ANNOTATION

of the dissertation work of Aukenova Bekzat Kabykenkyzy on the topic "Substantiation of parameters and development of a design of a variable-configuration blade for a bulldozer-terracer" for the degree of Doctor of Philosophy (PhD) specialty 6D071200 – Mechanical Engineering.

Brief description of the work. An author of the thesis work has studied and analyzed existing designs of working bodies of bulldozers-terracers and their operating conditions, and in the thesis work suggests an original three-section bulldozer blade with variable configuration as an initial configuration. The proposed design of the blade has a central section connected by joints with side movable sections at an angle to the mirror plane of the blade. Rotation of movable sections allows adjusting the shape of the cutting lip and body of the blade in order to conform to the soil conditions and technological requirements to the works being performed. In this case, the adjustable change of the blade shape allows combining advantages of spherical and semispherical blades, as well as blades with projecting middle lips, racking and rotating blades, straight blades and those of tracklayers.

Solution of a problem of controlled adjustment of the working body configuration of the bulldozer-terracer during one pass in accordance with the soil conditions and technological requirements to the works being performed could significantly reduce operation time and quantity of repeated passes of the bulldozer-terracer in specific conditions, thus significantly increasing the efficiency of the operating process of earthmoving machines.

Relevance of the thesis work. Large costs of labor, material and power resources consumed for performance of earth works show a clear need for continuous improvement of means of their mechanization.

At present time, rise of technical level, reliability and quality of manufacture, assurance of comfort and safety of work of an operator is accompanied by significant increase in the cost of new equipment. In these conditions, assurance of its optimum and sustainable use in terms of operation time and engineering capabilities is of particular significance.

With regard to bulldozers-terracers representing one of the most common types of earthmoving machines, the most productive working equipment of which is distinguished by its high specialization, such a requirement could only be met at sites with large scopes of same-type works.

The bulldozers-tracers are often operated on slopes with inclines and in case of emergencies, when earthworks are being performed under conditions, which are specifically inconvenient for bulldozers and sometimes require repeating replacement of the working body (bulldozer blade) by a working body, which is more suitable for the current work conditions. This could be a blade with a projecting middle lip, spherical or semispherical, or a blade having another shape, if its operation could positively affect the operation process. Replacement of a

bulldozer-terracer or their working bodies during work performance will adversely impact their productivity and work completion time.

In order to get rid of maintenance of a large park of inefficiently used specialized machines and interchangeable equipment, and prevent increase of costs of their relocation and reequipment, while performing limited volumes of various works at spaced sites, it makes sense to use bulldozers with all-purpose blades.

Solution of a problem of controlled adjustment of the working body of the bulldozer-terracer during one pass in order to conform to the soil conditions and technological requirements of the works being performed could significantly reduce operation time and quantity of repeated passes of the bulldozer, and, thereby, significantly increase the efficiency of the operating process of earthmoving machines.

Summing up what has been said, the topic of the thesis work aimed at development of an adaptable design of a new blade with variable configuration for the bulldozer-terracer, analysis of consistent patterns and justification of the process parameters and efficiency of works performed by it, specifically intensity and duration of the working process, is **relevant.**

The concept of the thesis work is to increase operating efficiency of new bulldozer equipment with variable configuration by intensifying its operation process by virtue of its ability to adjust the equipment to a wide variety of soils, requirements and conditions of works by means of controlled rotation of side sections of the blade as related to inclined joints set at the blade.

The thesis work covers a solution to a **problem**, which lies in expansion of functionality of highly specialized working equipment, and efficient assurance of uninterrupted operation of bulldozers-terracers under specific conditions without need in change of working equipment. The problem could be solved by creating alternative all-purpose bulldozer equipment with variable configuration, which could be controllably adjusted to varying operating conditions.

The main hypothesis of the thesis work is that it is possible to increase productivity of the bulldozer with simultaneous reduction of energy consumption while cutting soil by the blade with variable configuration through development and adaptation of work of the newly designed blade with variable configuration and its cutting lip to varying operation conditions. The newly designed blade joins a number of advantages of the straight blade, the blade with the projecting middles lip, blades of rotary and spherical type and tracklayer blades.

