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# Taking into account the regularities of physical processes in the constructions of working bodies of dynamic destruction

*Leonid Pelevin[1], Olexander Teteryatnuk[2], Svitlana Komotska[3], Fedyshun Bogdan[4]*

[1,2,3,4]Kyiv National University of Construction and Architecture,
31, Povitroflotskyi Avenue, Kyiv, Ukraine, 03037,
[1]pelevin.lie@knuba.edu.ua, https://orcid.org/0000-0002-4010-8556,
[2]teteriatnyk.oa@knuba.edu.ua, https://orcid.org/0000-0002-9983-0551,
[3]komotska.siu@knuba.edu.ua, https://orcid.org/0000-0001-8418-5302
[4]fedyshyn_bm@knuba.edu.ua

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**Abstract.** In construction and related branches of the national economy, there are many works related to the destruction and movement of soil (laying of communication lines, extraction of minerals and building materials, reclamation and military-engineering earthworks, etc.). Work equipment, which implements the principle of static soil destruction, is one of the most significant criteria that determines the high energy intensity of the work process of modern earth-moving machines. Even the foreign equipment with which state and communal enterprises are now equipped has better characteristics only due to its novelty and universal design. However, the main problem - reducing the energy intensity of soil massif development - remains unsolved.

The processes of destruction of working environments are destructive. All real processes are irreversible, that is, the entropy of an isolated (closed) system can only increase. For open systems, where there is an exchange of matter with the environment, as well as energy and momentum, entropy can decrease due to replenishment of the system with matter and energy, but the direction of natural processes does not change.

Complex and non-linear processes of development of work environments are characterized by both directions of flow of the components of these processes. The description of the evolution of systems due to the movement of working environments as degradation processes is proven and scientifically substantiated by the second law of thermodynamics, the evolution of the system in the sense of organization for all its components - by synergy.

The constructive implementation of the working bodies of construction machines in such a way, when the co-direction of the destruction processes with the flow of natural processes is implemented, allows to significantly increase the informativeness of the work of the construction machine. Such processes lead to a drastic reduction of resource costs per unit of production and improvement of all parameters of the development of working environments.

Considering the above, as well as the need to reduce Ukraine's energy dependence on other countries, there is a need to develop and create low-energy, high-speed working bodies of earthmoving machines.

When forming the face, it is necessary to take into account that the destruction process must coincide with the direction of the natural destruction process in order to reduce energy costs.

**Keywords:** entropy, informativeness, synergy, working environment, gravitational field, energy intensity.

## INTRODUCTION

For Ukraine, the characteristic features of the execution of a number of earthworks are characterized by the natural formation of a layer of freezing up to 20 cm deep in the soil massif after the winter seasons. In addition, the natural composition of the top layer of the soil is an environment with heterogeneous inclusions. Such properties of soil environments determine the peculiarities of the trenching technology during the laying of communications. Namely, the trench is formed after several passes of the trencher, which reduces the productivity of the machine. In addition, works on the laying of communication lines, as a rule, are performed in a short time and in a limited space.

When creating trenches under communication lines, earthmoving machines destroy the densest layer of the soil massif, and their working bodies work in difficult conditions, which causes them to wear out quickly and to lay down large coefficients of safety margin during design. The main types of work that are performed at the same time combine complex physical and mechanical processes, the implementation of which requires the use of special machines, which differ from ordinary ones both in terms of work principles and structural performance. Most of these machines use high-speed operating devices, the principle of operation of which is based on the theory of dynamic soil destruction. [1, 2].

Until now, research in the field of development of working environments was based on the study of specific regularities and did not touch general natural laws, which significantly limited the possibilities of creating high-quality models of the functioning of technical complexes for the development of working environments.

The direction of natural processes is determined by the second law of thermodynamics, from which it follows that the entropy of an isolated system can only increase, reaching a maximum in the state of thermodynamic equilibrium of the system. For open systems, where there is an exchange of matter with the environment, as well as energy and momentum, entropy can decrease due to the replenishment of the system with matter and energy, but the direction of all real processes in the direction of increasing entropy does not change in open systems. In complex, nonlinear, unbalanced and open systems, organization processes can occur, when the orderliness of the system increases due to the synergistic openness of such systems.

