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RESEARCH ARTICLE

COMBINED METHODS OF SOIL, CULTIVATION, USING SMALL TECHNICAL MEANS

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Abstract

Georgia is distinguished by mountainous regions, diverse natural climatic conditions and different types of soils. Therefore, soils require specific treatment that must meet the agrotechnical requirements of crops. In mountainous conditions, small technical means or low-power tractors are used for soil cultivation, since agricultural plots have a small area and the use of high-power technical means is inappropriate, which should ensure soil loosening, weeding, fertilizer application, and soil preparation for sowing. The scientific work discusses the working bodies of combined plows currently available, which are widely implemented in the world's agrotechnological industry, and their features in the mountainous terrain of Georgia, in particular on the example of the Samtskhe-Javakheti region. Multiple tests of existing technical means have shown that, in these conditions, full-fledged plowing of the soil and simultaneous surface cultivation greatly reduce labor costs and provide farmers with the opportunity to improve their economic performance in small-scale farming. All this will increase yields and promote the development of new farms. The aim of the scientific work is to study and analyze the physical composition of the Samtskhe-Javakheti soil and develop a combined plow design that will allow them to be used in mountainous conditions in accordance with the relevant agrotechnological requirements.

Introduction:-

To prepare the soil for planting or sowing agricultural crops with traction machines, it is necessary to carry out several operations with a set of machines consisting of at least a plow, cultivator, various harrows and rollers, which lengthens and increases the cost of pre-sowing soil cultivation. Multiple passes of powerful and heavy machine and tractor units across the field have an adverse effect on the agrophysical condition of the soil: the structure of the upper layers is destroyed and the lower horizons are compacted, which leads to the development of wind and water erosion, a decrease in the potential fertility of fields and crop failure. At this stage of development of agricultural mechanics, one of the promising directions of development of soil-cultivating equipment is the use of machines with active working bodies driven by the power take-off shaft of a tractor or other autonomous engine.Tillage machines with driven working bodies (tillage cutters, rotary plows) have a number of technological advantages over traditional moldboard plows, cultivator and harrows traditional machines: they can be used in a wide range of soil conditions - from over-dried to over-moistened and even flooded rice fields. Rotary tillage ensures high agronomic efficiency of the tilled layer. Driven

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working bodies can change the quality of tillage in a wide range, due to the selective combination of the rotation frequency of the working bodies and the forward speed of the machine. Depending on the kinematic mode, they can perform primary and pre-sowing tillage. In other words, there are great opportunities for managing the soil structure, and the necessary soil structure ensures its exchange characteristics and, accordingly, a higher yield. The monolithic state of the soil can be changed by combining the operation of traction and driven working bodies. The traction-driven concept of soil cultivation has a number of advantages over both traditional traction machines and purely driven ones. Traction-driven implements have a higher efficiency factor, reduced to the degree of soil crumbling, as well as the possibility of a qualitative transition from tools for soil loosening to tools for managing the state of the soil structure. The moldboard ploughs, chisel ploughs and plough-looseners used for primary soil cultivation have a number of serious drawbacks, the most significant of which are the need for additional cultivation of the arable land to bring it to a condition suitable for sowing or planting agricultural crops, as well as high traction resistance, requiring large tractors with the corresponding traction force for operation. Therefore, to improve soil crumbling, field leveling and reduction of traction resistance, ploughs and rippers are combined with various additional devices, mainly rotary, without a drive or with a forced drive from the tractor power take-off shaft or another engine. Table 1 presents diagrams of some such combinations with moldboard ploughs [26], [27].

