Plough hitch parameters for smooth tails

K Ravshanov¹, L Babajanov², Sh Kuziev², N Rashidov³ and Sh Kurbanov³

¹Karshi Branch of Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Karshi, Uzbekistan
²Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan
³Karshi Engineering Economic Institute, Karshi, Uzbekistan

h-ravshanov72@mail.ru

Abstract. Qualitative and energy performance of a plough largely depends on the parameters of the plough linkage mechanism. The aim of the research is to substantiate the parameters of plough linkage for smooth sloughing, which turns the layers within its furrow to a tractor of 1.4 classes. In researches methods of classical mechanics are applied. The effects of the field relief on the plough's angular vibrations leading to changes in the depth of the hull stroke and its power load are studied. The dependencies for determining the plough linkage parameters are obtained. Theoretical studies have shown that the plough's stroke uniformity and traction resistance are significantly affected by the longitudinal distance between the bodies, the vertical coordinate of the plough’s lower fingers and the height of the attachment triangle. In order to ensure the required uniformity of running at the working depth and minimum traction resistance, the following parameters of the attachment to tractors of class 1.4 are set: rack height and base width of the attachment triangle respectively 0.55-0.56 m and 0.70-0.75 m, the distance between the lower pins of the attachment and the plough support surface 0.45-0.50 m.

1. Introduction

One of the world's leading positions is occupied by the development and application of energy-saving and high-performance machines for main tillage [1-17]. At the same time, a great deal of attention is paid to the development of ploughs that perform smooth ploughing and turn the layers into their furrows [1].

Efficient use of tractors in energy-intensive and traction-intensive operations can be achieved by optimally attaching implements to the tractor [1, 7, 11, 18]. The optimum tractor mounting mechanism and the dimensions of the plough connection triangle are of great importance [18-20]. When the attachment plough is used with a smooth plough, the conditions of the attachment change. Since the parameters and operating principle of a smooth plough, which turns the layers within its furrow, are fundamentally different from the standard plough.

Availability of ploughs and placement of supporting wheels and other design features of the plough for smooth ploughing require clarification of the issues of aggregation and justification of parameters of the plough linkage mechanism. V.P.Goryachkin [19], D.A.Chudakov [20], P.N.Burchenko I.M.Panov [24] and others made a significant contribution to the development of the theory of mounted units.

M.L.Husyatskiy has studied the questions of aggregation of mounted machines with wheeled tractors. D.A.Chudakov has carried out considerable works on research of mounted machines with
tracked tractors. They gave rise to a new direction in the research of mounted units, namely, the study of the machine and the tractor as a whole.

During operation of the attached ploughing unit, a complex system of forces is created on the plough, changing continuously both in size and direction. Many scientists for serial ploughs have studied these forces to some extent. However, for a plough, many forces have not been sufficiently considered. V.A. Sakun, I.M. Panov and F.M. Mamatov [8–10], I.T. Ergashev [8] and H.A. Ravshanov [8, 9] were engaged in questions of substantiation of parameters of the frontal plough attachment. However, in these studies, the issues of ploughs aggregation for smooth ploughing with tractors of class 1.4 are not sufficiently studied.

The purpose of the study is to justify the parameters of the plough attachment for smooth ploughing, which turns the layers within its furrow to a tractor of class 1.4.

2. Methods

To substantiate the parameters of the mechanism of hinging a two-hulled plough for smooth ploughing with bodies carrying out the rotation of the formation with laying in its furrow, that is, without moving to the side, used the methods of classical mechanics, making a mathematical model that combines kinematic and statistical methods of research.

The following assumptions are made for this purpose [25]: Tractor's mover and plough's support wheels continuously copy the surface profile without crushing it; plough's operating elements are not affected by uneven soil resistance; the machine only makes small oscillations relative to equilibrium positions; tractor's oscillations in the cross-vertical plane do not affect the plough due to its small working width, which can be fully achieved by unblocking the tractor's left and right vertical struts during machine operation.

Perturbations $Z_1$ and $Z_2$ (Fig.1) from the field surface relief under the tractor mover will cause its small angular movements $\psi_t$ in the longitudinal-vertical plane.

$$\psi_t = \frac{Z_2 - Z_1}{L},$$

(1)

Where: $L$ is the distance between the contact points of the tractor's engine and the soil (tractor longitudinal base).

In this case, vertical movement of the tractor's centre of mass $O$ ($x_0, z_0$) is equal to (2).

$$Z_0 = \frac{x_3Z_1 + x_2Z_2}{x_2 + x_3},$$

(2)

Where: $x_3$ and $x_2$ are the longitudinal coordinates of the tractor's rear and front wheels.

