Modelling of soil destruction process by bulldozer using a spatially oriented working unit

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Abstract. The article uses approaches to creating a model for calculating soil cutting forces by spatially oriented working units of construction machines used on construction sites. The use of such a model is due to the need for continuous improvement of existing equipment and the creation of new ones, taking into account the existing needs. Today, there is a need for efficient performance of construction works related to the operation of construction equipment with dumping equipment. This, in turn, poses the task of determining the performance of mechanised earthworks in various working environments, one of the most common in Ukraine being marl clay, loam and argillaceous clay.

The main method of mechanical soil development is cutting. The main geometric conditions are the position of the cutting wedge edge relative to the cutting direction and the surface of the massif, the outline of the cutting edge, the outline and number of working surfaces of the cutting wedge, the number of so-called side cut surfaces and the so-called blocked cut surfaces. The peculiarity of the digging process is that its power and energy indicators depend on the kinematic conditions and geometric parameters – thickness, width and area of the cut, as well as on the angles of orientation of the working unit in space.

The computational model was created in accordance with the working hypothesis, where the movement of spatially oriented knives moves perpendicular to the blade equipment, at different ratios of the blade movement speed and knife movement, which creates spatial interaction with the working environment, and the deviation of the application of the full cutting force by an angle α.

In accordance with the working hypothesis, we obtained five plans for the movement of the spatially oriented blade of the blade. Depending on the plan of movement of the spatially oriented knife, its geometric interaction with the working environment changes and the cutting force changes accordingly.

The need to create more productive and efficient earthmoving equipment requires the use of modern design solutions. In the course of the study, a model for calculating the cutting of soils by spatially oriented earthmoving tools in the form of a dihedral knife of dump equipment was created. A comparison of soil cutting forces at different depths during the operation of a spatially oriented working body is also proposed. The results are summarised in the form of tabular data and graphs.

Keywords: parametrization, bulldozer blade, cutting force, spatially oriented, angle of rotation in plan.

INTRODUCTION

Most calculations of earthmoving equipment knives and teeth are based on the assumption that the parameters of the working tool do not change when it interacts with the soil [1,15].

Changes in parameters due to the multi-vector action of the working body parts are poorly understood. Therefore, it is particularly relevant to develop a methodology for determining the parameters and cutting forces of a spatially oriented blade of dumping equipment [14].

ANALYSIS OF RESEARCH

The main method of mechanical destruction of soils is cutting. The main geometric conditions are the position of the cutting wedge edge relative to the cutting direction and the surface of the massif, the outline of the cutting edge, the outline and number of working surfaces of the cutting wedge, the number of so-called side cut surfaces and the so-called blocked cut surfaces. These features are used to distinguish the different types of process and create a classification of cutting types [6,16,19,20].

When operating an earthmoving machine with an oblique cut, the interaction of the knife with the soil is spatial, which is manifested in the formation of a trapezoidal cross-section in the asymmetrical slot.

In order to quantify the influence of the spatial process, it is proposed to consider the force *P* as a component of parts corresponding to the nature of soil resistance in different parts of the fracture area in front of the knife. Thus, the force *P* of oblique cutting of soils is defined as the sum of three components P_f – the force to overcome soil resistance by the front edge of the knife, P_s – the force to overcome soil fracture resistance in the lateral extensions of the
65 slot, and $P_{s.c}$ – the force to overcome soil cut resistance by the side edges of the knife [17,18].

The difference between P_f for rectangular cutting and P_f for oblique cutting is proposed to be taken into account by the coefficient φ_f, which depends on the *h/b* ratio and the angle γ_{pl} of the knife's rotation in the plan.

The forces P_s and $P_{s.c}$ depend, in addition to the soil properties, only on the thickness of the cut and the angle γ_{pl} of the blade in the plan view. The effect of the angle of rotation of the knife in the plan on the change in these forces is taken into account by the coefficients φ_s and $\varphi_{s.c}$[2] (Fig. 7,8).

The *h/b* ratio between the thickness and the width of the cut, the size of the side extensions increases proportionally with increasing cut thickness, while the width remains constant [9,11]. When the cutting thickness reaches the so-called critical cutting depth, the growth of the lateral widening of the slot stops and the intensive growth of the areas of lateral soil cut by the knife ribs begins. The soil in front of the knife beyond the critical cutting depth is pressed into the massif on the sides of the knife and is not separated from the massif. Therefore, the critical cutting depth corresponds to the minimum power consumption [5,7,13].

The peculiarity of the digging process is that its power and energy indicators depend on the kinematic conditions and geometric parameters – thickness, width and cut area, as well as on the angles of orientation of the working body in space [3,8,].

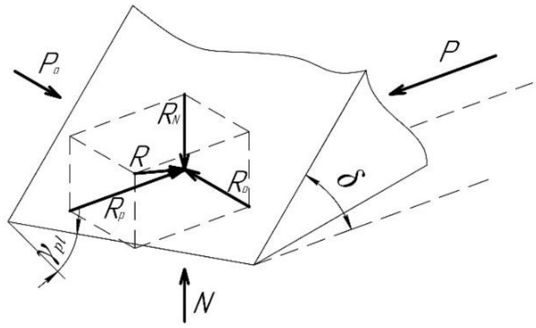

Fig. 1. *P* – frontal cutting force; *N* – is the normal cutting force; P_o – is the orthogonal cutting force; δ – cutting angle; γ_{pl} – angle of rotation in the plan.

RESEARCH AIM

Development of a methodology for calculating the parameterisation of soil cutting by a spatially oriented knife depending on the cutting force applied.

RESEARCH RESULTS

Using the data obtained during the vector calculation, we apply the vector denoting the direction of the cutting force to the spatially oriented knife of dynamic action, taking into account the angle α, an indicator of the direction of application of the cutting force, we can find the change in the angle γ_{pl} of the knife rotation in the plan [4].

The use of a dihedral knife results in two planar rotation angles $\gamma_{pl.v.1}$ and $\gamma_{pl.v.2}$ corresponding to each of the edges and a change in the cutting width *b*.

These parameters influence the cutting width *b,* so the definition of the cutting width is derived from the motion vector and calculated using equations b_1 and b_2, which are given below where *A* is the length of the knife edge [10,12].

$$b_I = A \cdot \cos(\gamma_{pl.v.1})$$
$$b_{II} = B \cdot \cos(\gamma_{pl.v.2})$$

The critical cutting depth for most soils at normal cutting angles of the blade is equal to the ratio *h/b* of the cutting depth *h* to the blade width *b* ranging from1 to 3.