Materials and Methods:-

Milling sections were used in some ploughs not only as skimmers, but also as soil deepeners. The drawing shows a scheme of a combined tiller with a small-capacity pulling machine and consists of the following parts: 1. Rotary working body, 2 plow, 3 plow frame, 4 bracket, suspension, reducer, 5 adjusting handle (Fig.1) the soil is covered with a layer of soil wrapped by a plow body. The total depth of cultivation reaches 0.5 m. Milling leads to an increase in the root layer and accumulation of moisture in the soil [7]. Similar ploughs with rotary subsoils were tested in Poland. The milling section consisted of two discs with six L-shaped knives on each. The diameter of the milling section was 0.45 m. With a distance between the discs of 0.2 m, the total width of the subsoiler was 0.7 m. The test report of the plough with rotary subsoilers noted that the plough had lower traction resistance compared to a plough with passive subsoilers. From an agronomic point of view, such soil cultivation increased the yield of agricultural crops due to the improvement of water-air and food regimes. All rotary tillage machines (rotary ploughs; marsh, field and row-crop cutters) are equipped with protective covers, which not only protect the knife drum, but also prevent excessive scattering of soil. The cover, as a rule, consists of a cylindrical part covering the drum and a folding shield. In addition, the cover with the shield serves for additional soil crumbling, distribution and incorporation of mineral and organic fertilizers, and incorporation of turf [8]. Experiments [10] have shown that when installing a casing and a milling drum with a gap of 5 cm to 20 cm, the degree of crumbling of the sedge bog soil did not change and was equal to 72.77%. However, the energy intensity with an increase in the gap from 2.5 cm to 20 cm decreased by 9%, and when working without a casing, the energy intensity was lower by 16 ... 19.5%. The protective casing has a significant effect on the dynamic and technological indicators of rotary tillage machines. Thus, the use of a protective casing of an optimal shape, at which the angle of incidence of the thrown soil particles on the inner surface of the casing is maximum, helps to reduce the amount of additional resistance created by it by 30 ... 35%.

Fig.1 Combined plow

Power characteristics of rotary working bodies. The diagram of the forces acting on a knife drum with a horizontal axis of rotation with L-shaped working bodies is shown in Fig. 2.10.

Assuming that the resistance P of all element's deviates from the normal of the working surface towards the blade by an angle of friction μ_1, we expand the force P into horizontal P_X and vertical P_Z components and obtain:

$$P_X = P\cos\Psi = P\sin(\varphi + \Psi')$$
$$P_z = P\sin\Psi = P\cos(\varphi + \Psi')$$

It follows from the diagram that with forward rotation, i.e. from top to bottom, the horizontal component P_X is directed in the same direction as the vehicle's assumed velocity v and the vertical component P_z is directed from bottom to top, in the opposite direction of the vehicle's gravity. With reverse rotation of the drum, from bottom to top, the directions of these forces are in the opposite direction.

The resistance force P at the drum shaft creates a resistance force

$$M_c = Ph$$

Where h is the arm of force P. M_c is the moment of resistance balanced by the moment of lift.

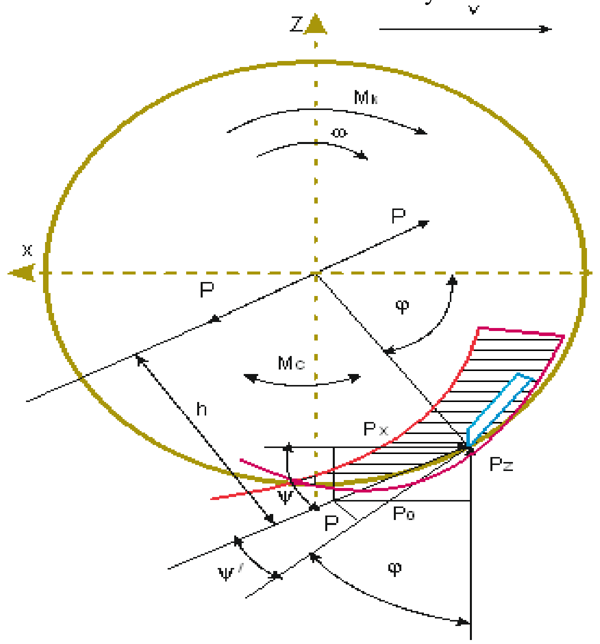

Fig. 2 Diagram of forces acting on the knife drum

$$M_{KP} = P_0 R$$

Where P_0 is the circular tension, and R is the radius of the drum
According to the scheme, to a first approximation, P is calculated on the attached blade:

$$P = P_0 \cos\Psi'$$

Then

$$P_X = P_0 \cos\Psi \cos\Psi'$$
$$P_Z = P_0 \sin\Psi \cos\Psi'$$

It has been experimentally established [10] that $\Psi' = 15^0$
The angle of inclination Ψ with respect to P is always determined for the moment taken:

$$\Psi = \mathrm{arctg}\frac{P_Z}{P_X} = \arccos\frac{P_X}{P}$$

From formula 1 it can be seen that the process of cutting the layer changes with the resistance of the blade as a function of the rotation angle φ, due to which the bending force P changes, the angle Ψ at the beginning of the circle is positive, and at the end of the cut it is negative ($\varphi > \frac{\pi}{2}$)

