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Application of (CAD) Modeling in Selection of Open Cast Mining Machines for Complex Structure Ore Deposits in Training of Mining Engineers

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ABSTRACT
Urgency of researching issue determined by creating a prognosis for analyzing specific mining and geological conditions and physical and mathematical properties of rocks in selecting types of mining machines like scrapers, bulldozers and combines. The aim of research: To search dependency between types of mining machines and properties of mining face and physical and mathematical characteristics of mined rock, to exclude possibility of risks and mistakes in projecting of surface mining objects using CAD systems. Methods of research: Mathematical and statistical modeling, analyzing of technical and project documentation of load and haul machines, prognosis of using special open-pit equipment with regard to researching of its quality, usability and high mobility, method of successive approximation, generalization, concretization, synthesis in studying of equipment performance, computer modeling. Results of research: Rising professional competency of students, as important factor of ecology, culture and education. Has been established determination of annual production rate of main open-pit equipment has been established. Have been developed engineer technologies and rational organization of running mining and loading works and load coefficient of open pit equipment. Have been conducted research and analyze of dependencies for production rate determination of scrapers, bulldozers and combines performance and developed fields of their application. Has been accomplished modeling of technological processes of bulldozer mined rocks. Practical meaning: This article aimed on adaptation of educational process to new conditions, in which it exists and orientated on development of perspective methodical and educational support of mining disciplines. Information represented by this article can be useful for professionals working in industry and projecting organizations which connected with open cast mining of complex structure ore deposits.

Keywords: open-cast mining, surface miner, complex structure, surface miner, CAD

INTRODUCTION

Selective mining of complex structure ore deposits, represented by flat thin ore layers, divided by layers of soft burden, rationally to perform by using flat layer mining technique. Bulk scale mining of such ore deposits with performing drilling and blasting reduces quality of mined minerals due mixing of rocks with different physical and mechanical properties [1]. During the choice of mining machines types for specific mining and technical conditions it is necessary to know that types of machines and properties of mining face should match physical and technical properties of mined ore.

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Main equipment used for flat layer surface mining is scrapers, bulldozers and open-pit combines. Scrapers and bulldozers have got a huge spread in mine stripping of ore deposits covered by soft rocks. Open-pit combines is used during open-cast mining of soft rocks [2-6]. Soft rocks or ore deposits are those which can be developed with specialized open-pit mining equipment without rock breaking by drilling and blasting techniques.

Scrapers are mining and hauling machines used for rock layer cutting and haulage rocks on the distance up to several kilometers with following bedding at the dumping site. Scraper is trailed or mobile bucket which has wide blade on the face of bucket's bottom. With that blade layers are cut. Bucket is labour body of the scraper, which cutting through rock massif under tractive and crowding forces. From the front, it has a damper with help of that the size of gap between cutting blade of the bucket and bottom edge damper is changed. The gap size expanding in dependency to thickness of the layer cut, which depends of physical and mechanical rock properties. After loading the bucket damper is closed, bucket is turning into hauling regime. The rock is forcibly dumped from the scraper's bucket. When damper is opened, waste rock is removed by movable rear wall. Turns of the damper, setting up bucket into ready-to-work and hauling regimes, moving of rear wall of the bucket are made by hydraulic cylinders mounted on the scraper.

Bulldozers is mining and hauling machine, equipped with dozer blade for rock layer cutting and haulage (pushing) and rocks leveling. The dozer blade is mounted from the front of the engine of tractor or on tractor frame. Bulldozers equipped with lifting and lowering hydraulic cylinders for dozer blade moving. Bulldozers are used in mining equipped with immovable dozer blade, mounted under 90° angle to the longitudinal axis of the engine. Frame connects dozer blade with tractor itself and gives it power crowding. To the rear dozer blade wall brackets are installed in which finger levers are put in, connected it to side bars of frame which allowing dozer blade tilt in vertical plane. On some bulldozers tilt dozer blade can be installed in horizontal plane under the angle of 27° on both sides from longitudinal axis or perpendicularly. Advantages of bulldozers are high usability and mobility [7].

Milling combines for surface mining allow to combine functions of mining and loading of rocks in one machine without any drilling or blasting or mechanical breaking by mounted rock breaking equipment.

METHODS

In the process of carrying our scientific research of the problem considered by this article following theoretical research methods have been used: complex analysis, synthesis, method of concretization, method of generalization, method of analogies in studying of operational work properties of scrapers, bulldozers and combines for open cast mining, methods of mathematical statistics have also been used.

