п}} + Q_{\text{р}} + Q_{\text{м}} + Q_{\text{о}} \ , \tag{4}$$

where $Q_1, Q_{\text{дв}}$ - fuel consumption, respectively, for movement with a load and in the empty direction, l;

$Q_{\text{п}}, Q_{\text{р}}, Q_{\text{м}}, Q_{\text{о}}$ - fuel, respectively, during loading, unloading, shunting operations, as well as during the waiting period for loading, l.

In expanded form

$$Q_{\text{ц}} = \sum_{i=1}^{n} l_j \left(g_{\text{гр}} + g_{\text{п}}\right) + \frac{g_1(t_{\text{п}} + t_{\text{о}}) + g_2 t_1 + g_3 t_2 + g_4 t_3}{60} \ , \tag{5}$$

where $g_{\text{гр}}, g_{\text{п}}$ - specific fuel consumption, respectively, of loaded and empty dump trucks on the j-th section of the route, l / km;

l_j - length of the j-th section of the route, km;

n – number of sections of the route;

g_1, g_2, g_3, g_4 - specific fuel consumption, respectively, at idle, during unloading and maneuvering operations, l / km;

t_1, t_2, t_3, t_4 - duration, respectively, loading, unloading, shunting operations and waiting for loading, min.

Specific fuel consumption of loaded and empty dump trucks (l / km) when driving on the j-m horizontal section of the route or on the rise (I 0) and the engines in traction mode

$$g = \frac{g_1(G_1 + k_{\text{п}} G_2)(w + i) k_{\text{п}}}{3{,}67 \cdot 10^2 \cdot \eta \rho} \ , \tag{6}$$

where G_1 – dump truck load capacity, t;

G_2 - own weight of dump truck, t;

w - rolling resistance coefficient on the j-th section of the route;

i - slope of the j-th section of the route;

ρ - density of diesel fuel (p=0.825 / 0.865 kg / l);

g_1- specific fuel consumption at rated engine load;

$k_п$- correction factor that takes into account the change in the value of the bottom in real conditions on the j-th section of the route;

$\eta_а$- the efficiency of the transmission dump truck.

Specific fuel consumption at rated engine load ($g_н$) is a passport value characterizing the actual fuel consumption to obtain 1 kW of useful energy.

$$g_н = \frac{3600}{Q_{дт}\eta_э} \quad , \tag{7}$$

where $Q_{дт}$ - heat of combustion of diesel fuel, kJ/g (=43.5 kJ/g);

$\eta_э$- effective efficiency of the engine.

Hence

$$g_н = \frac{3600}{g \cdot Q} \cdot 100\% \ , \tag{8}$$

A comprehensive assessment based on two criteria of energy efficiency gives the most complete and effective comparison of energy indicators of quarry vehicles.

The energy advantages of rail transport over road transport are explained by lower values of the coefficient of resistance to the movement of a loaded train (8-10 times) and the coefficient of packaging. The tare ratio of modern dump cars is 0.41-0.50, and domestic dump trucks 0.70-0.84. However, the implementation of these advantages when working on the rise of the mountain mass is limited by a relatively small slope of the railway tracks (40-60%) and a significant coefficient of their development (up to 1.5-1.8). Therefore, the aim of the thesis is to establish the laws of the influence of the magnitude of the guiding slope of the congresses on the level of energy consumption when lifting the rock mass from deep quarries.

To lift the train from the quarry, work A 0, equal to the product of the force F on the path S.

$$A_0 = F \cdot S \ , \tag{9}$$

where F is the resultant of the accelerating and decelerating forces acting on the train during its ascent from the quarry.

On the other hand, the work of this force is equal to the increment of the kinetic and potential energy of the train.

