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# Basing motoblock the main parametres of the potato digger

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**Abstract.** This article will consider the main parameters of a potato digger designed to work with tillers in order to increase the efficiency of mechanized potato harvesting in small and medium-sized farms. The study highlights the importance of optimizing the design and operational characteristics of the potato digger, such as digging depth, oscillation amplitude, sieving efficiency, and energy consumption. The study uses a combination of theoretical modeling and field experiments to evaluate the effectiveness of potato digging in various soil conditions and in the cultivation of various crops. The results show that proper adjustment of the digging mechanism and vibration frequency can significantly reduce soil resistance, increase work speed, and reduce damage to tubers during harvest. In addition, the results show the economic and environmental benefits of using potato diggers compatible with tillers, including reduced labor intensity and resource consumption. This research will help to develop innovative environmentally friendly solutions for small farms, meeting the demand for cost-effective mechanization in modern agriculture and ensuring high quality and productivity.

## 1 Introduction

Mechanization of potato harvesting is the main area of innovation in modern agriculture and is driven by the need to increase yields, reduce manual labor, and increase the efficiency of agricultural operations. Many countries, including Ukraine, Russia, Belarus, China, India, Italy and Germany, play an important role in the development and improvement of potato diggers. These machines are necessary for small and large farmers, offering technological solutions to optimize harvesting processes, taking into account different soil and crop conditions[1-4].

One of the important innovations in the design of potato diggers is the use of sectional plows. Ukrainian manufacturers have developed double-row vibrating potato diggers equipped with sectional plows and discs to optimize the harvesting process. Similarly, the Chinese company Xiear offers potato diggers with a cross-section of 450 mm and a width

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of 100 mm. These structural elements increase work efficiency by reducing soil resistance and minimizing the impact on tubers during harvest[5-7].

To further increase productivity, the researchers proposed modifying the sectional openers. For example, Ping Zhao recommends using curved surfaces in sectional openers to improve soil decomposition and reduce excess soil yield. Nevertheless, ahmir offers a design of sectional openers with adjustable installation angles relative to the horizon, which makes it possible to better adapt to various soil and cultural conditions. These improvements are aimed at reducing resistance to weeds and clogging, which are common problems during the potato harvest[8].

Despite these innovations, certain limitations remain in the existing potato digger designs. For example, the use of sectional plows often leads to excessive loosening of the soil in potato beds. This leads to soil accumulation before plowing, which leads to root loss and reduced yields. To solve this problem, some designers suggested including additional components in the potato digger design. For example, the Harp offers a design with discs with trapezoidal slots around the circumference, located at the edges of the plows to prevent the soil from falling. Similarly, the Indian company Peanut has developed potato diggers equipped with discs mounted on the edge of discs with a diameter of 500 to 550 mm. These modifications help minimize soil loss, increase yields, and effectively separate the soil from harvested tubers.

Given the global progress in potato diggers, it is important to consider the different soil and climatic conditions you face when harvesting potatoes. The physical and mechanical properties of the soil, as well as factors such as agrotechnical requirements, vary significantly depending on the region and the harvest period. Therefore, the design of potato diggers should contain general requirements that take these differences into account, while ensuring high efficiency and reliability in various agrotechnical conditions.

This study is based on international experience in the development of potato diggers, as well as knowledge gained in Ukraine, Russia, Belarus, China, India, Italy and Germany. By evaluating existing structures and their limitations, we strive to offer innovative solutions tailored to specific soil conditions and vegetation. Ultimately, the goal is to promote the development of mechanized potato harvesting technologies by supporting sustainable farming practices and improving the living conditions of farmers around the world [7,8].

## 2 Materials and methods

One of the main parameters of the potato digger working on the motoblock base is its length $L_{ku}$ . The length of the digger suspension device depends on the $L_{os}$, elevator length $L_{el}$, wheel diameter $D_{g'}$ . Their total length, in turn, should be less than the length of the motoblock steering wheel Lru. Because when driving a motoblock, the driver must have full control [6,7].

Therefore, the total length of the potato digger is determined by the condition of being smaller than the length of the streeng wheel of the motoblock

$$L_{ru} \geq L_{ku}. \tag{1}$$

The length of the potato digger is determined by the following expression

$$L_{ku} = L_l \cos\alpha + L_{el} \cos\beta + \frac{1}{2}\left(D_{g'i} - d_{yu}\right) + b, \tag{2}$$

Where $d_{st}$ is the diameter of the star, m;
b- longitudinal distance between plow and elevator, m;

β- the angel of installation of the elevator relative to thr horizon.