For approximate calculation -on heavy soils

$$P_X = 0{,}67P_0$$
$$P_Z = -0{,}45P_0$$

-on light soils

$$P_X = 0{,}88P_0$$
$$P_Z = -0{,}59P_0$$

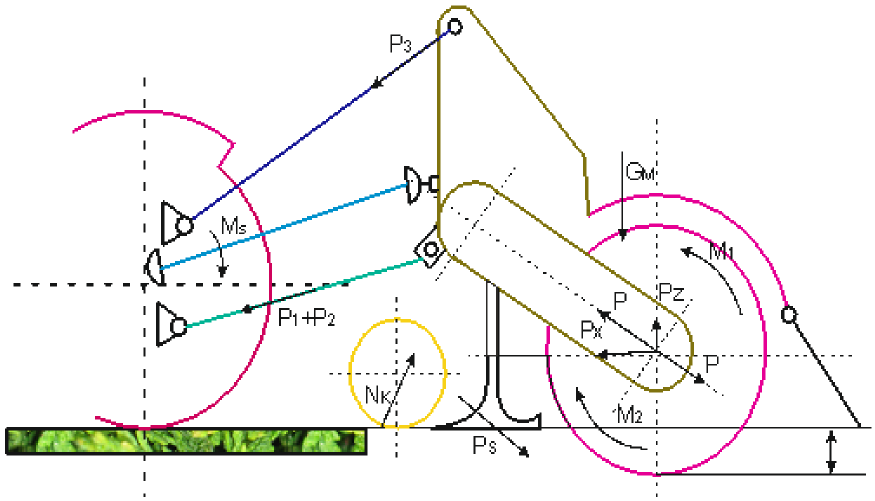

Fig. 3. Diagram of forces acting on the unit

To place the pawls in front of the drum, we must take into account the values of the resistance forces.
- the uniformly acting resistance force on the working body P
- Car's downforce G_M
- Equal pulling force P_L
- Reaction force acting on supporting wheels N_K
- Reactive force acting on the suspension system P_1, P_2, P_3

If we apply the equivalent force at point O, we get the forces P_X, P_Z If the downforce G_M exceeds the P_Z component of the force, the machine will sink into the soil. If the value of the P_X force increases, then it will be difficult to control the tractor. When installing a rotary working body, it should be taken into account that the equivalent pulling force P_L is directed sideways, opposite to the movement of the machine, therefore the horizontal component force P_X^L compensates for the P_X force, and the vertical component holds the machine for rear depth processing. In addition, the pawls reduce the load on the rotary body.

Car power balance:-
The total power consumption for a combined plow can be determined as follows.

$$N = N_1 + N_2 + N_3 + N_4 + N_5$$

Where N_1 is the power transmitted from the drive shaft, N_2 is the power of the tractor hitch, N_3 is the power loss from the transmission, N_4 is the power lost during movement, N_5 is the power loss due to slippage during movement.

N_1 power loss comes from soil cultivation, from the power of the thrust created to the propulsion of the machine.

$$N_1 = (N_{work} + N_{Disc} + N_{nov})\frac{1-\eta_k}{\eta_k}$$

where η_k is the lift coefficient
According to cutting theory, cutting rat.

$$k_Y = \frac{A_{cat}}{aBs} = \frac{kb\delta}{Bs}\ N/M^2$$

Where B is the width of the modes, A_{cat} is the work spent on cutting
The total vehicle capacity is:

$$N_{work} = k_Y aBv\ \ Kvt$$

For working soil transfer

$$A_{disc} = \frac{A_{disc\ 1}}{aBs} = \frac{\rho k_v^2 \nu_P^2}{g}$$

Let's consider $\frac{\rho k_v^2}{g} = k_{disc}$ and $\nu_P \approx \nu_0$

Then

$$N_{disc}\, aB\nu^3\lambda^2$$

While

$$N_{nov} = P_X \nu = P cos \nu \psi$$

The power requirement for a based machine is equal to:

$$N = N' + N'' + N'''$$

Where,N' is the power of the machine to move, $N''$is the power required for cutting, $N'''$is the power required for dumping soil, and $N'''$is the power required for the machine's transmission mechanisms.