The main objective of the dissertation study is to identify patterns, capabilities and operation parameters of the blade with variable configuration, which could be used to increase productivity and expand the scope of application of the bulldozer due to adjustability of the geometric shape of the angle-wise connected blade and its cutting lip to varying operation conditions.

The main tasks of the study are the following:

– conduct of a geometric analysis of parameters and capabilities of the variable-configuration blade depending on varying angle of axes of joints, which

could be moved longitudinally and transversally towards the plane of the middle section, and on the angle of movement (rotation) of side sections around the joints;

– identification of a dependence of a soil prism value on the main parameters and modes of operation of the blade (width of the middle section, angle of inclination of axes of joints in the transverse plane, angle of rotation of side sections around the joints, and excavation depth);

– identification of a dependence determining behavior of the horizontal component of resistance to excavation as related to main parameters and mode of operation of the blade (width of the middle section, angle of inclination of axes of joints in the transverse plane, angle of rotation of side sections around the joints, and excavation depth);

– identification of a dependence, which could be used for evaluation of productivity of bulldozers with consideration to influence of duration of the blade penetration process and hauling and linking properties of bulldozers, which could vary on soils of various density;

– development of a program and methodology for experimental studies of scale physical models of the blade with variable configuration, which could be controllably adjusted to the soil type and operation conditions;

– conduct of experimental researches of influence of length of the middle section, angle of inclination of joints in the transverse plane, angle of installation of side sections in plan and depth of excavation by the adjustable blade on values of the soil prism and horizontal component of resistance to excavation;

– development of a methodology for determination of main parameters of the variable-configuration blade, which could be adjusted to conform to operation conditions;

– determination of technical and economic efficiency of use of bulldozers with variable configuration, which could be adjusted to operation conditions and properties of the soil being excavated.

The object of the study is a physical model of the bulldozer blade with variable configuration, as well as processes of its interference with the soil during excavation.

The subject of the study is to determine consistent patterns of influence of the variable-configuration blade on relative indicators of soil excavation.

Methods of the study. Within the framework of the dissertation study the author has applied an integrated method of scientific researches. Theoretical studies were based on use of methods of a theory of numerical solutions of mathematical problems with the application of computing technologies and simulation modeling of interaction of the variable-configuration blade with the soil being excavated, as well as scientific provisions of theoretical mechanics and physical modeling as related to the bulldozer blade with variable configuration and its obliquely installed side sections.

Experimental studies have been conducted by carrying out a passive full factorial experiment with the application of the developed experimental model of the blade with variable configuration, and data analysis on the Excel program.

The following application program packages have been used in the course of the dissertation study: AutoCAD, КОМПАС-3D Viewer (COMPAS-3D Viewer), MATLAB, Microsoft Visual Studio C#, STATISTICA, EXCEL, 3D Surface Plotter.

The **scientific novelty** of the thesis work is as follows:

- a developed methodology of calculation of geometrical characteristics of movable bladed working bodies, including those with variable configuration and their separate sections as a function of the angle of rotation around an arbitrary axis and parameters determining location of a rotation axis;
- identified analytical dependences of resistance to soil elevation along the middle section expanding from bottom to top and horizontal component of resistance to excavation, as well as height and volume of the soil prism of the blade with variable configuration with obliquely installed side sections, geometric parameters of the blade, physical and mechanical properties of soil and excavation depth;
- an obtained improved formula of calculation of technical performance of the bulldozer-terracer on a specific soil taking into account a reasonable and specific for the case traction and speed mode and time required for the operation of deepening a retractable blade with variable configuration, which could be determined by the ratio of the vertical pressure on the cutting lip of the blade and the maximum bearing capacity of soil;
- identified regression dependences of the horizontal component of resistance to excavation and the mass of the soil prism on the angles of inclination of joints and installation of side sections, as well as on depth of excavation;
- a developed methodology of calculation of rational values of main parameters of the all-purpose bulldozer blade with variable configuration.

