ABSTRACT

of dissertation for the degree of Doctor of Philosophy (PhD)
6D070700 – Mining

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DEVELOPMENT OF THE MINING TRANSPORT SYSTEM OF IRON ORE MINES WITH THE INCREASE OF MINING DEPTH

Assessment of the current state of the scientific and technical problem being solved.

Improvement of the mining transport equipment associated with the increase of unit capacity of shovels (with a bucket capacity of 40 to 50 m^3), haul trucks (with a capacity of 300 t and higher), high-angle conveyors (with an angle of up to 50°) continues at the present state of development of the geotechnology of open pit mining, at the same time, achievements in the sphere of blasting technology (application of new types of explosives and blasting patterns), geomechanics (justification of the transition to steeper angles of pit walls, reinforcement of bench slopes, monitoring of the marginal solid), hydrogeology (pit dewatering) and more allow to create large ultra-deep open pits of the new generation.

All this leads to the fact that there are already pits with a depth of 450-500 m (already up to 700-800 m abroad, mostly mountain-top) and there is a real possibility of increasing their depth to 650-800 m. At the same time, new problems arise, among which one of the key ones is the problem of ensuring cargo transportation connection of the open pit space with the production complex on the surface.

The solution to the problem of transporting rock mass is directly related to increasing the productivity of the open pit and reducing the cost of the extracted mineral. Increasing the depth of the open pit involves changing the transportation schemes. The current trend indicates the expediency of switching from cyclic to cyclic-flow technologies (CFT), which provide the best economic indicators at great depths. In many iron ore open pits of Eurasia, the combined haul truck and railway mode of transport has been widely used. In the far abroad, motor transport is mainly used in mountain-top open pits, and on flat terrain in deep open pits, the expediency of switching to haul truck-conveyor transport using steep-slope conveyors is being studying.

Quite a lot of work has been devoted to solving the problems of the effective use of CFT in deep iron ore open pits. This once again underlines the strategic direction of the CFT in the development of geotechnology and geotechnics.

The fundamental principles of the effective development of open-pit mining technology using various modes of transport, the development of theoretical and practical foundations for the selection and justification of rational options for tapping deep horizons of open pits using cyclic-flow technology are reflected in

the works of the following Soviet, domestic, Russian and Ukrainian scientists: academicians of the USSR Academy of Sciences N.V. Melnikov, V.V. Rzhevsky, academicians of the Russian Academy of Sciences K.N. Trubetskoy, N.N. Melnikov, academicians of the National Academy of Science Republic of Kazakhstan B.R. Rakishev, N.S. Buktukov, academicians of the Academy of Mining Sciences of Ukraine A.Yu. Drizhenko, M.S. Chetverik, academician of the National Academy of Mining Sciences Republic of Kazakhstan S.K. Moldabayev, corresponding member. Academy of Sciences of the USSR A.O. Spivakovsky, corresponding member of RAS V.L. Yakovlev, prof. M.V. Vasilyev, V.A. Galkin, M.G. Novozhilov, V.S. Khokhryakov, M.G. Potapov, P.P. Bastan, T.I. Tomakov, K.E. Vinnitsky, V.P. Smirnov, A.N. Shilin, A.A. Kuleshov et al.

Relevance of the topic.

World practice shows that it is difficult to compete in the mineral raw materials market without switching to continuous flow process technology in deep open pits. Domestic iron ore open pits have reached critical depths at which it is impractical to use only rail, road transport and their combinations. Increasing the haulage distance by haul trucks increases operating costs exponentially.

The experience of operation of domestic open pits and the results of the analysis of the prospects for technological progress make it possible to state with sufficient confidence that in the next 10-15 years the transport systems of deep open pits will be formed on the basis of three types of transport: haul trucks, railway and conveyor, as well as their combinations.

The trade-off method, widely used in the practice of justifying design decisions, allows for some estimated time to determine capital and operating costs and evaluate the compared technological schemes of transport as a whole. However, the specifics of the development of deep-type open pits is that the mining conditions of operation differ significantly for different working horizons at the same time and change as the mining depth increases. In this regard, the effectiveness of a particular transport scheme can be assessed only taking into account the differentiation of the costs of transporting rock mass by various modes of transport, depending on the volume, haulage distance and lifting height of the cargo as the main factors that form the cost of transportation and the patterns of its changes as the open pit is processed.

It should also be taken into account that the technical and economic indicators of development for each specific deposit may vary significantly. Therefore, research on the optimization of the zone of application of various types of transport in deep and ultra-deep open pits is especially relevant at the present time. The economic feasibility of investments in the transition of mining operations to deep horizons depends on this.

The purpose of the research.

The purpose of the thesis research work is to develop a mining transport system of iron ore open pits with the increase of mining depth based on the establishment of the boundaries of the effective use of links of combined transport schemes using a high-angle conveyor to reduce the cost of transporting rock mass.

The object of research is the combined mining transport systems of deep pits.

The subject of the research is the change in the parameters of the schemes of combined open pit transport with the increase of mining depth

Research objectives, their place in the performance of research work in general.

