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XPERIMENTAL INVESTIGATION OF THE PARAMETERS OF A WORKING TOOL FOR REMOVING THE DISTURBED SOIL LAYER FROM THE CENTER OF A CRATER

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The article presents the results of theoretical and experimental studies of the process of removing a damaged soil layer inside a crater by means of a specially developed working tool. The structural scheme and the general configuration of the working tool are described in detail. For performing the technological operation, the tool was mounted on the boom of an excavator, which provided the required positioning, movement trajectory and interaction with the treated soil surface. The design of the working tool includes the use of channel flanges and angle-section elements that ensure gradual layer-by-layer cutting, separation and removal of the damaged soil from the inner surface of the crater. Such a design makes it possible to control the depth of soil removal and to reduce excessive disturbance of the underlying undamaged layers.

To determine the soil cutting force and to evaluate the nature of the mechanical loading during dynamic experimental studies, an electronic dynamometer equipped with an SBA interface was used. The dynamometer strain-gauge sensor was installed directly on the brackets of the working tool, which ensured continuous and reliable registration of force parameters during the cutting process. The obtained experimental data made it possible to assess the actual loading conditions of the tool and to compare them with the values predicted by the theoretical model.

A comparative analysis of theoretical calculations and experimental results was carried out. It was established that the discrepancy between the calculated and experimentally measured values of the soil cutting force ranged from 4.5 to 8.6%. Such a level of deviation indicates a sufficiently high adequacy of the adopted mathematical model to the real technological process. The comparison also confirmed that the previously determined values of cutting force and energy intensity for soil removal by the channel flanges and angle-section elements adequately describe the actual loading pattern during the cleaning of the damaged soil layer inside the crater.

The obtained results can be used for further improvement of the working tool design, substantiation of its principal geometric and operating parameters, optimization of cutting modes, and reduction of energy consumption. In addition, the developed approaches may contribute to increasing the efficiency, reliability and technological effectiveness of mechanized soil-cover restoration operations under conditions involving local soil damage and crater formation.

***Keywords**: working body, excavator boom, cutting force, crater, damaged soil layer.*

Fig. 5. Ref. 11.

1. Problem formulation

All types of military-technogenic impact cause intensive pollution and degradation of the soil cover. The action of all ammunition used in military operations is characterized by the formation of a shock wave and the formation of explosion products that spread in the environment.

ANALYTICAL SUBSTANTIATION OF THE INFLUENCE OF PULSATION PARAMETERS AND TEAT LINER CHARACTERISTICS ON MILK FLOW INTENSITY © 2026 by Elchyn ALIIEV, Yevhenii NOSENKO is licensed under CC BY 4.0
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First of all, soil deformation occurs in all directions of shock wave propagation. As a result of combustion, explosion and detonation of ammunition, various derivative products are formed, most of which are either toxic or hazardous pollutants.

There is a scattering of internal soil components over significant areas. The soil remaining in the impact zone undergoes intensive turbulence and dynamic compaction, and is also characterized by the presence of numerous metal fragments with residues of toxic explosives.

Also, in fields strewn with craters of various diameters and depths from explosions, it is impossible to safely carry out mechanized work with agricultural machinery.

Therefore, the transformation of contaminated lands into usable areas and the preservation of the fertility of agricultural soils is an urgent problem for ensuring food security in Ukraine.

2. Analysis of recent research and publications

The specified damages can be seen with the naked eye, to determine the chemical impact, it is necessary to do an analysis, because both thermal shock and explosion and soil rupture affect. At the same time, the biological component of the soil is also destroyed. Explosion craters and the area around the craters, depending on the radius of the debris, are contaminated with heavy metals (nickel, zinc, lead, cadmium, copper, etc.). During the explosions of missiles and air bombs, not only the air is polluted [1-3]. Harmful substances do not stay in the air for a long time, but return in the form of precipitation and accumulate in the soil. Hazardous substances have the property of getting through the soil into water or plants grown on it, these pollutants can migrate into the environment and accumulate in the body of plants and animals [4-6].

Heavy metals are present in all munitions, accumulate in the top 10 cm of soil and are biologically available to surrounding ecosystems. During high-order detonation, small metal fragments of shells are dispersed to different distances depending on their power and according to the radius of dispersion. Partial detonations scatter the largest fragments of the shell body [7, 8]. In [9] it was shown that the acid and alkaline buffering capacity of the upper soil layers after FPV drone strikes underwent the most significant decrease, which indicates an increased vulnerability of these soils to further chemical stress factors. X-ray fluorescence analysis revealed significantly elevated levels of potentially toxic metals (Pb, Zn, Cu, Cr, Co, As) in soils exposed to hostilities, which is clear evidence of anthropogenic contamination caused by explosive residues and military munitions.)

