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RESULTS OF THEORETICAL STUDIES ON DETERMINING THE MOTION OF A SOIL PARTICLE DISCHARGED FROM AN ADDITIONAL MOLDBOARD IN THE TRANSVERSE–VERTICAL PLANE

https://doi.org/10.5281/zenodo.19448356

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Abstract: *This article presents the results of theoretical studies conducted to ensure complete and deep incorporation of plant residues and weeds by a disk body under the following condition: soil particles discharged from the additional moldboard must fall onto the bottom of the furrow formed by the preceding body.*

Keywords: *plant residues, weeds, complete and deep incorporation, burial assurance, disk body, additional moldboard, discharged soil particles, preceding body, furrow bottom, condition.*

INTRODUCTION

In recent years, due to the widespread implementation of energy- and resource-saving technologies and machinery in agriculture, the use of disk plows—i.e., plows with spherical disk-shaped working bodies—for primary tillage (plowing) has become increasingly important. This is because they offer lower draft resistance compared to moldboard plows, provide higher productivity, and operate without clogging from plant residues and weeds [1].

The development of soil tillage machines equipped with disk working bodies, the substantiation of their parameters, and the study of soil–disk interaction processes have been widely investigated by foreign researchers such as X. Li, D. Zhang, F. Amran, O. Omafunnei, K. Wasfy, H. Harrison, W. Gill, C. Reavers, A. Bailey, R. Godwin, D. Seig, M. Alflott, M. Alam, J. Balloch, R. Reeder, A. Naim, S. Sulaiman, R. Davies, G. N. Sineokov, V. F. Strelbitskiy, F. M. Kanarev, P. S. Nartov, G. Teslyuk, M. Al-Jarrah, and others.

Based on these studies, various machines and devices have been developed, achieving certain positive results in agricultural production. However, the issues related to the development of disk plows equipped with

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additional moldboards have not been sufficiently studied.

Materials and methods: The research was conducted using the principles and methods of theoretical mechanics, agricultural mechanics, and mathematical statistics, as well as experimental design and tensometry methods. Standardized procedures specified in regulatory documents—such as O‘zDSt 3355:2018 "Testing of Agricultural Machinery. Deep Tillage Machines and Implements. Test Program and Methods," O‘zDSt 3193:2017 "Testing of Agricultural Machinery. Method for Energy Evaluation of Machines," and RD Uz 63.03-98 "Testing of Agricultural Machinery. Methods for Calculating the Economic Efficiency of Tested Agricultural Machinery"—were applied [2–4].

Results and discussion: To ensure complete and deep incorporation of plant residues and weeds, soil particles discharged from the additional moldboard of the disk body must fall onto the bottom of the furrow formed by the preceding body. This condition is satisfied when the following requirement is met:

$$L_k \prec B_e, \quad (1)$$

Here, L_k– is the transverse throwing distance of soil particles discharged from the additional moldboard relative to the direction of motion of the body, *m*;

B_e – is the width of the furrow formed by the body, *m*.

The value of L_K in expression (1) is determined [5]. For this purpose, based on the scheme shown in Figure 1, the transverse–vertical motion of a soil particle discharged from the additional moldboard was studied.

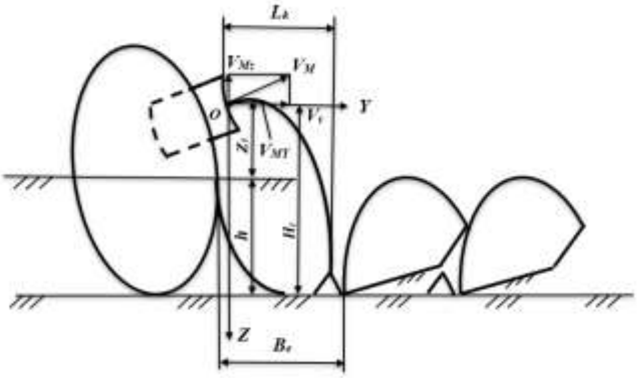

Figure 1. Scheme for studying the motion of a soil particle discharged from the additional moldboard in the transverse–vertical plane.

Accordingly, the following values were assumed: $V=2\ m/s$, $r_M=0.2\ m$, $\alpha=40^{\circ}$, $e=2{,}72$, $f=0{,}58$, $\varphi_0 = 0{,}11\ rad$, $R= 0{,}7\ m$, $g=9{,}81 m/s^2$, $\beta=20°$ $D=0{,}65\ m$ $\tau_M = 135^0$ Based on these parameters, the variation graphs of L_K as a function of φ_m and H were plotted according to expression (2), as shown in Figure 2.

