

ABSTRACT
dissertation work of
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«Justification parameters of a working body of single-bucket excavator for elimination of consequences of emergency situations», submitted for the doctor of philosophy degree (PhD) in the specialty 6D071300-Transport, transport equipment and technology

Introduction

Relevance of the research topic. The spurs of the Zailiysky Alatau, Dzhungarskiy, Talas Alatau, Karatau, Shu-Ili, Ketmen and Tarbagatay are considered to be areas of formation of mudflows in the Republic of Kazakhstan.

As a result of mudflows, artificial protective structures erected on the paths of their passage accumulate mudslide ground environment (MGE), consisting of water and transported by destroyed rocks, silt, clay, sand and stones of various sizes, moving at high speed. Construction and operation of anti-settlement structures, cleaning of mudflows and debris is impossible without the choice of means of mechanization with effective working bodies adapted to the specific mudflow ground environment.

The most difficult to work in the areas of dams and mudflow collectors are large-block soils, which require the creation of special working bodies (WB) in order to increase the efficiency of earthmoving machines (EM), widely used in emergency situations.

Traditional designs of working bodies of earthmoving-transport machines used for the development of mud deposits and other blockages are not adapted for work in such conditions, which leads to a decrease in their productivity by 20-25%.

Therefore, the task of justifying the parameters and creating a new working equipment for special purpose single-bucket excavators (SBE) for the development of mudflows with large-block inclusions, which allows to expand the functionality of these machines is relevant.

Purpose of research. Justification of the main parameters of excavator's a new working bodies equipped with a bucket with a hydro-controlled jaw, which provides expansion of functional and technological capabilities in the excavation of large-block soils of mudflows.

Research problem. In accordance with the idea and purpose of the work, the following research tasks are set:

- to establish the granulometric composition of mudslides on the Northern slope of the Zailiysky Alatau;
- to perform analysis of patent information on the designs of working bodies of single-bucket excavators, identify the main trends in their development, develop a morphological classification of patents, obtain mathematical dependencies of patenting dynamics, identify and suggest promising areas for improving WB, EM;
- to develop a method for determining the geometric and kinematic parameters of the mechanism extension of the working body of the excavator

bucket's hydraulic jaw, with the determination of the positions, speeds and accelerations of the points of its links;

- to develop a method for power analysis of the extension mechanism of the working body of the excavator bucket's hydraulic jaw, with the determination of reactions in the links of the mechanism;

- to establish rational parameters of single-bucket excavators and their working equipment based on statistical and computer modeling;

- perform an analysis of theoretical studies to justify the parameters of the bucket of an excavator with a hydro-controlled jaw for the development of mudflows.

The scientific novelty of the work:

- the granulometric composition of the total mudflow soil content fractions in river basins (Bolshaya Almatinka, Chemolgan,) of the Northern slope of the Zailiysky Alatau, as an object of interaction with WB and EM has been established;

- basic trends of constructions development of the EM working bodies based on the morphological classification, the obtained equation of the dynamics of patenting a new design of the excavator bucket with hydraulically controlled jaw for the development of coarse-grained soils mud offsets, which novelty is confirmed by patents for invention "A special working body of the hydraulic excavator" No. 33997. IPC E02F 3/48 E02F 3/60. Application 2018/0769. 1 from 22.10.2018 Official Bulletin, no. 45 of 08.11.2019 and "Working equipment of a hydraulic excavator with a hydro-controlled jaw" No. 34253. IPC E02F 3/60. Application 2019/0094.1 from 06.02.2019 Official Bulletin, no. 13 of 03.04.2020;

- developed algorithms and methods of defining the position coordinates of links, the equation of closure of independent contours of extension mechanism hydraulically controlled jaws of the excavator bucket in a vector form, which allowed us to determine the angular velocity and acceleration of links;

- developed an algorithm for kinematic analysis of the mechanism of the hydraulic jaw extension of the excavator bucket with implementation in the form of a program for PC, which allows to obtain numerical values of kinematic parameters, select a block diagram, determine the size of the working equipment links;

- correlation dependencies were obtained for selecting the most likely parameter ranges change for single-bucket excavators and working equipment based on the main parameter of the machine-mass;

- obtained dependences allow to determine the coupling reactions in kinematic pairs of the hydro-controlled bucket jaw mechanism of the excavator that arise from external loads;

- the results analysis of theoretical and experimental studies on the justification of the parameters of the hydro-controlled bucket jaw of the excavator is performed.