The vertical movement of the instantaneous centre of rotation of the attachment mechanism is equal to (3).

$$Z_z = Z_0 + (l_t - x_p)\psi_t,$$

(3)

Where: $l_t$ is the longitudinal coordinate of the tractor's centre of mass; $x_p$ is the longitudinal coordinate of the IWC linkage.

As a result, the plough's attachment mechanism will provide angular movement [24].

$$\psi_{1\pi} = \frac{Z_z}{x_p + x_0},$$

(4)

Where: $x_0$ is the longitudinal coordinate of the plough's support wheels.

The angle of rotation of the plough body is equal.
\[ \psi_{xz} = \frac{\Delta a_R}{l_1 + l_2}, \]  
\hspace{1cm} (5) 

Where: \( a_R \) is the vertical travel of the heel; \( l_1 \) is the distance from the support wheel to the sock of the last housing; \( l_2 \) is the length of the housing support.

\[ \Delta a_R = z_x (l_1 + l_2) \left( \frac{1}{x_p} + \frac{1}{x_Q} \right). \]  
\hspace{1cm} (6) 

Taking into account (1-3) this ratio will take shape:

\[ \Delta a_R = \frac{[Z_1(x_3-l_1+x_p)+Z_2(x_5+x_6-x_4)](l_1+l_2)}{L(x_p+x_Q)}. \]  
\hspace{1cm} (7) 

The longitudinal coordinate of the instantaneous center of rotation is determined by the following relationship [24; 25]

\[ x_p = \frac{h_1}{h_3-h_4} \sqrt{l_n^2-(h_1-h_2)^2}, \]  
\hspace{1cm} (8) 

Where: \( h_1, h_3, h_n \) are geometrical parameters of the tractor's attachment mechanism; \( h_2 \) is the distance from the supporting surface of the plough wheels to the axis of the lower pins of the attachment mechanism; \( h_3 \) is the height of the plough's attachment triangle stand.

Dependence (7) reflects the effect of tractor vibrations on the angular movements of the plough's working elements. This influence depends primarily on the attachment \((h_1, h_3, h_n)\) and running gear \((l_1)\) of the tractor. Besides, the length of the plough's support surface \((l_2)\) and the distance from the support wheel to the last body toe \((l_1)\) have a significant influence on the vibrations of the plough's implement. This should be selected as small as possible, taking the stability of the plough into account.

Figure 1. Calculation of the arable farm unit
The most significant factor affecting the plough's angular movements from tractor vibrations is the height of the stake \( h_3 \) of the plough's attachment triangle. The analysis of expression (7) shows that as it increases, the value of \( \Delta a_R \) decreases and vice versa.

To determine the rational values of the parameter \( h_3 \), one should consider its influence on the value of angular displacement of plough bodies due to changes in the relief of the field surface under the plough's support wheels. Disturbances of \( Z \) under them also cause its small angular displacements in the longitudinal-vertical plane. This is exactly what plough bodies are subjected to.

\[
\psi_{12} = \frac{\Delta a'_R}{(x_p + x_Q) + (l_1 + l_2)}. \tag{9}
\]

From where, taking into account expression (8), we determine the value of vertical heel oscillations of the plough heel from changes in terrain under the plough's support wheels \( (\Delta a_R) \):

\[
\Delta a'_R = \left[ (h_1 - h_4)x_Q + h_4\sqrt{l_n^2 - (h_1 - h_2)^2} + (h_1 - h_4)(l_1 + l_2) \right] Z_3 \over (h_1 - h_4)x_Q + h_4\sqrt{l_n^2 - (h_1 - h_2)^2}; \tag{10}
\]

From equation (10) we can see that the value of \( \Delta a'_R \) (as well as \( \Delta a_R \)) is influenced by both the geometric parameters of the tractor linkage \( (h_1, h_4 \text{ and } l_4) \) and structural ploughs \( (l_1, l_2, x_Q, h_2, h_3) \). Moreover, as the stand height \( (h_1) \) increases, the value of the plough's vibrations \( (\Delta a'_R) \) decreases and vice versa.

Analysis (7) and (10) shows that there are some optimal values of \( h_2, h_3, x_Q \) parameters that simultaneously minimize \( \Delta a_R \) \& \( \Delta a'_R \). Studies show that their determination will not be sufficient to determine the effect of only the plough's angular fluctuations. Therefore, let us consider the impact of each of them on the power load of the plough.