Vehicle displacement capacity

$$N' = \mu_K Q_z \gamma$$

Where μ_K is the coefficient of resistance to tire movement, Q_z is the vertical load on the tire, and γ is the vehicle's operating speed.

The vertical load Q_z on the tire is determined by the vehicle's equilibrium forces.

$$Q_Z = G_M \pm \sum_{i=1}^{n} P_{Z_i}$$

Results and Discussion:-

Field research In rotary plows, for forced ejection of the cut layers, the knives are placed on the shaft drum in opposite directions (Fig. 4) and reflectors are installed, which improve the speed regime during the operation of the rotary plow.

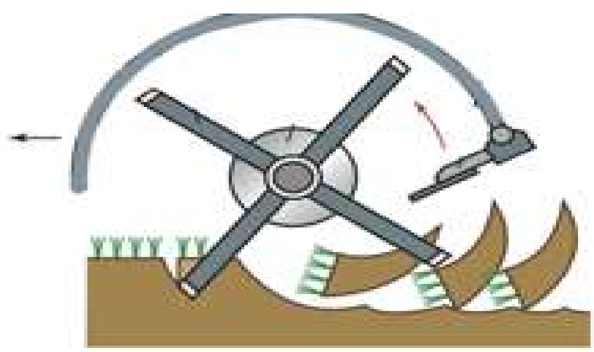

Fig. 4. Rotary plow operation diagram

We investigated the resistance of the plow's working parts on a field test rig, which is presented in (Fig. 5) A depth gauge 8 was installed on the frame on the field side, which continuously records the working depth as the plow moves.

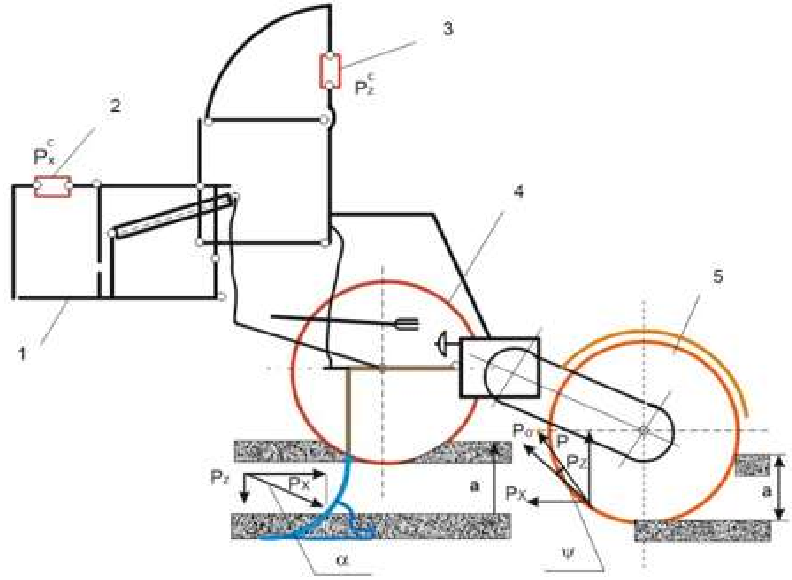

Fig. 5 Field test rig

Fig. 6. Potentiometer, depth gauge GMC-100 0.001 electric, LTR-EU-2 crate with LTR212 module

The cultivator directional paw 5 was installed on the front section, the rotary plow frame 1 was attached to the main frame with the help of a parallelogram mechanism, where the vertical P_X and P_Z resistance forces and the P_X^L and P_Z^L arrow-shaped cultivator resistance forces were determined using strain gauges 7, 8.