The practical value of the work is to develop the design, calculation methods and selection of parameters of the bucket of the excavator with a hydro-controlled jaw for performing earthworks when clearing (excavation) large-block soils of mudflows.

The following provisions are made for protection:

- results on determination of granulometric composition, total content of fractions of mudslide soils of river basins (Big Almaty, Chemolgan,) of the Northern slope of the Trans-Ili Alatau, which allowed to establish the most common types of soils that are subjected to the development of EM in the construction of various engineering facilities (dams, mud traps, etc.) and cleaning mudflows;

- morphological classification of patents for WB and EM; equations of patenting dynamics, identifying trends of their development; the new bucket design excavator with knuckle jaw which novelty is confirmed by patents of RK "Special working body of the hydraulic excavator" No. 33997. IPC E02F 3/48 E02F 3/60. Application 2018/0769. 1 dated 22.10.2018 Official Bulletin, no. 45 dated 08.11.2019 and "Working equipment of hydraulic excavator with hydro-controlled jaw" no. 34253. IPC E02F 3/60. Application 2019/0094.1 dated 06.02.2019 Official Bulletin, no. 13 dated 03.04.2020;

- algorithms and methods for determining the positions, coordinates of points of links; closed loop equations of independent contours of the mechanism for extending the hydro-controlled bucket jaw excavator in vector form to determine the angular velocities and accelerations of links;

- the algorithm for the kinematic analysis of the extension mechanism of hydraulically controlled jaw bucket, PC program, by definition, the numerical values of the kinematic parameters, selection of structural scheme, calculate the size of parts of work equipment excavator;

- a method for kinetostatic analysis of bucket attachments with an opening hydro-controlled jaw, which allows to determine the coupling reactions in kinematic pairs arising from external loads acting on the links of the mechanism;

- correlation dependencies for selecting the most likely changes ranges in the parameters of excavators and their working equipment by the main parameter of the machine-mass.

Implementation of work results. Research results are implemented:

- when designing and creating a new bucket with a hydraulically controlled jaw of an excavator for the development of coarse-grained soils mud offsets and as a practical necessity for the «Kazakhavtodor» LLP and the «Nectar» production cooperative;

- in the educational process when preparing students for the specialty 5B071300 - "Transport, transport equipment and technologies" in KazATC named after M. Tynyshpaev and ARSU named after K. Zhubanov.

Approbation of the results of the dissertation. The main provisions of the work were reported and approved at an expanded meeting of the Department "Motor Vehicles and life Safety" of JSC "Academy of Logistics and Transport" (Almaty, 2022), reported and approved at the following international and scientific conferences:

1. XLII, XLIII, XLIV international scientific and practical conference "Innovative technologies in transport: education, science, practice", KazATC, Almaty, 2018, 2019, 2020;

2. VIII international scientific Siberian transport forum (TRANS-Siberian-2019), Novosibirsk, Russia, 2019;

The results of the dissertation were published in 12 papers, including:

- in publications recommended by the CCSON:

1. Kinematic analysis of a special working body of a single-bucket excavator for the development of large-block soils. Vestnik of KazATC, No. 4, 2018. S. 122-130;

2. Trends in the development of working bodies of single-bucket excavators. Vestnik Of KazATC, No. 3, 2019. S. 73-79;

3. Working equipment of the excavator for processing mudflow waste. - Industrial transport of Kazakhstan, no. 1, 2020. pp. 75-82;

4. Determination of the main parameters of the excavator working body for the development of mudflow waste.- Bulletin of KazATK, No. 2, 2022. pp. 60-70;

5. Justification of the main parameters of the new working equipment of the grab excavator for the processing of coarse-grained soil. Bulletin of the L.N.Gumilyov ENU. № 4(141)/2022. pp. 7-18.