From the analysis of soil samples directly in the crater and in the area of impact on the soil cover after hostilities, it was established that concentrations of cadmium, chromium and lead were detected in the craters (in craters of 120–125 mm ammunition, the cadmium concentration coefficients are approximately 4–17 Clarks from the background, 82 mm – 4 Clarks, 152–155 mm shells – 2–18 Clarks, air bombs – 5–13 Clarks; lead concentration coefficients are approximately 4–22 Clarks in places of ruptures of 120–125 mm ammunition, 2.6–4 Clarks – 152–155 mm, 2.7 Clarks – 82 mm ammunition and 2.7–11 Clarks – aviation bombs). At the same time, the highest concentration of cadmium is noted on the slopes of the crater, while chromium – on its bottom. It should be noted that the type of ammunition was determined either by debris near the crater, or by the size of the crater [9].

Other important impacts on the soil cover are the consequences of the explosion, detonation or burning of heavy equipment on agricultural lands. It was established from the results of the analysis of the grain size composition of the soil that in places of burning heavy equipment and leakage of fuel and lubricants the content of physical clay decreased [10]. The consequences of pollution of natural resources due to military activities, disruption of the functioning of vital ecosystems and the associated threats to the health of people of current and future generations are described in a review article [10].

To analyze the extent of soil damage, it is necessary to assess the type and degree of contamination at each individual site. Based on these data, it is then necessary to determine the level of their suitability and the most optimal methods of restoration. Some may be completely suitable and only require cleaning. Others have been damaged to such an extent that it will be impossible to conduct any activity on them in the near future. In this case, it is necessary to restore the relief of agricultural lands, level and recultivate, that is, to return the soil to a healthy balance and fertility.

In this way, it is possible to carry out technical land reclamation, which involves first cleaning the craters from damaged and contaminated soil with heavy metals and other hazardous substances. After that, it is necessary to fill the craters, that is, level the surface. Further, disking and cultivation can be carried out on this land plot, and if necessary, plowing.

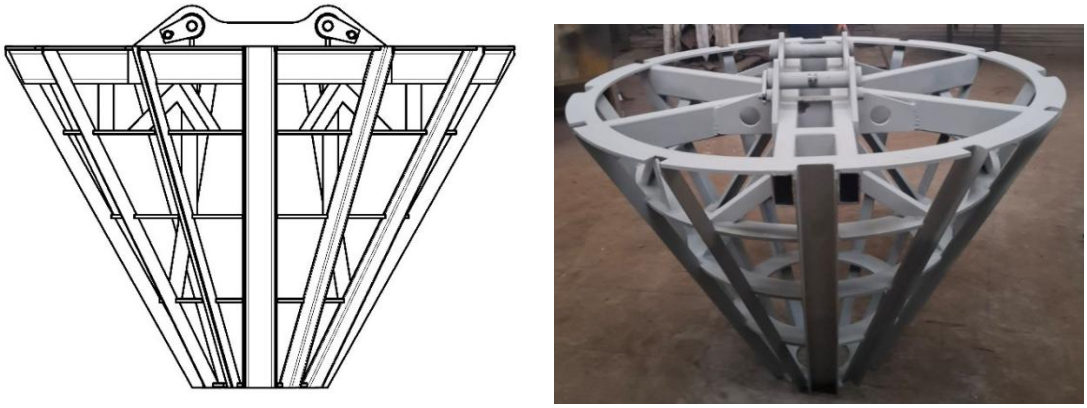
3. The purpose of the article

Creating a method that will allow converting land damaged by military actions into land suitable for use and preserving the fertility of agricultural soils by using a developed working body that will allow cleaning the damaged and contaminated soil layer in the middle of the crater.

4. Results and discussion

To study the process of cleaning the damaged layer of soil from the middle of the crater formed by the explosions, an experimental sample of the working body was manufactured.