The calculation was performed using the oblique cutting formula:

$$P = \varphi(\delta)\varphi_f m_f bh + \varphi_s m_s h^2 + \varphi_{s.c} m_{s.c} h$$

Where *b*, *h* – blade width and cutting depth.
m_f – strength coefficient characterising specific resistances in the frontal part of the notch (MPa) (Table 1).
m_s – strength coefficient characterising specific resistances in lateral extensions (MPa) (Table 1).
$m_{s.c}$ – strength coefficient characterising the specific resistances along the lateral cut lines (кN/m) (Table 1).
φ (δ) – coefficient that takes into account the effect of the cutting angle *δ* (at $\delta = 45^0$, φ = 1).
φ_f – is a coefficient that takes into account the influence of the angle γ_{pl} of the knife rotation in the plan, respectively, of the force P_f.
φ_s – is a coefficient that takes into account the influence of the angle γ_{pl} of the knife rotation in the plan, respectively, of the force P_s (Fig. 7).
$\varphi_{s.c}$ – is a coefficient that takes into account the influence of the angle γ_{pl} of the knife rotation in the plan, respectively, of the force $P_{s.c}$. (Fig. 8).

Formulas for determining the coefficient φ_f for each blade edge:

$$\varphi_{f.1} = 1 - 0{,}07\frac{h}{b_1}(\cot\delta + \cot 35^\circ)\sin 2\gamma_{pl.v.1}$$

$$\varphi_{f.2} = 1 - 0{,}07\frac{h}{b_2}(\cot\delta + \cot 35^\circ)\sin 2\gamma_{pl.v.2}$$

Table 1. Specific soil resistances

Soil	m_f, MPa	m_s, MPa	$m_{s.c}$, кN/m
Marl clay	0,3	0,021	0,4
Loam	0,15	0,013	1,42
Argillite	0,25	0,024	5,47

Table 2. Physical characteristics of soils

Soil	Dimensional characteristics of the destruction zone		
	μ	k_s	γ
Marl clay	14°	0,8	30°
Loam	18°	0,85	40°
Argillite	16°	0,9	30°

In accordance with the working hypothesis, five main provisions for parameterising a spatially oriented knife from an angle α ranging from 0° to 90° have been found:

1) When the angle α is equal to 0°:

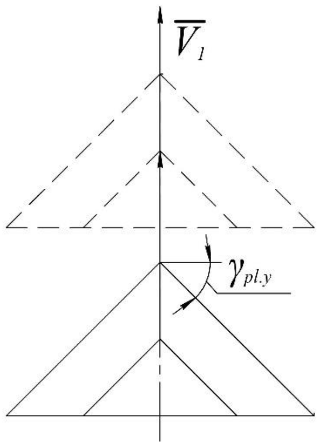

Fig. 2. Movement of a spatially oriented knife at an angle α, equal to 0°

Full cutting force:

$$P = 2P_{(V_1)}$$

$$P_{(V_1)} = \varphi(\delta)\varphi_f m_f b_1 h + \varphi_s m_s h^2 + \varphi_{s.c} m_{s.c} h$$

Normal cutting force:

$$N = P_{(V_1)} \cdot \left(\frac{\cos\gamma_{pl.v.1} - \tan\mu \sin\delta\varepsilon}{\tan\delta\cos\gamma_{pl.v.1} + \tan\mu\cos\delta\varepsilon} \right)$$

$$\varepsilon = \sqrt{\cos^2\gamma_{pl.v.1} + \tan^2\delta}$$

$$N_{com} = 2 \cdot N$$

With these operating parameters of the spatially oriented knife, the orthogonal cutting force is balanced.

2) When the angle α is equal to 90°:

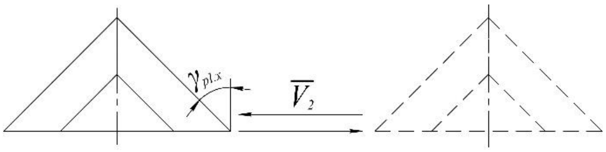

Fig. 3. Movement of a spatially oriented knife at an angle α, equal to 90°

Full cutting force for $\overline{V}_2$:

$$P_{(V_2)} = \varphi(\delta)\varphi_f m_f b_1 h + \varphi_s m_s h^2 + \varphi_{s.c} m_{s.c} h$$

Normal cutting force for $\overline{V}_2$:

$$N = P_{(V_2)} \cdot \left(\frac{\cos\gamma_{pl.v.1} - \tan\mu \sin\delta\varepsilon}{\tan\delta\cos\gamma_{pl.v.1} + \tan\mu\cos\delta\varepsilon} \right)$$

Orthogonal cutting force for $\overline{V}_2$:

$$P_o = P_{(V_2)} \cdot \left(\frac{\tan\delta\sin\gamma_{pl.v.1}}{\tan\delta\cos\gamma_{pl.v.1} + \tan\mu\cos\delta\varepsilon} \right)$$

Next, the knife cycle is constructed in accordance with the motion vectors $\overline{V}_\Sigma$, with such a complex movement, the interaction of the knife with the soil changes as γ_{pl} and b, change, instead, $\gamma_{pl.v.1}$, $\gamma_{pl.v.2}$, and b_1, b_2 appear, which are taken into account in the equations for determining the forces P, N, P_o.

3) When the angle α is less than 45°:

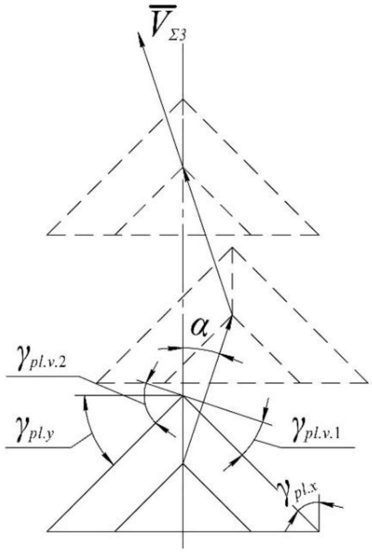

Fig. 4. Movement of a spatially oriented knife at an angle α <45°

Full cutting force for $\overline{V}_{\Sigma 3}$:

$$P_1 = \varphi(\delta)\varphi_{f.1} m_f b_1 h + \varphi_{s.1} m_s h^2 + \varphi_{s.c.1} m_{s.c} h$$

$$P_2 = \varphi(\delta)\varphi_{f.2} m_f b_2 h + \varphi_{s.2} m_s h^2 + \varphi_{s.c.2} m_{s.c} h$$

$$P_{com} = P_1 + P_2$$

Normal cutting force for $\overline{V}_{\Sigma 3}$:

$$N_1 = P_1 \cdot \left(\frac{\cos\gamma_{pl.v.1} - \tan\mu \sin\delta\varepsilon}{\tan\delta\cos\gamma_{pl.v.1} + \tan\mu\cos\delta\varepsilon} \right)$$

$$N_2 = P_2 \cdot \left(\frac{\cos\gamma_{pl.v.2} - \tan\mu \sin\delta\varepsilon_2}{\tan\delta\cos\gamma_{pl.v.2} + \tan\mu\cos\delta\varepsilon_2} \right)$$

$$\varepsilon_2 = \sqrt{\cos^2\gamma_{pl.v.2} + \tan^2\delta}$$

$$N_{com} = N_1 + N_2$$

Orthogonal cutting force for $\overline{V}_{\Sigma 3}$:

$$P_{o.1} = P_1 \cdot \left(\frac{\tan\delta\sin\gamma_{pl.v.1}}{\tan\delta\cos\gamma_{pl.v.1} + \tan\mu\cos\delta\varepsilon} \right)$$

$$P_{o.2} = P_2 \cdot \left(\frac{\tan\delta \sin\gamma_{pl.v.2}}{\tan\delta \cos\gamma_{pl.v.2} + \tan\mu \cos\delta\varepsilon} \right)$$

$$P_{o.com} = P_{o.2} - P_{o.1}$$

4) When the angle α is equal to 45°:

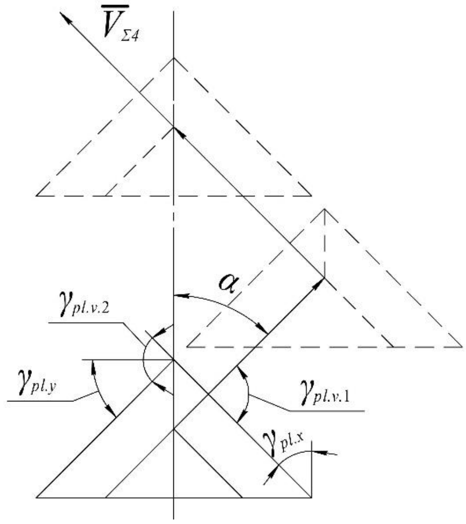

Fig. 5. Movement of a spatially oriented knife at an angle α, equal to 45°

Full cutting force for $\overline{V}_{\Sigma 4}$:

$$P = \varphi(\delta) m_f b_1 h + 2 m_s h^2 + 2 m_{s.c} h$$

Normal cutting force for $\overline{V}_{\Sigma 4}$:

$$N = P \cdot \cot(\delta + \mu)$$

With these operating parameters of the spatially oriented knife, there is no orthogonal cutting force.

5) When the angle α is greater than 45°:

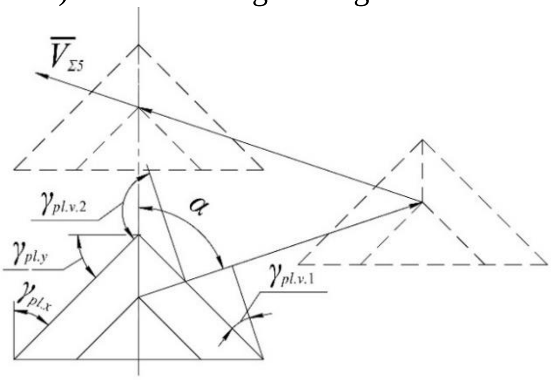

Fig. 6. Movement of a spatially oriented knife at an angle α >45°

Full cutting force for $\overline{V}_{\Sigma 5}$:

$$P = \varphi(\delta) \varphi_f m_f b_1 h + \varphi_s m_s h^2 + \varphi_{s.c} m_{s.c} h$$

Normal cutting force for $\overline{V}_{\Sigma 5}$:

$$N = P \cdot \left(\frac{\cos\gamma_{pl.v.1} - \tan\mu \sin\delta\varepsilon}{\tan\delta \cos\gamma_{pl.v.1} + \tan\mu \cos\delta\varepsilon} \right)$$

Orthogonal cutting force for $\overline{V}_{\Sigma 5}$:

$$P_o = P \cdot \left(\frac{\tan\delta \sin\gamma_{pl.v.1}}{\tan\delta \cos\gamma_{pl.v.1} + \tan\mu \cos\delta\varepsilon} \right)$$

Table 2: Coefficients φ_f

α	$\gamma_{pl.v.1}$	$\gamma_{pl.v.2}$	b_1	b_2	*h*, cm					
					10		20		35	
			cm		$\varphi_{f.1}$	$\varphi_{f.2}$	$\varphi_{f.1}$	$\varphi_{f.2}$	$\varphi_{f.1}$	$\varphi_{f.2}$
0°	45°	45°	10,5	10,5	0,83	0,83	0,66	0,66	0,4	0,4
10°	35°	55°	12.3	8,6	0,87	0,81	0,72	0,61	0,52	0,31
20°	25°	65°	13.6	6,4	0,9	0,79	0,79	0,57	0,64	0,24
30°	15°	75°	14.5	3,5	0,94	0,75	0,87	0,49	0,78	0,1
40°	5°	85°	15	1,5	0,98	0,8	0,95	0,58	0,92	0,27
45°	0°	90°	15	-	1	-	1	-	1	-
50°	5°	95°	15	-	0,98	-	0,95	-	0,92	-
60°	15°	105°	14,5	-	0,94	-	0,87	-	0,78	-
70°	25°	115°	13,6	-	0,9	-	0,79	-	0,64	-
80°	35°	125°	12,3	-	0,87	-	0,72	-	0,52	-
90°	45°	135°	10,5	-	0,83	-	0,66	-	0,4	-

