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DIRECTIONS FOR THE DEVELOPMENT OF TRANSPORT MACHINES FOR OPEN-PIT MINING

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The paper is devoted to the identification (in the form of an intermediate obtained result) of the main trends in the development of transport machines, their systematization, taking into account the current state of art, identification and assessment of the most significant trends in view of innovative prospects. The discussed technical solutions contribute to a significant modernization of transport systems of mining enterprises.

Key words: open-pit mining, development trends, systematization, technical solutions, transportation system, mining enterprises

INTRODUCTION

The current state of art with respect to transport systems for open-pit mining makes it possible to successfully using them in many mineral deposits. This is true for the developed processing routes, various mining and geological conditions, geographical and climatic zones, mining stages and concepts, etc. [1-5].

However, current trends in the development of mining and the need in reduced material and financial costs, energy consumption and improved competitiveness require continuous improvement of economic, operating, technological and other characteristics of transport machines [6]. Practical experience [7-9] proves that it is impossible to create a transport system that could ensure efficient development of the field throughout the entire open pit lifetime, and it is necessary to separate the strategies for the formation and development of mining transport systems both for the enterprises, being start-ups in green fields, and for already operational mining enterprises. With an increase in the depth of an open pit, it is expedient to use several types and standard sizes of transport machines, taking into account their advantages and disadvantages considering the depth of the open pit or combined use thereof (in the form of combined systems). Due to the specifics of particular enterprises, not all of the proposed technical solutions can be recommended for a widespread application in practice. For example, the dump truck park formation algorithm (figure 1) for a mining enterprise is complex and involves a lot of parameters [10]. In connection therewith, the study deals with the most viable directions for the development of transport machines, deemed to be sustained development trends based on actually applied solutions for constructional, structural and functional enhancement, which contribute to a significant modernization of transport systems of mining enterprises; the study does not consider local solutions used in a particular mining technique or virtual ones that require using a different principle of operation and new physical and technical effects [11].

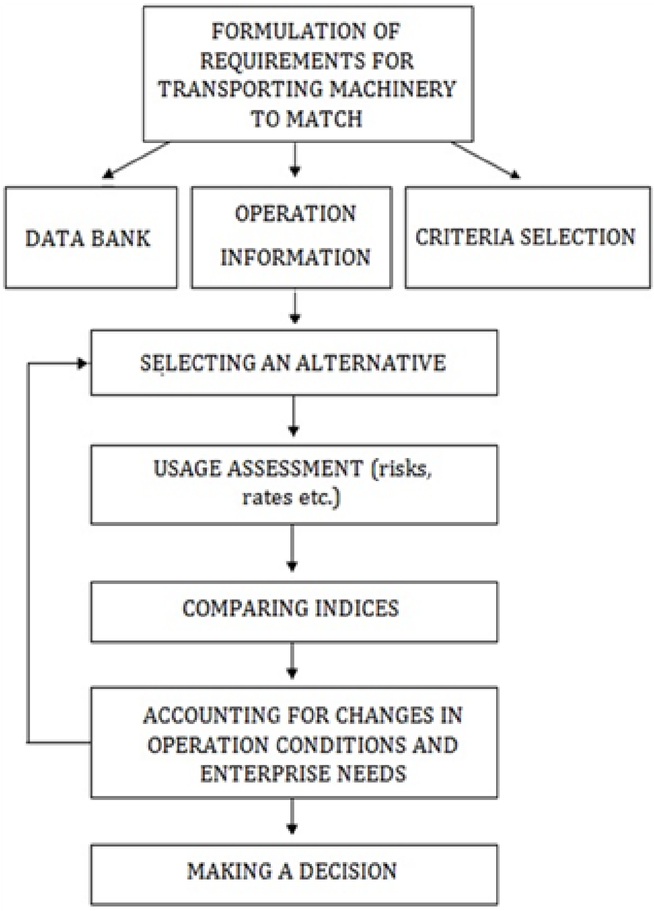

Figure 1: Algorithm of the dump truck park's formation

METHODS

The systematization of directions for the enhancement of transport equipment was conducted on the basis of fundamental criteria of the design and the state of art [12-13], considering current logistics requirements for transport [14].

When selecting development criteria based on the principle of progressive development for the next generations

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of machines, based on setting priorities when developing solutions to improve one but not to degrade other criteria, the potential improvement of constructional, structural and operating parameters of transport machines was accounted for to a sufficiently great extent and provided that the rest will have virtually stable effect. In view of the above, it is possible to reduce the number of other criteria in question, which simplifies presenting the research results [10].

We suggest the following criteria: functional - productivity, quality of the transportation and automation process [15-18] and technological criteria that include maintenance and repair [19, 20].

Functional criteria of development provide a quantitative characteristic of the main parameters for the performance of a machine, i.e., these criteria are determined on the basis of an analysis of a description of performance improvement when applying a technical solution. Since the functionality of a transport machine can be characterized by a variety of parameters, it is hardly possible to provide a limiting list of functional criteria [11]. In connection therewith, we have taken into consideration only the most important criteria for performing transport operations or optimization thereof during open-pit mining.

Direct economic criteria were not considered due to ambiguity of the determination for particular enterprises, the values, not fully confirmed by the developers, sometimes highly questionable and, consequently, their direct interest in selling their developments.

From the logistics requirements in the systematization of directions for the development, the key attention was focused on the possibility to improve controllability of transport operations [21-23].

It is worth noting that the generalization of technical solutions in the study and their systematization according to the criteria of the design and the state of art, considering the logistics requirements, coincide to a great extent for the main types of transport. During the selection, the key attention was focused on such actual solutions, which have outstanding significance, meet the requirements for the substantial improvement of technical characteristics (i.e., not inventive level) and are capable of providing great technological benefits when applied.

