Determination of resistance to gravity of working body with the pit softener installed in the two-layer plow during the main tillage

N Murodov1* and U Khasanov1

1Bukhara branch Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Bukhara, Uzbekistan

n.murodov@mail.ru

Abstract. This article is about the benefits of using an energy-efficient vertical soil that is designed to treat plow and plow soil without plowing, and advantages of inferior soil with fertile soil during plowing. In summary, the purpose of the proposed technical solution is to improve the reclamation condition of the soil by loosening the birch layer (plowing with the simultaneous loosening of the subsoil) and to reduce the tensile resistance of the plow during plowing. Simultaneously with plowing through the recommended deep softener, energy savings are achieved by loosening the subsoil layer and improving the movement stability of the plug.

1. Introduction

On Enforcement of the Decision of the President of the Republic of Uzbekistan Sh. Mirziyoyev “On additional measures to further improve the technical equipment of agriculture” No. PD-3459, extensive scientific and innovative work is being carried out to improve the use of modern techniques and technologies, including the effective use of modern science and technology to mechanize agriculture of the republic, to increase the productivity of agricultural products from farms [1]. One of the different aspects of our agriculture is that it is based on the cultivation of crops using irrigated lands with a strong agro-irrigation system. Three-quarters of arable land is irrigated fields. Therefore, the development of agriculture is associated with the development of mechanized processes to increase the productivity of irrigated fields in the future.

Today, the development of energy-resource-saving and high-performance machines for tillage is the leading industry in the world. The development of high-quality, high-energy, and energy-efficient machines and equipment for land recycling is a serious problem, given that more than 1.6 billion hectares of land are cultivated worldwide to grow various crops. At the same time, much attention is paid to the development and use of energy-saving plows [1, 2].

It is known that in the Bukhara region there are more than 140,000 hectares of arable land, under which there is gypsum, gravel, and sand, to ensure high crop yields and improve the physical and mechanical properties of the soil, the upper fertile part of these areas should be rotated annually, the lower gypsum, gravel and sand parts should not be turned over and should be softened at a depth of 10-15 sm without pulling out the fields [2].

As a solution to this problem, research is being carried out on a structure that allows loosening the soil layer under arable land during plowing.
Currently, hand-held deep softeners of various constructions are used to soften the underlying layers containing gypsum, gravel, and sand. This leads to increased labor, fuel, and other operating costs, as well as excessive compaction of the soil. Also, when treated with existing deep softening working bodies, a secondary dense compensation layer is formed in the soil. This, in turn, harms the deep development of plant roots and get high yields. The analysis of the literature and the results of the research show that basic tillage of the soil, ie along with plowing, implementation the process of smoothing the underlayment in one pass of the unit has proven its effectiveness in the world experience. However, the two-tiered PD-3-35 plugs, equipped with deep softeners in the form of arched claws, designed to perform this high-energy technological process, due to several technical and technological shortcomings, its high energy consumption, it is not being used properly in the field. Also when working with deep softeners in the form of arched claws, it has been proven by our scientists to form a secondary dense compensation layer in the subsoil of the soil drive.

Currently, the loosening of the subsoil is carried out either by plowing or after plowing with deep softeners separately and with two-tiered plows equipped with deep softening working bodies.

Based on the above, reducing the energy consumption of this process by improving the basic tillage process, ie the technological process of deep loosening of the subsoil along with plowing, is one of the most pressing issues in the agricultural sector [7, 8].

As a solution to this problem, research is being carried out on the structure, which allows softening the subsoil during the plowing process using a plug. The design of this device is as follows (Figure 1).

![Figure 1. Recommended plug circuit](image)

The two-layer plug works as follows. The upper plug body 2 cuts, overturns, splits the soil layer, and 4 deep softening working bodies are installed at the bottom of the groove formed by the forward transition of the lower body 3. The cutting blade of the deep softener 6 softens the compacted layer of soil and grinds the soil layer as a result of grinding with cutting element 5, the result is a compression that tends to a specific center, which results in a stable centering of the plug and helps to plow and soften the field with less energy.