Since

$$U_2-U_1=\Delta U=mg\Delta h \ , \qquad (10)$$

where U_2-U_1- change of potential energy, a

$$F=F_k \ \omega_0, \qquad (11)$$

Have

$$(F_k - \omega_0)S=\frac{m}{2}(V_2^2 - V_1^2) + mg\Delta h \ , \qquad (12)$$

where F_k - locomotive tractive effort, N;

ω_0 - total resistance to the movement of the train, N;

m-train weight, kg;

Δh - lift height of the train from the quarry, m

Since

$$F_kS=\frac{m}{2}(V_2^2 - V_1^2) + mg\Delta h \ + \omega_0 S \ , \qquad (13)$$

that

$$A=0{,}5m(V_2^2 - V_1^2) + mg\Delta h \ + \omega_0 S, \qquad (14)$$

where m - is the mass of the train, m / s;

g-acceleration of free fall, m / S2;

Δh - lifting height of the train from the quarry, m.

Thus, the expression (10) represents the level of energy costs for lifting the rock mass from the quarries as the amount of work performed by the vehicle during the movement from the calculated horizon to the mouth of the capital trench. The expression 0.5 m $(V_2^2 - V_1^2)$ characterizes the part of the work performed by the locomotive to give the train kinetic energy during acceleration from speed V1 to speed V2.

One of the main indicators characterizing the efficiency of conveyor transport is the energy intensity of cargo transportation. The main factors influencing the level of energy costs for lifting the rock mass by conveyor transport, in particular belt conveyors, are: the main resistance to the movement of the belt on the rollers, which determines the calculation of the installation power of the drive (the drive station is designed); the angle of inclination of the conveyor belt.

The expression of the specific effect on the rise of 1 ton of rock mass to a height of 1 m (by analogy with road and rail transport) has the form (kW*h*s / t•m)

$$D_{к} = \frac{2,673 \cdot 10^{-2}\left[k_{conp}(1+k_{т})\frac{\omega}{sin a_{K}}+1\right]}{N_{уд}\eta_{к}^{2}} \quad , \qquad (15)$$

where k_{conp} – coefficient that takes into account the share of resistance on the end drums of the conveyor;

$\omega_{к}$ - coefficient of resistance to the movement of the tape on the rollers, N / t;

$a_{к}$ - angle of inclination of conveyors, deg;

$N_{уд}$ - specific power of electric drive, kW / t;

k_{T} - the coefficient of tare of the conveyor.

The optimal longitudinal slope of the tracks according to the energy criterion for individual modes of transport and specific models of vehicles should be considered as a private optimum and a lower level of slope, which is recommended for the design of transport systems. It is determined by fuel efficiency, vehicle design parameters, road surface quality and is characterized by relative constancy for specific vehicle models. Final decisions on the guiding slope of the routes should be made on the basis of the global optimum-the specific energy intensity of the entire transport system (Fig.1.).

The use of the following physical criteria is justified to optimize the slopes of roads in the upland-deep pits:

- the value of specific energy costs for the rise (descent) of 1 ton of rock mass per 1 m (g / t•m);

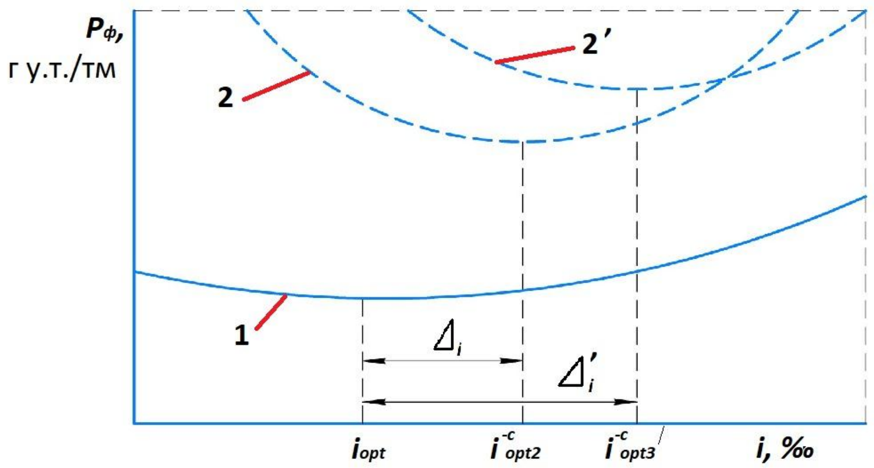
- total time of movement on a slope in the cargo and empty directions at rise (descent) of mountain weight on 1 m (with);

- specific action-a complex criterion, which is the product of the specific energy consumption for the rise (descent) of the rock mass by dump trucks at 1 m, and the time of the rise (descent) of the rock mass at 1 m (g•s/t•m). (Fig.2.).