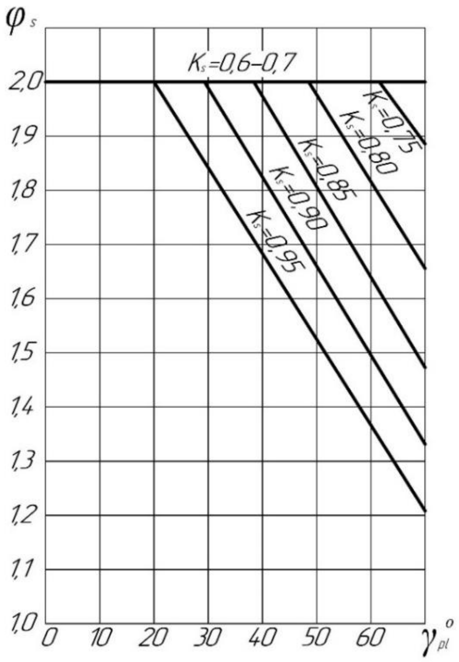

Fig. 7. Graph of dependencies $\varphi_s(\gamma_{pl})$

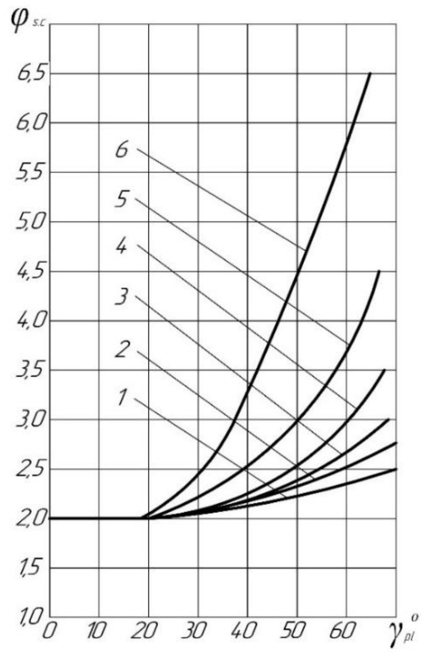

Fig. 8. Graph of dependencies $\varphi_{s.c}(\gamma_{pl})$

For values of k_s: 1 – 0.6; 2 – 0,7; 3 – 0,75; 4 – 0,8; 5 – 0,85; 6 – 0,9.

Table 3: Coefficients φ_s

α	$\gamma_{pl.v.1}$	$\gamma_{pl.v.2}$	b_1	b_2	k_s					
					0,8		0,85		0,9	
			cm		$\varphi_{s.1}$	$\varphi_{s.2}$	$\varphi_{s.1}$	$\varphi_{s.2}$	$\varphi_{s.1}$	$\varphi_{s.2}$
0°	45°	45°	10,5	10,5	2,0	2,0	1,88	1,88	1,75	1,75
10°	35°	55°	12.3	8,6	2,0	1,89	2,0	1,72	1,89	1,57
20°	25°	65°	13.6	6,4	2,0	1,73	2,0	1,55	2,0	1,41
30°	15°	75°	14.5	3,5	2,0	1,58	2,0	1,39	2,0	1,25
40°	5°	85°	15	1,5	2,0	1,41	2,0	1,22	2,0	0,9
45°	0°	90°	15	-	2,0	-	2,0	-	2,0	-
50°	5°	95°	15	-	2,0	-	2,0	-	2,0	-
60°	15°	105°	14,5	-	2,0	-	2,0	-	2,0	-
70°	25°	115°	13,6	-	2,0	-	2,0	-	2,0	-
80°	35°	125°	12,3	-	2,0	-	2,0	-	1,89	-
90°	45°	135°	10,5	-	2,0	-	1,88	-	1,75	-

Table 4. Coefficients $\varphi_{s.c.}$

α	$\gamma_{pl.v.1}$	$\gamma_{pl.v.2}$	b_1	b_2	k_s					
					0,8		0,85		0,9	
			cm		$\varphi_{s.c.1}$	$\varphi_{s.c.2}$	$\varphi_{s.c.1}$	$\varphi_{s.c.2}$	$\varphi_{s.c.1}$	$\varphi_{s.c.2}$
0°	45°	45°	10,5	10,5	2,29	2,29	2,66	2,66	3,64	3,64
10°	35°	55°	12.3	8,6	2,1	2,7	2,3	3,41	2,8	4,83
20°	25°	65°	13.6	6,4	2,05	3,3	2,1	4,27	2,2	6,19
30°	15°	75°	14.5	3,5	2,0	3,96	2,0	5,2	2,0	7,67
40°	5°	85°	15	1,5	2,0	4,65	2,0	6,17	2,0	9,21
45°	0°	90°	15	-	2,0	-	2,0	-	2,0	-
50°	5°	95°	15	-	2,0	-	2,0	-	2,0	-
60°	15°	105°	14,5	-	2,0	-	2,0	-	2,0	-
70°	25°	115°	13,6	-	2,05	-	2,1	-	2,2	-
80°	35°	125°	12,3	-	2,1	-	2,3	-	2,8	-
90°	45°	135°	10,5	-	2,29	-	2,66	-	3,64	-

Table 5. Cutting forces in marl clay

α	Marl clay								
	h, cm								
	10			20			35		
	P	*N*	P_o	*P*	*N*	P_o	*P*	*N*	P_o
0°	6,25	3,33	0,00	12,04	6,41	0,00	19,75	10,51	0,00
10°	6,31	3,33	0,70	12,11	6,40	1,30	20,19	10,70	1,82
20°	6,19	3,20	1,43	12,20	6,31	2,70	21,10	10,97	4,25
30°	5,87	2,95	1,82	12,08	6,07	3,84	22,29	11,16	7,23
40°	5,75	2,95	2,83	12,47	6,24	7,11	24,62	11,95	16,35
45°	5,00	3,00	0,00	10,84	6,51	0,00	21,18	12,72	0,00
50°	4,91	2,95	0,34	10,39	6,24	0,73	19,92	11,95	1,39
60°	4,59	2,73	0,98	9,41	5,60	2,01	17,30	10,30	3,70
70°	4,17	2,44	1,54	8,29	4,84	3,06	14,57	8,51	5,38
80°	3,71	2,10	2,03	7,16	4,04	3,92	12,15	6,86	6,66
90°	3,13	1,66	2,39	6,02	3,20	4,61	9,88	5,26	7,57

