Development of a frontal plow for smooth, furless plowing with cutoffs

F Mamatov¹, N Aldoshin², B. Mirzaev³, H Ravshanov³, Sh Kurbanov¹ and N Rashidov¹

¹Karshi Engineering Economic Institute, 180100, Kashkadarya, Uzbekistan
²Moscow Agricultural Academy named after K.A.Timiryazeva, Moscow, Russia
³Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, 100000, Tashkent, Uzbekistan

E-mail: bahadir.mirzaev@bk.ru

Abstract. The existing plows for smooth furrowless plowing do not provide a full turnover of layers within their own furrow and the incorporation of weeds, they have a high energy consumption. The aim of the study is to substantiate the parameters of the frontal plow cut-off, which ensures a high-quality performance of the technological process according to agrotechnical requirements with the lowest energy consumption during smooth furrowless plowing. An improved technology of smooth furrowless plowing has been developed, in which at first the seam is given a polygonal shape, then turned 180° within its own furrow. A frontal plow with offsets has been developed to implement the proposed technology. In the research, the laws and rules of theoretical mechanics, mathematical statistics, mathematical planning of experiments and methods of strain gauge were applied. It has been established by theoretical and experimental studies that when the frontal plow is cut off in the form of a triangular wedge, its height is 22 cm, the wing opening angle is 32°, the side edge angle is 36°, the required quality of smooth plowing is provided with the lowest energy consumption. With longitudinal distances between the plowshares of the body and the cut-off of at least 27 cm and between the disc coulter and the cut-off of 16 cm, the required quality of soil cultivation of the front plow is ensured in accordance with the established agro technical requirements.

1. Introduction

V.A.Sakun studied the design and use of plows for smooth plowing, study of their performance indicators and substantiation of parameters, as well as the study of the process of interaction of working bodies with the soil [1; 8; 10], V.V.Sharov [9], Ya.P.Lobachevsky [1-2; 4-8; 10], S.A. Zolotarev [3], N.A.Shpakovsky [12], O.A.Sizov [1; 10-11], A.I.Miltsev [13], L.Kaufman [14], D.Totten [14], F.M.Mamatov [18-23], I.T.Ergashev [20], N.V.Aldoshin [22-23], P.A.Ravshanov [24-25] and others.

The plows created as a result of these studies are used with some positive results in agricultural production [8-13; 18-24]. However, in these studies, the issues of substantiating the parameters of the frontal plow for smooth furrowless plowing, providing high quality work with minimal energy consumption, have not been sufficiently studied. The existing plows of smooth furrowless plowing have a number of disadvantages, including they do not provide a full turnover of layers within their
own furrow and the incorporation of weeds, they have a high energy consumption [9-15]. This results in poor quality soil cultivation and reduced productivity. The analysis of studies [10-14] showed that improving the quality of soil crumbling and the degree of incorporation of plant residues, as well as a decrease in fuel consumption, labor and other costs for smooth, furless plowing, can be achieved by applying coal removal on a frontal plow, which provides an improvement in the turnover of layers within its own furrow with the smallest costs.

The aim of the study is to substantiate the parameters of the frontal plow cut-off, which ensures a high-quality performance of the technological process according to agro technical requirements with the lowest energy consumption during smooth furless plowing.

2. Method

The studies applied the laws and rules of theoretical mechanics, mathematical statistics, mathematical planning of experiments and methods of strain gauging, as well as the methods given in the existing regulatory documents.

On the basis of the analysis of the research work carried out, an improved technology of seams turnover within its own furrow and a structural diagram of a frontal plow with off-take plows were developed.

![Figure 1. Scheme of the formation turnover technology within its own furrow: a – cross-sectional view of the field after cutting with a circular knife; b – a cross-sectional view of the field with located angle images; c – a view of the cross-section of the field after turning the cut edges of the soil layer with coal images; d – view of the cross-section of the field after turning the layers within its own furrow](image-url)

In the proposed technology, in order to facilitate the turnover of the seam within its own furrow and reduce its energy consumption, the left and right edges of the seam are first cut off and wrapped in its middle, after which the seam is turned 180° within its own furrow (Fig.1).

The front plow consists of a frame 1 equipped with a hinged device, disc knives 2, cutoffs 3 and 4, left and right-turning bodies 5 and 6, a backing plow 7 and a support-leveling roller 8. One-sided scrapers are installed only along the line of field cuts of the outermost bodies, and symmetrical angled - along the axis of symmetry of opposite bodies (Fig.2).