The change in the specific work for lifting 1 ton of rock mass in railway transport for different slopes of the route is shown in figure 3.

To determine the optimal values of the angle of inclination of a belt conveyor, taking into account the above charts, as well as the conclusion that the dynamics of the increase in linear load ($q_{м}$, kg•m) conveyor systems with the change in height of the transported rock mass, the dependences of the length of the conveyor from the average angle of elevation of a conveyor line and running load of the ribbon (figure 4).

A diagram of the growth of economic efficiency of container technology depending on the depth of the quarry with a capacity of million tons per year is presented in figure 5.



1 - specific energy consumption of main transport; 2, 2' - specific energy consumption of the transport system at the depth of the quarry $H_к$ и $H'_к$ / ; i_{opt}– optimal slope of the route according to the energy criterion (private optimum), i_{opt} = const; i_{opt1},i_{opt2} - optimal slopes of the main transport route according to the energy criterion of the transport system (global optimum); Δi , Δ'_i- intervals of change of an optimum bias with increase in depth of developments.

Figure 1-Selection of the optimal slope area for different types of quarry transport

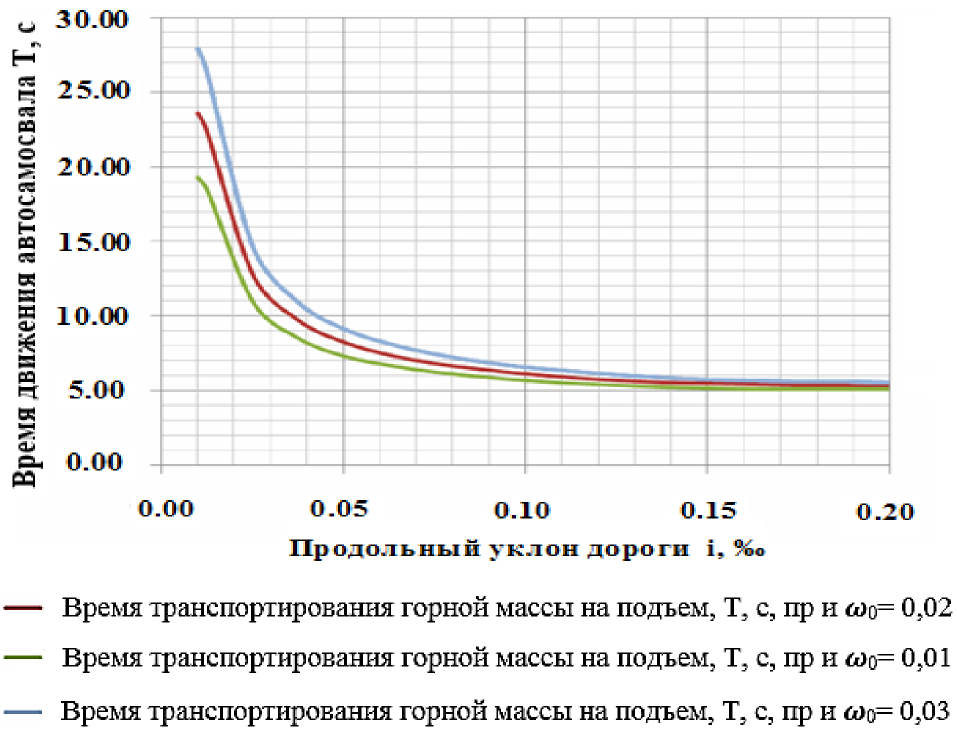
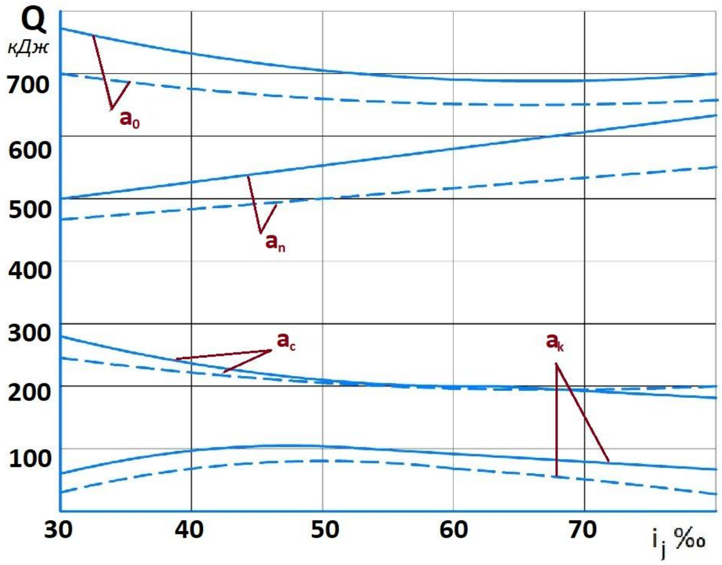