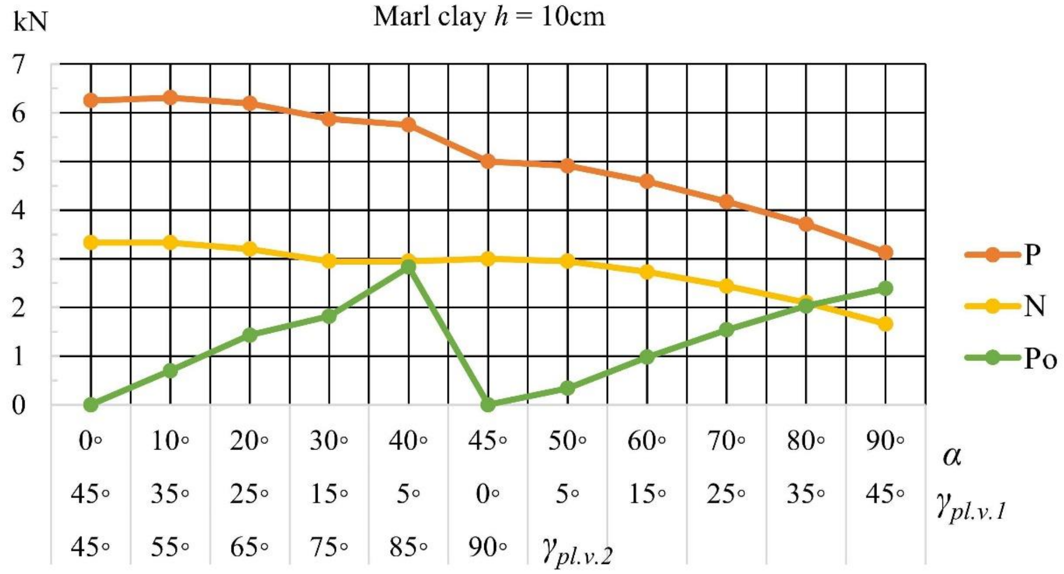

Fig. 9. Cutting forces in marl clay at working depth

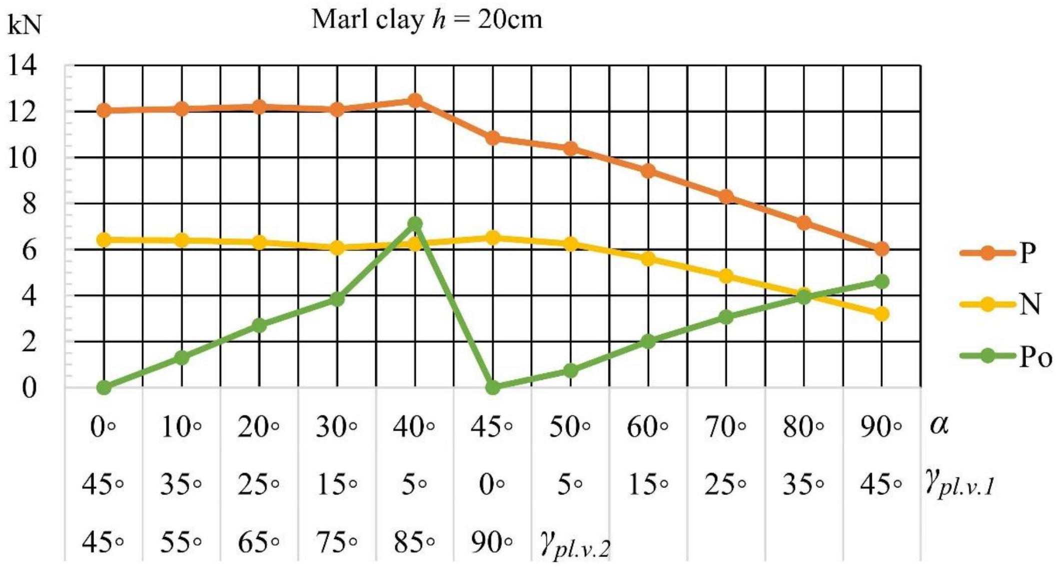

Fig. 10. Cutting forces in marl clay at subcritical depths

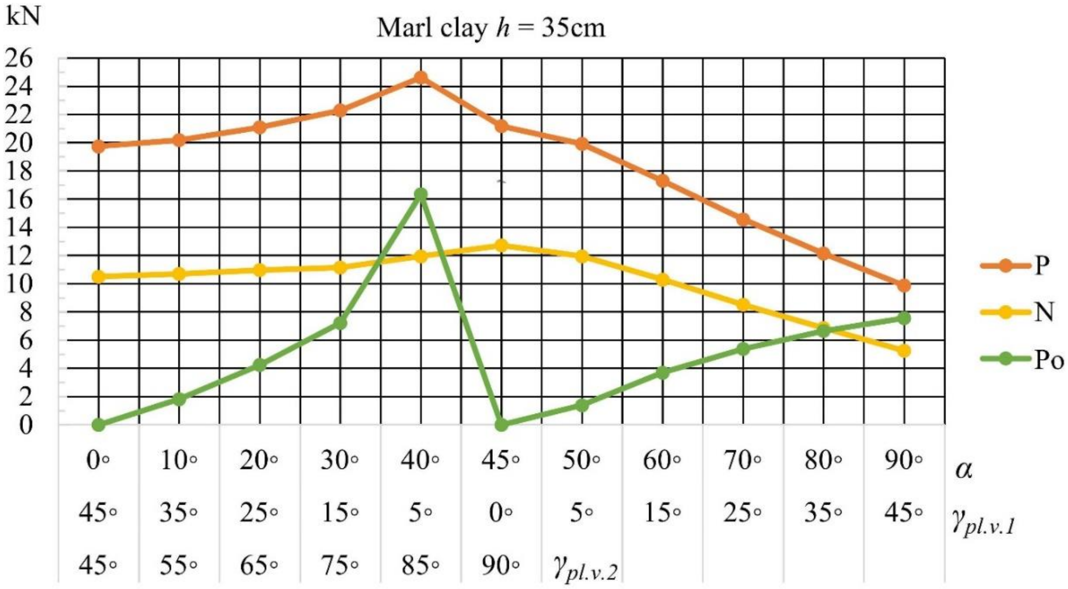

Fig. 11. Cutting forces in marl clay at critical depth

Table 6. Cutting forces in loam

α	Loam								
	h, cm								
	10			20			35		
	P	N	P_o	P	N	P_o	P	N	P_o
0°	3,86	1,66	0,00	7,62	3,28	0,00	13,04	5,62	0,00
10°	3,94	1,67	0,59	7,79	3,30	1,12	13,52	5,74	1,75
20°	3,96	1,58	1,28	7,97	3,18	2,51	14,20	5,70	4,22
30°	3,90	1,36	2,03	8,11	2,83	4,20	15,10	5,30	7,66
40°	3,96	1,40	3,63	8,53	2,99	7,91	16,65	5,81	15,62
45°	2,79	1,42	0,00	6,11	3,11	0,00	12,05	6,14	0,00
50°	2,75	1,40	0,18	5,88	2,99	0,39	11,42	5,81	0,75
60°	2,59	1,30	0,52	5,39	2,71	1,09	10,12	5,09	2,04
70°	2,39	1,17	0,83	4,86	2,38	1,69	8,80	4,31	3,06
80°	2,19	1,03	1,13	4,35	2,04	2,24	7,69	3,60	3,95
90°	1,93	0,83	1,38	3,81	1,64	2,73	6,52	2,81	4,66