Thus, the processes of destruction of working environments in order to reduce energy consumption should be co-directed with natural processes of destruction, and the construction of equipment, its working bodies, as well as the working processes of this equipment should be maximally informative in a synergistic sense. [3-5].

The aim of the work is to analyze the features of earthmoving equipment, the production indicators of which take into account the main provisions of energy saving and the justification of new approaches to the destruction of the working environment by systems of construction equipment, taking into account the co-entropic directionality and synergistic nature of these processes.

The task of this study is to determine the area of application of low-energy dynamic working bodies and the constructive and regime implementation of co-entropy and synergy of the destruction of working environments.

## PRESENTING MAIN MATERIAL

The analysis of construction machinery and its work processes, as well as the synthesis of new working bodies and machines, is based on the research of individual patterns of their work. This direction of research in the field of working environments is quite effective, but the narrowing of the direction of research accordingly limits the positive effect of their conduct.

The most energy-intensive of all earthworks operations is the destruction of the soil, in connection with which the development of soils is distinguished by the methods of their destruction, a characteristic type of energy action.

With static mechanical destruction, the cutting tool moves uniformly or with slight accelerations at a speed of up to 2–2,5 m/s. The energy intensity of the mechanical destruction of sandy and clayey soils, depending on their strength and the design of cutting tools, is 0,05...0,5 (kW·h)/m3, up to 85% of the total volume of earthworks is performed in this way [6].

The traditional scheme of operation of earthmoving machines is characterized by the fact that the energy from the engine is transferred to the working body with the help of transmission, pressure, running, traction mechanisms in various combinations. This leads to significant energy losses in the transmissions of these mechanisms and a decrease in the efficiency of the machines. The need to increase workloads and productivity leads to an increase in the mass of machines and the power of the engines installed on them, and these indicators cannot grow indefinitely.

Machines that provide increased mechanical and non-mechanical impact on the environment by working bodies with a relatively small mass, but with a separate special drive or with the help of intensifiers, are devoid of the listed disadvantages. Machines with non-traditional high-speed working bodies are becoming more and more popular due to the possibility of creating large working loads and speeds with a significant reduction in the weight of the machine, as well as the possibility of increasing the useful power of engines without increasing the size of the machines and their total capacities.

The theory of the destruction of working media under the action of high-speed loads of various types takes into account changes in the contact properties of the media, energy, speed and shape of the working body, and the time of destruction. The main principles and provisions of this theory formed the basis of modern calculation methods and the creation of work modes and constructions of soil- and rock-destruction equipment not only in Ukraine, but also abroad.

The development of environments during earthworks, as well as in the work processes of their development during the functioning of a complex of technical systems of construction equipment, is connected with the load, deformation and destruction of these environments [7]. The effectiveness of the development is evaluated by specific parameters: energy intensity, specific productivity, mass specific productivity and the general criterion of the effectiveness of the complex of technical systems of construction and construction equipment - specific entropy. The destruction of working environments is a destructive process – the process of destroying the structure of the working environment. All real processes are irreversible, that is, the entropy of an isolated (closed) system can only increase. When matter, energy and information can flow into an open system, the direction of natural processes does not change. To reduce energy costs for the destruction of working environments, it is necessary to form the work processes of technical system complexes in such a way that physical fields are involved in the destruction of these working environments (natural movement occurs exclusively through the action of four types of fundamental physical fields). During the destruction of working media, their macro-movement occurs in the gravitational field, therefore the form of the slaughter must be built in such a way as to use the energy of the gravitational field as much as possible for their destruction.

In complex, non-linear, unbalanced and open systems, organization processes can occur, when the orderliness of the system increases due to the synergistic openness of such systems. Both directions of flow of components of these processes are inherent in complex processes of development of working environments. The description of the evolution of systems due to the movement of working environments as degradation processes is proven and scientifically substantiated by the second law of thermodynamics, the evolution of the system in the sense of organization for all its components - by synergy [8,9].

