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COMPUTER MODELLING OF BASIC DESIGN AND OPERATIONAL GEOMETRICAL PARAMETERS OF DOUBLE DISC COULTERS

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In this difficult time of war for Ukraine, the issue of increasing the efficiency of agricultural production is an urgent state and scientific applied problem. One of the ways to solve it is to further improve the various technical means used, in particular for tillage before sowing and for simultaneous sowing. At the current stage of development, disc tools are quite promising among them. Compared to shelf implements, their main advantage is significantly lower energy consumption in many agricultural processes. Also, disc implements help to maintain proper soil structure and better meet environmental requirements.

The purpose of this publication is to present the proposed mathematical apparatus aimed at ensuring an effective computer definition of rational variants of double-disc coulters. The latter is realised through the detailed presentation and analysis of analytical dependencies between the basic geometrical structural and operational parameters of these products. This applies to the diameters of the discs, their deviation from the vertical, angles of rotation in the horizontal plane, the position of the vanishing points, the depth of tillage and the nature of the resulting furrow profiles. The presented mathematical apparatus and illustrated relevant geometric modelling techniques not only improve the accuracy of various calculations, such as agricultural mechanics, but also allow further improvement of the quality and productivity of computer-aided design of the agricultural implements under consideration, in particular, by means of structural and parametric shaping. This is carried out on the basis of variant computer-aided design based on the above methodology. It was developed by the Scientific School of Applied Geometry of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" and tested in the domestic aviation industry. Extension of the accentuated approach to agricultural mechanisation will contribute to further improvement of both existing theoretical provisions and existing practice. In the author's opinion, the outlined topic is a promising area for conducting appropriate applied research.

Key words: *computer-aided design, agricultural tillage tools, disc coulters, geometric modelling, structural and parametric shaping.*

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Introduction. The current period of life in Ukraine is quite difficult in many aspects, including military, social, economic, etc. In the latter case, the most pressing problem at the state level is to preserve and increase the efficiency of existing production. Under current conditions, agriculture plays a leading role in this regard. Therefore, the task of improving the technical and other means used in it is particularly relevant. Some of the priority areas are presented in the publication (Khudaverdiieva, 2022) regarding the cultivation of grain crops. It is emphasised that the growth of gross harvest should be carried out not only by increasing the area under crops, but also by improving the relevant material and technical base, introducing advanced resource-saving technologies and improving economic conditions. (Kravchenko, 2020) provides mechanisms for implementing innovations in agriculture, emphasising the importance of agricultural science for this purpose. The authors of (Rud et al., 2024) define precision agriculture as a modern innovation system. (Rudenko, 2019) analyses the multifactorial impact of computer technologies in the agricultural sector. The above aspects are also presented in (Abbasi et al., 2022).

One of the most promising areas for technical improvement is the further development of tillage tools, in particular disc tools. The latter, for example, are characterised by lower energy consumption compared to shelf tools for a large number of agricultural processes. Discs contribute to the preservation of soil structure and better meet environmental requirements. (Teslyuk et al., 2016) presents the results of theoretical and practical research on tillage disc units. The article (Parihar et al., 2023) reviews various coulters to compare their energy consumption, furrow profile formation, seed placement accuracy, sowing performance, etc. Zubko et al. (2016) concluded that the rational choice of a coulter depends on the characteristics of a particular soil and climatic zone. Researchers (Ahmad et al., 2020) study the application of the discrete element method to model the behaviour of disc coulters of different designs in rice fields. (Karayel et al., 2024) analyse the effect of the configuration of these tools on the productivity of corn sowing without tillage immediately after wheat harvesting with uneven soil coverage with plant residues. In Khosravani et al. (2023), the forces acting on the seeder depending on the angles of the discs are predicted by analytical means and the discrete element method. The authors (Kumar et al., 2021; Ranta et al., 2021; Malasli & Çelik, 2023) investigate the effect of the working speed of disc coulters on soil destruction and cutting of plant residues when using a no-till system. Zeng et al. (2021) and Xu et al. (2023) show that the geometry of discs is essential for ensuring high productivity of tillage technologies. The article (Sun et al., 2020) presents mechanisms for reducing the traction resistance of coulters by reproducing mechanical and biochemical tillage processes using the finite element method. The publication (Vanin et al., 2019) is devoted to the classification of tillage tool discs based on the methodology of structural and parametric shaping and their automated geometric modelling. The basic principles of this approach are presented in the monograph (Vanin et al., 2022). The publication (Yablonskyi et al., 2022) provides a generalised description of tools for computer-aided shaping of modern agricultural tillage tools.