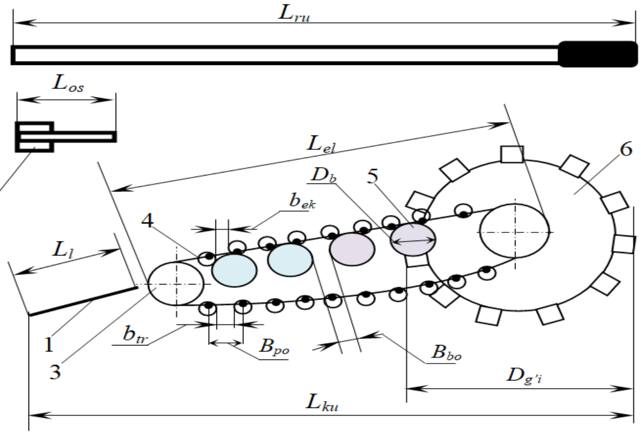


**Fig. 1**. Scheme of the potato digger working on a motoblock base

The length of the blade should be within the length of the excavator suspension device. The tip of the ploughshare can not be ahead of the junction of the motoblock and the digger suspension device, because when turning the motoblock, the tips of the ploughshare should not touch the wheels of the motoblock. Therefore, the length of the plow is determined by the following condition

$$L_l \leq \frac{L_{os}}{\cos\alpha}, \tag{3}$$

where α- is the installation angle of the lemex relative to the horizon,$^0$. Putting the values $L_{os}$= 30 sm, α=24$^0$ in expression (3) we determine that the length of the plow will be at most $L_l$= 33 sm.

Using expressions (2) and (3), the length of the elevator can be determined by the following expression

$$L_{el} = \left(L_{ku} - L_l \cos\alpha - \frac{1}{2}D_{g'i} + \frac{1}{2}d_{yu} - b\right)/\cos\beta,. \tag{4}$$

Putting the values $L_{ku}$ = 100 sm, $L_l$= 33 sm, $D_{g'I}$ = 45 sm, $d_{yu}$= 10 sm, b= 2.5 sm, β= 25$^0$ in expression (4), we determine that $L_{el}$= 53 sm. The distance between the pipes attached to the elevator shafts should be $b_{tr}$ = 2.5 sm. Therefore, in the elevator that we offer, one screw is removed at each interval. Then the distance between the rods is $V_{ro}$= 5 sm.

When choosing the diameter $b_{td}$ of the pipes to be put on the elevator, the distance between the elevator pipes should be 2.5 sm. Therefore, the pipe diameter $b_{td}$ is expressed by the following condition

$$b_{td} \leq \frac{B_{po}+2b_{tr}}{2} \tag{5}$$

By putting the values V5 and b=2.5 sm in expression 5, we determine that the diameter of the pipes will be at most 5 sm. Considering the length of the elevator, we can determine the number of drums installed between the excavator elevator. The diameter of the elevator stars should be taken into account. The number of drums are determined by the following expression

$$n_b = \frac{L_{el} - 2d_{yu} - 2B_{po}}{2B_{po}}, \tag{6}$$

Putting certain values of V, C in the expression (6), we determine that n= 3.3 units. By rounding the determined value, we can accept the number of drums as 3 pieces. The minimum value of $b_{ek}$ is determined by the following expression (7), when the pipes attached to the spikes are in contact with the drums

$$b_{ek} = B_{op} - d_{ch} - \frac{1}{2} b_{tr}, \tag{7}$$

where d is the screw diameter.

Putting certain values of $V_{or}$, $d_{ch}$=1.2 sm and $b_{tr}$ into the expression (7), we determine that it should be equal to $b_{ek}$=2.55 sm. When determining the diameter of the drums, we take the distance between the pins as the sides of the square drawn inside the circle.

Accordingly, the diameter of the drum is determined as follow

$$D_b = \sqrt{2} B_{op}. \tag{8}$$

According to the expression (8), the diameter of the drum is $D_b$ = 7 sm. The longitudinal distance $B_{bo}$ between the drums can be determined according to the following expression

$$B_{bo} = B_{op} - 2\left(D_b - B_{op}\right). \tag{9}$$

Putting certain values of $V_{or}$ and $D_b$ in the expression (9), we determine that $B_{bo}$ = 1 sm.