Figure 2 - Dependence of the time of movement of BelAZ dump-

7512 (120 t) in the cargo and empty directions when lifting (descent) of the mountain mass at 1 m, when working on the rise of the mountain mass



a_o – total work for lifting 1 ton of rock mass; a_k – work related to giving the train kinetic energy; a_n – work associated with the change in potential energy; a_c – work related to overcoming resistance to the movement of the train on the track.

Figure 3-Change in the specific work, (a), performed by the locomotive to lift 1 ton of rock mass from a quarry depth of 300 m at different slopes of the route

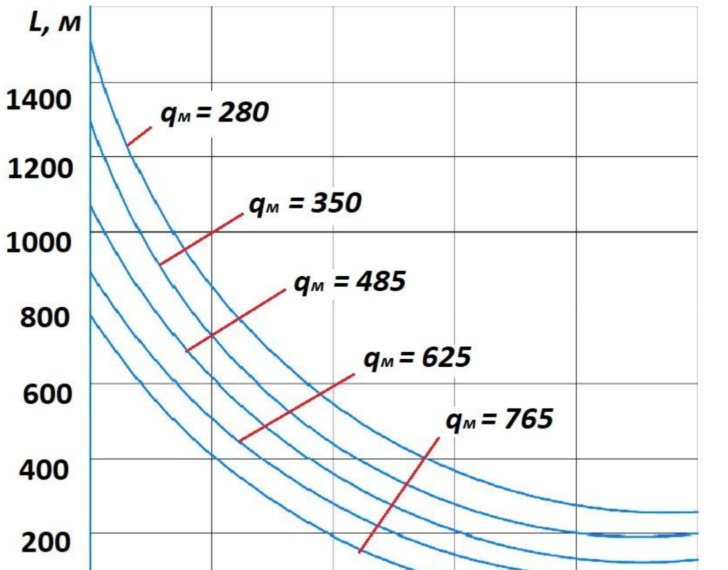


Figure 4-Dependence of the conveyor length (L) on the average lifting angle (α) of the conveyor route and the linear load on the belt (QM, kg * m)

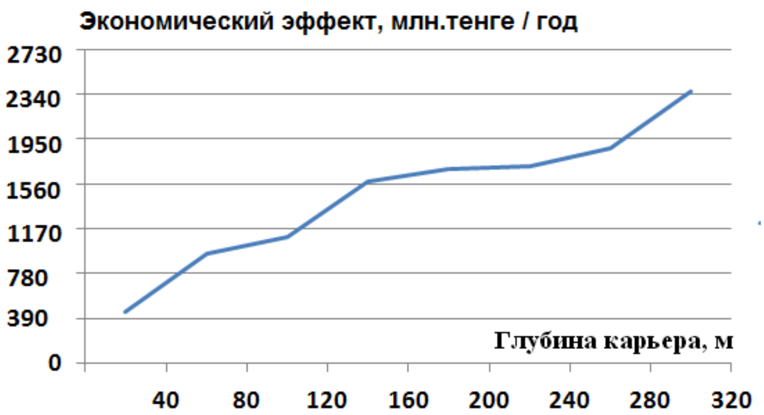


Figure 5-Dependence of economic efficiency of container technology implementation on quarry depth

Analyzing the graph (Fig.5) it can be concluded that the economic efficiency of the introduction of container lifting at the quarry increases with the depth of development. This is due to lower operating costs such as diesel fuel consumption, depreciation charges and lower equipment repair costs.