The issues of designing double-disc coulters are analysed in the literature (Ahmad et al., 2015; Wang et al., 2020; Li et al., 2023; Sugirbay et al., 2023; Ye et al., 2023; Chen et al., 2024; Rosu et al., 2024; Tukhtakuziev et al., 2024) and are considered further in the presentation of the relevant material. The main purpose of this publication is to present the proposed mathematical tools for computer modelling of the basic structural and operational geometrical parameters of double disc coulters. These tools serve as one of the foundations for further effective computer-aided design, comprehensive structural and parametric optimisation of these agricultural tillage tools.

Materials and methods of research. The purpose of the coulter is to form a furrow of the required profile in the surface soil layer, to apply seeds and fertilisers evenly along it and to sprinkle them with soil of a fine lumpy composition. Agrotechnical requirements do not allow mixing with the lower soil layers in order to preserve moisture. At the same time, the field surface should be levelled as much as possible and the bottom of the furrow should be compacted.

Today, for sowing seeds of most industrial crops (cereals, legumes, vegetables), two- and single-disc coulters are most often used. The advantage of the former, despite their certain technical complexity, is their suitability for use on soils of various types and structures.

From the point of view of forming the furrow profile, the main conceptual components of the double disc coulter design (Fig. 1) are the riser (body) 1, axle 2, and flat discs 3. It should be noted that such components as seed conduits, flanges, cleaners, wrappers, etc. are not considered in the aspect under study. This also applies to additional structural means that eliminate the ridge formed by the discs along the row axis, as well as the issue of soil shedding from the furrow walls. These tasks may be the subject of further scientific research.

The left image (Fig. 1) is a view in the direction of the coulter's working movement, and the right image corresponds to the axonometric projection. The discs are installed symmetrically relative to the longitudinal vertical plane of the tool, forming an angle β of deviation from the vertical at first, and then rotated by an angle α in the horizontal plane. During their operation, they rotate, cut the soil, spread and compact it, forming a furrow. Its profile depends on the diameter *D* of the discs, the required processing depth *a*, the angles β and α, which determine the position of the vanishing point, which corresponds to the minimum distance between the discs. Depending on the size of these angles, a distinction is made between conventional and narrow row coulters. In the latter case, two closely spaced furrows are created.

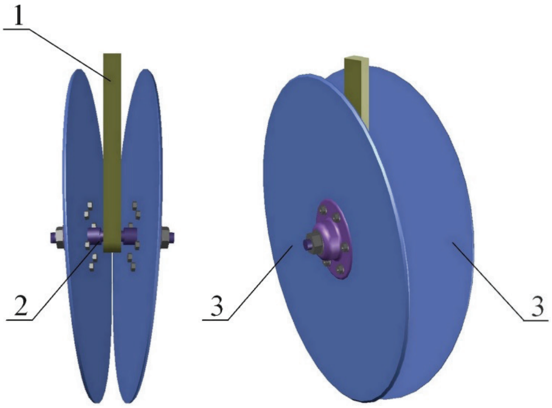


Fig. 1. The main conceptual design components of a double disc coulter: 1 – riser (body); 2 – axle; 3 – disc with hub and rolling element

The purpose of the publication is to define the analytical dependencies between the above structural and operational parameters. This mathematical apparatus was also generalised by using an additional value in the form of the angle γ of rotation of the given implement around the axis perpendicular to the plane of its symmetry. On the basis of the proposed approach, a conceptual design of an improved adjustable double-disc coulter was developed.

Results. Let us use the Cartesian coordinate system *Oxyz* (Fig. 2), the *x*-axis of which is opposite to the direction of movement of the coulter, the *Oxy* plane is horizontal, and the *z*-axis is vertical. The equation of a circle of diameter *D* located in the *Oxz* plane with a centre at point *O* and a shaping parameter in the form of an angle *u*, which is counted counterclockwise from the *x*-axis, is

$$x = \frac{D}{2}\cos(u), \quad y = 0, \quad z = -\frac{D}{2}\sin(u), \tag{1}$$

where $u \in [0^0, 360^0]$.