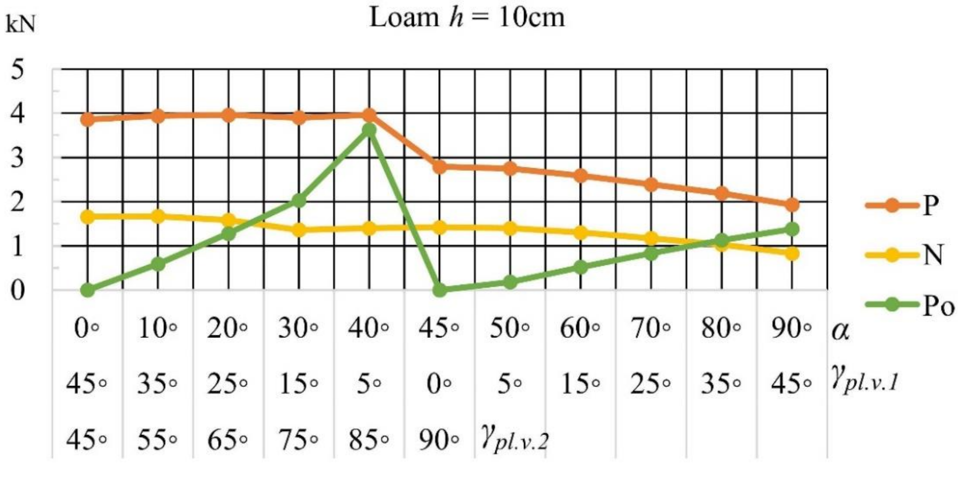

Fig. 12. Cutting forces in loam at working depth

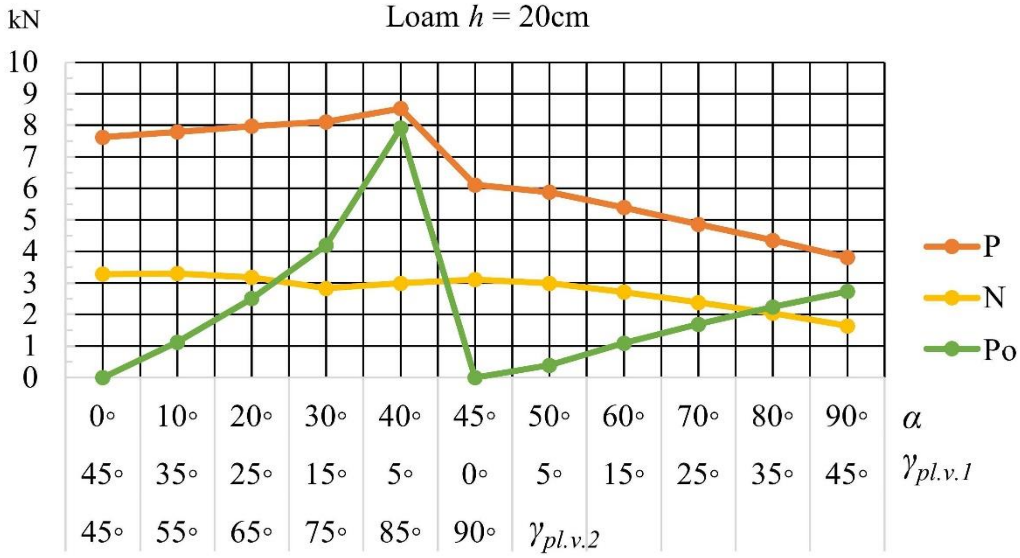

Fig. 13. Cutting forces in loam at subcritical depths

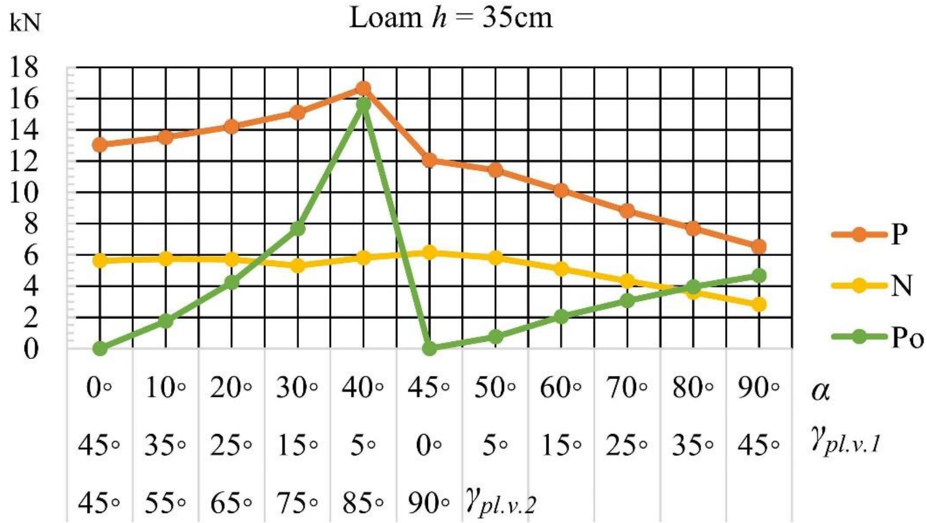

Fig. 14. Cutting forces in loam at critical depth

Table 7. Cutting forces in argillite

α	Argillite								
	h, cm								
	10			20			35		
	P	*N*	P_o	*P*	*N*	P_o	*P*	*N*	P_o
0°	9,18	4,41	0,00	18,25	8,77	0,00	31,58	15,16	0,00
10°	9,42	4,40	2,36	18,72	8,76	4,62	32,71	15,32	7,67
20°	9,73	4,11	5,33	19,65	8,33	10,56	35,05	14,96	18,11
30°	10,13	3,27	9,59	20,86	6,81	19,39	38,27	12,72	34,44
40°	10,80	2,91	18,68	22,61	6,22	38,22	42,42	12,06	69,23
45°	5,32	2,95	0,00	11,61	6,43	0,00	22,83	12,66	0,00
50°	5,25	2,91	0,36	11,23	6,22	0,76	21,78	12,06	1,48
60°	4,98	2,73	1,03	10,42	5,71	2,16	19,61	10,75	4,07
70°	4,74	2,54	1,70	9,70	5,20	3,47	17,71	9,49	6,34
80°	4,66	2,40	2,47	9,31	4,79	4,94	16,51	8,51	8,76
90°	4,59	2,20	3,40	9,13	4,38	6,75	15,79	7,58	11,69