For the analysis of the forces acting on the plough, let us make an assumption of the equality of the forces applied to each of its working bodies, which are replaced by the total applied to the average conditional body at point \( E \) \( (x_R, z_R) \) and the wheel at point \( F \) \( (x_Q, z_Q) \). According to the calculated scheme of the equation of plough equilibrium in the longitudinal-vertical plane:

\[
\begin{align*}
\sum x &= -P_x + Q_x + \sum P_i = Q; \\
\sum z &= P_z + Q_z - \sum R_z - G_{z_R} = 0; \\
\sum M_z &= Q_z(h_1 + z_p) + Q_z(x_Q + z_p) + \sum R_z(Q_{z_R} + h_1 + z_p) - \sum R_z(x_Q + l_2 + z_p) - G_y(x_Q + z_p); \tag{11}
\end{align*}
\]

Where: \( P_x \) and \( P_z \) are horizontal and vertical components of the tractor traction forces; \( \sum P_i \) and \( \sum P_i \) are horizontal and vertical components of the soil reaction forces on the plough's working elements; \( Q_z \) is the vertical load on the wheel rim; \( Q_x \) is resistance force of the plough's wheel; \( x_Q, z_p \) are horizontal and vertical coordinates of the plough linkage; \( G_{z_R} \) is plough gravity; \( h_1, Q_{z_R}, x_R, x_Q, l_k \) are geometrical parameters according to the calculation scheme (Fig.).

It is known that

\[
Q_z = \mu Q_z; \quad \sum R_z = \eta K; \quad \sum R_z = \delta \Sigma R_z, \tag{12}
\]

Where: \( \mu \) is rolling resistance coefficient of the support wheel; \( \eta \) is plough efficiency; \( K \) is soil specific resistance; \( a \) is plowing depth; \( b \) is hull working width; \( \delta \) is proportionality coefficient.

Taking into account the values \( Q_{z_R}, Q_z \) and \( \Sigma R_z \) from the system of equations (11) we have

\[
P_x = \mu Q_z + 2(\eta K); \tag{13}
\]
The first equation of the system (12) shows that as the reference reaction $Q_{z\text{ref}}$ increases, the plough's drag resistance increases. Therefore, the vertical reaction on the support wheels should be minimal, but sufficient to ensure a stable run at the working depth.

It can be seen from its third equation that the value of the reference reaction depends mainly on the position of the instantaneous center of rotation, determined by the kinematic parameters of the linkage. The horizontal coordinate of the plough's instantaneous centre of rotation ($k$) is determined by equation (8), while the vertical coordinate is related to the parameters of the linkage mechanism.

$$z_p = \frac{h_1}{h_3 - h_2} (h_1 - h_2)$$  \hspace{1cm} (13)

3. Results and discussion

By formulas (7), (8), (10) and (12) an algorithm and a computer program were compiled. Analysis of the dependence of the $Q_z$ value on the $x_Q$ parameter, which characterizes the location of the plough relative to the linkage, shows that the closer it is to the tractor, the less vertical reaction to the support wheel. However, when selecting $x_Q$, the tractor plough wheel should be considered to have no contact with the transport position of the plough. On this basis, we recommend $x_Q=1.1-1.3$ m for the tractor in drawbar class 1.4. Changing the distance between the supporting surface of the plough wheels and the axle of the lower pins ($h_2$) to its total traction resistance ($R_z$) has no significant influence. It also remains practically constant both at different stand values ($h_3$) and when the distance between the plough and the tractor is changed.

Analysis of the data shows that the influence of tractor vibrations on the angular movements of the plough's working bodies when hitting the unevenness of the field of its rear wheels is insignificant in comparison with the hitting of the front wheels. Therefore, to identify the optimal parameter $h_3$, which simultaneously minimizes the value of $\Delta Q_g$ and $\Delta a_R$, it is necessary and sufficient to determine the nature of angular movements of plough's working elements from the tractor's vibrations when hitting the unevenness of the field surface of its front wheels, on the one hand, and its supporting wheel, on the other.

From Fig.2a. we can see that with increasing $h_2=0.45-0.50$ m $Q_z$ value practically remains constant for different soil conditions. As it follows from Fig.2b. the height $h_3$ of the plough's hinge stand, at which $Q_z$ values remain constant, is equal to 0.55-0.56 m for different soil conditions.
Figure 2. Dependence of the load on the plough's support wheel $Q_x$ on the change in the linkage mechanism parameters $h_2(a)$ and $h_3(b)$.

4. Conclusions
1. Theoretical studies have shown that the plough's stroke uniformity and traction resistance are significantly affected by the longitudinal distance between the bodies, the vertical coordinate of the plough's lower fingers $h_2$ and the height of the attachment triangle $h_3$.