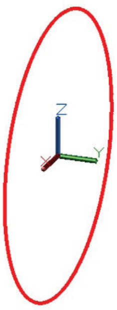


Fig. 2. The outer circle of the disc, positioned vertically along the direction of travel of the coulter

Rotate the circle that represents the disc around the *x*-axis by an angle of β counterclockwise (Fig. 3).

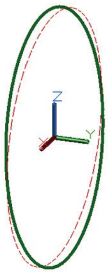


Fig. 3. Disc rotated around the *x*-axis

In this case, the dashed line shows the initial position of the object. Based on expressions (1) using transformation matrices in homogeneous coordinates

$$[x \quad y \quad z \quad 1]\cdot\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & \cos\beta & \sin\beta & 0\\ 0 & -\sin\beta & \cos\beta & 0\\ 0 & 0 & 0 & 1\end{bmatrix}=$$

$$=[x \quad y\cos\beta - z\sin\beta \quad y\sin\beta + z\cos\beta \quad 1],$$

we obtain the equation of the new circle

$$x=\frac{D}{2}\cos(u),\quad y=\frac{D}{2}\sin\beta\sin(u),\quad z=-\frac{D}{2}\cos\beta\sin(u), \tag{2}$$

where $u\in[0^0, 360^0]$.

Next, rotate it by an angle of α clockwise around the *z*-axis (Fig. 4), where the view along the coulter movement is shown and the previous disc positions are shown with thin lines.

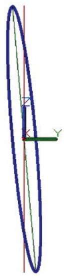


Fig. 4. Disc additionally rotated around the *z*-axis

The analytical description of the constructed figure is determined on the basis of the relations (2) and the corresponding coordinate transformation matrices

$$[x \quad y \quad z \quad 1]\cdot\begin{bmatrix}\cos\alpha & -\sin\alpha & 0 & 0\\ \sin\alpha & \cos\alpha & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}=$$

$$=[x\cos\alpha + y\sin\alpha \quad -x\sin\alpha + y\cos\alpha \quad z \quad 1],$$

As a result, for the first disc we have

$$x=\frac{D}{2}(\cos\alpha\cos(u)+\sin\alpha\sin\beta\sin(u)),$$

$$y=\frac{D}{2}(\cos\alpha\sin\beta\sin(u)-\sin\alpha\cos(u)),$$

$$z=-\frac{D}{2}\cos\beta\sin(u), \tag{3}$$

where $u\in[0^0, 360^0]$.

The point *S* of disc convergence is illustrated in Fig. 5.

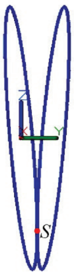


Fig. 5. Point *S* of disc convergence

Its analytical definition is carried out using the ordinate of expression (3), i.e.

$$y'(u)=\frac{D}{2}(\sin\alpha\sin(u)+\cos\alpha\sin\beta\cos(u))=0. \tag{4}$$

From equation (4) it follows

$$\operatorname{tg}(u)=-\operatorname{ctg}\alpha\sin\beta, \tag{5}$$

where

$$\alpha\in(0^0,\ 90^0),\quad \beta\in(0^0,\ 90^0). \tag{6}$$

Dependencies (5) and (6) allow us to determine the required parameter u_S of the point *S* of disc convergence. For the gaps in (6), the value of (5) is negative. Since *S* is located in the front lower part of the disc, and the arctangent function has a set of values (-90⁰, 90⁰), then

$$u_S=\operatorname{arctg}(-\operatorname{ctg}\alpha\sin\beta)+180^0. \tag{7}$$

Based on the calculated u_S and formulas (3), we calculate the coordinates of the point of convergence of the discs

$$S=(x_S,\ y_S, z_S). \tag{8}$$

The influence of the angles α and β on the height of the ridge in the middle of the furrow can be estimated (Fig. 6) using the surface graph (7). As can be seen, with an increase in α , its upper point (u_S) increases, and with an increase in β, it decreases.