Based on the results of the analysis of automobile, railway and conveyor mining transport development directions, the selected applied solutions, being the most significant and promising for assessing their development for short-term prospects by types of mining transport, are summarized in the tables: for automobile (Table 1), railway (Table 2) and conveyor (Table 3) transport.

Table 1: Development directions and technical solutions in truck transport

Directions	Solutions	Advantages	Disadvantages
Increase in (or operational control over) productivity	Increased carrying capacity and unit capacity	Reduced costs for transportation by up to 25%	Increased costs for purchasing machines and creating the required infrastructure (roads, maintenance and repair, loading and unloading devices)
	The use of several transport units, optionally, combined into a road train	Increased traction and braking forces on slopes, in a road train Autonomous work at faces and during unloading	No domestic developments. High level of dispatching is required
Improving the quality of transport operations due to automation with the transition to full robotization	Means of automobile automation systems with the transition to full robotization and navigation	Remote and operational control, accounting and diagnostics of operating and technical parameters Dispatching, including remote	Increased expenses up to 15% of the cost There is a probability of failure (including of psychological nature) or malicious interference
Improving the use of technology when performing technical maintenance	Quick-detachable wheels with tires	Reduced labor costs and idle time	No domestic techniques
	The use of an electric traction drive of alternating current	Reduced maintenance costs	Under development

Table 2: Development directions and technical solutions in railway transport

Directions	Solutions	Advantages	Disadvantages
Improving the use of technology when performing technical maintenance	Combined power plants with hydrogen fuel cells	Dispensing with the contact line and diesel engines, simplified maintenance	High cost even under development
	Cassette-type bearings for wheel pairs	Extended lifetime up to 16 years Thrice less frequent servicing	Thrice higher in price and the absence of serial production
Improving the quality of transport operations due to automation with the transition to full robotization	The use of means of automation systems of rolling stock, railway lines and means of communication with the transition to full robotization and navigation	- Remote and operational control and accounting of operating and technical parameters Dispatching, including remote	Increased expenses up to 20% of the cost
Increase in (or operational control over) productivity	Multiple-unit type wagons with increased volume of transported cargo	Increase in the volume of transported cargo up to 40% while maintaining the standard train length Reducing the fleet of cars	Under development

RESULTS AND DISCUSSION

The technical solutions selected and presented in the tables are fully disclosed in the Internet information systems and, to avoid advertising, are given in the tables in the form of their proved advantages, disadvantages and assessment of their implementation. More detailed descriptions thereof can be found on information resources by referring to the names (given in italics in the tables).

The return on investment (ROI, simple rate of return) [24], determined by the ratio of annual profit to investments involved in the project would allow one to determine and assess the project profitability. However, the difficulties of determining profits that have not been received yet and an unknown amount of investments for an abstract open pit will compromise the reliability of the resulting assessment of solutions. Actually, the rate of return is determined for the specific conditions of the de-

Table 3: Development directions and technical solutions in belt conveyor transport

Directions	Solutions	Advantages	Disadvantages
Improving the quality of transport operations due to automation with the transition to full robotization	The use of means of automation systems for loading and reloading devices with the transition to full robotization and navigation	Remote and operational control and accounting of operating and technical parameters and synchronized combined action Dispatching, including remote	Increased expenses by 10% of the cost
Functionality enhancement	The use of conveyors with suspended and folded belts	The use on complex and changing transportation routes Increase in a tilt angle, size of the transported cargo	Project individuality
Increase in (or operational control over) productivity with adaptation to fluctuations in traffic	Speed regulation and asynchronous motor belt drive control systems in combination with loading and reloading bins as a function of cargo traffic	Work in transport conveyor lines, which are flexible in terms of productivity	High level of dispatching is required
	Drive is in the form of motor-drum assemblies	Reduced cost and dimensions of the drive	Project individuality

velopment use, i.e., by the consumer of equipment, and the developer determines the amount of investments.

Also known is a principle, used in legal practice to determine the amount of losses from a decrease in the volume of production or sales of products, in the form of not received profits. It is defined as the difference between the price and the total planned cost per unit of products (works, services), multiplied by the number of products (works, services) not produced or not sold as a result of improper actions by the counterparty. Similar methods are used in the patent law in case of violation of the rights. In contrast to the meaning of terms "affected - accused," applied in legal practice, in this case, the enterprise can be considered as affected party if it does not use a technical solution for various reasons and bears, if not direct damage, then, substantially, loss of expected profits in the form of funds that could have been obtained. The amount of lost profits requires a complex economic analysis, since this refers to its hypothetical calculation, simulation of economic process under conditions of an expected, but never happened, event [25-26].

It is apparent that the profit margin of producing companies will vary significantly, so the actual amount of lost profits for business owners can be very different.

The absence of reliable data results to performing an expert comparative assessment of promising technical solutions (economic attractiveness of the project) in order of importance (as presented in the table) based on data on the increased performance, carrying capacity, lifespan and cost increase (costs for manufacturing additional equipment) and information on the payback period of the project.

CONCLUSION

The considered state of art in the field of transport engineering and trends in the enhancement of mining transport engineering with the criteria used in the study (including the level of logistics management, automation, productivity, labor costs for repair and maintenance, etc.) made it possible to determine current directions for further development of mining transport machines.

The research results reveal the investment attractiveness of using the considered technical solutions, improve the competitiveness and efficiency of the creation and use of transport machines and contribute to a significant modernization of transport systems of mining enterprises.

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