The working body consists of a frame in the form of circles, to which channels and angles are welded (Fig. 1). The welded structure is reinforced with metal rings in height. A bracket is welded to the working body from above for attachment to the excavator boom with the possibility of rotation. The working body is fixed to the excavator boom using brackets. Using the hydraulic system, the working body can rotate at an angle and make turns around the axis of the body. Rotating the working body makes it possible to select the angle of inclination of the working body relative to the surface of the crater, the surface layer of which must be cleaned. The edges of the shelves of the channels and angles welded to the working body will make it possible to remove the top layer of the crater surface and thus free it from damaged molten soil containing heavy metals and other harmful substances.



a ***b***

Fig. 1. Structural diagram (a) and general view (b) of the working body for cleaning the damaged soil layer in the middle of the crater

To conduct field experimental studies of the process of cleaning the surface layer of soil, the developed working body was fixed on the excavator boom using brackets. Studies of the working process of cleaning the damaged layer of soil in the middle of the crater were carried out on the experimental field of the Institute of Mechanics and Automation of Agroindustrial Production of the National Agrarian Academy of Sciences of Ukraine in loamy soil with a humidity of 10–20%, adhesion of soil particles within 0.04…0.06 MPa.

To conduct dynamic experimental studies, the working body was manufactured with the following parameters: height H = 1 m; diameter of the upper part D = 1.5 m; diameter of the lower part d = 0.4 m. The working elements were channels No. 10 GOST 8240-97 and angles 45x45x5 GOST 8509-93, in which the shelf length is bsh = 46 mm and bk = 45 mm.

In Fig. 2 shows a general view of the excavator with the working body installed and measuring equipment when clearing the soil layer.

To determine the force of cutting the soil by the shelves of the channels and angles, an electronic dynamometer with an SBA interface was used, the strain gauge of which was fixed to the brackets of the working body.

Fig. 3 shows general views of the strain gauge and electronic dynamometer, which were used when measuring the force of cutting the soil.



Fig. 2. General view of an excavator with an installed working body when clearing a soil layer



a *b*

Fig. 3. General views of the tensile-compressive strain gauge CAS SBA-a00L (a) and the electronic dynamometer DE-2.0-0.5 (b), which were used to measure the soil shear force

The principle of operation of the dynamometer is based on the conversion of the cable tension force into an electrical signal, which is processed by the electronic unit in order to display the traction force on the digital indicator.

The electronic dynamometer DE-2.0-0.5 can operate both in the mode of displaying the current force value and in the mode of fixing the maximum force. The dynamometer measures the signal from the strain gauge and the deformation that occurred as a result of the force is converted into an electrical signal by a special sensor.

The dynamometer has a digital display of force (indicator board) and an LED indication of operating modes. Control is via a push-button keyboard. All operation of the electronic dynamometer is controlled by a microprocessor according to a program recorded in a non-volatile memory device (ROM). Settings are stored in a reprogrammable ROM. The electronic dynamometer DE-2.0-0.5 can operate both in the mode of displaying the current force value and in the mode of fixing the maximum force.

In Fig. Figure 4 shows a storyboard of the process of cleaning the damaged soil layer by the working body.

When cleaning the surface contaminated soil layer with a working body on which a strain gauge is fixed, by pulling the cable, the electronic dynamometer converts the force into an electrical signal, which is processed using the appropriate program on a laptop and displayed in the form of oscillograms on the monitor.

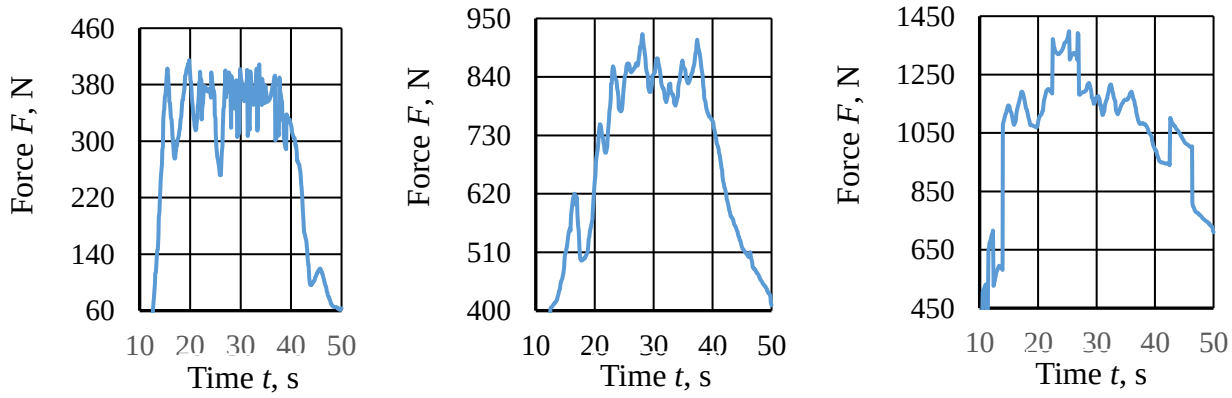


Fig. 4. Storyboard of the process of cleaning the damaged soil layer with a working body

As a result of field experiments, Fig. 5 shows the obtained oscillogram of the soil cutting force values to a depth that was equal to the length of the shelf of the channel or angle of the working body, i.e. 45 mm, for hard sandy loam, hard loam and semi-hard clay.