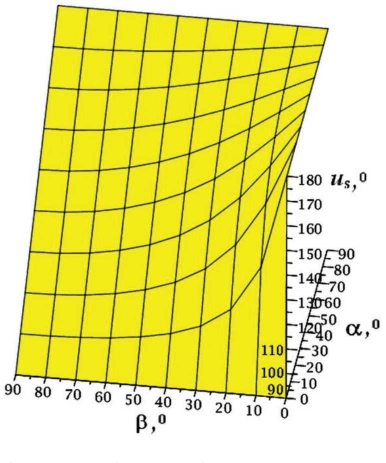


Fig. 6. Influence of α and β angles on the crest height

The equation of the circle of the second disc is obtained by applying the coordinate transformation matrices

$$[x \quad y \quad z \quad 1]\cdot\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ -x_S & -y_S & -z_S & 1\end{bmatrix}\cdot$$

$$\cdot\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & -1 & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 1 & 1\end{bmatrix}\cdot\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ x_S & y_S & z_S & 1\end{bmatrix}=$$

$$=[x \quad 2y_s \; -y \quad z \quad 1],$$

ordinates (8) and dependencies (3).

Then for the second disc

$$x=\frac{D}{2}(\cos\alpha\cos(u)+\sin\alpha\sin\beta\sin(u)),$$

$$y=\ 2y_S+\frac{D}{2}(\sin\alpha\cos(u)-\cos\alpha\sin\beta\sin(u)),$$

$$z=-\ \frac{D}{2}\cos\beta\sin(u), \tag{9}$$

where $u \in [0^0, 360^0]$.

Note that the above coordinate transformation result can also be obtained using the relation

$$y_s\ =\frac{y_1+y_2}{2},$$

where y_1 and y_2 are the ordinates of the points of the first and second discs.

According to expressions (3) and (9), the lowest points of the discs correspond to the parameter u=90^0. The distance between them (Fig. 7)

$$b_н=2y_S+\frac{D}{2}(\sin\alpha\cos(90^0)-\cos\alpha\sin\beta\sin(90^0))-$$

$$-\frac{D}{2}(\cos\alpha\sin\beta\sin(90^0)-\sin\alpha\cos(90^0))=$$

$$=\ \ 2y_S-D\cos\alpha\sin\beta. \tag{10}$$

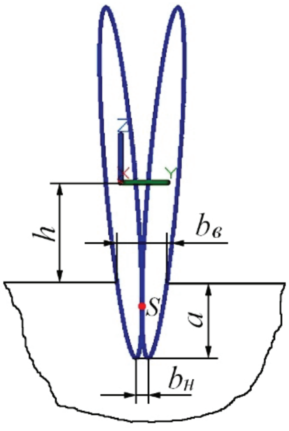


Fig. 7. Dependence of the furrow profile on the depth *a* of tillage

The width of the upper part $b_в$ of the furrow is influenced by the depth a of tillage, its sum with the distance h to the ground, based on the figure and the calculations performed, is equal to

$$a+h=\ \frac{D}{2}\cos\beta. \tag{11}$$

Using the application of formulas (3) and (9) from relation (11), we have

$$h=\frac{D}{2}\cos\beta-a=\ \frac{D}{2}\cos\beta\sin(u_в), \tag{12}$$

where $u_в$ is the parameter corresponding to the starting points of the disc circles at height *h*.

Based on dependence (12), we obtain

$$u_в=\arcsin(1-\frac{2a}{D\cos\beta}). \tag{13}$$

The maximum working depth of the disc is approximately two-thirds of its radius, i.e.

$$a_{\max}=\frac{D}{2}\cdot\frac{2}{3}\cdot\cos\beta=\frac{D}{3}\cos\beta. \tag{14}$$

Based on relations (13) and (14)

$$u_{\min}=\arcsin(1-\frac{2a_{\max}}{D\cos\beta})=$$

$$=\arcsin(1-\frac{2D\cos\beta}{3D\cos\beta})=\arcsin(\frac{1}{3})\approx 19.5^0;$$

$$u_{\max}=180^0-u_{\min}=180^0-19.5^0=160.5^0; \tag{15}$$

where $u_{\min}$, $u_{\max}$ are the minimum and maximum values of the parameter of the arc of the disc circle that forms the furrow profile.