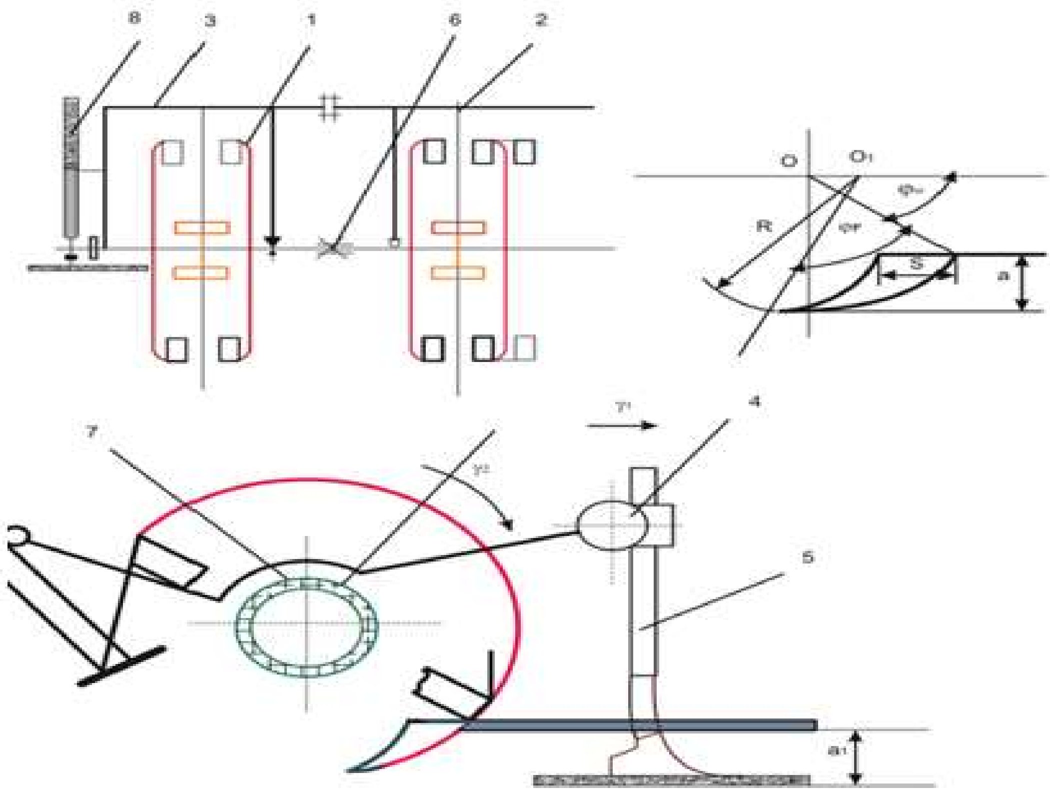

Fig. 7. Plow section diagram

As a result of the measurements, we obtained the M_{rot} dependences of the turning moment of the bladed rotary section on the angle of rotation As a result of the measurements, we obtained the M_{rad} dependences of the turning moment of the bladed rotary section on the angle of rotation ϕ. The analysis was performed for both heavy and medium soils, and presented in the following table

Table 1. The relationship between the torque and the angle of rotation

Heavy soils		Light soils	
M_{rad} (n. m)	φ_0	M_{rad} (n. m)	φ
0	0	0	0
40	12	40	8
50	19	50	15
80	22	80	19
100	24	100	21
120	27	120	24
160	45	160	49
120	68	120	80
80	80	80	88
40	87	40	118
0	160	0	160

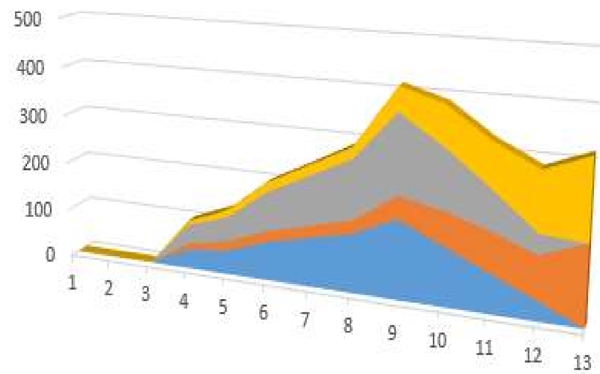

Fig.8. Dependence of the turning moment on the angle of rotation

The graph shows that at the beginning of the cutting of the blade there was a sharp increase in the moment M_{crit}, mainly on heavy soils and the maximum value was 450 times. The soil removal area δ indicates that the maximum turning moment $M_{critical}$ and δ_{max} were 20^0. The turning moment was zero when the turning angle was ϕ=1600. As a result of the measurements, we found that the main work process load occurs when the blade turns in the soil during contact, and we presented the work losses at this time in the form of a table.