Figure 1 shows the disk working attachment of the earthmoving machine, the peculiarity of which is that its bottom is formed in such a way that the soil to be destroyed is located above the operating device [10].

This is achieved due to the fact that the working body is inclined at an angle $\alpha$ in the direction opposite to the feed rate $V_F$. In this case, part of the soil destruction work is performed by the gravitational field.

The force of gravity acting on the soil is directed at the separation of soil particles from the massif, moves the soil separated from the massif to the end plane of the disk of the working body, then the disk takes the soil into the dump due to the rotational movement. In addition, a small closed volume of soil located above the working body is subjected to stress waves (deformations), which reduces the strength limit of the soil.

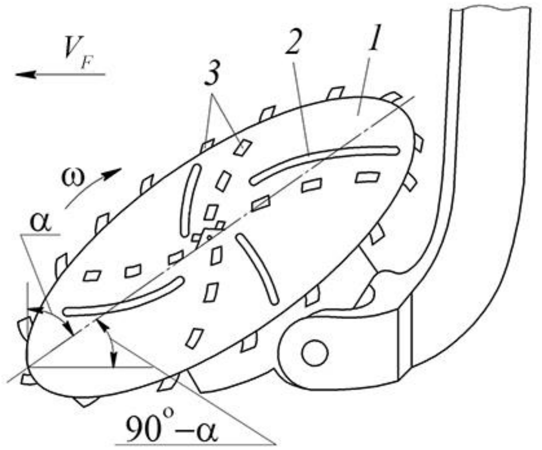


**Fig. 1.** Disk working body of the earthmoving machine: *1*– disk, *2*– throwing elements, *3*– cutting elements

A similar advantage, in addition to several others, is used by a conical cutter (Fig. 2). The working body, developed by the department of construction machines of KNUCA, has in the axial section the shape of a truncated cone, which is located with a larger base towards the bottom [11]. The sides of the conical cutter form a cutting edge with the base. Cutting and casting elements are located on the side surfaces in concentric circles of different diameters. They are located in concentric circles of different diameters in such a way as to avoid continuous cutting. To ensure the planning of the bottom and walls of the trench, and additional transportation of soil outside the trench, a cleaning casing is installed.

During the operation of the conical cutter, part of the soil massif is destroyed due to undercutting and cutting of the soil by the cutting edge and cutting and throwing elements. The destruction of the soil in the gaps between the cutting and throwing elements arises from stresses exceeding the strength limit of the soil, which are formed from the superimposition of deformation waves in the massif due to the high speed of rotation of the working body. The shape of the conical cutter allows to ensure the destruction of part of the soil mass due to the gravitational field. The angle α at the base is chosen to be smaller than the angle δ of the friction of the soil on the steel, which ensures the rise of the soil along the surface of the cone of the cutter, and the centrifugal force acts in the direction of the open surface of the massif, which allows the destroyed soil to be thrown out of the trench. To prevent the developed soil from entering the trench again, behind the cone cutter, a cleaning casing is installed, which also profiles the bottom and walls of the trench.

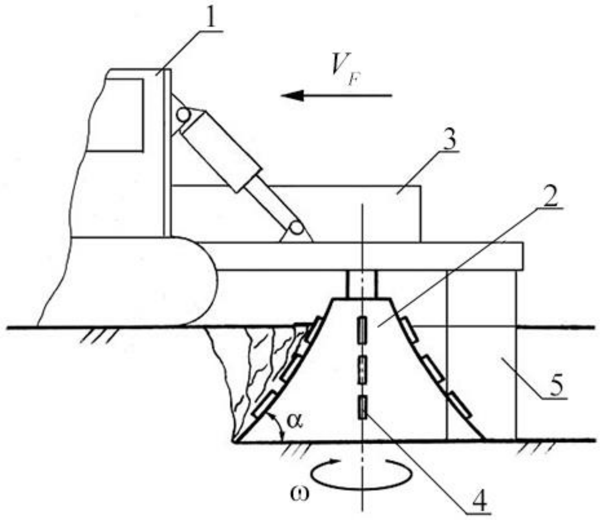


**Fig. 2.** Cone cutter in working position: *1* – base machine, *2* – cone cutter, *3* – drive of the working attachment, *4*– cutting and throwing elements, *5* – cleaning casing