So, in this case

$$u\in[u_{\min},\ u_{\max}]=[19.5^0;\ 160.5^0]\ . \tag{16}$$

By analogy, for a particular such arc

$$u\in[u_в,\ 180^0-u_в]\ . \tag{17}$$

Note that in expression (17)

$$u_в<90^0. \tag{18}$$

The value $b_в$ of the width of the upper part of the furrow is calculated as

$$b_в=2y_S+\frac{D}{2}(\sin\alpha\cos(u_в)-\cos\alpha\sin\beta\sin(u_в))-$$

$$-\frac{D}{2}(\cos\alpha\sin\beta\sin(u_в)-\sin\alpha\cos(u_в))=$$

$$=\ \ 2y_S+D(\sin\alpha\cos(u_в)-\cos\alpha\sin\beta\sin(u_в)). \tag{19}$$

Thus, the relations (1) ... (19) for the considered double-disc coulters analytically describe their basic structural and operational geometric parameters and are further used for proper automated design.

In the *Oxyz* coordinate system (Fig. 2), the coulter moves along the *x*-axis. The placement of these tools along the *y*-axis provides the required row spacing, and along the *z*-axis the required tillage depth. In addition to the analysed angles β and α, respectively, the rotation of the discs around the *x* and *z* axis, the resulting furrow profile is also affected by a possible rotation around the *y*-axis by an angle of γ. In order to generalise the above mathematical apparatus, this issue is considered further.

Let the position of the specified centre *C* of the rotation be determined by the coordinates

$$C = (x_C,\ y_S, z_C). \tag{20}$$

The definition of the equations of the circle of the first disc is based on the transformation matrices

$$[x\ \ y\ \ z\ \ 1]\cdot\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -x_C & -y_S & -z_C & 1 \end{bmatrix}\cdot$$

$$\cdot\begin{bmatrix} \cos\gamma & 0 & -\sin\gamma & 0 \\ 0 & 1 & 0 & 0 \\ \sin\gamma & 0 & \cos\gamma & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}\cdot\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ x_C & y_S & z_C & 1 \end{bmatrix} =$$

$$= [(x - x_c)\cos\gamma + (z - z_c)\sin\gamma +$$

$$+ x_c \quad y \quad (x_c - x)\sin\gamma + (z - z_c)\cos\gamma + z_c \quad 1],$$

values (20) and dependencies (3).

As a result, for the first disc

$$x = \frac{D}{2}(\cos\alpha\cos(u) + \sin\alpha\sin\beta\sin(u))\cos\gamma + (1 - \cos\gamma)\, x_c -$$

$$-(\frac{D}{2}\cos\beta\sin(u) + z_C)\sin\gamma,$$

$$y = \frac{D}{2}(\cos\alpha\sin\beta\sin(u) - \sin\alpha\cos(u)),$$

$$z = (x_c - \frac{D}{2}(\cos\alpha\cos(u) + \sin\alpha\sin\beta\sin(u)))\sin\gamma + (1 - \cos\gamma)z_c -$$

$$- \frac{D}{2}\cos\beta\cos\gamma\sin(u), \tag{21}$$

where $u \in [0^0,\ 360^0]$.

As with expressions (3) and (9), which differ only in their ordinates due to the symmetry of the discs, a similar situation is also found in the case of (21). Therefore, in the circle of the second disc, the abscissa and apposites correspond to the last formulas given, and the ordinates correspond to the relation (9). Note that in dependencies (21), the value of the angle γ can be either positive or negative. Its specific range is determined by the existing conditions.

Thus, we have outlined the basic theoretical provisions of the proposed approach to the use of an additional control value for the structural and operational parameters of a double-disc coulter in the form of the angle of rotation of this tool around its transverse horizontal axis. The next part of the article is devoted to illustrations of the practical implementation of the developed methodology and its comparison with the results of other studies.

Discussion. Let us consider some aspects of the use of the above mathematical apparatus. For computer-aided design, one of the most important aspects is the ability of geometric models to effectively create various variants of the designed technical objects. In many cases, the basis for this is the appropriate flexible analytical dependencies. Let's show this using specific examples from our case.

Suppose that the following sets of parameters of double disc coulters are to be analysed:

$$D = (300\text{ mm},\ 350\text{ mm},\ 400\text{ mm}),$$

$$\alpha = (5^0, 8^0,\ 12^0),\quad \beta = (0^0,\ 5^0, 10^0,\ 15^0,\ 20^0,\ 25^0),$$

$$\gamma = (-30^0, -15^0,\ -5^0, 0^0,\ 5^0),$$

$$x_C = (-20\text{ mm},\ -10\text{ mm},\ 0\text{ mm}),$$

$$z_C = (110\text{ mm},\ 130\text{ mm},\ 150\text{ mm}), \tag{22}$$

which achieve their maximum working depth.

