

INITIAL DATA FOR DEVELOPING A MODEL OF THE PROCESS OF SEED FURROW FORMATION BY A WEDGE-SHAPED DISC

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Abstract. *In the conditions of domestic agriculture, especially in the soil protection system of tillage, when a significant part of crop residues remains on the soil surface, both disc and anchor coulters do not form a seed furrow with sufficient quality. The created seedbed is not dense enough, including due to soil shedding, which reduces the field germination of seeds and, as a result, crop yields. The article substantiates the initial conditions for developing a model of seed furrow formation when soil is compacted with a wedge-shaped disc.*

Keywords. *Geometric modelling, seed furrow, wedge-shaped disc, soil reaction components.*

Problem Statement. Special attention is paid to the quality indicators of the technological process of sowing crops, as they affect the germination of sown seeds, the labour intensity of crop care, and, most importantly, the final result – the yield. It has been established that in order to ensure the most favourable conditions for germination, seeds should be placed in a furrow with a compacted bottom and covered with loose soil. The compaction of the furrow bottom causes the inflow of moisture and nutrients to the seeds from below, which increases their germination, and the loose top layer above the seeds in the furrow does not allow moisture to evaporate and, at the same time, provides air flow to the sprouts, which also has a favourable effect on their growth and development [1, 2, 3].

The analysis of the existing technological methods of sowing crop seeds and the design of furrow forming implements has shown that modern implements do not create favourable conditions for seed germination and do not work satisfactorily in domestic agriculture, especially in the system of soil conservation tillage, where up to half of the plant residues remain on the soil surface. For example, single or double disc coulters do not compact the bottom of the furrow sufficiently and place the seed unevenly over the depth, anchor coulters get clogged with plant residues, especially in direct drilling, and combined coulters have a complex design. Therefore, the problem of shaping the furrow profile, i.e. improving the furrow forming bodies, is relevant.

Analysis of Recent Research. The quality of the sowing process depends heavily on the technical sophistication of the implement used. Usually, this process is performed by the working bodies of seeders-coulters. Domestic and foreign scientists have proved that the process of sowing seeds includes several operations [4, 5]:

- formation of a furrow of the required depth and width with a compacted bottom;
- directing the seed to the compacted bottom of the furrow;
- random shedding of soil from the furrow walls and partial covering of seeds;
- forced additional soil recycling in the area of the row axis and its compaction.

In addition, according to Salo et al. (2024), seeds that fall to the bottom of a seed furrow at a certain speed after a vertical flight do not remain stationary at the point of contact with the furrow bottom, but bounce several times to different heights before remaining stationary, fixed by the soil. During the next downward fall, after bouncing off the furrow bottom, the seed in most cases falls on a layer of soil of a certain thickness that has covered the bottom as a result of shedding. As a result, the coulters form a furrow of a given depth, and the seeds are located in the furrow at different depths [4]. In addition, the “galloping” of seeds worsens the uniformity of their placement along the row [6].

Formulation of Goals (Task Setting). The aim of the study is to substantiate the initial data for modelling the technological process of seed sowing under the condition of forming a seed furrow with a wedge-shaped disc.

Main Part. Taking into account the disadvantages of disc and anchor coulters, we propose an improved sowing technology, in which the uniformity of the seed placement depth is increased by eliminating soil shedding from the walls to the bottom of the furrow, i.e. to the seedbed. In this case, a wedge-shaped disc is used as a furrow-forming tool.

A wedge-shaped disc consists of a cylindrical part with radius r_l and width b_l and a conical part with taper angle α , height h_k and width b_0 , i.e., the disc has the shape of an equilateral trapezoid in its periphery in radial section (Fig. 1).

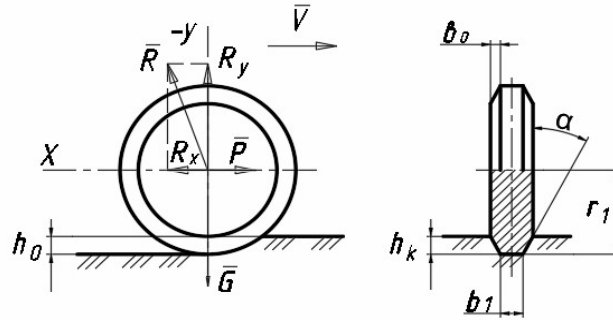


Fig. 1. Diagram of interaction between disc and soil

Rolling at a certain depth $h_0 \approx h_k$ under the influence of traction force P and deepening under the influence of vertical force G , the disc compresses the soil like a roller and forms a seed furrow with a depth h_0 . In the adopted xOy coordinate system, the disc is subjected to a reaction R from the soil (Fig. 2).

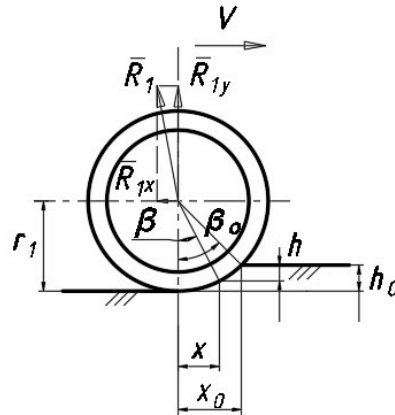


Fig. 2. Diagram of forces acting on the cylindrical part of the disc

The projections of R onto the coordinate axes Ox , Oy are as follows:

$$R_x = R_{1x} + 2R_{2x}, \quad (1)$$

$$R_y = R_{1y} + 2R_{2y}, \quad (2)$$

where R_{1x} , R_{1y} are the reaction components of the cylindrical part, R_{2x} , R_{2y} – of the conical part.