Figure 6 shows the results of calculating the energy consumption options for transporting materials in quarries depending on different elevations for technologies using dump trucks and conveyor belts. The values of energy consumption are correlated to the mass of the transported material and the shortest horizontal distance of transportation. The third curve describes the ratio of energy consumption between dump trucks and conveyor belts.

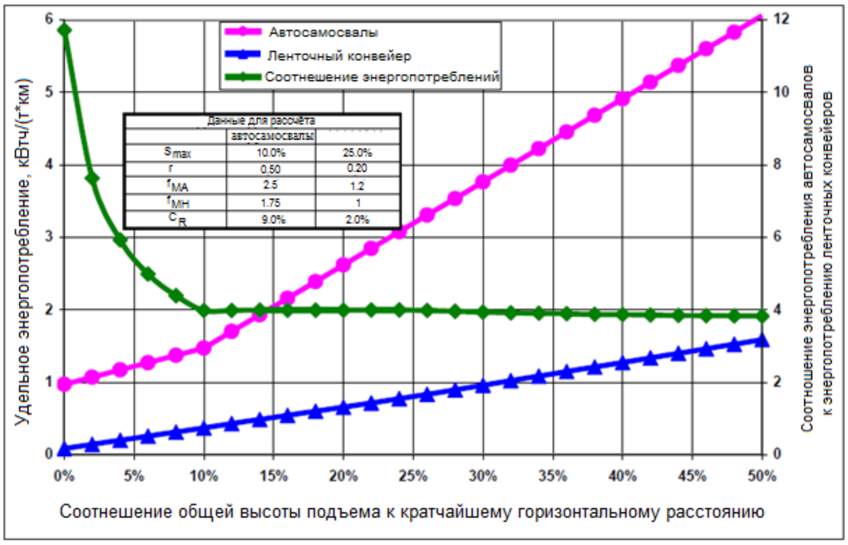


Figure 6-Diagram of energy consumption when changing the lifting height for transportation by dump trucks and belt conveyors

For implementation in open-pit mining, a new road-conveyor-container (a-K-K) technology for transporting rock mass is proposed, which will increase the performance of open-pit mining to save energy and preserve the environment at a qualitatively new level.

The refusal to lift the mountain mass by motor transport makes it possible to increase the maximum slopes of the road trains, as they will be used to move only empty cars. A possible transition from slopes of 8% to slopes of 15% will reduce the area allocated in the quarry for the placement of road trains.

Known recommendations on the choice of rational parameters of transshipment points in the cyclic flow technology with the use of dump trucks can not be used because of the design and technological features of the transport system with vehicles.

To solve this problem, a method for determining the rational energy parameters of transshipment points with cyclic flow technology with the use of dump trucks has been developed. Let the hopper reloading point receives Poisson flow with the parameter λ, the service time of each dump truck tobs is a random value that obeys the exponential distribution law with the parameter μ, all unloading points at the reloading point of the same performance.

Based on the conditions of ensuring the smooth operation of the loading equipment in his career, coming in the transshipment cargo point QA (performance trucks) must be equal to the quarry capacity Q, i.e. QA=QK. Taking into account the uneven operation of loading and transport equipment, the productivity of the quarry (t / h) can be represented as

$$Q_K = N_э Q_э^{тех} K_э К_в К_{нер}^{э} К_{нер}^{от}, \quad (16)$$

where *Nэ* – number of working excavators in the quarry, PCs.;

$Q_э^{тех}$- technical performance of the excavator,

$K_э$- ratio of optic Cup;

$К_в$- the utilization of the excavator.

$К_{нер}^{э}$- the irregularity factor of the work of the excavators;

$К_{нер}^{от}$- the coefficient of unevenness of the dump truck;

Figure 7 shows a graph of the dependence of the rational capacity of the hopper on the productivity of the quarry for the following indicators:

$Q_k = 5 \div 20$ млн.$\frac{т}{год}$; $q_а = 60$ т;

$t_{obc} = 90$ с – для автосамосвалов грузоподъемностью 60 т;

$t_{obc} = 120$ с – для автосамосвалов грузоподъемностью 91 т.