During the research, the cutting force values by the shelves of the channels or angles of the developed working body when cleaning the surface soil layer in the middle of the crater were recorded in ten-fold repeatability.

From the comparison of the theoretical calculations presented in the article [11] and field experimental studies, it was found that the error between the obtained results is within 4.5…8.6%.



a *b* *c*

Fig. 5. Oscillogram of cutting force values for different soil types: a – hard sandy loam; b – hard loam; c – semi-hard clay

Thus, according to the results of comparative studies, it was established that the previously carried out calculation of the force of cutting the soil by the shelves of the channels and angles of the working body

adequately reflects the real process of cleaning the damaged layer of soil in the middle of the crater.

The study of the cutting force will allow not only to determine the rational design parameters of the working body for cleaning the damaged soil inside the craters, but also to select an excavator to which the developed working body is attached, and to determine the requirements for the engine, transmission and fuel consumption of the energy intensity of cleaning one cubic meter of contaminated damaged soil layer.

5. Conclusion

1. The article shows the structural diagram and general view of the working body, which allows in field conditions to conduct research on the process of cleaning the damaged soil layer from the middle of the crater formed as a result of explosions.

2. A methodology for conducting experimental research on the working body for cleaning the damaged soil layer in the middle of the crater has been developed. Based on a comparison of the theoretical calculations and experimental studies, it was established that the error between the results obtained is within 4.5…8.6%. Thus, according to the results of comparative studies, it was established that the previously performed calculation of the force and energy intensity of cutting the soil by the shelves of the channels and angles of the working body adequately reflects the real process of cleaning the damaged soil layer in the middle of the crater.

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ЕКСПЕРИМЕНТАЛЬНЕ ДОСЛІДЖЕННЯ ПАРАМЕТРІВ РОБОЧОГО ОРГАНУ ДЛЯ ЗЧИЩЕННЯ ПОШКОДЖЕНОГО ШАРУ ҐРУНТУ У СЕРЕДИНІ ВИРВИ

У статті наведено результати теоретичних та експериментальних досліджень процесу зчищення пошкодженого шару ґрунту всередині вирви за допомогою спеціально розробленого робочого органу. Представлено його конструктивну схему, загальний вигляд і особливості взаємодії з ґрунтовим середовищем під час виконання технологічної операції. Для проведення досліджень робочий орган закріплювали на стрілі екскаватора, що забезпечувало необхідне позиціонування, переміщення та регулювання глибини зчищення пошкодженого шару. Конструкція робочого органу передбачає використання полиць швелерів та кутників, які забезпечують поступове пошарове зрізання, руйнування та видалення пошкодженого ґрунту з внутрішньої поверхні вирви.

Для визначення сили різання ґрунту та оцінювання характеру навантаження під час динамічних експериментальних досліджень використано електронний динамометр з інтерфейсом SBA. Тензодатчик динамометра встановлювали безпосередньо на кронштейнах робочого органу, що дало змогу реєструвати силові параметри процесу в реальному часі та одержати достовірні експериментальні дані. Проведено порівняння результатів теоретичних розрахунків із даними експериментальних досліджень.

Встановлено, що розбіжність між розрахунковими та експериментальними значеннями сили різання ґрунту знаходиться в межах 4,5–8,6 %, що свідчить про достатню адекватність прийнятої математичної моделі реальному технологічному процесу. Підтверджено, що попередньо визначені значення сили та енергоємності різання ґрунту полицями швелерів і кутників достовірно відображають характер навантаження. Отримані результати можуть бути використані для подальшого удосконалення конструкції робочого органу, обґрунтування його геометричних параметрів і режимів роботи, зменшення енергоємності процесу та підвищення ефективності механізованого відновлення пошкодженого ґрунтового покриву.

Ключові слова: *робочий орган, стріла екскаватора, сила різання, вирва, пошкоджений шар ґрунту.*
Рис. 5. Літ. 11.

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