- publications in the international peer-reviewed scientific journal:

6. Determination of Kinematic and Force Parameters of the Special Bucket Shovel for the Development of Large-Block Soils. International Journal of Mechanical Engineering and Robotics Research, Vol. 9, No. 6, pp. 813-824, June 2020. DOI: 10.18178/ijmerr.9.6.813-824

- publications in the materials or abstracts of international conferences, including the materials of foreign conferences:

7. Special working bodies of earthmoving machines for emergency response. Materials of the XLII International scientific and practical conference "Innovative technologies in transport: education, science, practice", April 18, 2018, Almaty, KazATC named after M. Tynyshpaev. volume 4, pp. 263 to 268

8. Trends in the development of working bodies of single-bucket excavators for emergency response. Materials of the XLIII International scientific and practical conference "Innovative technologies in transport: education, science, practice", April 17, 2019, Almaty, KazATC named after M. Tynyshpaev. volume 3, pp. 21-26

9. Capture of large objects by the earthmoving machines implemented during operation on motor and toting roads.VIII International Scientific Siberian Transport Forum. TransSiberia 2019, Volume 2. p. 285-296

10. Development of grabbing device's morphological classification of single-bucket excavator's working bodies. Materials of the XLIV International scientific and practical conference "Innovative technologies in transport: education, science, practice", April 17, 2020, Almaty, KazATC named after M. Tynyshpaev. volume 2, pp. 92-93

- scientific publications in journals of science:

11. Methodological and mathematical description of the interaction of the earthmoving machine gripper and stone objects. Scientific journal "Bulletin of Eurasian science". 2019, no. 11, Volume 11. pp. 1-13

12. Power analysis of the interaction of the earthmoving machine gripper and stone objects. Scientific journal "Bulletin of Eurasian science". 2020, No. 1 (January-February), Volume 12. S. 1-9

Structure and scope of the dissertation. The dissertation work consists of an introduction, content, the main part of 5 sections, discussion and conclusions, appendices. The content of the work is presented on 105 pages of typewritten text, includes 14 tables, 43 figures, a list of references- 86 titles, 7 appendices on 40 pages.

In the first chapter, an analysis of research on the improvement of earthmoving equipment and their WB was carried out, which showed that the working equipment of the traditional type used for the development of mudflow soils with large-block inclusions are not adapted to such environments.

Analysis of trends in the development of WB EM structures based on the study and processing of scientific, technical and patent information has shown that the most widespread are WB with adaptation to the developed environment, therefore, in the future it is necessary to study the soils of mudflows. Therefore, the problem of creating a new special-purpose working body for the development of such environments is relevant for our country, a significant part of the regions of which are located in mudslide and earthquake-prone zones.

The analysis of the current state of the working equipment and working bodies of single-bucket excavators allowed us to formulate an urgent problem on the justification of the main parameters of the new working equipment of the excavator equipped with a bucket with a hydro-controlled jaw, providing the expansion of their functional and technological capabilities in the development of mudflows with large-block inclusions. The design of high-performance SBE is inextricably linked with the improvement of their working bodies based on the use of proven statistical and computer modeling methods, fundamental provisions of theoretical mechanics, theory of mechanisms and machines.

In the second chapter, the analysis of the granulometric composition of large-block soils of mudflow deposits in dams and mudflow traps was carried out, which showed that boulders with a diameter $d \geq 1000$ mm make up 2.88%; small fractions $D = 0.1 - 5$ mm - 41%; large fragments $d > 500$ mm – 32.38%. Analysis of the total content of fractions in the mudflow soil environment in the sediments of the northern slope of the Trans-Ili Alatau showed that boulders $d > 200$ mm make up 21.7%; pebbles (crushed stone) with the size of fractions $d = 10-20$ mm – 26.35%; gravel $d = 2-10$ mm – 19.53%; sand $d = 0.05-2$ mm – 28.28 % ; dusty particles $d = 0.005 - 0.05$ mm – 2.72%; clay particles $d = 0.005 - 1.42$ %. The most difficult to develop in the dams, mud traps are large-block soils, which require the creation of special WB EM in order to increase the effectiveness of traditional EM, widely used in emergency situations.

A morphological classification of patent information according to the working bodies of single-bucket excavators has been developed, which allows to systematize, encode patent information, use a PC for its processing and identify options for promising design solutions to improve WB SBE.