It is known that the soil environment is changeable and unstable due to chemical, thermal, bacteriological, and other processes. Therefore, the parameters of the tillage device should be adjusted according to the properties of the soil during tillage. Therefore, it is recommended to install the cutting element at an angle $\alpha = 30^\circ$ to $45^\circ$ to the wall of the overturned layer. To do this, it is sufficient to
fasten the two fingers 7, which connect the cutting element to the stand 5, and the flanges 6 to the frame 4 using 8 fingers (Figure 2).

In summary, the purpose of the proposed technical solution is to improve the reclamation condition of the soil by loosening the birch layer (plowing with the simultaneous loosening of the subsoil) and to reduce the tensile resistance of the plow during plowing. Simultaneously with plowing through the recommended deep softener, energy savings are achieved by loosening the subsoil layer and improving the movement stability of the plug.[3]

2. Materials and Methods
During operation, the following forces are influenced by the plug housing (Figure 3):

\[ R'_{xy} \] is the reaction force of the soil, which has an equal effect on the body;
\[ R_x, R_y \] is the transverse and longitudinal soil reaction force organizers;
\[ F_{xN}, F_x, N \] are the reaction forces acting on a plow field board, and its longitudinal and normal components;
\[ R'_{xy}, R_x, R_y \] are the longitudinal and transverse soil components equally acting on the pit softener [9, 10]
As can be seen in Figure 1, the use of a vertical pane-shaped working body as a pit loosening of the soil subsurface layer reduces the reaction force on on a field board, reducing the amount of harmful resistance.

The main reason for the reduction of the reaction forces generated on the board is that the surface of the piter softener is perpendicular to the working surface of the main body, which partially interferes with the \( R_{sxy} \) and the \( R_{lxy} \) in the pit softener. Balance. As a result, the compressive strength of the board increases

The softener resistance of the pits to the attraction \( R'_{sxy} \) consists of the working body of the softener (\( R' \)), since it does not participate in the impact on the soil since its column is mounted on the rear of the plow body.

\[ R = 2N \sin \alpha + 2T \cos \alpha. \]  
(1)

Considering \( T = fN = N \tan \varphi \) the formula looks like this:

\[ R = 2N \sin \alpha + 2N \tan \varphi \cos \alpha = 2N \frac{\sin(\alpha + \varphi)}{\cos \varphi}. \]  
(2)

as it is known [57], normal force \( N \) consists of dynamic and static constituents, ie

\[ N = N' + N'' \]  
(3)

Static constants of the normal force can be determined by the following formula:

\[ N' = \rho_{ud} S_{sh} \]  
(4)

There \( \rho_{ud} \) Specific resistance of the soil formed at the edges of the soil from the crushing of the soil in the horizontal plane, Pa

\( S_{sh} \) is the softener edge area, m

\( \rho_{ud} \) and \( S_{sh} \) The physical and mechanical properties of the soil and the parameters of softening can be obtained by:

\[ N_c = \frac{q \rho^2 (2h - h_0)}{4 \sin \alpha} \]  
(5)

\( q \) here is the coefficient of total crushing of the soil underground stratum, N/m³.
(5) The formula shows that the static component of the normal force depends on the coefficient of soil crushing, the width of the working body, the angle of tensile strength, and the length of sharpening and the depth of the working body.

Equipped with a developed deep softener plow consists of a combination of the total sliding resistance of the body, the plow body, and the resistance of the deep softener.

\[ R_{\text{gen}} = R_{\text{xy}}^n + R_{\text{xy}}^l \]  \hfill (6)

\( R_{\text{xy}}^n \) is the soil reaction power acting equally on the body;
\( R_{\text{xy}}^l \) is the soil reaction power acting equally on the deep softener.

The total resistance of the housing consists of the following components

\[ R_{\text{xy}}^n = R_{r_n} + R_{z_n} + R_{c_n} + R_{d_n} + R_{L_0_n} \]  \hfill (7)

Here:
\( R_{r_n} \) is the power spent to soften a piece of layered soil using a body share, \( H \);
\( R_{z_n} \) is the power spent on softening the soil with the body blade ploughshare, \( H \);
\( R_{c_n} \) is the power expended to the static lifting of with a ploughshare the body, \( H \);
\( R_{d_n} \) is the power expended to the dynamic lifting of with a ploughshare the body, \( H \);
\( R_{L_0_n} \) is the body tilt surface resistance, \( H \).