In the process of plowing, the disc knives 2 make vertical cuts to a depth of 12-13 cm and are separated from the array of layers with a width of bn (Fig.1a). Angles 2 and 3 cut off the left and right faces \( A_1A_2, B_1B_2, I_1I_2 \), and \( E_1E_2 \) of the \( ABCD \) and \( EFGH \) formations and, accordingly, turn them to the left and right sides (Fig.1c). As a result, polyhedral strata \( a \) and \( b \) are formed. Under the influence of left and right-turning hulls and backplows, the formation in the form of a polygon without difficulty
turns 180° into its own furrow (Fig. 1d). This improves the quality of seams turnover and reduces energy consumption for this technological process.

Figure 2. Structural diagram of a frontal plow with off-take: 1 – frame; 2 – circular knife; 3, 4 – removable; 5, 6 – left and right turn buildings; 7 – backfill; 8 – skating rink

The rational place for installing the angle pickup is taken to be behind the disk along the axis of its symmetry (Fig. 3). In this position, the front edge of the fillet moves along the slot formed by the disc, which improves its working process.

To protect the toe cap from wear and reduce its traction resistance, the lower edge C can be set at the level of the lower point E of the non-sharpened surface of the disc. Then the longitudinal distance between the circular knife and the angle knife can be determined proceeding from the exclusion of touching the front face of the angle cutter on the disk blade

\[ l_1 = (R+S) \sin \alpha - \left[ R - \frac{1}{2} t_d \ctg \frac{i_1}{2} - (R+S) \cos \alpha \right] \ctg \alpha , \]

where \( R \) – is the radius of the circular knife, cm; \( S \) – the gap between the blade of the circular knife and the front edge is removable, cm; \( \alpha \)– angle of entry of the front facet into the soil, degree; \( t_d \) – thickness of the circular knife, cm; \( i_1 \) – angle of sharpening of the circular knife, degree.

With \( R=22.5 \text{ cm}, S=2 \text{ cm}, \alpha=50^\circ, t_d=0.5 \text{ cm} \) and \( i_1 = 25^\circ \), according to expression (1), the longitudinal distance from the axis of the circular knife to the nose must be at least 16 cm.

Figure 3. Scheme for determining the longitudinal distance \( (l_1) \) between the circular knife and the angle pick: 1 – circular knife; 2 – carbon removal
The longitudinal distance between the coal removal and the body (Fig. 4) was determined based on the condition that the soil deformation zone treated by the body did not reach the structural elements.

\[ L_2 \geq b_b \cot \gamma + (a - \frac{1}{2} b_l \sin \varepsilon_1) \cot \varphi \frac{\sin(\gamma_1 + \varphi)}{\sin \gamma_1}, \]  

(2)

where \( b_b \) – is the capture width of the grip, m; \( \gamma \) – angle of the aperture can be removed, degree; \( \varepsilon_1 \) – angle of installation of the share blade to the furrow wall, degree; \( \varphi \) – soil friction angle, degree.

With \( a = 25 \) cm, \( b_b = 10 \) cm, \( b_l = 52.5 \) cm, \( \gamma = 32^\circ \), \( \gamma_1 = 45^\circ \), \( \varphi = 25^\circ \), \( \varepsilon_1 = 33^\circ \) and \( b_l = 12.2 \) cm according to expression (2), the longitudinal distance between the angle the body must be at least 27 cm.

The main parameters of the offset are: the height of the offset \( H_b \), cm; length can be angled \( l_b \), cm; the angle of entry of the front facet is removable into the soil \( \alpha \), degree; the angle of inclination of the side face is offset \( \delta \), degree; aperture angle \( \gamma \), degree; rotation angle \( \beta \), degree; the angle of inclination of the working face is angular to the horizontal plane \( \varepsilon \), degrees.

The height of the grip \( H_b \) is determined depending on the depth of processing the grip \( ab \) and the width of the grip \( b_b \), according to the following formula

\[ H_b = a_b + \frac{1}{3} \sqrt{b_b^2 + 4a_b^2}. \]  

(3)

With \( a_b = 12 \) cm and \( b_b = 8-10 \) cm, according to expression (3), the height of the angular removal should be within \( H_b = 21-22 \) cm.

The angle of entry of the front face into the soil \( \alpha \) influences the shear and crumbling of the seam cut out by the coal removal.

We determine it based on the condition of the shift of the soil particle according to the angle

\[ \alpha \leq \frac{\pi}{2} - \varphi. \]  

(4)

**Figure 4.** Scheme for determining the longitudinal distance \( (L_2) \) between the body and the offset: 1 – offset; 2 – case; 3 – share
At $\phi = 25\text{-}30^\circ$, according to expression (4), the angle of entry of the front face of the angle into the soil should be in the range of $\alpha = 35\text{-}50^\circ$. We accept $\alpha = 50^\circ$.