Without the means of automated processing of the elements of tuples (22), the productive generation of rational varieties of the given tillage tools is very problematic. In the above case, according to the basic rule of combinatorics, the number of possible variants can reach

$$N = 3\cdot3\cdot6\cdot5\cdot3\cdot3 = 2430.$$

A certain way out of this situation is the methodology of structural-parametric forming mentioned at the end of the first part of the article. However, for its successful application, analytical expressions similar to those proposed in this publication describing the relevant subject area are required. After the general comments, let's move on to the direct illustrations, which will be performed on the example of furrow profile formation. Its shape and dimensions largely determine the nature of many operational parameters of the studied agrotechnical processes and are closely related to the chosen design of disc tillage tools.

Let us first consider a conventional coulter, the theoretical furrow profile of which is calculated by the ordinates and appliers of dependencies (3) and (9). At the same time, we take into account the value u_S of relations (7), $u_{\min}$ and $u_{\max}$ of formulas (15). As a result, we have

$$u \in [19.5^0;\ \min(u_S,\ 160.5^0)]. \tag{23}$$

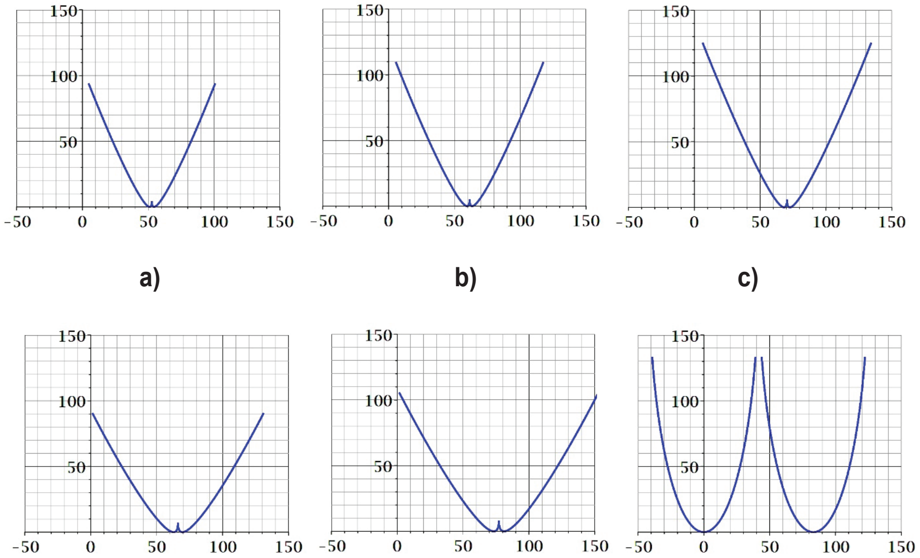
To make the graphs clearer, let's move the *Oxy* plane to the level of the furrow bottom. Then the applications will be equal to

$$z = -\frac{D}{2}\cos\beta\sin(u) + \frac{D}{2}\cos\beta = \frac{D}{2}\cos\beta(1 - \sin(u)). \tag{24}$$

Some constructed profiles, taking into account expressions (23) and (24), are shown in Fig. 8, where the graphs are given in mm.

These images allow us to visually assess the influence of the design parameters of double disc coulters on their performance characteristics in the form of furrow profiles. Note that Fig. 8f corresponds to the case of narrow-row sowing.

Comparing the obtained scientific results with the information from other studies, we emphasise the following points. Practical experiments (Ahmad et al., 2015; Rosu et al., 2024) confirm the furrow shape defined theoretically in this paper. This also applies (Chen et al., 2024) to the proper computations by the discrete element method. The publication (Sugirbay et al., 2023) uses a similar basic design of a double-disc coulter to the one considered in this paper. (Tukhtakuziev et al., 2024) uses a similar calculation scheme, but a different mathematical apparatus. The paper (Wang et al., 2020) analyses the impact of an additional furrow compaction device. The article (Ye et al.,



a) b) c)