Studies show that with an increase in the productivity of the quarry twice the rational capacity of the hopper increases by 1.7 times at $q_а = 60$ tons and 1.8 times at 91 tons. Increasing the capacity of dump trucks from 60 to 91 tons, other things being equal, makes it necessary to increase the capacity of the hopper by 1.3 times.

The materials presented in the dissertation and the systematized conclusions testify to the significant reserves of increasing the energy efficiency of transport systems of deep pits.

The feasibility of using simulation models to study the parameters of multi-link road-conveyor-container (r-c-c) transport systems at quarries is due to the following:

1. Structural and functional complexity of systems, the analytical description of which is significantly difficult. Simulation models can be built without the involvement of complex mathematical apparatus with the obligatory preservation of their logical structure.

2. The need to take into account the stochastic nature of mining and transport processes. The application of the Queuing theory apparatus for these purposes, taking into account the adaptation of the model to solving a wide range of problems, objectively leads to an increase in its dimension, complexity, and decrease in the accuracy of calculations. Simulation models are the most effective for the study of the energy performance of the system in dynamics, when random factors participate in its functioning (Fig.8).

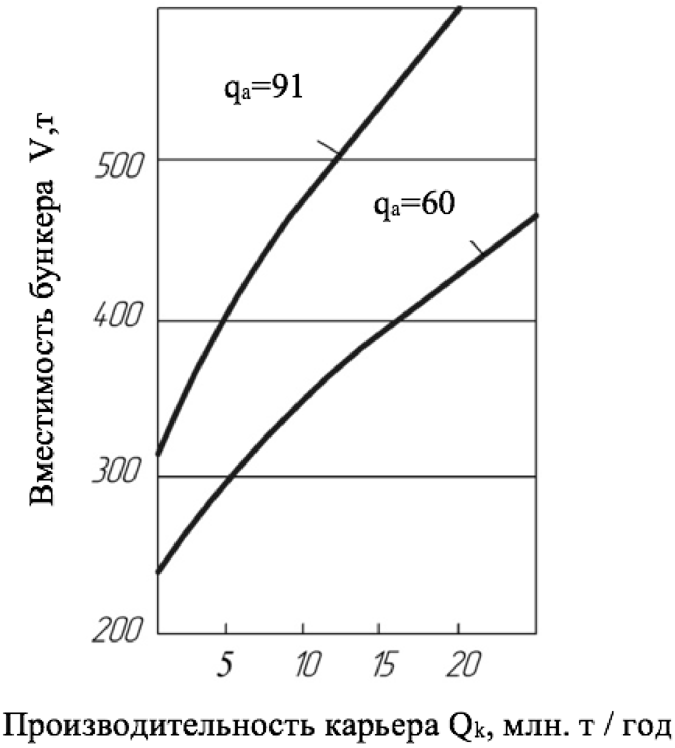


Figure 7-Dependence of the rational capacity of the hopper V on the performance of the quarry Qk

In order to unify and simplify the modeling process gamma distribution is used to identify distributions of random variables:

$$f(a,v,x) = \frac{a}{\Gamma(v)} x^{v-1} e^{-ax} \quad ,$$

$$v = \frac{1}{v^2} : a = \frac{v}{x} \quad ,$$

where v and x are respectively the coefficient of variation and the expectation of the value.

The functioning of ACC transport can be described by a set of state vectors and moments of state change of system elements.

State vector of road transport VSSA = (VS1, VS2)

VS1 = 1- the presence of a flow of dump trucks;

O - the lack of flow of dump trucks

The vector of States VS2 is formed at the moment of arrival of the next dump truck at the crushing and transshipment point

VS2 = 1- the dump truck is unloaded;

O - no unloading

Vector of moments of change of States in functioning of automobile link

VS = {MLPA, MNOA,MPA},

where MPLA - the moment of resumption of the organized flow of dump trucks;

MNOA-the moment of interruption of the flow of dump trucks;

MRA-the moment of unloading dump trucks.

