Computer modeling the moldboards’ surface in autocad system

T Juraev [10080-0082-0361-0299]

1Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan
tojiddin_1968@mail.ru

Abstract. There are considered the tasks of the computer modeling of moldboard’s working surface in the article. The proposed solution was developed by geometric and computer modeling of moldboard’s working surface elements. As surface elements were chosen the frontal contour, a directory curve, and the generative lines with their pre-set conditions, which were given by specialists. The geometric models of working surface elements, which were developed based on research results were implemented in the AutoCAD system. The researches were carried out using the constructive geometric modeling methods and systems and based to surface modeling methods of Descriptive Geometry and traditional methodology of designing the moldboards. The proposed models, algorithms, and methodology can reduce the design period, simplify the geometric parameters setting, and facilitate the work of designers. The solution is required in educational, research, and production processes in Agriculture Engineering and can be used in developing other technical objects with geometrically complex surfaces.

1. Introduction
In contemporary conditions, it is important to conduct engineering design based on information and communication technologies using geometric modeling methods and systems. It is especially demanded in the designing process of complexity technical surfaces, such as moldboards. Moldboards are one of the most common and very geometrically complex working organs of agricultural machines. Therefore, their geometric complexity requires the development of a geometric model and an algorithm for its implementation in computer-aided design systems, which is an urgent task for specialists. Many research and development projects have been proposed for the development of moldboards, and a number of models and methods have been developed. In particular, they are considered fundamentally by V.P.Goryachkin, L.V.Gachev, G.N.Sineokov, I.M.Panov, and others [1-4]. In Uzbekistan, the issue was partially handled by R.I.Baymetov, A.T.Tuhtaquziev, F.M.Mamatov [5]. In these works, traditionally, problems were solved on the basis of analytical and experimental methods. However, the analysis of the essential parameters of working surfaces shows that many of these problems in nature are geometrically, and the use of geometric modeling methods in solving these problems gives effective results. Thanks to the work of geometric scientists S.M.Kolotov, N.F.Chetverukhin, V.E.Mikhailenko, S.A.Frolov, K.I.Valkov, V.S.Obukhova, D.V.Voloshinov, D.F.Kuchkarova, Sh.K.Muradov, and others have been developed geometric models, algorithms, and methods for various areas of engineering research. However, these developments are almost not used in the research of working surfaces. If we consider that such developments are necessary for the application of computer-aided design, then the importance of this issue will become even more clear.
The use of modern synthetic methods makes it much easier to solve these problems, its simplicity, accessibility, and significantly reduces the time, labor, and material costs for their solution, which is confirmed by the wide use of these methods [6-16]. The analysis carried out in subordinate design and research institutions, as well as at agricultural machinery enterprises in Uzbekistan, which are directly related to this problem, shows that the issues of developing moldboards based on computer modeling, taking into account the conditions of modern production, have not been sufficiently studied. The purpose of the study is to develop a computer modeling methodology for the development of moldboard type working organs by the geometric modeling method [17-21].

2. Materials and methods

2.1. Modeling moldboard’s working surface geometric elements in AutoCAD

Determining a frontal contour of the moldboard’s working surface. One of the modeling stage the moldboard’s working surface is determining its frontal contour, by constructing a wrapping diagram of soil layer along a cross-section of the furrow [1-4]. According to the traditional designing method of the moldboard’s surface, the frontal contour was used to constructing projections of the plow body. However, it also used for three-dimensional computer modeling of the moldboard’s working surface. The simplicity, accessibility, and visibility of this diagram, which can be geometrically modeled, makes it possible to easily and quickly solve this problem using the AutoCAD system [17-21]. From the diagram, it is evident that: depth of plugging - a and width of the plough’s body - b are the main input modeling parameters as pre-set conditions; the angle of the rolled away soil layer to the horizon - δ, the height of the plowed ridges - h and moving soil layer to the plowed field – l, at the steady-state position of the soil layer, are the main output modeling parameters (Figure 1).

Creating a directory curve’s dynamic block of the moldboard’s working surface. As it knows, in the AutoCAD system, we can create dynamic blocks of 2D models that allow me to automatization the process of optimizing geometric parameters. Let's consider creating a dynamic block "Flat directory curve", in which we can set the conics according to pre-set conditions of the working surface’s directory curve, with the necessary curvature, which affects the technological parameters of the working surface (Figure 2). In this block, the pre-set conditions are the parameters of size dependencies, and the optimized ones are user parameters.