2. To ensure the required uniformity of stroke on the depth of processing and the minimum traction resistance are set the following parameters of the attachment to the tractor class 1.4: height of the stand and width of the base of the connection triangle of the attachment respectively 0.55-0.56 m and 0.70-0.75 m, the distance between the lower fingers of the attachment and the supporting surface of the plough 0.45-0.50 m.

References
[1] Mirzaev B Mamatov F & Tursunov O 2019 A justification of broach-plow’s parameters of the ridge-stepped ploughing https://doi.org/10.1051/e3sconf/20199705035
[2] Mirzaev B Mamatov F Avazov I & Mardonov S 2019 Technologies and technical means for anti-erosion differentiated soil treatment system E3S Web of Conferences https://doi.org/10.1051/e3sconf/20199705036
[3] Mamatov F Mirzaev B Shoumarova M Berdimuratov P Khodzhaev D 2009 Comb former parameters for a cotton seeder International Journal of Engineering and Advanced Technology (IJEAT) 9 (1) DOI: 10.35940/ijeat.A2932.109119. P.4824-4826
[4] Mirzaev B Mamatov F Ergashev I Ravshanov H Mirzaxodjaev Sh Kurbanov Sh Kodirov U Ergashev G 2019 Effect of fragmentation and pacing at spot ploughing on dry soils E3S Web of Conferences https://doi.org/10.1051/e3sconf/201913501065
[5] Mirzaev B Mamatov F Ergashev I Islomov Yo Toshtemirov B Tursunov O 2019 Restoring degraded rangelands in Uzbekistan Procedia Environmental Science, Engineering and Management 6 pp 395-404
[6] Mirzaev B Mamatov F Ergashev I Ravshanov H Mirzaxodjaev Sh Kurbanov Sh Kodirov U Ergashev G 2019 Effect of fragmentation and pacing at spot ploughing on dry soils E3S Web of Conferences https://doi.org/10.1051/e3sconf/201913501065
[7] Mirzaev B Mamatov F Chuyanov D Ravshanov X Shodmonov G Tavashov R Fayzullayev X Combined machine for preparing soil for cropping of melons and gourds XII International Scientific Conference on Agricultural Machinery Industry doi.org/10.1088/1755-1315/403/1/012158
[8] Mirzaev B Mamatov F Aldoshin N Amonov M 2019 Anti-erosion two-stage tillage by ripper Proceeding of 7th International Conference on Trends in Agricultural Engineering (Prague Czech Republic) pp 391-396
[9] Umurzakov U Mirzaev B Mamatov F Ravshanov H Kurbonov S 2019 A rationale of broach-plow's parameters of the ridge-stepped ploughing of slopes 403 (1) 01216312 https://www.scopus.com/sourceid/19900195068
[10] Mamatov F M Mirzaev B S 2014 Erosion preventive technology of crested ladder-shaped tillage and plow design European Applied Sciences. (Stuttgart Germany) 4 pp 71-73
[11] Mamatov F M Mirzaev B S 2017 The new antierosion and water saving technologies and tools for soil cultivation under the conditions of Uzbekistan 4 pp 16-20
[12] Lobachevskij Ja P Mamatov F M Jergashev I T 1991 Frontal plow for cotton growing Khlopok (Moscow) 6 pp 35-37.
[13] Mamatov F M Ergashev I T Mirzaev B S Mirzaxodjaev Sh 2011 Combined Front Plow Rural machine operator (Moskva) 10 pp 10-11
[14] Mamatov F M Mirzaev B S 2014 Erosion preventive technology of crested ladder-shaped tillage and plow design European Applied Sciences Stuttgart (Germany) 4 pp 71-73
[15] Mamatov F M Mirzaev B S 2017 The new antierosion and water saving technologies and tools for soil cultivation under the conditions of Uzbekistan Ecology and Construction 4 pp 16-20
[16] Mamatov F M Batirov Z L Khalilov V S Kholiyarov J B 2019 Three-tier fertilizer application with a current distributor of a deep-ripper Agricultural Machines and Technologies 13 (4) pp 48-53 DOI 10.22314/2073-7599-2019-13-4-48-53
[17] Mamatov F M Mirzaev B S Chujanov D Sh Jergashev G D 2011 Unit for pre-sowing soil preparation Rural machine operator (Moskva) 7 pp 12-14
[18] Abezin V G 2004 Mechanization of melon cultivation based on resource-saving soil-protective technologies (Volgograd) p 478
[19] Jem A D Zhukov VN Qodirov A Je 1989 Recommendations on the use of mechanized technology and a complex of machines for the cultivation of gourds (Tashkent) pp 1-13
[20] Malyukov V I 1982 Melon breeding mechanization (Volgograd, Nizh.-Volzh. Kn. izd-vo) pp 6-14