Table.2. Work process losses during knife turning

Turnaround speed	Heavy soils			Medium soils			Light soils		
γ_0 (m.sec)	A common	A work	A Common- A work	A common	A work	A Common- A work	A common	A work	A Common- A work
2,78	124,2	324,01	199,8	341,7	228,8	112,9	313,23	181,02	132,31
4,20	497,1	400,08	97,2	400,92	297.2	103,72	348,09	221,28	126,21
5,01	621,2	531,13	90,07	434,6	334,83	99,77	361,24	250,9	110,34
4,9	1649,1	1300,1	349	1030,1	600,39	429,7			
6,9	2284,2	1459,9	824,3	1420,1	800,1	620			

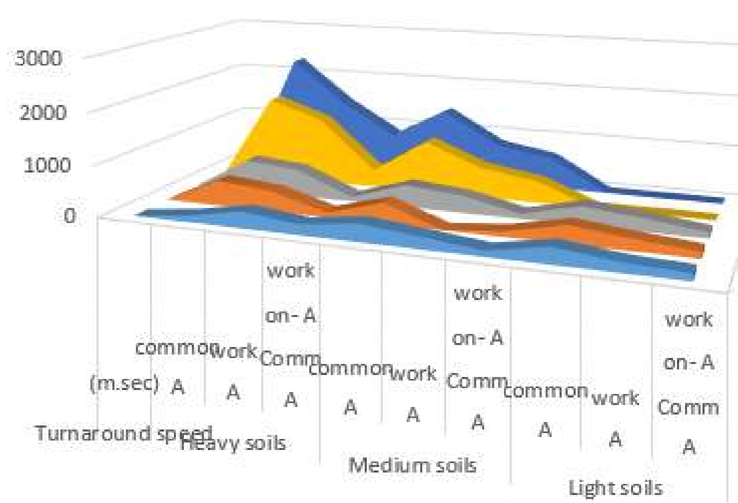

Fig.9 Power analysis of a rotary working body

The power characteristics of a rotary working body include: horizontal P_X , vertical P_Z and resistance forces of the right action P, as well as rotational tension P_0 and torque M_{turn} . When installing the cultivator paw on a rotary machine, the total horizontal $P_X^C = P_X + P_X^{paw}$ paw and vertical $P_Z^C = P_z + P_Z^{paw}$ paw components will act. To determine the forces P_X, P_z, P_X^{paw} , P_Z^{paw} , P_X^c and P_Z^c a dynamometer was used, and for this purpose a rotary plow with a width of 1.04-2.00 mods was additionally installed on the frame. Two arrow-shaped cultivator 2 tines were installed in front of the drum. We obtained the following values for the dependence of the torque on the depth of the tines and presented them in the form of a graph in the dependence of the supply S in Fig. 10.