The technical solution of the problem is to base the parameters of potato digger digging plows, such as the coverage width, length, the opening and installation angles of its muzzle with respect to the horizon, as well as the upper portion of the soil slab to the sieves. Its main parameters are the installation of the ploughshare of the potato digger machine in relation to the bottom of the soil, that is, the angle of entry into the soil α, the opening angle of the ploughshare tip γ, and the length $L_{lu}$ and width $V_{lu}$ (figure 2). In order to insure the free sliding of the soil blade along the surface of the plow should not exceed 30° .

Based on the above and taking into account the physic-mechanical properties of potatoes and potato husks, we can justify the width and length of the offered plow. The width of the ploughshare of the potato digger, its length and the angle of installation relative to the horizon are selected based on the condition of digging potatoes completely from the ground (figure 3).

The total width of the plow is determined by the following condition

$$B_{lu} \geq b_{o'r} + 3\sigma + 2в, \tag{10}$$

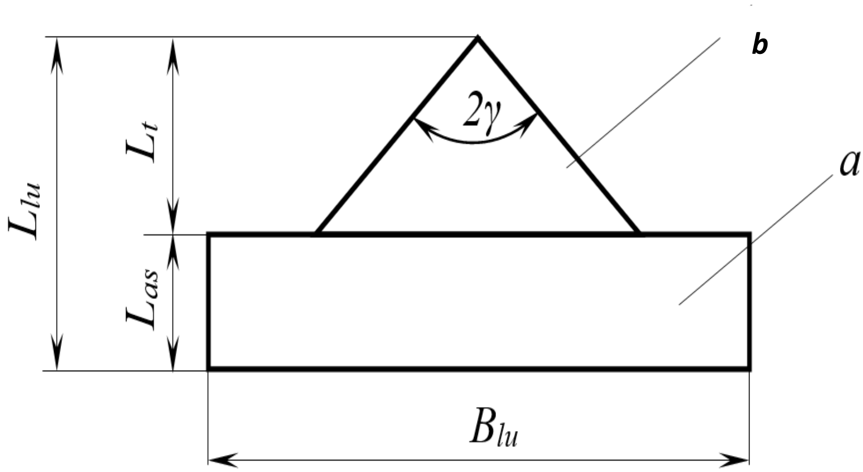


**Fig. 2.** Parameters of Lemex a– the base of the plow ; b) – the muzzle part of the plow ;

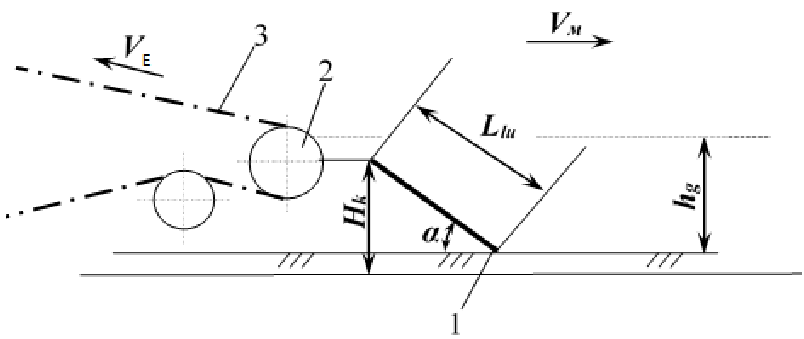


**Fig. 3.** The scheme for determining the angle of installation of the plow relative to the horizon, where 1 – ploughshare ; 2 – the front star of the elevator ; 3 – elevator $B_{or}$ – is the average width of the potato nest located in the field, m; σ – mean square deviation of the width of the potato nest ; v – lateral deviation of the potato bush in the horizontal direction.

Putting the experimentally found values of $b_{o'r}$=27.1 sm, σ=± 1.8 sm to the above (10) expressions and taking into account that v= 2.5 sm, we make $B_{lu}$≥38 sm equal to or greater than it.

The width of the muzzle part of the ploughshare is determined by the following condition

$$B_t \geq b_{o'r} + 3\sigma. \tag{11}$$

If we put the above values of $b_{o'r}$ and σ in the expression (11), we will find that B≥32.5 sm is equal to or greater than it. In this case, the total length of the plow should not exceed 27 sm according to previous studies [1-3].