The expressions for determining the reactions R_{1x} , R_{1y} are known from the classical theory of calculation and design of tillage rollers of agricultural machines [7]:

$$R_{1x} = qh_0^2 b_l / 2, \quad (3)$$

$$R_{1y} = 2qb_l(2r_l)^{1/2} h_0^{3/2}/3, \quad (4)$$

where q is the coefficient of soil volume compression, H/m^3 .

R_{1y} is the vertical component of the soil response, which is approximately determined by solving the integral:

$$R_{1y} = \int_0^{x_0} qhb_1 dx. \quad (5)$$

Given that the angle between the force vectors R_{1y} and R_1 is quite small, for practical calculations, we can take $R_{1y} \approx R_1$, similarly to $R_{2y} \approx R_2$, with sufficient accuracy.

In addition to the normal reaction N , the conical part of the disc is also subjected to the friction force F_T (Fig. 3), so the total reaction R_2 will be equal:

$$R_2 = Ntg\varphi\cos\alpha + N\sin\alpha = N\sin(\alpha + \varphi)/\cos\varphi, \quad (6)$$

where φ is the angle of friction of the soil on the disc.

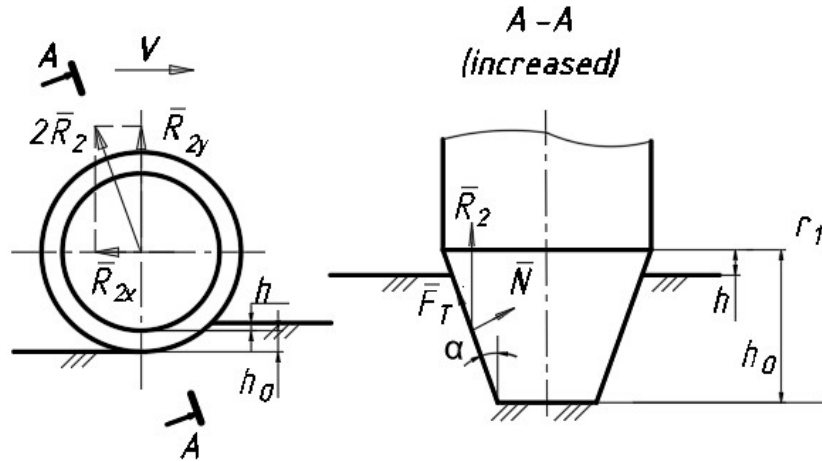


Fig. 3. Diagram of forces acting on the trapezoidal part of the disc

Let us represent the conical part of the disc by an infinitely large number of cylindrical discs of width db , each of which is subjected to the elementary normal reaction given above in (4). Then, in accordance with (4) and (5), the elementary reaction dR_2 acting on the element db of the conical part width:

$$dR_2 = 2qb(2r)^{1/2} h^{3/2} \sin(\alpha + \varphi)/3\cos\varphi, \quad (7)$$

where

$$h = b/tg\alpha; r = r_1 - h_0 + b/tg\alpha. \quad (8)$$

Let's integrate expression (7) and expression (9), which is derived from (3):

$$dR_{2x} = qh^2 db \sin(\alpha + \varphi) / 2 \cos \varphi, \quad (9)$$

get R_2 та R_{2x} .

Conclusions. As a result of the conducted research, initial data were obtained for the development of a model of the process of forming a seed furrow by a wedge-shaped disk in the form of soil reaction to working surfaces. Further research is associated with specific calculations of parameters depending on soil conditions and size and weight characteristics of seeds.

References

1. Malasli, M. & Çelik, A. (2023). Effects of the disc and tilt angle of a single disc – type furrow opener of a no-till seeder on residue distribution and the furrow profile. *Turkish Journal of Agriculture and Forestry*, Vol. 47: No. 6, Article 19. <https://doi.org/10.55730/1300-011X.3146>.
2. Yablonskyi, P., Rogovskii, I., Virchenko, G., Borek, K., Volokha, M. & Golova, O. (2025). Geometric modeling of disc furrow profile. *Journal of Engineering Sciences*, Vol. 12(1), E1–E8. [https://doi.org/10.21272/jes.2025.12\(1\).e1](https://doi.org/10.21272/jes.2025.12(1).e1).
3. Vanin, V., Volokha, M., Lazarchuk, M., Baskova, H. & Mikhlevska, N. (2024). Teoretychni doslidzhennya shchodo vdoskonalennya kombinovanoi sival'ky-kul'tyvatora dlya soyi. [Theoretical studies on improvement of the combined soybean seeder-cultivator]. *Prykladna heometriya ta inzhenerna hrafika*. Kyiv: KNUBA, 2024. Vyp. 105, 23–32. <https://doi.org/10.32347/0131-579x.2023.105.23-32>. [in Ukrainian]
4. Salo, V., Vovnianko, B., Leshchenko, S. & Luzan, P. (2024). Improvement of quality indicators of sowing process. *Agricultural Machines*, 50, 113–119. <https://doi.org/10.36910/acm.vi50.1398>
5. Parihar, D., Dogra, B. & Narang, M. (2023). Performance Evaluation of Different Furrow Openers for Sustainable Tillage: A Review. *Indian Journal of Ecology*, 50(4), 1133–1142. <https://doi.org/10.55362/IJE/2023/4025>
6. Zubko, V.M., Sirenko V.F. & Kuzina T.V. (2016). Analiz konstruktsii soshnykiv posivnykh mashyn. [Analysis of constructions coulter sowing machines]. *Engineering of nature management*, 1(5), 98–102. [in Ukrainian].
7. Letoshnev, M.N. (1955). *Agricultural machines: theory, calculation, design and testing*. M.: Gos. ed.-in the village of-x. lit.