The angle of inclination of the lateral face is offset equal to the angle of inclination of the seam cut by it

$$\delta_b = \arctg \frac{b_b}{a_b}. \quad (5)$$

With $a_b = 12 \text{ cm}$ and $b_b = 8\text{-}10 \text{ cm}$, according to expression (5), the angle of inclination of the lateral edge of the angle should be within $\delta = 33\text{-}39^\circ$. We take $\delta = 36^\circ$.

The angle of the opening is determined from the condition of the soil shift along the surface of the coal removal and the exclusion of unloading the soil in front of it

$$\gamma \leq \frac{\pi}{4} - \frac{\phi}{2}. \quad (6)$$

At $\phi = 25\text{-}30^\circ$ according to expression (6), the angle of the aperture angle should be within $\gamma = 30\text{-}32^\circ$. We accept $\gamma = 32^\circ$.

The angle of rotation is determined by the following formula

$$\beta = \arctg \frac{tg \alpha}{tg \gamma}. \quad (7)$$

At $\alpha = 50^\circ$ and $\gamma = 32^\circ$, according to expression (7), the angle of rotation of the gantry should be $\beta = 55^\circ$.

The value of the angle of inclination of the working face is angular to the horizontal plane $\varepsilon$ depends on the angles $\alpha$ and $\gamma$, that is

$$\varepsilon = \arctg \frac{cos \gamma}{tg \beta}. \quad (8)$$

At $\beta = 55^\circ$ and $\gamma = 32^\circ$, according to expression (8), the angle of inclination of the working face is angular to the horizontal plane to be $\varepsilon = 31^\circ$.

The length of the grip $lb$ is determined depending on the angle of entry of the front face of the grip $\alpha$, the depth of processing $ab$ and the width of the grip of the grip $bb$ according to the following formula

$$l_b = (a_b + \frac{1}{3} \sqrt{b_b^2 + 4a_b^2})ctg \alpha_b. \quad (9)$$

According to expression (9), for $a_b = 12 \text{ cm}$, $\alpha = 50^\circ$ and $b_b = 8\text{-}10 \text{ cm}$, the length of the fillet should be within $l_b = 26\text{-}27 \text{ cm}$.

3. Results and Discussions

Experimental studies have studied the effect of the positioning scheme of the scraper, the longitudinal distance between the circular knife and the scraper, the longitudinal distance between the scraper and the body, the width of capture and the depth of processing the scraper, as well as the working speed on the quality indicators and traction resistance of the front plow. The experiments were carried out in the grain fields of the experimental section of the Institute of Mechanization and Electrification of Agriculture.

According to the data of the experiments, it was found that at a front plow speed of 6.5-8.5 km/h to ensure the required quality of work with minimal energy consumption, the longitudinal distance from the center of the circular knife to the tip of the angle must be at least 16 cm (Fig.5a), the longitudinal distance between the angled and the body is at least 27 cm (Fig.5b), the angle of inclination of the working face is $36^\circ$, the depth of processing and the width of capture are 12, and 10 cm, respectively.
Figure 5. Graphs of the dependence of the plow pulling resistance ($R$) and the degree of soil crumbling ($F_{<50}$) on the longitudinal distances between the circular knife and the cutter ($l_1$) and between the cutter and the body ($L_2$).

4. Conclusions
Placement on the frame of the frontal plow of circular knives, offsets, left and right wrapping bodies and a slatted roller, in an individual order and consistently allows it to be made compact and mounted.

When the frontal plow is removed in the form of a triangular wedge, its height is 22 cm, the wing opening angle is 32°, the angle of inclination of the side edge is 36°, the required quality of smooth plowing is ensured with the least energy consumption.

According to the results of the studies, it was found that the required quality of soil cultivation with a frontal plow in accordance with the established agrotechnical requirements with minimal energy consumption is ensured with longitudinal distances between the body share and the cutter of at least 27 cm and between the circular knife and the cutter 16 cm.

Acknowledgments
We thank all our colleagues who worked closely with us on this paper.