The practical significance of the thesis work consists in justification of the design and the developed methodology for determination of main parameters of the all-purpose retractable blade with variable configuration, and in obtained patents for the design of working equipment of the bulldozer-terracer.

The thesis work has been executed in the International School of Engineering under the EKTU named after D. Serikbayev, experimental studies have been carried out in a soil channel of the Applied-Research Laboratory of Quality and Reliability of Road-Building Machines under the Moscow Automobile and Road Construction State Technical University (MADI) at a stand for physical modeling of working processes of earthmoving and transport machines under supervision of Professor G. V. Kustarev. Data received within studies have been processed at the Wrocław University of Science and Technology, Poland, under supervision of Professor Marek Mlynczak.

The following scientific provisions are brought up for defense:

- a methodology of calculation of geometrical parameters of movable (retractable) bladed working bodies with variable configuration and their separate sections as a function of the angle of rotation and location of a rotation (retraction) axis;

- theoretical dependences of main parameters of the process of soil excavation with all-purpose three-section adjustable blade with variable configuration on influencing factors and soil conditions;
- an improved dependency of determination of the technical performance of the bulldozer-terracer;
- results of experimental studies of the process of soil excavation with the all-purpose retractable blade with variable configuration.

Personal contribution of the candidate for the degree. The work has been conducted personally by the author. The author has conducted a patent analysis of well-known designs, a review of theoretical researches in the field of standard and joint-connected working bodies of bulldozers and, in particular, bulldozers-terracers. The author has developed and studied the mathematical model of calculation of parameters of the new all-purpose blade with variable configuration, has developed and manufactured an experimental stand, has modeled a special mixture simulating soil, and has selected convenient recording equipment. The author has also received and compared analytical and experimental dependences describing the operation of the all-purpose bulldozer blade with variable configuration.

Practical evaluation of the work. The results of the studies have been reported and discussed at international scientific conferences, as follows: at the 80th (2022) International Research-Methodological and Scientific-Research Conference in the Moscow Automobile and Road Construction State Technical University (MADI, Moscow, RF); at the VI International Scientific and Practical Conference "Science and Education in the Modern World: Challenges of the XXI Century" (2020) (Bobek Association of Legal Entities, Nur-Sultan); at the VII International Scientific and Technical Conference of Students, Masters and Young Scientists "Creativity of Youth for Innovative Development of Kazakhstan", EKTU (2022); at the International Research and Practice Conference "Integration of Science, Education and Industry is the Basis for the Implementation of the Nation's Plan" (Saginov Readings No. 12) devoted to the 30th anniversary of Independence of the Republic of Kazakhstan (2020), Karaganda Technical University.

Publications. According to the Requirements, 4 scientific papers have been published on the topic of the thesis work, including two articles in journals indexable in the Scopus database with a percentile rank above 25, one article in a journal recommended by the Committee for Quality Assurance in the Sphere of Education of the Ministry of Education of the Republic of Kazakhstan; and 1 RK patent for invention has been received. In addition to the mandatory requirements, the author has also obtained 1 RK utility model patent.

Implementation of the research results. The calculation methodology and design solutions for the bulldozer blade with variable configuration have been accepted for application by ADD Alyans LLP, Ust-Kamenogorsk.

Structure and volume of the thesis work. The thesis work is documented on 162 pages of typewritten (word) text. The work consists of the following sections:

terms and abbreviations, an introduction, 4 sections and a conclusion. The work includes 67 figures, 10 tables, a list of 214 reference links and 2 appendices.

The following results have been received in the course of the dissertation study:

The thesis work covers the following scientifically substantiated results, the implementation of which provides a solution to the important applied problem of development of a methodology for calculation of design parameters of the bulldozer blade with variable configuration ensuring efficient excavation of various soils due to the controlled adjustment of the working body of the bulldozer-terracer to the soil conditions and process requirements to the work being performed:

1. Having performed a constructive analysis of patent and scientific and technical solutions, it has been proved that the study of joint-connected blades for bulldozers-terracers has significant advantages and good perspectives over other compared types of blade designs. Such an analysis has also indicated prospectivity of the chosen design in terms of reduction of interaction of the middle and lateral soil flows moving along the sections of the spherical-type blade without decrease in the soil prism volume.