In further research, the idea arose to modernize the conical milling cutter by dividing it into two cones - upper and lower (Fig. 3). Rolling bodies are installed between the upper and lower cones. The cones rotate in opposite directions and with different angular velocities. This prevents lateral efforts during the development of the working environment. In this way, the problem of ensuring course stability of the base machine is solved [12].

The gravitational field performs the greatest part of soil destruction in the soil destruction method implemented by high-speed equipment (Figure 4), and especially by quasi-static equipment (Figure 5). The essence of the method of destruction of working environments of coentropic directionality is explained by the following proposed constructions of the working equipment.


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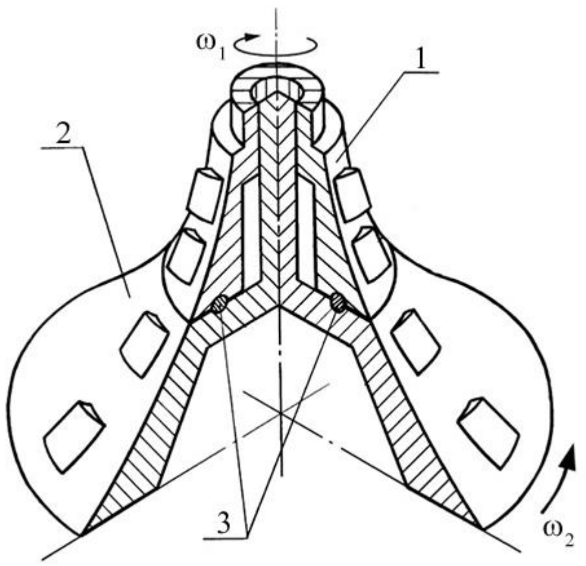


**Fig. 3.** Modernized conical milling cutter: *1* – upper cone, *2* – lower cone, *3* – rolling elements, *4* – cutting and throwing elements, *5* – cleaning casing

The method of soil destruction by high-speed working equipment is implemented as follows. When developing a trench with a depth of *H*, the working attachment is located in the lower part in such a way that it develops the soil with a height of *H*–Δ*H*, that is, the thickness of the soil Δ*H* is not developed by the working attachment and remains undisturbed. The destruction of this part of the soil occurs due to the force of gravity acting on the roller. That is, the lower part of the trench is developed by the working body due to the movement of the riser with the speed $V_F$ and angular velocity ω of the working body, which is provided to the working body by the drive, and the upper part Δ*H* is destroyed by the roller due to the force of gravity $F=mg$, where *m* is the mass of the roller and the separated soil from the array (the roller also moves with speed $V_F$ and has the ability to move for some distance in the vertical direction). Depending on specific conditions, a dynamic force may also act on the soil in the vertical direction. Ruined soil due to the force of gravity falls on the end surface of the working body and is carried out of the trench by the excavator shovels.

The method of soil destruction by quasi-static working equipment is implemented as follows. The working body is located in the trench similarly to the previous case. Due to the fact that the working body consists of a rim and spokes, the soil developed by the cutting elements due to the inclination of the wheel at an angle α in the direction opposite to the feed speed $V_F$, under the influence of gravity, enters the conveyor, and from it to the tray and is removed outside the trench.

Due to the fact that a significant part of the soil is destroyed due to the gravitational field (the natural movement of matter in the physical field occurs in the direction from a higher field potential to a lower field potential), the energy consumption by the drives of the working body and the basic machine for the development of the trench is significantly reduced, that is, this method soil destruction is less energy-intensive. The design envisages an additional conveyor that can be installed separately for the excavation of soil with a thickness of Δ*H*, which is destroyed exclusively by the gravitational field.

