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Abstract: *The article presents the results of scientific research into the analysis of factors influencing the efficiency and productivity of excavator-truck complex in quarries. According to the given data it has been established that there are different scientific approaches to providing effective work of an open-pit excavator-automobile complex.*

It is pointed out that the efficiency of work of the excavator-and-truck complex depends on the mountain-geological conditions of the deposit, the physical and geotechnical properties of the rock mass, the geometrical capacity of the dump truck body and the excavator bucket, the relations between them, the idle time of the mining equipment, the distance of the rock mass transportation, the time of loading, the coefficient of the dump truck loading capacity, the characteristics of the highways, etc. However in the majority of the scientific publications is marked the importance of observance of optimum correlation between dump truck body capacity and excavator bucket capacity for the purpose of providing highly productive work of the complex of the mining equipment.

Keywords: *open pit, equipment, productivity, excavator-automobile complex, dump truck body capacity, excavator bucket capacity, rock mass.*

Introduction. Excavator-truck complex (ETC) at surface mines is a separate part of the technological system of the mining enterprise. The effectiveness of its work depends on the interaction of the individual elements, namely, excavators and dump trucks. They, in turn, are characterized by specific technological and design parameters.

In determining the factors affecting the efficiency of ETC in general, apply a theoretical approach, the experimental approach, as well as modeling. The use of theoretical dependences obtained in studies concerning the effective operation of ETC usually gives overestimated results, since in this case all negative factors are not taken into account in the process of excavation and loading operations. Experimental methods of research are characterized by the highest accuracy of results, but their use is effective only in specific mining and technical conditions of a particular mine. In addition, at carrying out experimental researches it is necessary a long duration of time and considerable material expenses. Modeling on the basis of application of specialized software complexes allows to estimate influence of separate factors on efficiency of operation of the complex. However, in this case, ETC operation will be simulated for ideal conditions. Accordingly, the research result will be inaccurate. Therefore, when investigating the factors influencing the efficiency of the complex operation, it is necessary to try to apply a comprehensive approach with the use of all previously considered research methods.

Purpose and objectives. The purpose of the study – to establish the main factors affecting the effective operation of the excavator-truck complex in the quarry.

The task of the study – on the basis of a detailed analysis of literary sources, to determine the factors of influence on the performance of excavator-truck complex and to identify the main ones.

Material and results of the research. A significant number of scientific works are devoted to the issues of increasing the efficiency of ETC operation. As noted by experts, one of the most important factors in improving the efficiency of ETC at mines is organizational improvement of the process of loading and transportation of rock mass [1]. In this case, the vast majority of scientists believe that the productivity of individual mining-loading and transport equipment in the development of rock mass is the main indicator of the effective operation of the complex of equipment [2]. Consequently, the main condition for maximum efficiency of excavators and dump trucks is their coherence.

Scientists who researched the work of ETC directly in quarries, noted that the capacity of the body of dump truck is the most important design parameter, which depends on the relationship between the capacity of the bucket excavator, the density of the extracted rock mass and the distance of its transportation [1]. It is suggested to form a complex of mining-loading and transport equipment in such a way that the number of

excavator buckets in the car body provides the maximum coefficient of loading capacity of vehicles. In this case, the duration of loading vehicles should be minimal, and the capacity of the dump truck body should be able to take the required volume of rock mass.

In order to optimize the ETC operation, it is also proposed, at the first stage, to establish the required number of dump trucks to service one excavator, and at the second stage – to determine the route by which dump trucks should move from the excavator face to the place of rock mass unloading and in the opposite direction [3]. According to scientists, this will ensure the maximum productivity of the equipment complex and lead to a reduction in the overall cost of field development.

There is a direction of research in which scientists prove that the effectiveness of the complex of equipment depends on the consistency of their parameters, that is, the capacity of the car body should be determined by the capacity of the excavator bucket. The criterion of choosing the type of equipment must be a certain ratio between the volume of the body of the dump truck V_a and the volume of the bucket of the excavator E. Researchers specify that minimal value of this ratio V_a/E must be 4 buckets in a body, and maximal value must not exceed 6-8 [4]. And to increase productivity of ETC it is necessary to reduce duration of technological stops of the equipment to a minimum.

Other scientists recommend to carry out a choice of dump truck on the basis of a condition of observance of a parity of capacity of a body of the dump truck to capacity of a bucket of the excavator within the limits from 3 up to 6 [5]. Thus for effective work of ETC six criteria of a choice of an excavator and dump truck are offered. These include: geological and geotechnical conditions of field development, excavator digging force, technological parameters of rock mass excavation, production indicators of the enterprise, operating characteristics of equipment, as well as the cost of production.

There are also studies, which indicate that for the correct choice of AEC equipment, it is necessary to take into account a certain ratio of dump body and excavator bucket volumes. Based on the results of modeling the work of excavation and loading and transport equipment in the quarry and considering the possible technological stops of the equipment and the duration of excavation and loading and transport processes, scientists have proved that the most optimal for specific conditions of the study is the ratio $V_a/E<4$.