2. A methodology has been developed to calculate geometrical parameters of the new blade with variable configuration depending on the center-to-center distance of rotary joints, their angles of inclination to the vertical (transverse and longitudinal) planes of the bulldozer and the angle of independent rotation of side sections. It has been established that the projecting part of the middle lip and oblique setting of side lips could result in concentration of vertical and crowd specific forces as that of the straight blade with the projecting middle lip. In this case it becomes possible to ensure the same ability of common excavation of soils with strength of up to 35 for class 10 tractors. It has been also determined that increase in inclination of axes towards the vertical plane up to 21^0 makes it possible to reduce compressing the middle layer components of resistance of side sections to excavation by up to 1.4 times compared to the spherical blade.

3. As for the blade with variable configuration containing obliquely but frontwards installed side sections, theoretical dependences of volume and height of soil prism have been identified. Such dependences could be used in calculation of traction and determination of performance of the bulldozer, and in evaluation of the role and significance of the considered geometrical characteristics of the blade, excavation depth and physical and mechanical properties of soil. The dependences could also be used to determine the entire volume of soil being moved.

4. Analytical dependences of resistance to soil elevation along the expanding middle section and horizontal component of resistance to excavation by the blade with variable configuration with obliquely installed side sections have been identified. Such dependences could be applied to evaluate geometric parameters of the blade, physical and mechanical properties of soil and excavation depth, and to identify resistance to excavation in the process of calculation of traction and determination of performance of the bulldozer.

5. As a result of the experimental studies conducted, it has been determined that main parameters of the blade with variable configuration (length of the middle section, angle of inclination or obliqueness of rotational joints of side sections towards the longitudinal vertical plane, angle of inclination of side sections compared to the middle section) and the average excavation depth influence the volumetric mass of the accumulative soil prism and the value of the horizontal component of resistance to excavation.

The results of the experimental studies confirm reliability of the theoretical dependences, which have been analytically identified. It has been also confirmed that excavation of soil by the blade with variable configuration is more efficient. And it has been proved that applying the similar excavation effort the mass of the soil excavated with the blade with variable configuration on paddy-field soil (cohesive soil) could exceed the soil prism accumulated by spherical and straight blades by 1.15 and 1.5 times, respectively.

6. An improved formula has been obtained on a specific soil model taking into account the reasonable traction and speed mode and time required for the operation of deepening. Using the formula, it is possible to identify the technical operation of the bulldozer when excavating soil to a high degree of accuracy.

An analytical dependence has been identified, which characterizes influence of the ratio of the vertical pressure on the cutting lip of the blade and the maximum bearing capacity of soil on bulldozer performance. Results of calculations by formula have been confirmed by comparative tests of performance of bulldozers with various blades (straight, spherical and those with variable configuration), which were carried out in MADI and EKTU named after D. Serikbayev. The improved formula could be used for a more reasonable evaluation of performance indexes of working processes of bulldozers-terracers, including those with the developed blade with variable configuration.

7. The experimental and theoretical dependences obtained during the studies have made it possible to develop a methodology for definition of main parameters of the blades with variable configuration taking into account functional limitations. Ranges of rational values of main parameters of $b/B_0 = 0.375 – 0.45$; $\Theta = 12\text{-}16^0$; $\alpha_y = 18\text{-}25^0$ have been identified for the excavation angle of $\alpha_{ymax}=30^0$. Selection of parameters within these ranges will result in the most efficient excavation of soils with the maximum strength by bulldozers-terracers. Such selection will also allow performing the most common types of work.

8. It has been established that, with a reduction of the average volumes of works performed at one construction site, the economic effect of usage of the bulldozer with the blade with variable configuration increases. As for class 10 bulldozers, which average volume of works performed at one site equals to 7,500 m^3, annual economic effect from the use of one blade with variable configuration could be no less than KZT 22,200.