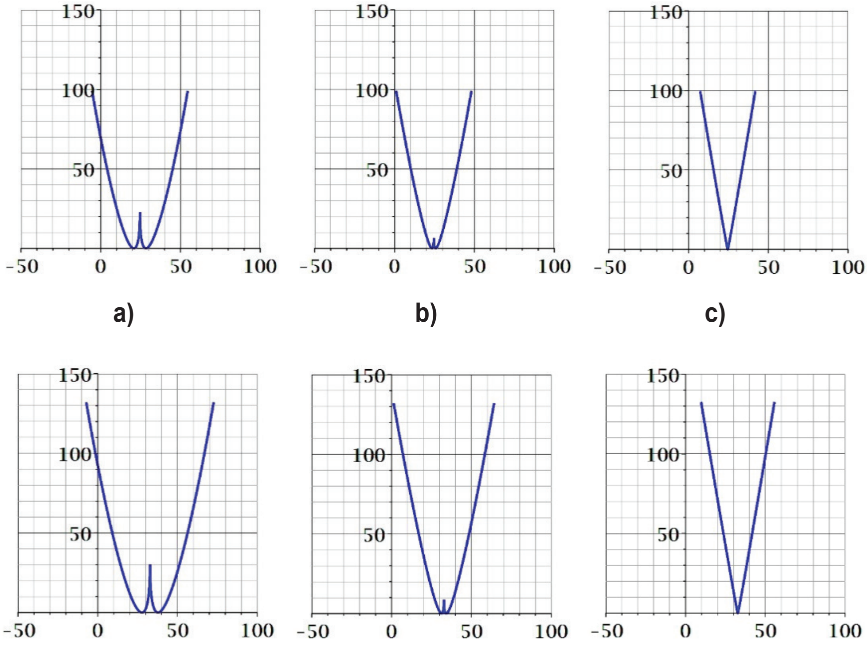
d) e) f)

Fig. 8. Profiles of the maximum furrow:
a – D=300 mm, $\alpha=5^0$, $\beta=20^0$; b – D=350 mm, $\alpha=5^0$, $\beta=20^0$; c – D=400 mm, $\alpha=5^0$, $\beta=20^0$; d – D = 300 mm, $\alpha=8^0$, $\beta=25^0$;
e – D=350 mm, $\alpha=8^0$, $\beta=25^0$; f – D=400 mm, $\alpha=12^0$, $\beta=0^0$

2023) is devoted to the study of a fluted double-disc coulter. In this case, the results obtained by the discrete element method regarding the furrow geometry coincide with the results obtained in this paper with a certain accuracy.

The variation of the angle γ is illustrated in Fig. 9, where the graphs are given in mm. It can be seen that with proper control, the desired reduction of the ridge at the bottom of the furrow is achieved. It also generates a slightly different shape and size of the furrow.

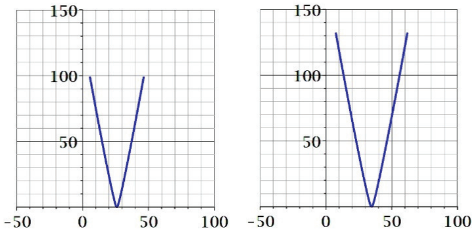
If necessary, for example, increase the furrow width shown in Fig. 9c and Fig. 9f, this can be done by increasing the angle α (Fig. 10).



a) b) c)

d) e) f)

Fig. 9. Effect of angle γ on the furrow profile of a double disc coulter with $\alpha=5^0$, $\beta=8^0$, x_c=0 mm, z_c=110 mm:
a – D=300 mm, $\gamma=0^0$; b – D=300 mm, $\gamma=-15^0$; c – D=300 mm, $\gamma=-30^0$;
d – D=400 mm, $\gamma=0^0$; e – D=400 mm, $\gamma=-15^0$; f – D=400 mm, $\gamma=-30^0$



a) b)

Fig. 10. Furrow width control by application $\alpha=6^0$, $\beta=8^0$, $x_c=0$ mm, $z_c=110$ mm, $\gamma=-30^0$: a – $D=300$ mm; b – $D=400$ mm

The following image (Fig. 11) shows the technical implementation of the above improvement. Compared to Fig. 1, an additional adjustment bracket is used to provide the necessary discrete fixation of the discs by rotating them to the desired angle γ around the specified axis.