Some scientists note that the effective work of AEC is determined only by the ratio of the number of dump trucks and excavators working in the quarry, and the productivity of the complex depends on the downtime of the quarry equipment [6]. The parameters of mining-loading and transport equipment, in this case, are not taken into account.

To optimize the operation of ETC, some researchers propose to use the weighted average size of a piece of rock mass as the main criterion [7]. In their opinion, it will allow to establish optimum operating modes of each technological process, cost and general technical and economic indicators of ETC activity. The productivity of dump trucks will be determined by the organization of excavation and loading operations, and the quality of rock destruction will affect the duration of loading the dump truck. Also, the choice of excavator bucket capacity and the degree of vehicle loading depends on the size of the rock mass.

To establish the optimal number of means of transportation of rock mass in the section scientists recommended to use the ratios that take into account the time from the moment of departure of the dump truck from the bottom after loading to the dump (or to the point of unloading) and its return, as well as the duration of loading dump truck [8]. It is noted that the average duration of dump truck loading depends on the excavator bucket filling factor and the duration of its cycle. In turn, the excavator bucket filling factor depends on the properties of the rock mass, and the cycle time is related to the bucket capacity, strength and mechanical properties of the rock.

Other researchers point out that the efficiency of ETC operation depends on the operating conditions of the quarry equipment, the number of its units, the degree of maintenance and repair, the qualification of the maintenance personnel and the production base of the enterprise. Taking into account these indicators, it is possible to optimize the length of transportation, to provide the proper maneuverability of vehicles, to reduce the duration of trips, to eliminate delays in work and, consequently, to reduce the total cost of extraction of raw materials.

To increase the efficiency of ETC, it is recommended to use the optimization method based on the implementation of the scheme of structural reservation of vehicles to ensure uninterrupted delivery of goods. This scheme of equipment operation will ensure fulfillment of the planned volume of rock mass transportation due to prompt redistribution of motor transport units between mining and overburden excavators in case of failure of mining and transport equipment. For implementation of the ETC optimization method it is necessary to have a geographic information system at a mining enterprise.

It is also proposed to apply the method of mass service theory [7] at quarries in order to optimize the work of excavator-transport complex. Using a model of queues, the authors show the relationship between the number of dump trucks and the coefficient of using excavators, as well as the productivity and length of the transport queue while waiting for loading. The method makes it possible to determine the optimal number of dump trucks through cost analysis to find the minimum cost of ETC operation.

Experts note that one of the main problems associated with the efficient operation of quarries is the rational distribution of dump trucks and excavators in the mining faces. In order to minimize the operating costs of quarry equipment, a linear programming model for distribution of dump trucks and excavators by faces is presented. The results of scientific research show that with the help of this model it is possible to achieve a significant reduction of operating costs for excavation and transportation of rock mass.

Scientists have developed a simulation model, which makes it possible to increase the operational performance of ETC by optimizing the distribution of dump trucks by faces [7]. It is suggested to reduce downtime of dump trucks and excavators at the expense of combined fixing of dump trucks for excavators. The transport process is practically not considered in the study. From all parameters affecting the process of movement of rock mass, we consider only the distance of transportation and speed of dumper trucks.

Conclusions. The analysis of the factors which determine the effectiveness of the excavator-truck complex in the pit has shown that mining-geological conditions of the deposit, the properties of the rock mass, the geometric capacity of the dump truck body, the excavator bucket capacity, the ratio of dump truck body capacity to excavator bucket capacity, mining equipment down time, dump truck driving speed, the distance of rock mass transportation, loading time, the factor of using dump truck lifting capacity.

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ВСТАНОВЛЕННЯ ФАКТОРІВ, ЩО ВИЗНАЧАЮТЬ ЕФЕКТИВНІСТЬ ЕКСКАВАТОРНИХ КОМПЛЕКСІВ ПІД ЧАС ЇХ РОБОТИ В КАР'ЄРАХ

Анотація: *В статті представлено результати наукових досліджень щодо аналізу чинників, які впливають на ефективність та продуктивність роботи екскаваторно-автомобільного комплексу на кар'єрах. У відповідності до наведених даних встановлено, що існують різні наукові підходи щодо забезпечення ефективної роботи кар'єрного екскаваторно-автомобільного комплексу.*

Зазначено, що ефективність роботи екскаваторно-автомобільного комплексу залежить від гірничо-геологічних умов родовища, фізико-механічних властивостей гірничої маси, геометричної ємності кузова автосамоскида та ковша екскаватора, співвідношення між ними, простоїв гірничого устаткування, відстані транспортування гірничої маси, часу навантаження, коефіцієнту використання вантажопідйомності автосамоскида, характеристик автодоріг та ін. Однак в більшості наукових публікаціях відмічена важливість дотримання оптимального співвідношення між місткістю кузова автосамоскида та місткістю ковша екскаватора з метою забезпечення високопродуктивної роботи комплексу обладнання.

Ключові слова: *кар'єр, обладнання, продуктивність, екскаваторно-автомобільний комплекс, місткість кузова автосамоскида, місткість ковша екскаватора, гірнича маса.*