The Figure 6 shows a working body with coentropic destruction of the working medium, where the working medium is above the working body and the gravitational field does part of the work of soil destruction. This realizes the co-direction of the destruction with the course of natural processes, and the working body and its work process have increased informativeness.

During the destruction of the working environment with the formation of the work process, the cutting force and energy consumption are significantly reduced as follows. Accordingly, the production of entropy decreases as a result of involvement in the process of destruction of the gravitational field, the effect of which is caused by a change in the angle of inclination of the working body. Increasing or decreasing the angle, respectively, decreases or increases the share of the gravitational field in the total energy of the work process [13].

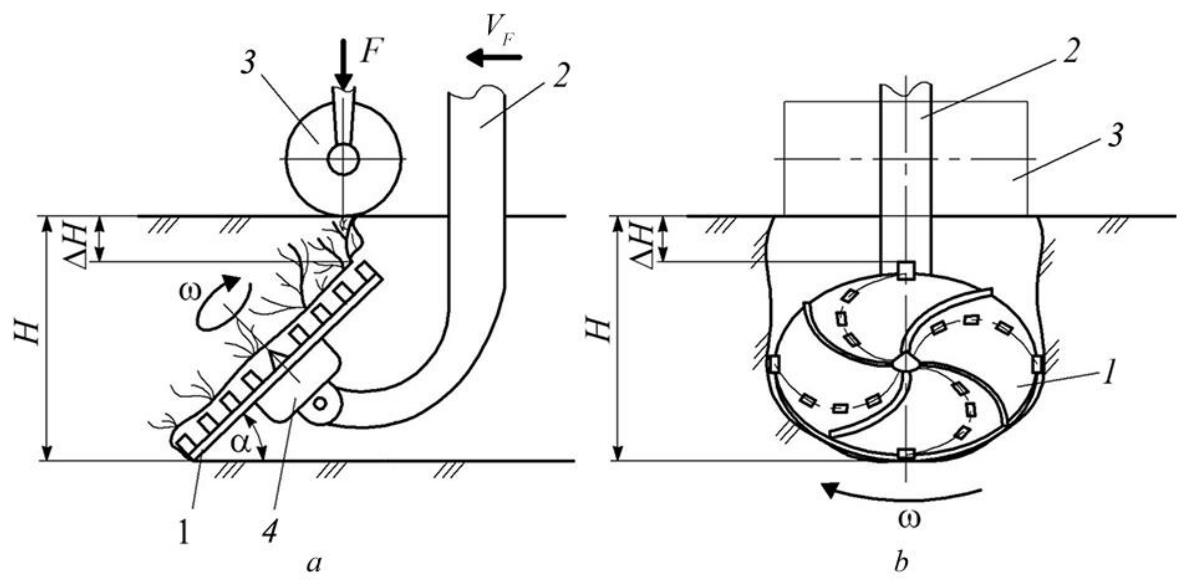


**Fig. 4.** Rapid ground-breaking equipment:
*a* – side view, *b* – front view; *1* – disk working body, *2* – rack, *3* – cats; *4* – drive of the working body