The power expended on softening the clay subsoil using a body share, [20, 22].

\[ R_{r_n} = \frac{\pi}{4} \sigma_n \varepsilon_n a_n [1.5(1+k_n)-\frac{\sqrt{k_n}}{\sin\varepsilon_n}]+\frac{tg\phi_n ctg\gamma_n (1+\sin\gamma_n)}{\cos\varepsilon_n} \]  \hfill (8)

Here \( \sigma_n \) is the power at the break of the soil layer, \( \text{Pa} \);
\( \varepsilon_n \) is the body cover width, \( \text{m} \);
\( a_n \) is the thickness of the soil layer, \( \text{m} \);
\( k_n \) is the coefficient without unity;
\( \varepsilon_n \) is the angle between the bottom of the furrow and the ploughshare, degree;
\( \gamma_n \) is the mounting angle relative to the wall that holds the body ploughshare, degree;
\( \phi_n \) is the coefficient of friction, degree.

The force spent crushing the soil through the blade of the ploughshare body

\[ R_{r_n} = q_n h_n^2 a_n \frac{ctg\theta_n \sin(\theta_n + \phi_n)}{\cos\phi_n \sin\gamma_n} \]  \hfill (9)

Here \( q_n \) is the coefficient of volumetric crushing of the lower body soil layer, \( \text{N m}^{-3} \);
\( h_n \) is the height of the rear edge of the share body, \( \text{m} \);
\( \theta_n \) is the angle between the back edge and the bottom of deep furrow, degree.

The power expended on the static lifting of the soil layer with the ploughshare body [13, 14, 15],
Here $\rho_{nn}$ is the soil density, kg/m³;

$g$ is the acceleration of gravity, m/s²;

$c_n$ is the corpus ploughshare width, m;

$$\varepsilon'_{n} = \arctg(\tan c_n \sin \gamma_n)$$

The power expended to the dynamic lifting of with a ploughshare the body:

$$R_{i_n} = 2\rho_{nn} a_n c_n V^2 \sin \varepsilon_n \sin \gamma_n \sin(\varepsilon_n + \phi_n) \cos \phi_n$$

Here $V$ is the aggregate movement speed, m/s;

The resistance of the body overturning surface

$$R_{Lo_n} = P_{G_H} + P_{i_H} + P_{n_H}$$

Resistance to soil weight

$$P_{G_H} = a_n c_n \rho_{nn} g k_y r_n \lambda_n$$

Here $r_n$ is the radius of the overthrow at the given point of the inverted surface, m;

$k_y$ is the soil settling coefficient;

$\lambda_n$ is the coefficient taking into account the influence of the parameters ($\varepsilon_1, \varepsilon_2, \gamma$) of the angle of the rolling surface on the weight of the soil on a rising surface.

Resistance of soil inertia power [11, 12, 21, 22].

$$P_{i_H} = a_n c_n \rho_{nn} k_y^{-1} V^2 \xi_n$$

where $\xi_n$ is the coefficient taking into account the effect of the inverting surface angle parameters on the resistance under the influence of soil inertia.

The resistance which appears in a result of soil sticking to the work surface

$$P_{n_H} = q_{cn} c_n r_n \mu_n$$

where $q_{cn}$ is the comparable stickiness of the soil to the surface of the tipper, H/m²;

$\mu_n$ is a coefficient that takes into account the effect of the turning surface angle parameters on the resistance.

Substituting the values (3.8), (3.9) and (3.10) and (3.7), we obtain:

$$R_{Lo_n} = a_n c_n \rho_{nn} k_y (r_n g \lambda + k_y^{-2} V^2 \xi_n) + q_{cn} c_n r_n \mu_n$$