With the aim of searching for conditions for raising operational production of open-pit mining equipment used for layer mining of complex structure ore deposits, represented by alternating soft rock deposits of useful thickness and layers of burden, has been carried out complex review of project and technical documentation of projecting and existing ore mining open-pits.

A broad overview of literature sources in the field of surface mining of ore deposits has allowed to find dependencies for determination of annual production rate of main open-pit mining equipment.

RESULTS

To select specific scraper model, it is necessary to provide prevailing of pull force of the scraper over summarized scraping resistance. The choice and calculations are carried out by method of successive approximation. Basic calculation model is based on considering mining and geological conditions, and physical and mechanical properties of rocks. Total rock resistance to scarpering is directly proportional to the product of milling chip thickness, resistivity of rocks to scraping and wideness of scraper's bucket. Main properties of scraper are: drive engine output, weight of the vehicle, dimensions and maximum thickness of rock layer cut, wheel base, hauling and work speeds, axel load.

$$Q_{skr.} = \frac{3600 \cdot E \cdot T \cdot \kappa_H \cdot \kappa_{\text{u}} \cdot N}{t_c \cdot \kappa_{\text{p}}}$$

Determination of scrapers annual production rate, used as mining and loading machine in surface mining, can be done by utilizing method of mathematical statistics, rationally to make it by following dependency (cubic meters per year)

description: E – bucket capacity of the scraper (cubic meters); T – duration of working shift (hours); $K_{\text{н}}$ – coefficient of bucket loading; K_{u} –coefficient of using shift time; N – number of scraper working shifts per year; t_{c} - duration of scraper working cycle (seconds); K_{p} – coefficient of waste rock disintegration.

Duration of one scraper cycle work is determined by duration of performing operations like loading and dumping the bucket of the scraper taking into account to additional time for lowering and lifting the bucket, time

for haulage of loaded scraper to waste rock dump and haulage of empty scraper to the mining face, also by time for maneuvering and turns. Duration of performing various operations from the cycle is calculated by searching form quotient from division length of this area to the speed of operation performing by the scraper.

Loaded scraper length of haulage is directly proportional to the bucket capacity with considering coefficient of loading and coefficient of rock losses in the process of a drawing prism formation, inversely proportional to product of bucket width, average thickness of layer cut by the scraper in the process of dumping the bucket with taking into account disintegration coefficient. Scraper length of haulage is also directly proportional to the bucket capacity with considering loading coefficient and inversely proportional product of bucket width and average thickness layer dumped in the process of bucket dumping.

Time of loaded scraper haulage to a dump site and empty scraper haulage to the mining face depends of a length of loaded and empty sections of haulage shoulder work of the scraper with taking into account coefficient, which considering time losses due gear changes and average speed of empty and loaded scraper haulage.

The area of effective use of the scrapers in open-pit mining of complex structure ore deposits represented by flat ore layers and divided by layers of soft waste rocks, is mining layers of soft rocks with their excavation by scrapers and haulage to the internal open-pit waste rock dump, in this case rational length of haulage can be up to 1.5 kilometers.

One of the most effective ways for raising production rate of the scrapers is improving their dozer blade system with aim to reduce crowding force and providing required strength, stiffness, and good planning characteristics [8]. Scraper bucket in mining of soft rocks should be loaded in the process of greatest penetration of a blade system, because in this case the most effective loading of the labour body is carried out and less rocks left in drawing prism of the scraper, however in this case forces needed for penetration of the blade system into rock massif are raised.

With insufficient pull force base scraper tractor in open cast mining usually use tractors equipped with tracks or bulldozers which pull the scrapers in the process of scraper bucket intrusion into the rock massif, in the process of loading and in cases of moving scraper out from impassable working areas. For these aims open-pit scraper equipped by special support mounted on the main scraper frame.