According to the analysis of the conducted literatures, the opening angle of the muzzle part of the plow is determined by the following condition [1-4]

$$\gamma < 2(90 - \phi), \tag{12}$$

where $\gamma$ is the angle of friction of the plant roots against the plow blade, $^0$, ($\gamma$=40-50$^0$).

According to the formula (12), we can take the average value of the opening angle of the blade as 90$^0$. Taking into account the value of the opening angle of the blade tip in the formula (12) above, if the part of the blade tip is considered as an equilateral right-angled triangle, the length of the blade is determined by the following expression (13)

$$L_t = \frac{b_{o'r}+3\sigma}{2}. \quad (13)$$

It is assumed that $B_t$=$b_{o'r}$+σ=34 sm and putting it in expression (13), it follows that $L_t$=17 sm. Knowing the value of the length of the nose part of the plow, we determine the length of the plow base $L_{as}$.

$$L_{as} = L_{lu} - L_t. \quad (14)$$

Putting certain values in the expression (14), we determine that $L_{as}$=10 sm.

## 3 Results and discussions

It is known from the literature that potato digger plowshares can be considered as two-sided plows (Figure. 5) and it is general resistance to traction can be expressed as follows [6]

$$R = R_1 + R_2 + R_3 + R_4, \quad (15)$$

where R is the total resistance of the plow, N;

$R_1$- the resistance created by the ploughshare cutting the oil, N;

$R_2$ – the resistance formed by the deformation of the soil by the plow, N;

$R_3$ – the resistance created by the movement of the soil along the surface of the plow and its rise, N.

We determine the resistance created by the plow blade cutting the soil according to the following expression

$$R_1 = [\sigma] b_q B_{lu}, \quad (16)$$

where [σ] is the horizontal crushing resistance of the soil;

$b_q$- thickness of plow blade;

$V_{lu}$ – the width of section ploughshare to fully cover the potato field.

We determine the resistance force generated by the deformation of the soil by the working body using the scheme presented in Figure 5.

To find $R_2$, we project the force $Q_y$ and the resulting frictional force in the direction of movement using the scheme shown in Figure 5

$$R_2 = Q\left[\cos\psi_{bp} + f\sin\left(\alpha+\psi_{bp}\right)\cos\alpha\right], \quad (17)$$

where $Q_y$ is the soil's resistance to decay;

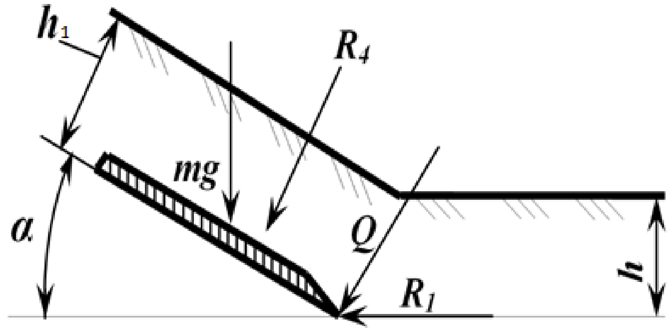


**Fig. 4.** The diagram of the forces acting on the ploughshare in cutting the soil layer.

f- the angle of friction of the soil to the working surface of the ploughshare, °
$\psi_{bp}$- angle of longitudinal splitting of the soil, °;

$$x\psi_{bp} = \frac{\pi}{2} - \frac{1}{2}(\alpha + \phi_1 + \phi_2), \tag{18}$$

Where $\gamma_1$, $\gamma_2$ are the external and internal friction coefficients of the soil. We determine the value of $Q_y$ according to the following expression.