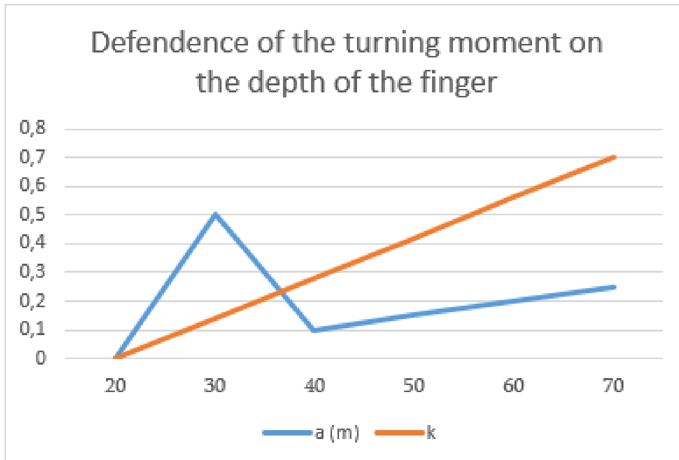

Fig.10. Dependence of turning moment on finger depth

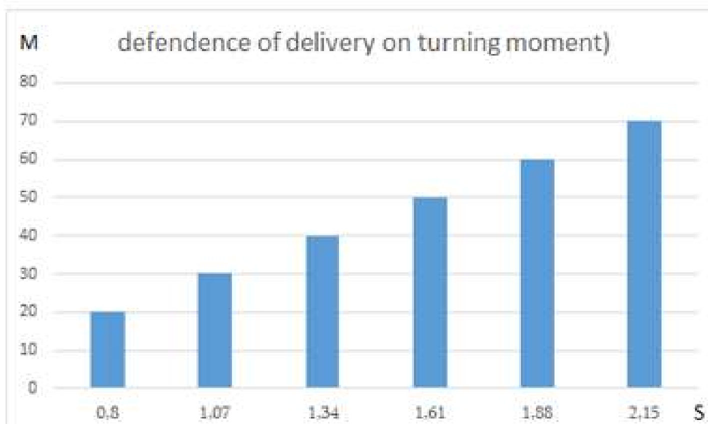

Fig.11. Dependence of supply S on the turning moment

The figure shows that as the speed increases, the value of the torque increases, while with increasing finger depth and density, the torque M_{rad} increases with a small intensity. From the graph, we can conclude that with an increase in the feed from 0.15 meters to 0.19 meters, the M_{rad} is 12-16%, and with an increase in the finger depth stroke in the range from 0 to 0.25, as well as the viscosity from 0 to 0.8, the M_{rad} value of the torque decreased by 45%. The study confirmed that the M_{rad} value of the turning moment varies unevenly with depth in the interval $a_{fin} = 0 - 0{,}16$m. The M_{rad} moment decreases intensively and amounts to approximately 28%, while in the interval $a_{fin} = 0{,}16 - 9{,}26$m it amounts to only 6.5-7.8%. We have confirmed through research that a 30-35% reduction in the M_{rad} torque can be achieved by placing the cultivator tines at a depth of 0.10-0.18 m, corresponding to a density of $k_P = 0{,}4 - 0{,}65$. The power characteristics of the laboratory equipment can be presented in the following table

Table. 3. Power characteristics of the car

Options	Soil types					
	Low humus soils of western Georgia			Black earth soils of Eastern Georgia (Akhalkalaki region)		
Soil density	0,14-0,19			0,16-0,25		
Number of paws Z	1	2	3	2	2	2
The fashion of the feet B (mm)	330	330	330	330	330	330
Depth of paw movement a_{fing} (mm)	15	15	20	15	20	24
Plowed area F (cm^2)	1500	950	2554	1500	950	2554
Plowing density K	0,60	0,35	0,82	0,40	0,62	0,75
Drum depth movement (cm)	27					
The range of doll fashions (cm)	104					