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$$\frac{1}{g}\Bigg\{\Bigg(2V\frac{r_M}{D}\cos\alpha\Bigg)^2+k^2\Bigg\{-\frac{1}{e^{2f\left(\frac{r_M}{R}-\varphi_0\right)}}\Bigg[\frac{6fgR}{\left(1+4f^2\right)}\times$$

$$\times\cos\left(\varphi_0+\beta\right)\cos\tau_M+2gR\frac{\left(1-2f^2\right)}{\left(1+4f^2\right)}\sin\left(\varphi_0+\beta\right)\cos\tau_M+$$

$$+4V^2\frac{R^2}{D^2}\cos^2\alpha\left(\frac{\sin2\varphi_0}{f}-\sin^2\varphi_0\right)\Bigg]+\frac{6fgR}{(1+4f^2)}\times$$

$$\times\cos\left(\arcsin\frac{r_M}{R}+\beta\right)\cos\tau_M+2gR\frac{(1-2f^2)}{(1+4f^2)}\sin\left(\arcsin\frac{r_M}{R}+\beta\right)\cos\tau_M+$$

$$+4V^2\frac{R^2}{D^2}\cos^2\alpha\Bigg\{\frac{\sin2\arcsin\frac{r_M}{R}}{f}-\Bigg(\left(\frac{r_M}{R}\right)^2\Bigg\}\Bigg\}^{\frac{1}{2}}\Bigg\}\times$$

$$\times\Bigg\{\Bigg\{\Bigg(2V\frac{r_M}{D}\cos\alpha\Bigg)^2+k^2\Bigg\{-\frac{1}{e^{2f\left(\frac{r_M}{R}-\varphi_0\right)}}\Bigg[\frac{6fgR}{\left(1+4f^2\right)}\times$$

$$\times\cos\left(\varphi_0+\beta\right)\cos\tau_M+2gR\frac{\left(1-2f^2\right)}{\left(1+4f^2\right)}\sin\left(\varphi_0+\beta\right)\cos\tau_M+$$

$$+4V^2\frac{R^2}{D^2}\cos^2\alpha\left(\frac{\sin2\varphi_0}{f}-\sin^2\varphi_0\right)\Bigg]+\frac{6fgR}{(1+4f^2)}\times$$

$$\times\cos\left(\arcsin\frac{r_M}{R}+\beta\right)\cos\tau_M+2gR\frac{(1-2f^2)}{(1+4f^2)}\sin\left(\arcsin\frac{r_M}{R}+\beta\right)\cos\tau_M+$$

$$+4V^2\frac{R^2}{D^2}\cos^2\alpha\Bigg\{\frac{\sin2\arcsin\frac{r}{R}}{f}-\Bigg(\left(\frac{r_M}{R}\right)^2\Bigg\}\Bigg\}^{\frac{1}{2}}\Bigg\}\sin\gamma+$$

$$+\Bigg\{\Bigg\{\Bigg(2V\frac{r_M}{D}\cos\alpha\Bigg)^2+k^2\Bigg\{-\frac{1}{e^{2f\left(\frac{r_M}{R}-\varphi_0\right)}}\Bigg[\frac{6fgR}{\left(1+4f^2\right)}\times$$

$$\times\cos\left(\varphi_0+\beta\right)\cos\tau_M+2gR\frac{\left(1-2f^2\right)}{\left(1+4f^2\right)}\sin\left(\varphi_0+\beta\right)\cos\tau_M+$$

$$+4V^2\frac{R^2}{D^2}\cos^2\alpha\left(\frac{\sin2\varphi_0}{f}-\sin^2\varphi_0\right)\Bigg]+\frac{6fgR}{(1+4f^2)}\times$$

$$\times\cos\left(\arcsin\frac{r_M}{R}+\beta\right)\cos\tau_M+2gR\frac{(1-2f^2)}{(1+4f^2)}\sin\left(\arcsin\frac{r_M}{R}+\beta\right)\cos\tau_M+$$

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$$+4V^2\frac{R^2}{D^2}\cos^2\alpha\left\{\frac{\sin 2\arcsin\frac{r}{R}}{f}-\left(\left(\frac{r_M}{R}\right)^2\right\}\right\}^{\frac{1}{2}}\right\}^2\times$$

$$\times\sin^2\gamma\ \}+2g\left[H+L_K\sin\varepsilon+R_m\sin\frac{\delta}{2}(1-tg\varepsilon)\right]\}^{\frac{1}{2}}\}\}\cos\gamma\cos\varphi_m\prec B_e. \qquad (2)$$