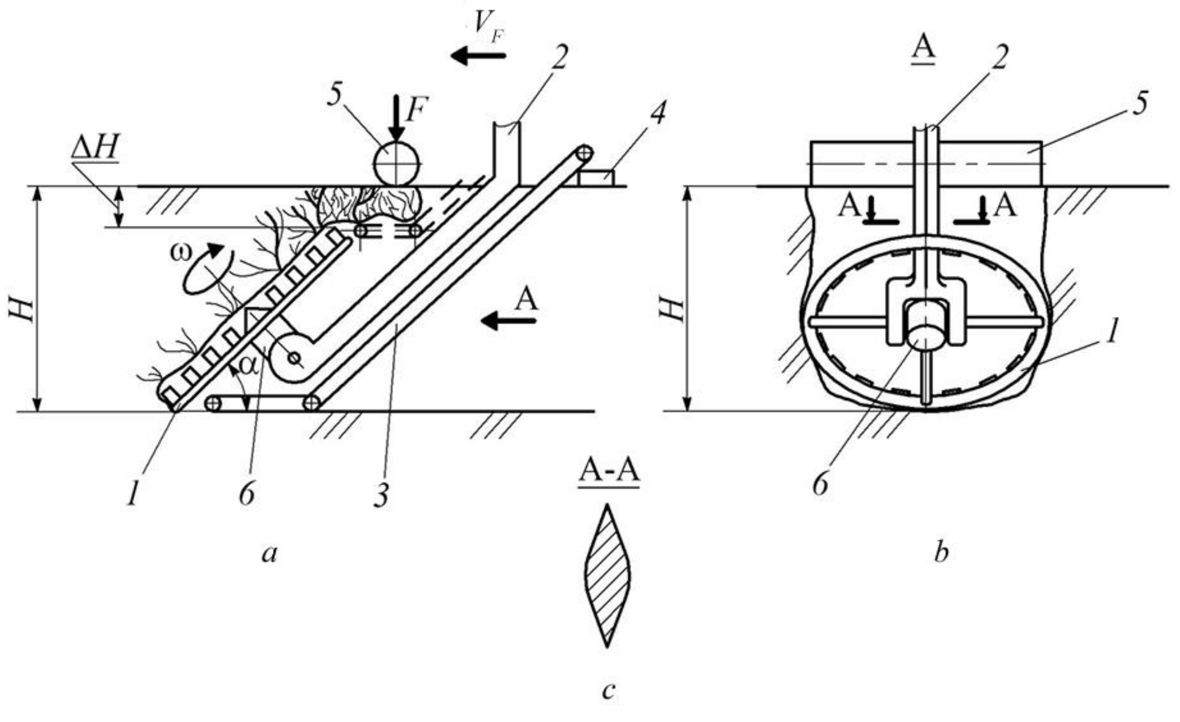


**Fig. 5.** Quasi-static soil demolition equipment:
*a* – side view, *b* – rear view (conveyor and tray not conventionally shown); *1* – disk working body, *2* – rack, *3* – conveyor, *4*– tray, *5* – roll, *6* – drive of working body

Experimental studies of the power parameters of the disk working attachment confirmed that when the angle of inclination of the disk changes, competing problems arise, namely: with a decrease in the angle of inclination, the strength of soil resistance to destruction decreases, but at the same time, the productivity of the working body also decreases, due to the fact that the cross section decreases breakaway trench. In addition, the smaller the angle of inclination of the working body, the greater the effect of self-collapse of the soil on the disk plane.



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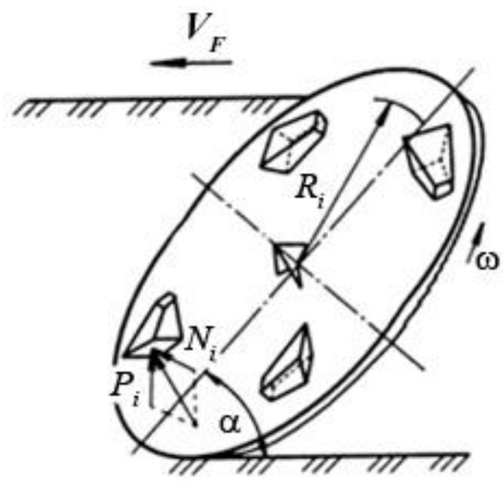


**Fig. 6.** Disk working body with co-entropy destruction of the working environment

When the angle of inclination of the disc increases, the resistance of the soil to destruction increases slightly, but the productivity of the working body also increases, because the cross-sectional area of the trench that breaks away increases.

The graph (Figure 7) shows the dependence of the performance of the disk working attachment Π on its angle $\alpha$ of inclination. It can be seen from the graph that the optimal angle of inclination of the working body lies within $65°...75°$.

When $\alpha < 65°$ the working plane of the disc is used inefficiently due to the reduction of its working area, and when $\alpha < 75°$ there is no phenomenon of self-collapse of the soil on the disc plane, the productivity of the working attachment also decreases.