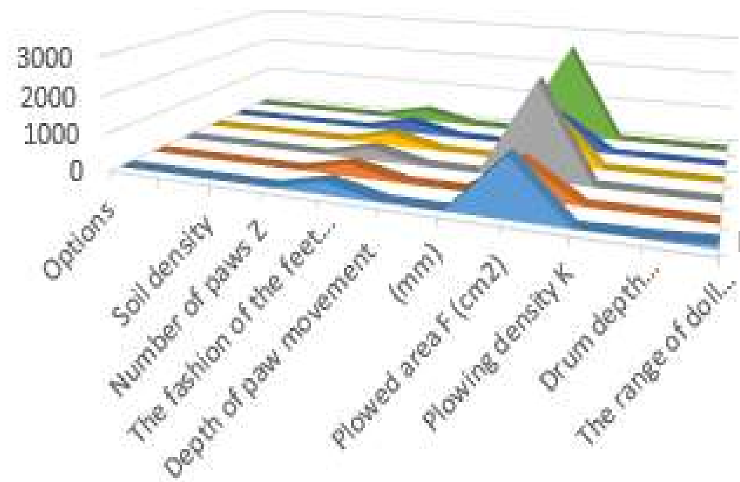

Fig. 12. Power characteristics of the car

The increase in power values P_X^{fin} fin and P_z^{fin} with increasing speed is presented in the form of graph 3.14. The figure shows that with an increase in depth of travel from 0.10-0.16 mm, the horizontal P_x^{ping} increases by 1.8-2.1 times, and the vertical component P_Z^{ping} by 1.2-1.9 times. The value of this component depends on the shape of the paws. In the case of the same depth ($a_{ping} = o,16$ m), the component P_X^{fin} in the case of an arrow-shaped paw is 1.3-1.4 times higher, and P_z^{fin} – 2.6-2.8 times higher than in the case of a drum-shaped paw. To compare the drum-shaped and arrow-shaped pawls during deepening, the equilibrium tilt angle should be determined, $\beta_{ping} = \mathrm{arctg}\left(\frac{P_Z^{ping}}{P_X^{ping}}\right)$ with the coefficient $m = \mathrm{tg}\beta_{ping}$, and the resistance $k = \frac{P_x^{ping}}{F} = \frac{P_X^{ping}}{a_{ping}\ b_{ping}}$ where $a_{ping}\, b_{ping}$ are power indices and can be represented in the form of Table

Table 4. Equilibrium power indicators

Paw type	Soil density in m.pa.	Corner β_{ping}	Depth coefficient m.	Resistance $n/cm^2.10^{-1}$
Arrow-shaped	0,8-1,2	22-29	0,4-0,54	0,35-0,40
Smooth	1,4-1,8	8-12	0,16-0,21	0,72-0,84

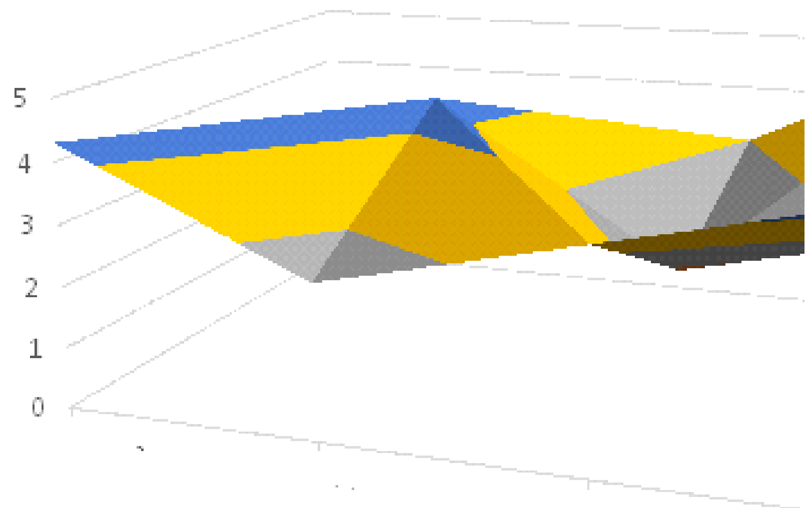

Fig.13 Equilibrium power indicators

Conclusion:-

The scientific work discusses the technical means of combined soil cultivation in the mining conditions of Georgia, the purpose of which is full-fledged cultivation of the soil, which largely reduces labor productivity. The black soil soils of the Akhalkalaki region were used as a test plot, and the structural parameters of the combined plow and the analysis of the power impact on the rotary working body were studied. The energy and power spent on cutting were calculated. A machine test rig was structurally assembled for field conditions and the main tools and devices were installed on it, which directly measure the depth of soil plowing, torques and forces acting on the working body during the machine's work process. The kinematic scheme of the soil cultivation machine was outlined and the dependence of the torque M on the angle of rotation φ for different types of soil conditions was presented. Work losses during loading, power characteristics and the dependence of power on the depth of the disk were investigated. The selection of the machine's structural parts was optimized and the dependence of other factors affecting the machine was investigated. The studies showed that the presented technical means simultaneously performs both plowing and belt crushing operations and somewhat reduces labor costs in the soil cultivation option.

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