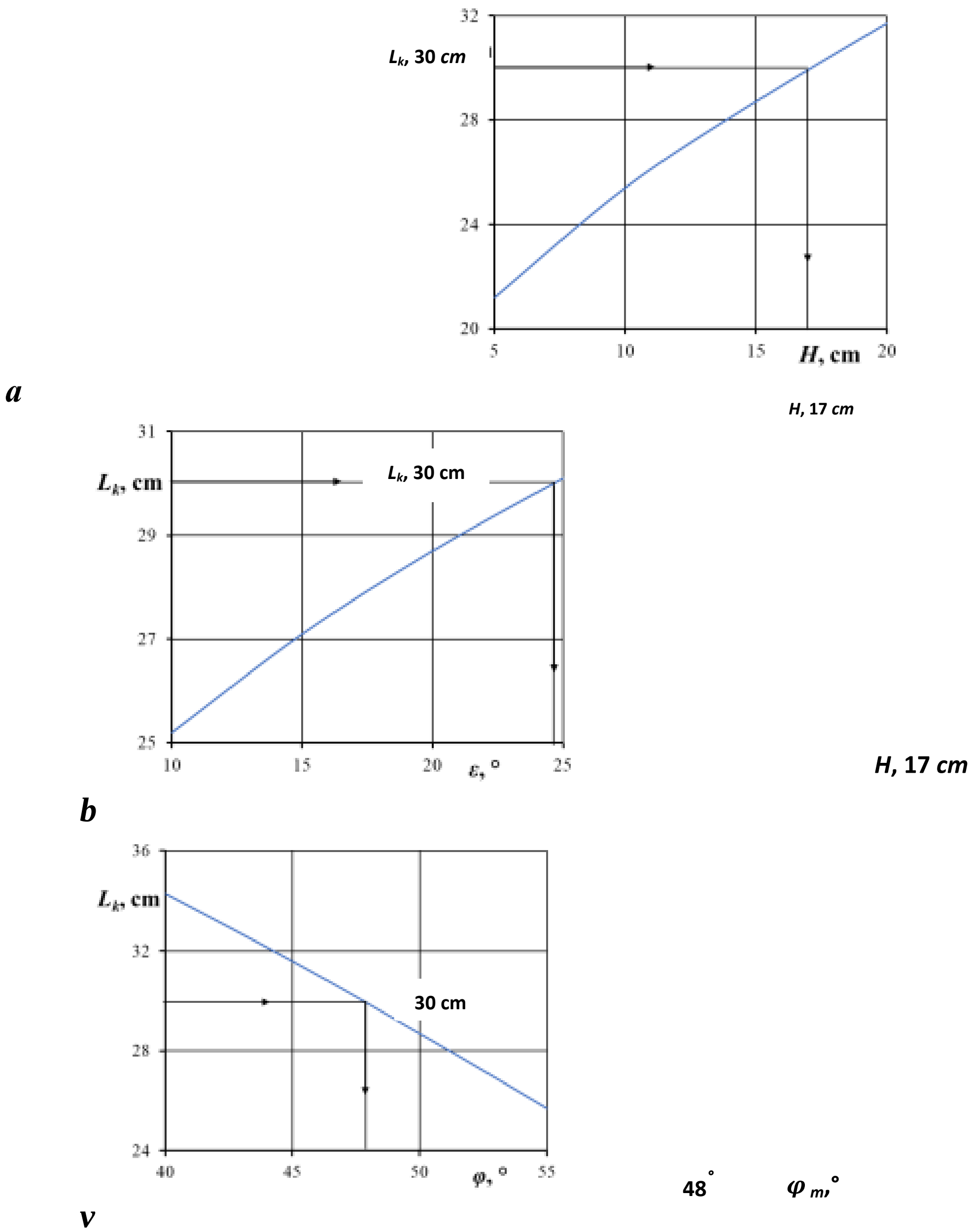

Figure 2. Graphs of variation of L_K as a function of $H(a)$, $\varepsilon(b)$ and $\varphi(v)$

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Conclusion: Assuming B_e=30 cm the graphs presented in Figure 2 indicate that, in order to satisfy condition (1) and ensure that soil particles discharged from the additional moldboard fall onto the bottom of the furrow formed by the preceding body, the distance H and the angle ε must not exceed 17.0 cm and 24°8′, respectively, while the angle must not be less than 48°..

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