The results of experimental studies show that when the angle of inclination of the working body increases, the strength of soil resistance to destruction *P* increases due to the fact that the effect of self-collapse of the soil decreases. At the same time, it was established that the root mean square deviation of the cutting force practically does not change when the angle changes.

Thus, under the condition of minimizing dynamic loads and soil resistance to destruction, the number of soil-destroying elements in one ring row, i.e., those that work according to the "track in track" scheme, should not exceed 4...5 pcs. In further studies, we assume that the number of such elements $m = 4$.

During the destruction of the working environment with the formation of the work process in such a way that the working body develops the environment only in the lower part of the trench, the cutting force and energy intensity are significantly reduced. Accordingly, the production of entropy decreases as a result of involvement in the process of destruction of the gravitational field, the effect of which is caused by a change in the angle of inclination of the working body. Increasing or decreasing the angle, respectively, decreases or increases the share of the gravitational field in the total energy of the work process.

In addition, competing factors arise in the work of working attachments, as was noted. In the design of a disk working body with increased co-entropy destruction of the working medium, these competing factors act together in one direction. A feature of the design of the disc working body with coentropic destruction of the working medium is that the diameter of the disc *D* is greater than the depth of the trench *H*, and in high-speed earth-shattering equipment, the diameter *D* is less than the depth of the trench H. Thus, when the angle $\alpha$ of the working attachment is reduced, the cutting force $F\tau$ decreases and the development productivity increases working environments Π at a constant power, due to an increase in the feed rate $V_F$ (Figure 8).

Taking into account the above, experimental studies were carried out for high-speed earth-shattering equipment with the following parameters: the diameter of the working body *D*=0.5m, the depth of the trench being developed *H*=0.7m.