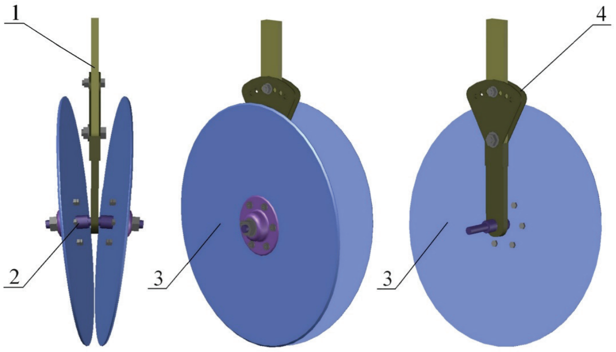


Fig. 11. Improved conceptual design of the double disc coulter: 1 – riser (body); 2 – axle; 3 – disc with hub and rolling element; 4 – adjustment bracket

Thus, a mathematical apparatus has been developed that combines the basic structural and operational geometric parameters of double-disc coulters. On its basis, a new conceptual design of this tillage tool was created, which improves the quality of seed placement in the soil, thereby increasing its field germination.

Conclusions. The main results of the study are the development of a new mathematical apparatus for computer geometric modelling of the basic structural and operational parameters of double-disc coulters. On the basis of this, an improved design of this tillage tool is proposed, which is able to flexibly adapt to the changing agrotechnical conditions of its application. The prospects of this research in theoretical terms include the areas of direct combination with the methodology of structural and parametric shaping, implementation in the environment of specific computer-aided design systems, such as Autodesk Inventor, Solidworks, Catia, etc. This will allow for effective variant computer-aided design of these technical objects for the purpose of their comprehensive optimisation. In terms of practical aspects, it is important to conduct proper field experiments to clarify certain parameters and characteristics of the prototypes of the analysed weapons. As a result, all of this can serve as a justification for the industrial production of the considered double-disc coulters.

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Комп'ютерне моделювання базових конструкційно-експлуатаційних геометричних параметрів дводискових сошників

У нинішній складний воєнний час для України питання підвищення ефективності сільськогосподарського виробництва становить актуальну державну та наукову прикладну проблему. Один із шляхів її вирішення полягає *в подальшому вдосконаленні різноманітних застосовуваних технічних засобів, зокрема для обробітку ґрунту перед посівом та за умови одночасної сівби. На теперішньому етапі розвитку серед них доволі перспективні дискові знаряддя. У порівнянні з полицевими їхньою головною перевагою є суттєво менші енергетичні витрати при виконанні багатьох агротехнічних процесів. Також дискові робочі органи сприяють збереженню належної структури ґрунту, краще відповідають екологічним вимогам.*

Мета даної публікації полягає у викладенні запропонованого математичного апарату, який спрямований на забезпечення ефективної комп'ютерної дефініції раціональних варіантів дводискових сошників. Останнє реалізується завдяки докладно поданим і проаналізованим аналітичним залежностям між базовими геометричними конструкційно-експлуатаційними параметрами зазначених виробів. Це стосується діаметрів дисків, їхнього відхилення від вертикалі, кутів повороту в горизонтальній площині, положення точок сходження, глибини обробітку ґрунту та характеру отримуваних при цьому профілів борозни. Наведений математичний апарат і проілюстровані відповідні прийоми геометричного моделювання сприяють не тільки підвищенню точності різноманітних розрахунків, наприклад, землеробської механіки, а й дозволяють надалі покращувати якість та продуктивність автоматизованого проєктування розглянутих сільськогосподарських знарядь, зокрема, засобами структурно-параметричного формоутворення. Це здійснюється на основі варіантного комп'ютерного конструювання, що спирається на вказану методологію. Її напрацьовано науковою школою прикладної геометрії Національного технічного університету України «Київський політехнічний інститут імені Ігоря Сікорського» й апробовано у вітчизняній авіаційній галузі. Поширення акцентованого підходу на засоби механізації сільськогосподарського виробництва сприятиме подальшому вдосконаленню як існуючих теоретичних положень, так і наявної практики. Окреслена тематика становить, на думку автора, відповідний перспективний напрямок проведення належних прикладних наукових досліджень.

Ключові слова: *автоматизоване проєктування, сільськогосподарські ґрунтообробні знаряддя, дискові сошники, геометричне моделювання, структурно-параметричне формоутворення.*