The block diagram of the simulating algorithm is shown in Fig. 8. Input of initial data is carried out in block A_2 B_2. In blocks A_4 B_4 and L_2A_2, the interval of the working state of the K th conveyor TRK(K) is determined by the corresponding distribution.

Currently, Kazakhstan's quarries have significant organizational opportunities to reduce diesel fuel consumption, including:

- improving the management of vehicles, including the introduction of automated control systems with computer devices;
- improving the quality of maintenance and repair of dump trucks;
- improvement of rationing and planning of fuel consumption.

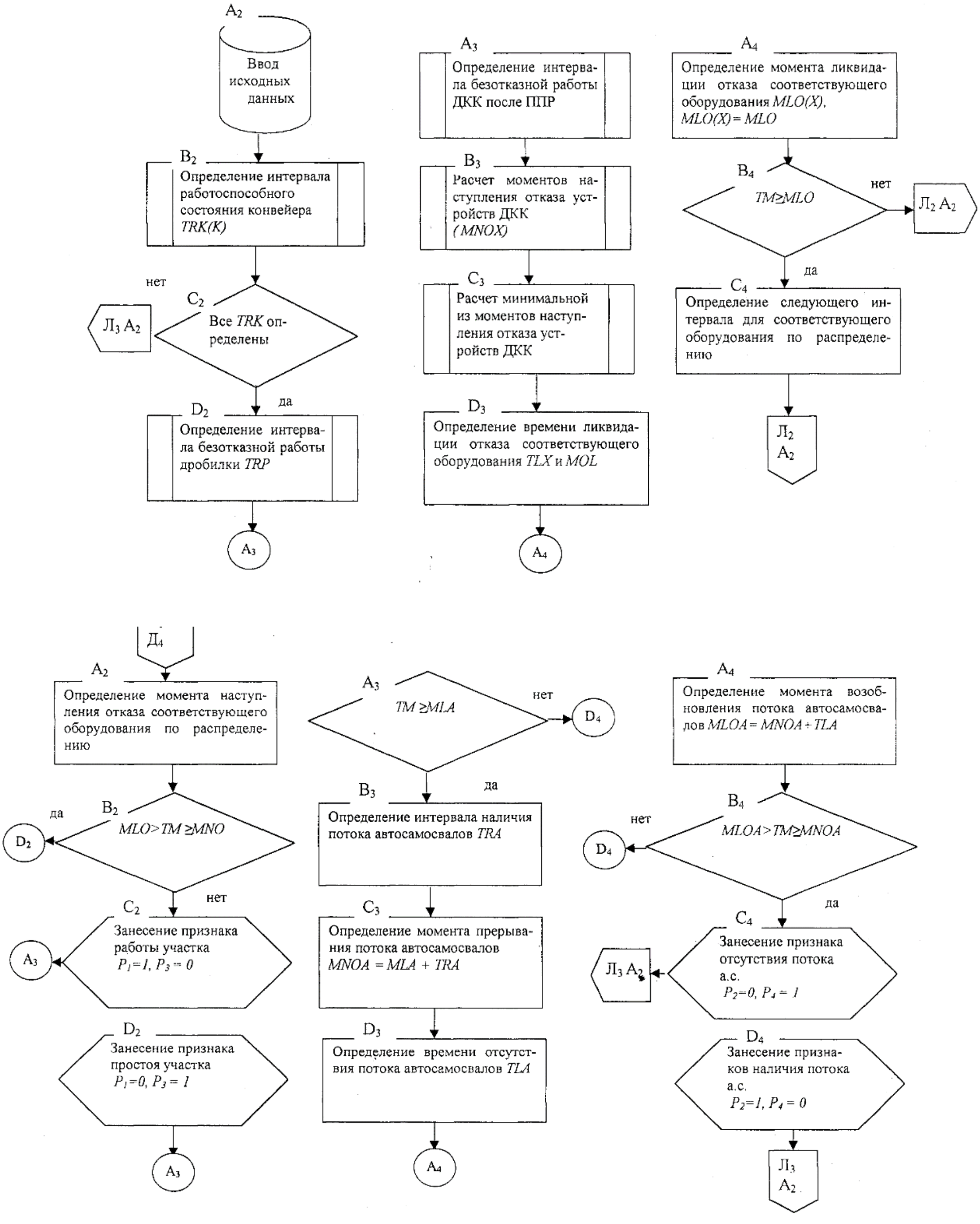


Figure 8-Block diagram of the algorithm of the simulation model of a-k-k. transport