The equations of patenting dynamics are obtained, which allow us to identify the main trends in the improvement of WB SBE and the classification signs according to which this improvement is taking place and which characterize the prospects for the development of a particular constructive solution and orient designers, technologists when choosing ways to improve WB SBE.

The analysis of the identified promising patents shows that the main technical directions in improving the designs of WB SBE that increase their efficiency are such as special-purpose buckets; loading and unloading of working bodies and work in cramped conditions, etc.

For further development, a direction has been adopted for the development of special purpose buckets. A very promising patent of a bucket with a hydrofected anterior jaw has been identified, which is accepted as a basic design for further development.

In the third chapter, an algorithm and a method for determining the positions of the hydraulic jaw of a new working body of a single-bucket excavator are developed. Coordinate systems are defined in each structural group of the mechanism and the positions of the coordinates of the links of the structural groups are determined. The transition of the coordinates of the points of the links of structural groups relative to a stationary system is performed using the coordinate system transformation formula with simultaneous transfer and rotation of the axes.

An algorithm for determining the coordinates of link points has been developed, which leads to the formation of a rotation matrix and radii – vectors of link points relative to the origin of local coordinate systems. If the angles determining the position of the links relative to a fixed coordinate system are known, then it is not difficult to determine the coordinates of any point of any link using formed matrices and vectors, using formulas for transferring and rotating coordinate axes relative to fixed coordinate systems.

The equations of closeness of independent contours of the mechanism of extension of the hydraulic jaw of the bucket OE are obtained, expressed in vector form, allowing to determine the angular velocities and accelerations of the links of the mechanism.

The algorithm of kinematic analysis of the working organ of the hydraulic jaw of the SBE bucket is implemented in the form of PC programs compiled in the programming language Maple 18. The Essential Tool for Mathematics and Modeling. Numerical values of the kinematic parameters of the mechanism under study were obtained, which made it possible to select a structural scheme and determine the dimensions of the links of the mechanism of the hydraulic jaw of the SBE bucket.

In the fourth chapter, a method of kinetostatic analysis and determination of the coupling reaction in kinematic pairs of the excavator bucket hydraulic jaw opening mechanism arising from external loads acting on the links of the mechanism is proposed, which makes it possible to determine the coupling reactions in kinematic pairs.

Numerical and graphical values of the kinetostatic parameters of the mechanism under study were obtained by computer modeling, according to the

developed program for a PC, which made it possible to calculate the reactions in the hinges of the hydraulic jaw opening mechanism of the excavator bucket.

The calculation of the hydraulic drive of the mechanism of extension of the hydraulic jaw of the excavator bucket for the development of mudflows with large-block inclusions was performed.

In the fifth chapter, it was revealed that the parameters of SBE are interconnected by complex multilateral dependencies that have a pronounced stochastic character. Most reliably, these dependencies can be determined by statistical methods that allow us to derive regression equations. To use these methods, an information data bank was created, including data of 4375 technical parameters for 565 models of SBE of leading foreign companies and the CIS, taking into account the world design experience.

In the modern world, the competitiveness and quality of newly created and operated technical means crucially depends on the use of information technologies that correspond to all stages of the life cycle of machines and mechanisms. The application of these technologies involves the use of mathematical modeling to describe the processes and phenomena associated with the operation of technical means.

In the course of the research, a review and critical analysis of methods for determining the parameters of road construction machinery and mechanisms and ways to assess their perfection were carried out. The issue of determining the design parameters of a technical means is fundamental for the design process of promising and competitive samples of technical means, the correct solution of which determines the effect in the future. To systematize information about the parameters of machines, it is proposed to classify them by importance into main and main ones.

To compare and classify machines of the same type, the main parameter is usually used, which determines the size of the machine and gives a general idea of the technical capabilities of the compared machines. For example, excavators are classified by weight.

The main parameters of the design of the technical means are those parameters that, under the conditions of the known principle of operation and structure of the machine, make it possible to assess its efficiency and costs under given conditions of the sphere of production and operation. The effectiveness of the use of technical means in construction production is estimated by the number of products of a given quality produced per unit of time, i.e. productivity. As a rule, the main parameters of the technical means are: one of the sizes of the working body, the mass of the machine and the power of its power plant. The main parameter characterizing the size of the working body for an excavator, scraper, loader is the bucket capacity, for a bulldozer, grader - the length of the blade. The correspondence of the dimensions of the working body to the mass, power and traction characteristics of the machine uniquely determines its efficiency.