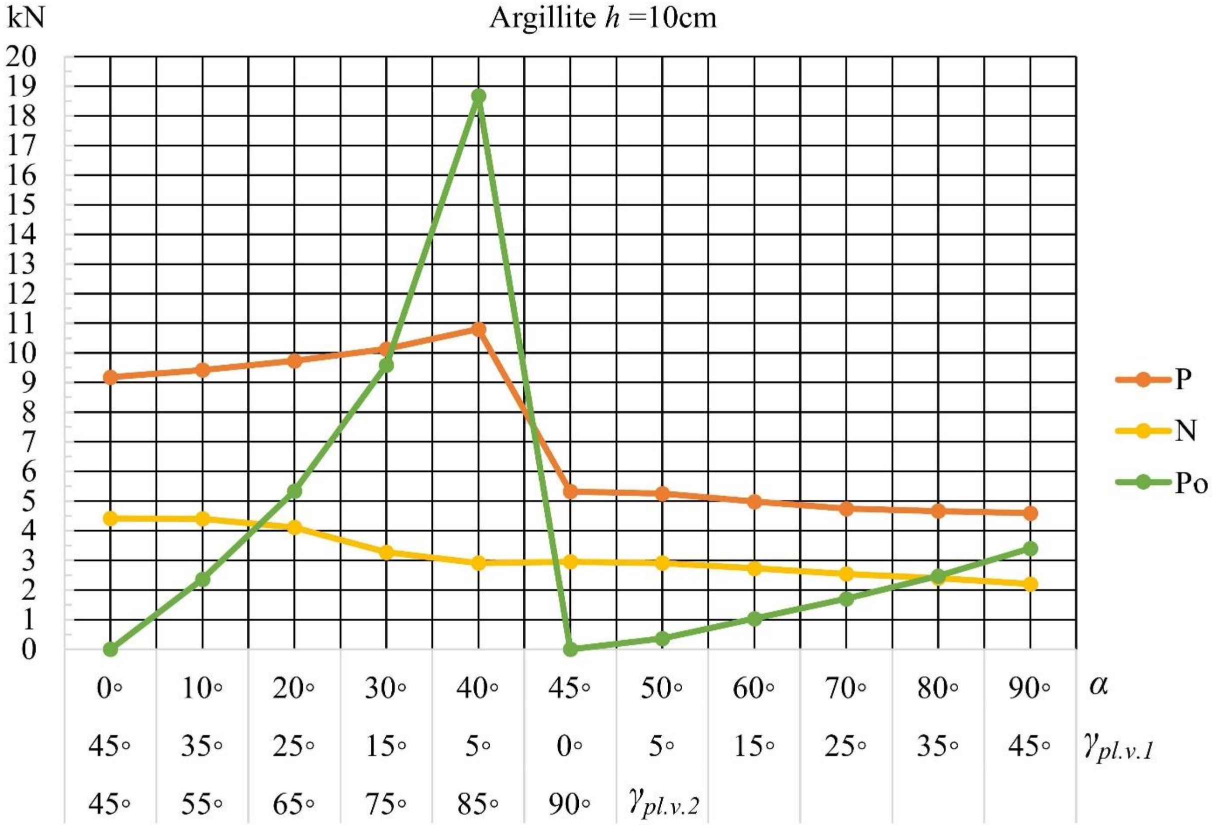

Fig. 15. Cutting forces in argillite at working depth

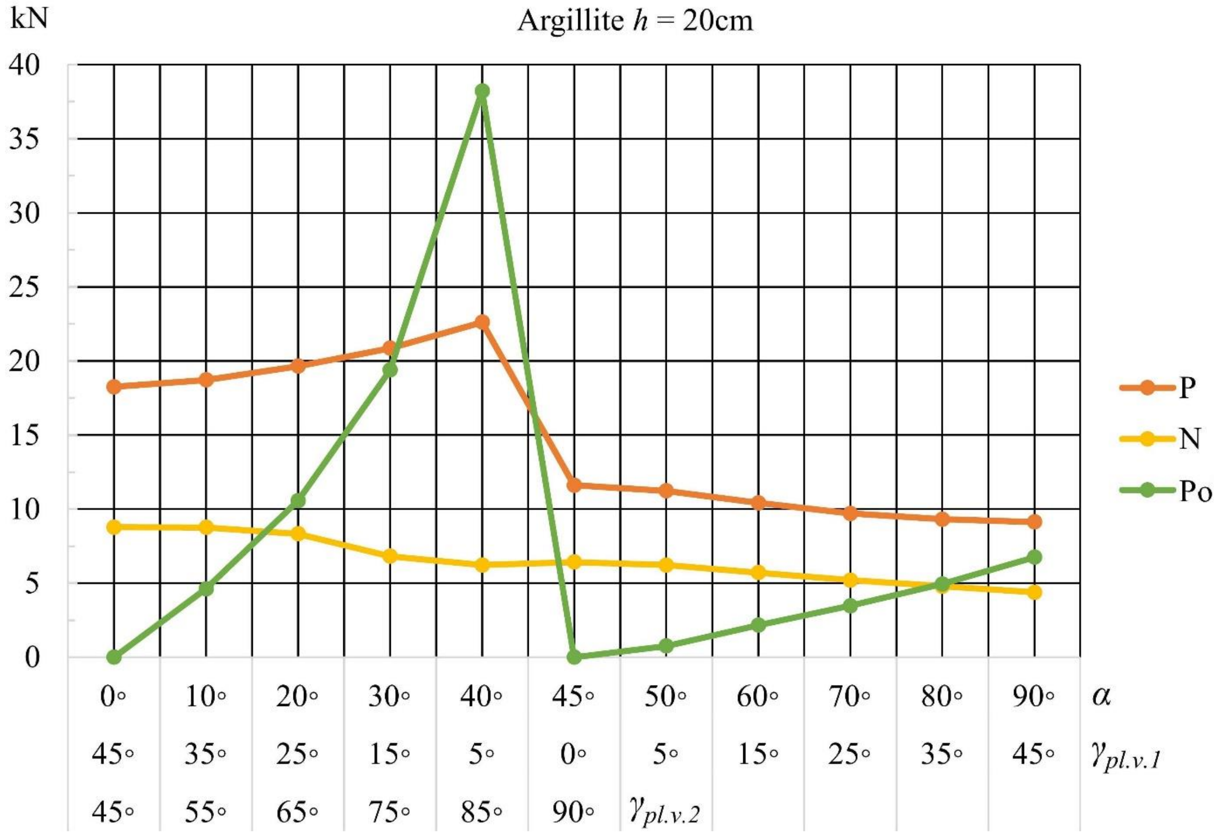

Fig. 16. Cutting forces in argillite at subcritical depths

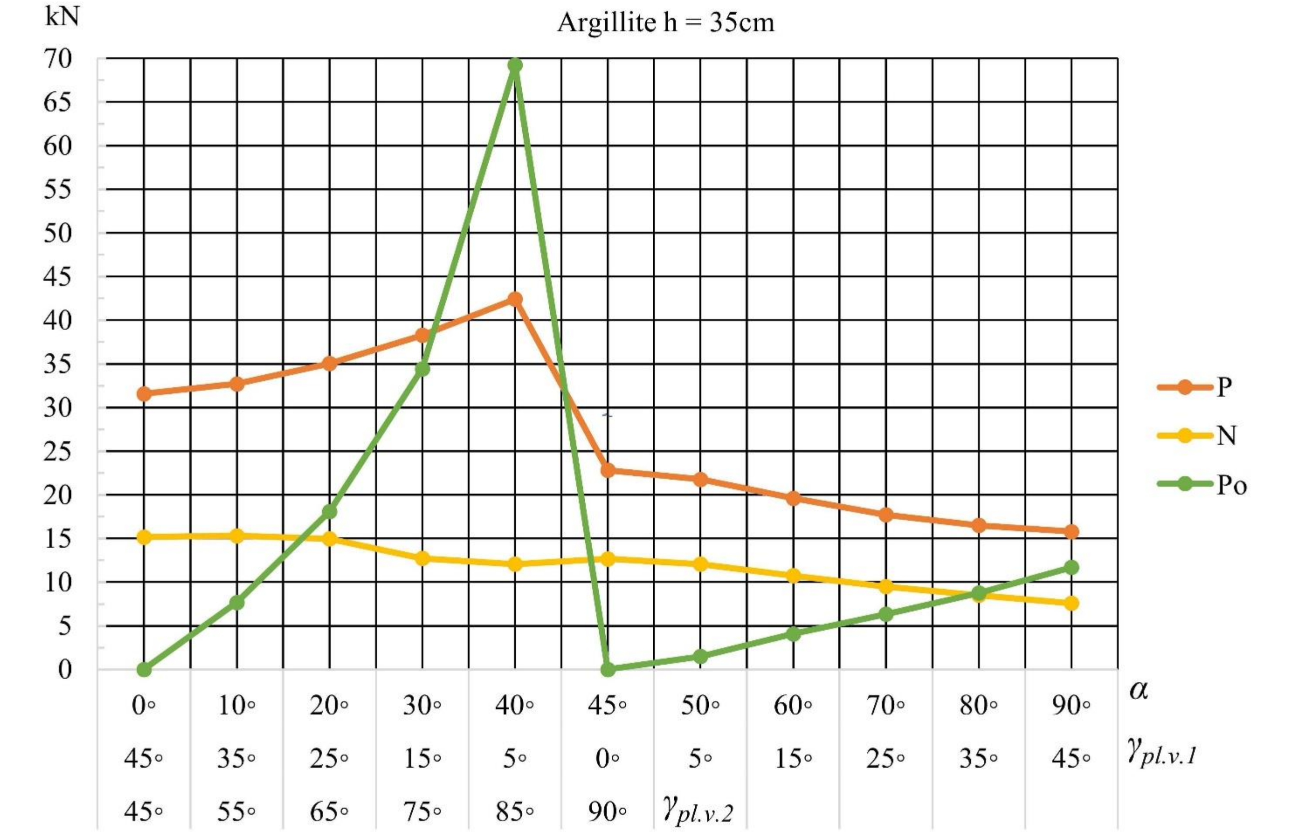

Fig. 17. Cutting forces in argillite at critical depths

CONCLUSIONS

1. The motion plans of a spatially oriented knife are constructed depending on $\overline{V}_{\Sigma}$, found when determining the cutting direction at the velocity ratios.
2. The cutting forces of a spatially oriented knife were calculated, depending on the deviations by the angle α which in turn shows the ratio of the speeds of the dumping equipment and the working body, for such soils as loam, marl clay, and argillite, with an *h/b* ratio of 0,4 to 3,5, which meets the criteria for cutting at critical depths at different interactions of the knife with the soil.
3. The coefficients of influence of the angle of rotation in the plan are found φ_f, φ_s, $\varphi_{s.c}$.
4. The calculations are presented as tabu-
77 lar data below and a graphical representation of the cutting forces P, N, P_o by a spatially oriented knife of the blade is constructed.
5. It was found that when changing the speed ratio, the angle γ_{pl} of rotation of the knife in the plan changes and this accordingly affects the *P* cutting force, with an increase in α it decreases, *N* normal force, with an increase in α it decreases, and *Po* orthogonal cutting force, with an increase in α it increases.

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Розробка моделі процесу руйнування ґрунту з використанням просторово орієнтованого робочого органу

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Анотація. У статті використано підходи до створення моделі розрахунку зусиль різання ґрунту просторово орієнтованими робочими органами будівельних машин, які застосовуються на будівельних майданчиках. Використання такої моделі обумовлено необхідністю постійного вдосконалення існуючої техніки та створення нової з урахуванням існуючих потреб.