![Figure 1. Determining the frontal contour by constructing a wrapping diagram](image-url)
Figure 2. Creating the dynamic block of directory curve

Giving the generative lines’ positions of moldboard’s working surface. Another modeling stage of moldboard’s working surface is setting the positions of its generative lines. As it’s known, the most suitable for the moldboard’s working surface are linear surfaces [1-4]. In this case, the position of the generative lines are determined not only a type of the linear surface but also the moldboard’s working surface. Setting the positions that make up the AutoCAD system is much more convenient. For a cylindrical surface, it is sufficient to set the position of one initial generative line $l_0$ at the angle $\gamma_0$ (Figure 3a), and for the conic surface, we should also add a second final generative line (Figure 3b). For combined surfaces which consist of pieces of various linear surfaces, the positions of generative lines are setting separately for each component. In this case, the final generative line of the previous component is also the initial generative line of the next component, since they are linear surfaces. For example, for the moldboard’s surface with a combination of cylindrical and conic pieces, we set the generative line $l_i$ at the height $z_i$ and the angle $\gamma_i$, which is common to them, that are the pre-set conditions (Figure 3c).

Figure 3. Giving the generative lines in various surfaces
2.2. Flowcharting usage of the moldboard’s working surface elements.
In contrast traditional designing process, where the moldboard’s working surface elements have a single application character, the computer models of moldboard’s working surface elements become multiuser. But proposed computer models required developing user geometric algorithms which flowcharting (Figure 4), which can later be used to automatization the process of optimizing the geometric parameters of the moldboard’s working surface. The optimization process is accompanied visually and graphical display of the entered values.

![Figure 4. Algorithm for multiuse moldboard’s working surface element models](image)

3. Results and discussion
3.1. Setting-up the moldboard’s working surface elements
Setting-up the moldboard’s working surface elements required the location of computer models as block-objects. From technological reasons of manufacturing and working process, linear surfaces are mainly chosen as the working surface of the moldboard. Therefore, the whole modeling of the moldboard’s working surface in the AutoCAD system, we must place the line segments as generative lines, in the "Directory curve" block. Based on the traditional methodology, we should set a minimum of three characteristic generative lines: lower, intermediate, and upper generative lines parallel to the furrow bottom, at different heights, and different inclination angles to the furrow wall. They are the “Generative lines” block. The lower generative line \((z_0, \gamma_0)\) is located on the point A of directory curve and perpendicular to the directory curve’s plane, the intermediate generative line in a characteristic height \((z_{\text{min}}=m, \gamma_{\text{min}})\), and the upper generative line on the upper edge of moldboard \((H=z_{\text{max}}, \gamma_{\text{max}})\). We should take the length of the generative lines more than it is necessary to obtain the moldboard’s working surface blade. We have to set-up a “frontal contour” block perpendicular to the furrow bottom and furrow wall (Figure 5).

![Figure 5. Setting up working surface elements as block-objects](image)
3.2. Computer modeling the moldboard’s surface

Modeling a geometric surface. The 3D computer modeling of moldboard’s working surface is different than traditional methodology. First go to the mode “Modeling a surface” with the command “Modeling a surface by sections”, further sequentially select the generative lines as sections. As it knows, the system modeling’s a surface by setting intermediate generative lines in average values. Therefore, increasing the number of setting generative lines and clarifying the $\gamma$ and $z$ parameters’ changing rule determine the smoothness, curvature, and torsion of the surface, which is one of the ways to optimize the parameters of the moldboard’s working surface. During of modeling process, the AutoCAD system defines the surface as a "Piecewise linear surface" or "Smooth surface". If we set the minimum number of generative lines (three), it is recommended to select the mode "Smooth surface". When the working surface crossing with planes parallel to the furrow bottom (the plane of parallelism) in the section we can’t get the straight lines, they will be curves, but close rather in length to the assumed generative lines. This explains that the system modeling’s a smooth surface close to a linear surface, and increasing the setting number of generative lines by the refined parameters $\gamma$ and $h$, within the limits of $z_0-z_{\text{min}}$ and $z_{\text{min}}-z_{\text{max}}$, determines the correspondence of the obtained surface to the required. The results of virtual experiments show that the modeling of a surface by several generative lines by "Smooth surface" mode is the most acceptable (Figure 6a).

Modeling the moldboard’s surface from the modeled geometric surface. To do it, use the command "Extrude" to create a solid from block "Frontal contour". Extrusion the contour in the necessary amount, transform the solid into a surface. Using the command “Section” in the submenu "3D operations" of the main menu "Edit", make the intersection of the working surface with the obtained surface by extrusion. In this case, the submenu "Surface" is selected as the cutting element. After crossing the operation, leaving only the moldboard’s surface, removing unnecessary parts (Figure 6b).