Conclusion

As a result of performed researches, this new solution of actual applied problems of improving the energy efficiency of transport systems of deep open pits, namely the development of the method of energy evaluation of different types of quarry transport, optimization gradients of transport and communications and the development of automated methods of planning and regulation of diesel fuel consumption on the basis of GIS data bank.

The main scientific conclusions, results and practical recommendations are as follows:

1. The method of energy estimation of transport systems of deep pits is developed. It justifies the use as the main criterion for assessing the value of specific costs of primary energy (equivalent fuel) per lift 1 tons of rock by 1 m, as - specific actions, representing the work of specific energy consumption for lifting the rock mass and the time of ascent is between power inputs performance and organization of work of transport.

2. It is established that the energy efficiency of conveyor transport ($P_к$) is 2.0 times higher than that of electrified railway transport ($P_ж$), and 2.0 - 2.5 times higher than that of road transport (P_a).

3. 3. Optimization technique of slope career tracks based on the criterion of energy consumption for lifting the rock mass. It is established: for dump trucks with Electromechanical transmission, the optimal guiding slope is determined by the quality of the road surface and is: for roads with asphalt concrete coating 80-100, for crushed stone roads 90-110, for roads without coating on a rock base 100-120 ‰; for electrified railway and conveyor transport, the optimal slope (angle of inclination of the conveyor lift) is: when operating traction units 40-50, electric traction 30-40, belt conveyors with a clamping belt of high performance, their angle of inclination is 380-40°.

4. 4. The optimal longitudinal slope of the routes of individual modes of transport according to the energy criterion should be considered as a particular optimum and the lower limit of the slope adopted in the design of transport systems. The final decision on the guiding bias should be taken from the global optimum-the specific energy intensity of the entire transport system and economic indicators. Typically in deep open pit mines, the value of the optimal slope of the main modes of transport, established the energy consumption of the transport system, 10 - 25% higher values for the energy of a particular mode of transport.

5. Due to the complexity and dynamism of the operating conditions of dump trucks in deep quarries, it is advisable to plan and normalize energy indicators on the basis of the developed complex methodology, including: experimental-analytical method of studying and describing the energy indicators of quarry vehicles; creation of geoinformation model of road communications; geoinformation data block-a set of databases of mining equipment, systems of road communications, primary surveying information and software tools for their

interaction, management and processing; creation and maintenance of the block of information-advising (expert) data.

6. The application of a comprehensive methodology for calculating the energy performance of transport systems allows to increase the scientific validity and accuracy of planning and rationing of diesel fuel consumption by dump trucks by 9-12% compared to existing methods.

7. Improving the energy efficiency of open-cut transport systems (17 - 20%) is provided by deep input of main types of transport (railway tunnels, cell complexes) and the organization of transportations under the scheme "top-down". The main directions of improving the energy efficiency of dump trucks on the main transport are the introduction of dump trucks with automatic hydromechanical transmission and the use of increased (10 - 12%) slopes of roads, and on the Assembly-optimization of opening schemes by temporary congresses. Developed on the basis of research "Method of automated calculation of energy indicators of quarry vehicles" and "Linear differentiated norms of diesel fuel consumption by dump trucks" adopted for implementation at the career of JSC "Aktogay".

8Grounded theoretically and practically permissible tension load and the clamping of the conveyor belt in the transition area of the boot node SIC by varying the elastic characteristics of the rubber tapes; the values obtained for the pre-tension and the radius of the transitional phase, obtained on the basis of the developed complex methods of research. The mathematical model of the stressed state and carrying clamping strips, which is described by a system of equations, the variable parameters which are the moduli of elasticity of the ribbons in the longitudinal and transverse direction, Poisson's ratios and the load acting on the tape.