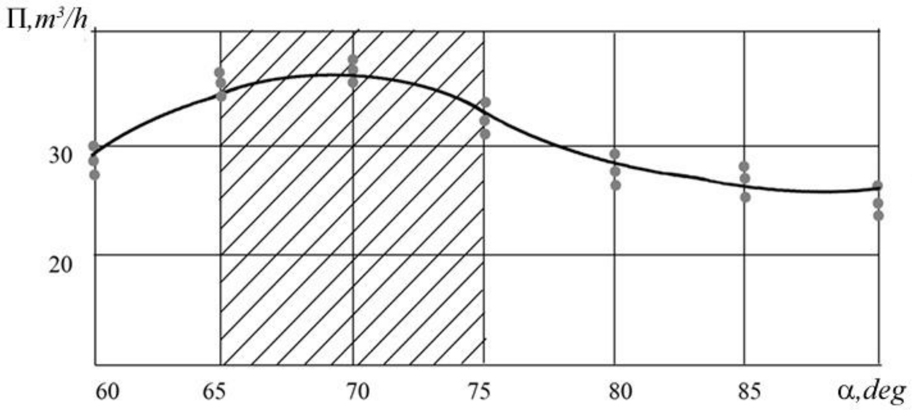


**Fig. 7.** Dependence of productivity П on the angle $\alpha$ of inclination of the disk

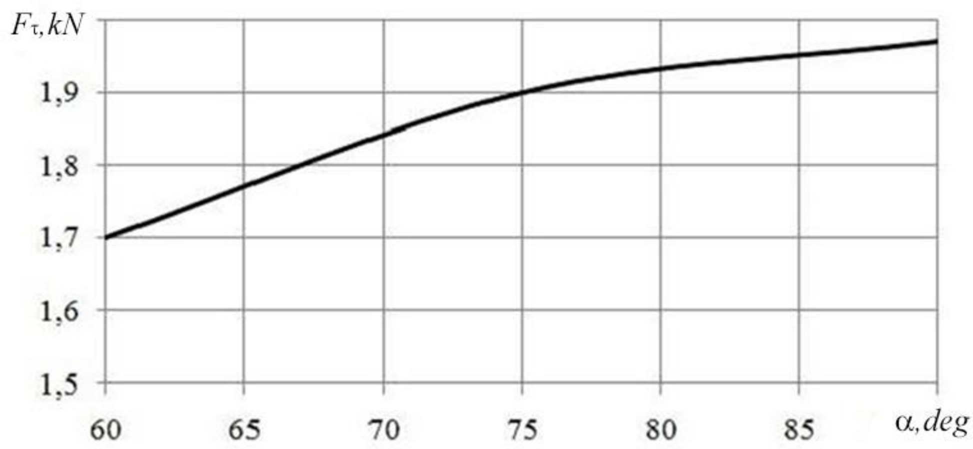


**Fig. 8.** Dependence $F_\tau$ on angle $\alpha$

When comparing the disc working body with co-entropic destruction and the high-speed earth-shattering equipment, it was shown that the energy capacity at the corner is $\alpha = 60°$ equal to, respectively: for the working attachment with co-entropic destruction e = 8.7 kJ/$m^3$; for high-speed soil-destroying equipment e= 5.8 kJ/$m^3$. In addition, the production of thermodynamic entropy with all the same parameters of the destruction of the working medium is 1.5 times less in high-speed soil-destroying equipment.

## CONCLUSIONS

Thus, when organizing the work of destruction with competing factors acting in the same direction, entropy production is reduced: due to the increased informativeness of the construction of working bodies and the maximum involvement of the gravitational field due to the co-entropic directionality of the destruction of working environments.

Such processes lead to a drastic reduction of resource costs per unit of production and improvement of all parameters of the development of working environments.

The task of further research is the synthesis of work equipment in the direction of increasing informativeness and determining the regularities of processes of destruction of working environments by working bodies of increased coentropic directionality.



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## Врахування закономірностей фізичних процесів в конструкціях робочих органів динамічного руйнування


*Леонід Пелевін*[1], *Олександр Тетерятник*[2], *Світлана Комоцька*[3], *Федишин Богдан*[4]

[1,2,3,4]*Київський національний університет будівництва і архітектури*



**Анотація.** У будівництві та суміжних з ним галузях народного господарства багато робіт, що пов'язані із руйнуванням і переміщенням ґрунтів (прокладка комунікацій, видобуток корисних копалин і будівельних матеріалів, меліоративні та військово-інженерні земляні роботи та ін.). Робоче обладнання, яке реалізує принцип статичного руйнування ґрунту, є одним із найважливіших критеріїв, що визначає високу енергоємність робочого процесу сучасних землерийних машин. Навіть іноземна техніка, якою зараз оснащені державні та комунальні підприємства, має кращі характеристики лише завдяки своїй новизні та універсальності. Проте основна проблема – зниження енергоємності розробки ґрунтового масиву – залишається невирішеною.

Процеси руйнування робочих середовищ мають деструктивний характер. Усі реальні процеси незворотні, тобто ентропія ізольованої (замкнутої) системи може лише зростати. Для відкритих систем, де відбувається обмін речовиною з навколишнім середовищем, а також енергією та імпульсом, ентропія може зменшуватися за рахунок поповнення системи речовиною та енергією, але спрямованість природних процесів не змінюється.

Складні та нелінійні процеси розвитку виробничих середовищ характеризуються обома напрямками протікання компонентів цих процесів. Опис еволюції систем внаслідок руху робочих середовищ як процесів деградації доведено та науково обґрунтовано другим законом термодинаміки, еволюція системи в сенсі організації всіх її компонентів – синергією.

Конструктивне виконання робочих органів будівельних машин таким чином, коли реалізується співнапрямок процесів руйнування з перебігом природних процесів, дозволяє значно підвищити інформативність роботи будівельної машини. Такі процеси призводять до різкого зниження витрат ресурсів на одиницю продукції та покращення всіх параметрів розвитку виробничих середовищ.

Враховуючи вищевикладене, а також необхідність зменшення енергетичної залежності України від інших країн, виникає потреба у розробці та створенні низькоенергетичних високошвидкісних робочих органів землерийних машин.

При формуванні вибою необхідно враховувати, що процес руйнування повинен збігатися з напрямком процесу природного руйнування з метою зменшення енергетичних витрат.

**Ключові слова**: ентропія, інформативність, синергія, робоче середовище, гравітаційне поле, енергоємність.