The process of calculating model choice for bulldozer is guided by properties of ore deposits which is planned to be mined their mining and geological conditions and physical and mechanical properties of mined rocks. Main properties of bulldozer are power of tractor, weight, dimensions and capacity of dozer blade, transport and working speeds. Annual production rate of tractor with dozer equipment installed, which is used on waste rock dumps, can be determined by following dependency (cubic meters per year)

$$Q_{\mathrm{b}} = \frac{3600 \cdot V_o \cdot k_{\mathrm{q}} \cdot T \cdot k_{\mathrm{u}} \cdot N}{t_c \cdot k_{\mathrm{p}}}$$

Description: V_{o} – volume of rock hauling by dozer blade (cubic meters); k_{q} – coefficient taking into account change in production rate of bulldozer due slope grade and length of rock haulage; T – duration of working shift (hours); k_{u} – coefficient of bulldozer usage through the shift time; N – number of bulldozer working shifts per year; t_{c} - duration of bulldozer working cycle (seconds); K_{p} – coefficient of rock disintegration.

Duration of bulldozer one work cycle is determined by duration of performing loading operations, time of loaded haulage, time of empty haulage, also time needed for maneuvers, turns and auxiliary operations. Production rate of bulldozers depends of rock volume hauled in one run, if frozen rocks are mined then thickness of melted layer should be taken into account [9].

Bulldozers, trailed and mobile scraper can mine and haul soft rocks with vehicle loading coefficient or using shift time equals to one without dependency on number of these vehicles in use [10].

In maintenance of several open-pit working areas much rationally to use wheeled bulldozers, which have high mobility and moving relatively faster from one working area to another, that is hard for vehicles equipped with tracks, carriers of those are not adapted to travel long distances [11].

Estimated area of bulldozers effective application in surface mining of complex structure ore deposits is mining of burden with low thickness with dumping waste rock on pit-walls. Also, bulldozers are effective equipment for cleaning roof layer of ore deposit and preparation of working areas for main open-pit mining equipment. On some mining adventures bulldozers are used as equipment for earth stockpiling filled soil, with the purpose of their subsequent shoveling [12].

Leveling of rock dumps surfaces by bulldozers is widely spread method of dump process mechanization in surface mining because of simple technology for waste rock disposal. Bulldozers are main dumping equipment on waste rock dumps, haulage of burden which is provided by dump trucks, also on internal waste rock dumps which are created by non-transportation scheme with single bucket excavators with dragline working equipment in stripped area of developing ore deposits.

Figure 1. Digital topographic model of the surface area of conditional mineral deposits, developed by students in AutoCAD

Milling open-pit combines are varied by location of the labour body related to engine one. Units with central location of labour body under vehicle frame have got the widest spread, this location of labour body allows to use pressure generated by weight of the combine in labour body, that allow to mine the massif of hard rocks. The combines with frontal location of cutter drum have also got wide spread, this location of labour body is allowed to form bench slope in end position and combines with labour body located on a boom are allowed to use selective mining in planed mining face.

Operational production of milling open-pit combines much lower than technical one due part of production time is used for maintenance of milling combine milling labour equipment, its maneuvering in the working area arrival at a stope, waiting for dump trucks and changing them during loading.

$$Q_{\text{s.m.}} = v_{\text{m}} \cdot b \cdot c \cdot T \cdot k_{\text{c}} \cdot k_{\text{o}} \cdot k_{\text{r}} \cdot k_{\text{m}} \cdot N$$

description: v_{m} – technical speed of rock milling (meters per minute); b and c – width and depth of milling stope of the combine (meters); T – duration of calculating operational period; k_{c} – coefficient which considers professional qualification of operator; k_{o} – coefficient which considers time losses for maintenance; k_{r} – coefficient which considers time losses during waiting for dump trucks and dump trucks changing; k_{m} – coefficient which considers time losses due combine maneuvers and turns ; N – number of open-pit combine working shifts per year.

Milling open-pit combine in thin layer surface mining technology is the main mining machine working in combination with open-pit dump trucks, which is used for preliminary breaking of soft rock massif and loading hauling vehicles [13-15].

In the process of milling combines main work time delays are connected with waiting for dump trucks and changing them for loading. Improvement of thin layer mining effectiveness with performing mining and hauling works by milling combines is possible with using combines in combination with scrapers [16]. In this case milling combine works as equipment for preliminary mining works, therefore scraper is used as mining and hauling machine.

For deep understanding of received knowledge and skills modern computer technologies are used, which need not only for receiving additional volume of knowledge, but for forming skills needed for students to use them in specific production conditions.

The process of using information technologies in technical high school aimed at satisfying industry demands in engineers with needed qualification, determination of conditions, methods of wide-profile technicians training, who are not only good professionals but people who have creative skills, without that the solving of modern problems is unthinkable. That is forming an intellectual sphere of engineer, his horizons of thinking and readiness for professional projecting effort.