На сьогодні день існує потреба в ефективному виконанні будівельних робіт, пов'язаних з роботою будівельної техніки відвальним обладнанням. Це, в свою чергу, ставить завдання визначення виконання механізованих земляних робіт при різних робочих середовищах, одними з найрозповсюдженіших на території України являються мергелисті глини, суглинки та аргіліти.

Основним способом механічної розробки ґрунтів являється, різання. Основними геометричними умовами пропонується вважати положення кромки ріжучого клину відносно напрямку різання і поверхні масиву, обриси ріжучої кромки, обриси і кількість робочих поверхонь ріжучого клину, число поверхнею так званого бокового зрізу і так званих блокованих поверхонь зрізу. Особливість процесу копання полягає в тому, що його силові й енергетичні показники залежать від кінематичних умов, та від геометричних параметрів – товщини, ширини і площі зрізу, а також від кутів орієнтації робочого органа в просторі

Створення розрахункової моделі проводилося відповідно до робочої гіпотези, де переміщення просторово орієнтованих ножів рухається перпендикулярно до відвального обладнання, при різних співвідношеннях швидкостей руху відвалу та переміщенню ножів, що створює просторову взаємодію з робочим середовищем, та відхилення прикладання повної сили різання на кут α.

Відповідно до робочої гіпотези, ми отримали п’ять планів переміщення просторово орієнтованого ножа відвалу. В залежності від плану переміщення просторово орієнтованого ножа змінюється його геометрична взаємодія з робочим середовищем і відповідно змінюється сила різання.

Необхідність створення більш продуктивної та ефективної землерийної техніки вимагає застосування сучасних конструктивних рішень. В ході дослідження було створено модель розрахунку різання ґрунтів просторово орієнтованими землерийними робочими органами у вигляді двогранного ножа відвального обладнання. Також запропоновано порівняння сил різання ґрунтів на різних глибинах при роботі просторово орієнтованого робочого органу. Результати узагальнено у вигляді табличних даних та графіків.

Ключові слова: параметризація, бульдозерний відвал, сила різання, просторова орієнтація, кут повороту в плані.