![Figure 6. Modeling the geometric surface (a), obtaining moldboard’s surface (b)](image)

Influence of the frontal contour position to forming moldboard’s working surface. To get the moldboard’s surface, cross the working surface with moldboard’s frontal contour. The position of frontal contour relative to the working surface plays an important role in the formation of the moldboard’s surface. Therefore, we have to set frontal contour relatively according to the pre-set conditions of the working surface (Figure 7a). However, changing its position in the $XZ$ plane, within the acceptable range, taking into account directory curve parameters, allows optimizing the parameters of the moldboard’s working surface. By placing the frontal contour in different positions, and taking the directory curve as the base element, we can get different moldboard’s working surfaces from the obtained geometric surface (Figure 7b).
3.3. Approximately sweeping the moldboard’s surface pattern

Obtaining template lines of moldboard’s surface. As it knows, for the production of the moldboard, we need to prepare a stamping form of press machine. And to control the conformity of the stamping form with a designed work surface and to control the quality of the manufactured moldboards, it is necessary to prepare batteries consisting of templates. Therefore, obtaining template lines of the working surface is one of the main stages of the design process of moldboards. But getting these lines in traditional design requires sufficient time, labor, and skill from designers. And with computer modeling, this task can be much easier, which requires the development of the necessary methodology. The analysis of works devoted to this problem shows that the traditional method of obtaining template lines based on graphical and analytical methods for solving problems, which has a sufficient theoretical base and a well-developed methodology, is also applicable in computer modeling. It should be noted that, although CAD is widely used in the world practice of moldboard designing, including obtaining template lines, in the Republic of Uzbekistan these features have not yet been applied in practice. Therefore, obtaining template lines is a crucial step in the design process, and unlike traditional design, performing this task in a CAD system has the advantage that the surface section can be produced in any desired direction and quantity. To obtain template lines with the required accuracy, we develop a method that determines the sequence of solving the problem using geometric tools of a CAD system that has its specifics in contrast to traditional design. Let's look at getting template lines in traditional cross-sections and additional longitudinal sections, as well as a sweep based on them. It is known that templates copy the cross-section lines of the surface and the die shape of the moldboards. These surfaces are mostly non-sweepable, and its sweep to the plane is performed approximately, graphically, using the cutting planes method of Descriptive Geometry. Based on this technique and the capabilities of the geometric tools of the CAD system, it is possible to make a sequence of performing this task, which serves as an algorithm for automating this stage of design. Since the initial design stage is based on CAD technology in all types of CAD (AutoCAD, Pro/Engineer, Solid Works, Gemma-3D, COMPASS), we will consider performing this task in a widely distributed and easily accessible in AutoCAD system. In contrast to the traditional method, computer modeling allows to get template lines in any direction. As an example, let's consider getting template lines in the cross and longitudinal sections. This task is performed in the following order in the AutoCAD system:

Setting planes perpendicular to the ploughshare blade. Let's set the "UCS - the user’s coordinate system" vertically to the XY plane and perpendicular to the ploughshare blade at the intersection point of a straight line perpendicular to the ploughshare blade. Using them, we set the cutting plane using the command "Flat surface-Plane" (Figure 8a). The plane can be "Copied" and set in the required number and interval.

Section of moldboard’s surface with cross-cutting planes. To do it, select the command "Section" in the submenu "3D operations" of the main menu "Edit". According to the menu instructions: "Select objects to cut" - select the moldboard surface; "Cutting object" - select the cutting plane as the cutting
object; "Leave both parts" - leave both parts of the dissected moldboard’s surface. This operation is repeated in the required number and interval.

Obtaining transverse template lines. To select intersection lines as template lines, use the command "Spline". Draw a spline along the intersection lines, where the spline points should belong to the dissected edge of the surface (Figure 8a). To make it easier to work and study the current part of the dissected surface, we can temporarily close the cutting planes and unnecessary parts of the surface, saving them to other layers. The obtained template lines u1, u2, ..., un are necessary for further determining the parameters, sweeping, and performing engineering calculations. The templates are placed in the specified interval, for surface control, with the inner side (for the stamping form) or outer side (for the moldboard) in the battery.

Getting longitudinal template lines. It should be noted that in the AutoCAD system, "Modeling a surface by sections" is performed in several ways. For example, when modeling a "Piecewise linear surface", there will be no need to conduct longitudinal sections, since the generative lines are set by the system itself. But in this case, the smoothness of the surface will be very low. To increase the smoothness of the surface, we will also increase the number of specified generative lines v1, v2, ... vn. If we modeling "Smooth surface", we will need to dissect it with horizontal sectioning planes along the generative lines (Figure 8b). In this case, since the system converts a linear surface to a smooth surface, we get a curve in the section, although the surface is set to be straight. Increasing the setting number of generative lines brings the curved intersection line closer to the straight line. Since the curve has a very small curvature, we take it as a generative straight line of linear surface, which makes it possible to obtain the intersection points of v-longitudinal (generative) and u - transverse (template) lines.