In accordance with the set goal, the main tasks are formulated and solved in the thesis work:

1. Study, analysis and systematization of in-pit means of transport with the cyclic-flow technology to select the optimal strategy for the formation of a mining transport system of deep pits;

2. Development of an optimization dynamic economic and mathematical model to substantiate the feasibility of using high-angle conveyors as part of a combined haul truck-conveyor-railway transportation scheme in deep iron ore open pits;

3. Development of a calculation algorithm and, based on it, an economic and mathematical model for establishing the optimal depth of the railway and conveyor transport entry during the transition to a combined haul truck-conveyor-railway transportation scheme for ultra-deep iron ore open pits.

Research methods.

Both traditional and modern methods of scientific research were used to achieve the goal and solve the set thesis tasks. Traditional methods include: analysis of scientific and patent literature, systematization, classification, description, comparison, application of engineering formulas and scientific facts, heuristic models, planning of computational experiments and processing of experimental data. When constructing the calculation algorithm, in particular, the abstraction and analytical methods were used to isolate the parameters that most significantly affect the depth of introduction of cycles of the cyclic-flow technology. The developed algorithm was applied in the formation of an economic and mathematical model for optimizing the parameters of the transport system during the completion of the Kachar iron ore open pit.

Scientific provisions submitted for defense:

1. The choice of the optimal strategy for the formation of a mining transport system of deep open pits is achieved on the basis of a dynamic economic and mathematical model, which includes, from the standpoint of a systematic approach, the relationship of the parameters of open pit transport with the mining conditions and parameters of the open pit changing during operation;

2. In the conditions of open-pit mining of iron ore deposits with a thick thickness of covering dense rocks (up to 160 m), the efficiency of the mining transport system from a depth of 300-350 m is ensured when switching to a

combined haul truck-conveyor-railway mode of transport using high-angle conveyors with a lifting height of ore up to 315 m, and rock overburden - up to 270 m;

3. For the conditions of ultra-deep iron ore open pits, using the Kacharsky open pit as an example, on the basis of an economic and mathematical model, the boundaries of effective use of types of in-pit transport in depth have been established: the optimal depth of railway transport entry in combined haul truck-railway transport is limited to 149 m, and the conveyor lift in combined haul truck-conveyor-railway transport using high-angle conveyors is 344 m.

Scientific novelty:

1. In the context of development of the theory of configuration of in-pit transportation means with the cyclic-flow technology, the following was done:

- systematization of vehicles, the distinguishing features of which are the nature of work in time, the method of moving cargo, the turning radius, the annual volume of traffic, the rational distance of transportation and the depth of lifting cargo from the open pit, the maximum size of the transported piece of rock and the main required characteristics and parameters;

- systematization of lifting and transport equipment of CFT complexes for the use on steep pit walls of deep open pits, which shows the types of equipment, design parameters, power consumption, capacity, conditions of use, manufacturers, combination with equipment of related processes;

2. A dynamic economic and mathematical model has been developed for establishing the boundaries of the effective use of high-angle conveyors in a combined haul truck-conveyor-railway mode of transport, which allows determining their payback period and reduced profit by reducing transport costs.

3. An economic and mathematical model has been developed to optimize the depth of railway and conveyor transport entry, which allows to establish the boundaries of their effective use when switching to a combined haul truck-conveyor-railway transportation scheme for ultra-deep iron ore open pits.

Practical value of the work.

The methods and sequence of research , as well as the developed algorithm, can be applied when performing similar work for other deposits of solid minerals being developed in an open pit manner, which is confirmed by the Act of acceptance of the results of the thesis for implementation in the project by the design company Antal LLP as scientifically sound provisions for the design of combined transport schemes in the development of steep-falling deposits of the Republic of Kazakhstan.

Personal contribution of the author.

The thesis work is an independent complete scientific work. All theoretical and practical results submitted for defense were obtained by the author independently and published in professional publications. Search and analysis of literary sources on the subject of thesis research, development of computer,

heuristic and analytical models, economic evaluation of the proposed technology was carried out by the author personally.

Publications and approbation of the work.

11 scientific articles have been published on the topic of the thesis:

- 2 articles in journals included in the Scopus and Web of Science database – "Mining of Mineral Deposits" CiteScore=2.2, Percentile (Geotechnical Engineering and Engineering Geology) – 50th; and "Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu" CiteScore=1.9, Percentile (Geotechnical Engineering and Engineering Geology) - 45th;
- 3 articles in journals recommended by the Committee for Control in the Sphere of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan;
- 1 report and 2 publications in local scientific and practical conferences;
- 1 report at the international conference of the Far abroad MPES-2017 (Lulea, Sweden) and 2 publications in the collections of international SGEM conferences indexed in Scopus.

The main results of the thesis research are as follows:

1. The systematization of vehicles for deep open pits and the systematization of lifting and transport equipment of CFT complexes for the use on steep pit walls of deep open pits were carried out. Cyclic-flow technology complexes for the conditions of the Kacharsky open pit were selected, configured and justified;
2. An algorithm of optimization of working zones from top to bottom in terms of depth has been developed and tested for the railway transport, haul trucks for lifting with reloading of rock mass to railway transport, as well as lowering and lifting with reloading of rock mass to the conveyor lift;
3. It is proved that the transition from a combined haul truck-railway to a combined haul truck-conveyor-railway mode of transport is economically feasible and will expand the boundaries of the effective use of an open method of development of iron ore deposits.

The structure and scope of the thesis.

The thesis work consists of an introduction, four sections, a conclusion, a list of references and appendices. The volume of the thesis is 142 pages of typewritten text, 18 tables, 33 figures, a list of references, including 95 titles and 3 applications.