Substituting formulas (3.3), (3.4), (3.5), (3.6) and (3.11) into (3.2), we obtain an expression that allows us to determine the total resistance of the housing in the following form.
\[ R_{cn} = \varepsilon_n \left\{ a_n \left[ \frac{\pi}{4} + \frac{1.5(1 + k_n)}{\sqrt{k_n}} \right] - \frac{\sin \varepsilon_n + \tan \phi_n c \tan \gamma_n (1 + \sin \gamma_n)}{\cos \varepsilon_n} + \right. \]

\[ + \frac{\rho_n g}{\cos \phi_n} \sin \left[ \arctan (\tan \varepsilon_n \sin \gamma_n) + \phi_n \right] \left\{ c_n \frac{\cos \varepsilon_n + 2 \frac{V^2}{g} \sin \gamma_n \sin \varepsilon_n}{\sin \gamma_n} \right\} \]

\[ + \rho_n k_n (r_n g \lambda_n + k_n^2 \gamma_n^2 \xi_n) \right\} + q_n c_n r_n \mu_n \}

\] (17)

Softening working body \((R_n)\) consist of softener resistance to gravity \(R_{cp}\), because its column is mounted on the rear of the plow body, it does not participate in the process of contact with the ground [17, 18, 19].

4. Conclusions

Therefore, the tensile strength of the softener depends on the angle of installation and the velocity of the work relative to the direction of movement of the softener. Theoretical studies have shown that the slope of the softener is less than 25... 35 degrees relative to the direction of the work surface.

References

[1] Mirziyoyev Sh M 2018 Decision of the President of the Republic of Uzbekistan On additional measures to further improve the technical equipment of agriculture No PD-3459

[2] Murtazoev A N 2018 Interim report on the project of young scientists on the topic Justification of the improved parameters of well softeners during the main tillage in plows

[3] Goryachkin V P 1968 Collected works T 1 Moskva, Kolos p 720

[4] Boyometov R I 1984 The main and pre-sowing soil cultivation // Perspective technological processes of mechanization of cotton cultivation pp 3-32

[5] Mukhamedjanov M V 1978 The root system and productivity of cotton Tashkent, Uzbekistan p 328

[6] Ruhm Eduard 1970 Issuing one with conventional plow procedures 25 No 10 pp 326-328

[7] Tukubaev A B, Khushvaktov B V 1998 The development of plows for wheeled tractors company “Case”. STS UzAME pp 40 – 54

[8] Baymetov R I, Khushvaktov B V 1999 The development of plows for wheeled tractors company “Case”. STS UzAME pp 36 – 66

[9] Butenin N V, Lunts Y L, Merkin D R 1985 The course of theoretical mechanics Dynamics 3(2) p 196

[10] Baymetov R I, Bibutov N S 1983 Technical means for loosening the subsurface horizon // Mechanization of cotton production No 7 pp 7 – 8

[11] Muradov M M 1969 Study of the main parameters of a soil-cultivating paw for a two-tier plow for plowing under cotton p 134

[12] Bibutov N S 1983 Research and justification of the parameters of the working body of the deepripper for the cotton seed zone p 18

[13] Mamatov F M 1992 Mechanic – technological substantiation of technical means for basic tillage in cotton growing zones p 33 Moscow

[14] Ergashev I T 2003 Mechanic-technological fundamentals of technology and technical means for smooth beardless plowing p 41
[16] Tukhtakuziev A 1998 Mechanic-technological basis for increasing the efficiency of tillage machines of the cotton-growing complex p 31
[17] Juraev F U 2000 Substantiation of the shape and parameters of the working bodies of the chisel-cultivator for decompression of gypsum soils in irrigated agriculture p 122
[18] Muradov Sh M 2001 Justification of the parameters of the working bodies for loosening the subsurface layer without compaction of the bottom of the furrow p 16
[19] Murodov N M 2008 Technological fundamentals and parameters of energy-saving technical means for basic tillage in cotton growing p 42
[20] Murodov N M 2003 Two-layer plug State Patent Office of the Republic of Uzbekistan. Utility model patent No. FAP00176. 2003, Newsletter. No 6
[21] Murodov M M and Murodov N M Study of the technological process of the work of a soil-digging cut-out case 2004 UKRNDIPVT named after L. Pogorily technical and technological aspects of development and testing of new equipment and technologies for agriculture of Ukraine 7(21) pp 223 – 227
[22] Yudkin V V 1984 Traction resistance of plow cutters of deep rippers Mechanization and electrification of social agriculture No 5 pp 15-17 Moscow