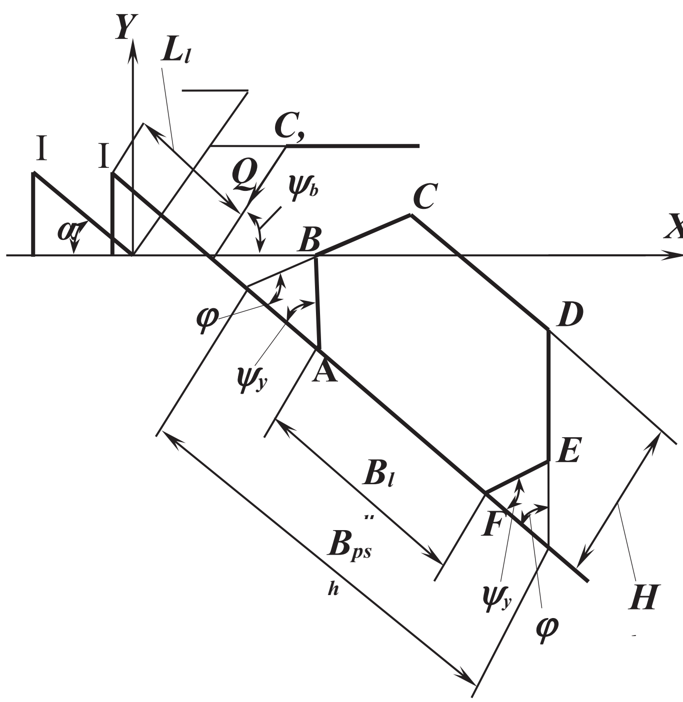


**Fig. 5.** The scheme for determining the resistance to pulling the energy-resource-saving sectional plow of the root-fruit digger.

$$Q_y = [\tau_k] S_{ABCDEF}, \tag{19}$$

Where [ $\tau_k$ ] – is the limit value of the test stress generated along the cleavage plane; $S_{ABCDEF}$- ABCDEF –face of the plane of cleavage.

Based on the scheme presented in Figure 5

$$S_{ABCDEF}=\left[\left(B_{lu}+\frac{(B_{psh}-B_{lu})tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\times\frac{(B_{psh}-B_{lu})tg\,\psi_{yo}tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right]\times\frac{1}{sin\,\psi_{bp}}+$$
$$+\left[\left(\frac{B_{lu}+в_{sh}}{2}+\frac{(B_{psh}-B_{lu})tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\times\left(H_k-\frac{(B_{psh}-B_{lu})tg\psi_{yo}tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\right]\times\frac{1}{sin\,\psi_{bp}} \quad (20)$$

Where $V_{psh}$ – is the width of potato bush, m;
$\Psi_{yo}$ –the angle of lateral fragmentation of the soil, $^o$;
$V_{sh}$ – the upper base of potato bush, $^o$;
$Y_g$- the angle of deviation of the side of the pusher, $^o$.

Putting the value of $S_{ABCDEF}$ according to the expression (20) into (19), then putting this obtained value of Q into (17) and taking into account the expression (19), we get the following expression [ 3, 5 ]

$$R_2=[\tau_k]\times\left\{\left[\left(B_{lu}+\frac{(B_{psh}-B_{lu})tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\times\left(\frac{(B_{psh}-B_{lu})tg\,\psi_{yo}tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\right]+\right.$$
$$\left.+\left[\left(\frac{B_{lu}+b_{sh}}{2}+\frac{(B_{psh}-B_{lu})tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\times\left(H_k-\left(\frac{(B_{psh}-B_{lu})tg\,\psi_{yo}tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\right)\right]\right\}\times$$
$$\times\frac{\left(sin\frac{1}{2}(\alpha+\phi_1+\phi_2)+f\,cos\frac{1}{2}(\alpha-\phi_1-\phi_2)\,cos\,\alpha\right)}{sin\,\psi_{bp}} \quad (21)$$

Taking into account its humidity, we determine the resistance forces created by the lifting of the soil along the surface of the working body and the inertial force according to the following expressions [3-5]

$$R_3=B_{lu}\left(L_{as}+\frac{b_{o'r}+3\sigma}{2}-\frac{B_{lu}}{sin\,\gamma}\right)\left(L_{as}+\frac{b_{o'r}+3\sigma}{2}\right)h\rho gtg(\alpha+\phi_1)\left(1+\frac{W}{100}\right), \quad (22)$$

$$R_4=\rho\times\left\{\left[\left(B_{lu}+\frac{(B_{psh}-B_{lu})tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\times\left(\frac{(B_{psh}-B_{lu})tg\,\psi_{yo}tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\right]+\right.$$
$$\left.+\left[\left(\frac{B_{lu}+b_{sh}}{2}+\frac{(B_{psh}-B_{lu})tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\left(H_k-\frac{B_{psh}-B_{lu}}{2(ctg\psi_{yo}+ctg\varphi_g)}\right)\right]\right\}\times\frac{1}{sin\,\psi_{bp}}\times$$
$$\times V^2\frac{sin\,\alpha\,sin(\alpha+\phi_1)}{cos\,\phi_1\,cos^2\frac{1}{2}(\alpha+\phi_1+\phi_2)}\left[1+\frac{W}{100}\right), \quad (23)$$

Where h is the elevation height of the soil along the surface of the working body, m;
P – soil density, kg/m$^3$ ;
g- acceleration of free fall, m/s$^2$ ;
W- soil moisture, percent.