The mass determines the production potential of the machine and is one of the main price-forming factors.

The power of the machine's power plant determines the speed of work operations and energy consumption. The availability of the power reserve necessary for the efficient operation of the machine is revealed by the analysis of the power balance.

In addition to the main and basic parameters, information sources about technical means use additional parameters or simply parameters that determine the design features of machines.

The experience of designing and research aimed at substantiating the parameters of road construction machinery structures is reflected in the works of scientists, whose methodology according to the method of solving the task can be classified and presented by the following two methods: probabilistic and statistical analysis of the interrelationships of machine design parameters and the criterion method for determining the parameters of machine design.

Currently, probabilistic and statistical methods have become the main methods for the formal mathematical description of complex phenomena in various fields of science and technology. One of these complex processes is the process of creating and releasing road construction machines (SDM). The list of countries of firms and factories producing these machines, and in particular the number of their models, indicates the mass character of this process.

The probabilistic-statistical method for determining the relationships of machine design parameters is performed according to the following scheme:

- 1 Collection of information data based on the technical characteristics of machines specified in prospectuses, catalogs, project documentation of domestic and foreign companies, as well as in other literary sources.

- 2 Analysis of statistical information in order to establish (determine) a function approximating the correlation fields of interrelations of machine design parameters.

The probabilistic-statistical method of determining the parameters of the machine allows you to create a machine design, the performance of which is confirmed by the experience of operating a similar machine in the conditions of production of material goods. For an engineer, obtaining such information is of great importance. At the same time, information is received in a short time and at low labor costs.

Regardless of the MM nomenclature, the following main parameters are used to evaluate them: the purpose of the machine, engine power, traction, weight, overall dimensions, performance, characteristics (dimensions) of the working body, effort, speed, ground pressure of running equipment, specific energy consumption, fuel, lubricants and other operational materials per unit of machine performance.

One of the most effective methods of processing initial information is correlation and regression analysis. Its application solves three different, but related tasks: assessing the strength of the connection, determining and evaluating the significance of the parameters of the regression equation, determining the confidence limits of the regression equation. In the process of processing the initial information, it is desirable to identify linear connections or connections that are

easily reduced to linear ones. However, in general, the nature of the relationships can be extremely diverse and determined by a dependency involving various parameters. The main method of determining the parameters of the regression equation is the least squares method.

The most expedient is to express the parameters of the machine through one main (defining) parameter. Then the main parameters under study can be determined by the main parameter in a probabilistic form. It is established that the bucket capacity should be considered the determining parameter for excavators.

Using the developed program and the standard function of the linear software package for working with MICROSOFT EXCEL - 2007 spreadsheets, a pair correlation analysis was performed and 18 regression equations were obtained linking the main parameters of single-bucket excavators and their working equipment. Graphical dependencies corresponding to these equations are constructed on a PC.

The method of calculating the efficiency of single-bucket excavators by integral and generalized indicators when performing earthworks with various types of working bodies is given. The use of the upgraded handle on the excavator pays off in 4.11 years. Despite the high cost of the machine-shift, the cost of developing 1000 m³ of soil for the upgraded excavator is lower, and the annual economic effect of the introduction of the machine will amount to 668774.82 tenge.

Conclusion

In the dissertation work, the main technical parameters of the new working body of a hydraulic excavator with a hydro-controlled jaw for the development of large-block soils of mudflows are substantiated. This design of the hinged working body, as theoretical studies have shown, allows you to expand the functional and technological capabilities of excavators and increase the efficiency of their operation.

The certificates of the implementation of the results of the dissertation work were obtained as practically significant for AF LLP "Kazakhavtodor", a letter of support from the production cooperative "Nectar" and for use in lectures and practical classes of special disciplines in the preparation of students in the specialty 5B071300 – "Transport, transport equipment and technologies" in KazATK named after M.Tynyshpaeva and ARSU named after K.Zhubanov.