References
[1] Sackun V.A., Lobachevsky Y.P., Sizov O.A., Sharov V.V. New Technology and Equipment for Level Ploughing Silsoe Research Institute. Translation. – №34. Silsoe, England, 1991. – P.1-7. (In Russian)
[2] Ismailova, Z., Choriev, R., Salomova, R., Jumanazarova, Z. Use of economic and geographical methods of agricultural development. Journal of Critical Reviews. 2020. 7(5). Pp. 409–412. DOI:10.31838/jcr.07.05.84. Zolotarev S.A. Obosnovanie tehnologicheskogo processa i parametrov pluga dlja gladkoj vpashki: Diss. … kand. teh. nauk. – Moskva: MGAU, – 2005. – 225 s. (In Russian)
[3] Lobachevskij J.P., Mamatov F.M., Jergashev I.T. Frontal'nyj plug dlja hlopkovodstva// Hlopok. – 1991. – №6. – S. 35-37. (In Russian)
[4] Lobachevskij J.P. Semejstvo frontal'nyh plugov dlja gladkoj vpashki: Dis. ... dok. teh. nauk. – Moskva: MGAU, 2000. – 335 c. (In Russian)
[5] Lobachevsky Y.P. New concept to fp loughing: Technology and Equipment. Agricultural Equipment Technology Conference” AET C1997”. Paper №97-AET C103. Louisville, Kentucky. – USA, 1997. – P.1-10. (In Russian)
[6] Lobachevsky Y.P. New technology of the flat ploughing and design of the fron tploughs. A n ASA E Meeting Presentation. Paper № 961071. Phoenix, Arizona, – USA, 1996. – P.1-8. (In Russian)
[7] Sakun V.A., Lobatchewsky Y.P. Lang fristige trends in derent wick lungvon boden bear beitung sgeraten. Agrar technisch eberichte. Institut fur Agrar technik und Universitat Hohenheim. - Stuttgart,1993. – P.76-82. (In Russian)
[8] Sharov V.V. Obosnovanie osnovnyh parametrov rotornogo pluga dlja gladkoj vspaski: Diss. … kand. teh. nauk. – M.: 1986. – 227 s. (In Russian)
[9] Sizov O.A., Lobachevskij Ja.P., Sakun V.A. Sovremennyj jetap i puti dal'njejšeho razvitija pahotnyh agregatov // Tehnika v sel'skom hozjajstve. 1991. – №3. – 0.9-12. (In Russian).
[10] Sizov O.A., Mamedova L.V., Bliev A.A. Tehnologicheskie i konstruktivnye osobennosti perspektivnyh plugov dlja gladkoj vspaski i novyj metod ocenki ee jeffektivnosti. Sb. nauch. trudov, t.120. – M.: VIM,1989. – S.231. (In Russian)
[11] Shpakovskij N.A. Intensifikacija processa obrabotki pochvy na osnove primenenija frontal'nogo pluga. Diss…. kan. teh. nauk. – M., 1991. – 186 c. (In Russian)
[12] A.S. 470258. Frontal'nyj plug/ Mil'cev A.I., Kirjuhin V.G., Korotkov V.S., Moskvicheva V.D. // B.I. – 1975. – № 18. (In Russian)
[13] Kaufman L.C., Totten D.S. Development of an inverting moldboard plow // Trens ASAE, 1972. – №1. – pp.50-58.
[14] Donald K. Shannon Precision Agriculture, Wil lit Work An Extension Deminstration Project. – Emerging Technologies for 21st century, ASAE/CSAE, 1999. – p № 99. 1140. 335.
[15] Nichols M. Method of research in soil dynamic a supplied to implement design.-Auburn, 1929. – p.229.
[16] Robert J. Monson. The Application of Enhanced GPS Systems for Navigation in Precision Agriculture. – Managing today's technology, ASAE,1996. – p. № 961023.
[17] Mamatov F., Mirzaev B., Batirov Z., Toshtemirov S., Tursunov O., Bobojonov L. Justification of machine parameters for ridge forming with simultaneous application of fertilizers // CONMECHYDRO – 2020. IOP Conf. Series: Materials Science and Engineering 883 (2020) 012165. doi:10.1088/1757-899X/883/1/012165.
[18] Mamatov F., Mirzaev B., Aldoshin N and Amonov M. Anti-erosion two-stage tillage by ripper Proceeding of 7th International Conference on Trends in Agricultural Engineering 17th – 20th September (Prague Czech Republic) – pp 391-396.
[19] Aldoshin N. Didmanidze O., Mirzayev B., Mamatov F. Harvesting of mixed crops by axial rotary combines // Proceeding of 7th International Conference on Trends in Agricultural Engineering 2019. 17th - 20th September 2019 Prague, Czech Republic. – pp.20-26.
[20] Ravshanov Kh., Fayzullaev Kh., Ismoilov I., Irgashov D., Mamatov S. The machine for the preparation of the soil in sowing of plow crops under film // International scientific conference «Construction mechanics, hydraulics and water resources engineering» CONMECHYDRO-2020. – Tashkent, 2020. doi:10.1088/1757-899X/883/1/012138.