Putting the values of $R_1$, $R_2$, $R_3$, and $R_4$ according to the expressions (17), (21), (22) and (23) into expression (16), we get the following final expression for determining the traction resistance of the working body in the form of a three-sided blade of a digging plow

$$R=[\sigma]b_qB_{lu}+[\tau_k]\times\left\{\left[\left(B_{lu}+\frac{(B_{psh}-B_{lu})tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\times\left(\frac{(B_{psh}-B_{lu})tg\,\psi_{yo}tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\right]+\right.$$

$$+\left[\left(\frac{B_{lu}+b_{sh}}{2}+\frac{(B_{psh}-B_{lu})tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\times\left(H_k-\left(\frac{(B_{psh}-B_{lu})tg\,\psi_{yo}tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\right)\right]\Bigg\}\times$$

$$\times\frac{\left(\sin\frac{1}{2}(\alpha+\phi_1+\phi_2)+f\cos\frac{1}{2}(\alpha-\phi_1-\phi_2)\cos\alpha\right)}{\sin\psi_{bp}}+$$

$$+B_{lu}\left(L_{as}+\frac{b_{o'r}+3\sigma}{2}-\frac{B_{lu}}{\sin\gamma}\right)\left(L_{as}+\frac{b_{o'r}+3\sigma}{2}\right)h\rho gtg(\alpha+\phi_1)\left(1+\frac{W}{100}\right)+$$

$$+\rho\times\left\{\left[\left(B_{lu}+\frac{(B_{psh}-B_{lu})tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\times\left(\frac{(B_{psh}-B_{lu})tg\,\psi_{yo}tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\right]+\right.$$

$$\left.+\left[\left(\frac{B_{lu}+b_{sh}}{2}+\frac{(B_{psh}-B_{lu})tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\left(H_k-\frac{(B_{psh}-B_{lu})tg\psi_{yo}tg\varphi_g}{2(tg\psi_{yo}+tg\varphi_g)}\right)\right]\right\}\times\frac{1}{\sin\psi_{bp}} \quad (24)$$

$$\times V^2\frac{\sin\alpha\sin(\alpha+\phi_1)}{\cos\phi_1\cos^2\frac{1}{2}(\alpha+\phi_1+\phi_2)}\left[1+\frac{W}{100}\right).$$

According to the analysis of this expression, the traction resistance of the ploughshare depends on its parameters ( L, t, V ), the digging depth of the ploughshare (h), the physical and mechanical properties of the soil ([σ], [$\tau_k$],$y_1$, $y_2$, p, W, f) and, therefore, the speed of movement of the aggregate. Taking $L_{lu}$=0,27m, t=0,0005m, $V_{lu}$ =0,39m, [σ]=1,44*$10^6$ $P_a$, [$\tau_k$]=2*$10^4$ $P_a$, $y_1$=$30^0$, $y_2$=$40^0$, p= 1100kg/$m^3$, W=15%, f=0,5774, the calculations based on the expression (24) showed that the resistance to traction of the working body of the potato digger at a speed of 1,0m/s is 0,65 kN.

## 4 Conclusions

Due to the low quality of the sieving device of the potato digger operating on the basis of the motoblock, polyethylene pipes were inserted into the sieve spikes of the digger, and drums were installed at the bottom of the elevator. The pipes, which are worn on the wheels, move in a circular motion when they are touched by the drums, and move up and down to crush the soil layer. In order for the offered potato digger to work correctly with the motoblock, its length should be $L_{ku}$=100 sm, the length of the suspension device should be $L_{os}$=30 sm, and the length of the elevator should be $L_{el}$=53sm. In order to ensure the complete digging of the potato crop at the expense of low energy, the width of the ploughshare is greater than or equal to $B_{lu}$≥39 sm, the length is $L_{lu}$=27 sm, the angle of installation relative to the horizon is α=$25^0$, the opening angles of the tip of the muzzle are 2γ=80-$90^0$ it is selected based on the condition of digging completely from the bush.

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