In the process of carried out gradual monitoring of educational process it becomes obvious, that in present time any production is virtually impossible without using information and computer technologies. In modern industrial automated projecting system software (CAD) methods of bulk modeling of geometric models of projecting objects are widely used.

As a result there is necessity in qualified engineers who are able to create bulk geometric objects with specified characteristics; it creates special demands to education of engineer-technical specializations students [17].

Starting stage of surface mining objects modeling with using of CAD programs includes: development of digital topographic model of surface of area where ore deposit is located (**Figure 1**).

After that projecting of mining works which are needed for development of modeled ore deposit. In the process of creating 3D model of open-pit mine it is needed to work with numerous views of object, for visualizing control of the correct model state (**Figure 2**).

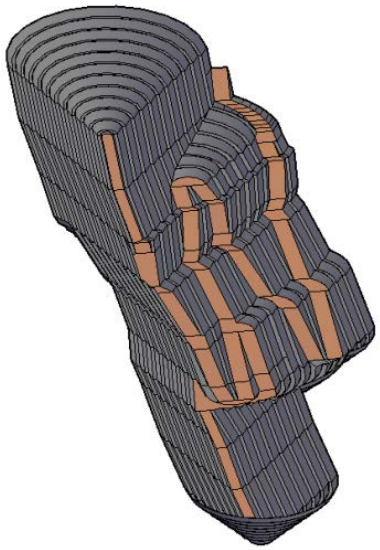

Figure 2. A digital opencast mine model developed by students in the AutoCAD

On a last stage of this work ore deposit reserves is calculated, existing within pit outline, by creating block model of ore deposit on the basis of ore deposit outline within borders of open-pit. On the basis of block model analysis and borders of open-pit following items are determined: total ore reserves; starting capital development construction routes and development of surface mining workings; choice of main open-pit mining equipment. All of this excludes possible risks and mistakes on projecting stage of open-pit mines [18].

DISCUSSIONS AND CONCLUSION

On modern stage of development of science and technology and for improvement of projecting effectiveness of surface mining with using of thin layer technologies of mining and loading works by scrapers, bulldozers and surface mining combines it is necessary to provide choice of specific type of the scraper with prevailing of pull force of the scraper over summarized scraping resistance with calculations by method of successive approximation.

Total rock resistance to scarpering is in direct proportion to the product of milling chip thickness, resistivity of rocks to scraping and wideness of scraper's bucket.

Main properties of scraper are: drive engine output, constructive machine mass, dimensions and maximum thickness of soil layer cut, wheel base, hauling and work speeds, and axel load.

Advantage of bulldozers is high usability and mobility.

Milling combines for surface mining allow to combine functions of mining and loading of rocks in one machine without any drilling or blasting or mechanical breaking by mounted rock breaking equipment.

Have been suggested rational organization, load ratio of open pit equipment and engineer technologies of running mining and loading.

Effectiveness of surface mining of complex structure ore deposits in many aspects depends of main open-pit mining equipment selection. Represented in article conditions for effective equipment usage for thin layer mining allow mining engineers to make a more rational choice of equipment for open cast mining.

Load coefficient of open-pit equipment for thin layer mining of soft rocks shows ratio of equipment operational time to full time of its work within time interval considered (often within one shift), its value has direct proportion on operational production rate of types open-pit mining machines considered by this article. Rational organization of selective mining of complex structure ore deposits, their useful thickness represented by flat thin layers, divided by layers of soft waste rock, will allow to reduce mineral losses and rates of dilution, also it will improve performance of surface mining equipment and engineering and economic performance of open cast mining of ore deposit as whole

Information represented by article is practically important for adaptation of educational process to new conditions, with surface mining of solid rocks with useful thickness represented by flat thin layers and orientated to development of new educational and methodical support for mining disciplines.

Information presented in this article can be useful for professionals working in industry and in projecting organizations which connected with open cast mining of complex structure ore deposits. Has been carried out an analysis of dependencies for determination of operational production rate of rock layer mining equipment used in

surface mining which allowed to substantiate main properties and characteristic impacting on annual production rate of mobile scrapers, open–pit bulldozers and milling combines.

Technical solutions for raising operational production rate of rock layer mining equipment allow to reduce operational spending for maintenance of scrapers, bulldozers and milling open-pit combines and raise total effectiveness of mining methods of complex structure ore deposits.

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