Getting the moldboard’s pattern by sweeping the working surface based on template lines. As it knows, moldboards are made by a pattern of sheet steel. Since the moldboard’s surface is not flat and is not sweepable, firstly deploy its surface approximately. In this case, the 3D model of the surface is expanded to the plane in the required accuracy. The intersection of the longitudinal and transverse lines that make up the surface frame gives its "Discrete points". Discrete points are of great importance in the design and study of the working surface. By their location in the frame, discrete points are divided into three categories: contour, nodal, and intermediate (Figure 9a). To sweep the surface using template lines, first determine the length of lines between these points. To do it, we translate "Spline" to "Polyline", then the system automatically determines their lengths. We divide the transverse lines in each longitudinal section with the command "Break at the point". Expanded transverse lines are placed vertically by preserving the cross-section intervals. We mark discrete nodal points on them, and their connection in the longitudinal direction gives the approximate length of the longitudinal lines. The deviation of the section curves from the straight line determines the deformed places of the surface after stamping. To get the outline of the pattern, it is enough to select contour points, and nodal and intermediate points are necessary for the study of the designed surface (Figure 9b).
4. Conclusions
The geometric models of a frontal contour, a directory curve, and the formatives’ positions of moldboard’s working surface were developed on the substantiated parameters of geometric modeling. The developed geometric models were implemented in the AutoCAD system as computer models of working surface elements with static and dynamic characteristics. Implementation of the geometric models and algorithms in the AutoCAD system, although they are static, is acceptable for transmitting and integrating them into subsequent production systems in digital economy conditions. The proposed geometric and computer models of the working surface frame by template lines can be used in the study and justification of its parameters. The developed algorithms and models can be used in writing subprograms "Moldboard’s Surface Setting", "Moldboard’s Surface Modeling" and "Moldboard’s Surface Sweeping" as software support for automatization the moldboards’ designing process. Based on these developments the author proposes a computer modeling method of moldboard’s working surface in the AutoCAD system. This method provides to increase visualization, quality, and efficiency of the design process. In contrast to traditional design, where each project is implemented one-time, computer-modeled projects have a reusable character, which allows one project to consider many options. However, the developed models, algorithms, and methodology of moldboards’ surface in AutoCAD system are not so perfect, they are novelty and importance in the condition of Uzbekistan. This method greatly facilitates the design process, provides the necessary accuracy of the manufactured product, also is affordable mean for Universities, Designing Bureaus, and Enterprises.

Acknowledgments
The correspondent author is grateful to the government of Uzbekistan, the leaderships of Tashkent Institute of Irrigation and Agriculture Mechanization Engineers (TIIAME), Peter the Great St. Petersburg Polytechnic University (SPbPU), Bukhara Engineering Technological Institute (BETI), St. Petersburg State University of Telecommunications (SPbSUT) and Bukhara branch of TIIAME for an arrangement of conditions for studying and conducting these researches, as well as to prof. D.F.Kuchkarova (TIIAME), prof. D.V.Voloshinov (SPbSUT and SPbPU) and prof. N.M.Muradov (Bukhara branch TIIAME) for their scientific consultations.

References
[1] Goryachkin V P 1965 Theory of soil destruction (Moscow Kolos) pp 369-381
[2] Goryachkin V P 1949 Theory of the wedge (Moscow Kolos) pp 382-389
[3] Sineokov G N Panov I M 1977 Theory and calculation of tillage machines (Moscow Machinery) p 328
[4] Gachev L V 1961 Theory of a share moldboard surface (Zernograd) 317 p
[5] Mirzaev B Mamatov F Ergashev I Ravshanov H Mirzaxodjaev Sh Kurbanov Sh Kodirov U and
Ergashev G 2019 Effect of fragmentation and pacing at spot ploughing on dry soils E3S Web of Conferences 135 01065 IITESE-2019 https://doi.org/10.1051/e3sconf/201913501065

[6] Lysych M N Shabanov M L and Bukhtoyarov L D 2019 Research of process overcoming obstacles by tillage tools FORESTY 2018 IOP Conference Series: Earth and Environmental Science 226 012045. IOP Publishing doi:10.1088/1755-1315/226/1/012045

[7] Hassmae Maher Rachid Moussadek Abdelmjid Zouahri Ahmed Douaik Houria Dakak Mouloud El Mouldane and Ahmed Ghanimi 2020 Effect of no tillage on the physico-chemical properties of soils of the El Koudia region (Rabat Morocco) E3S Web of Conferences 150 0 https://doi.org/10.1051/e3sconf/2020150 EDE7-2019

[8] Yueming Wang Na Lia Yunhai Maa Jin Tonga Wilhelm Pfleging Jiyu Suna 2019 Field experiments evaluating a biometric shark-inspired (BioS) subsoil for tillage resistance reduction https://doi.org/10.1016/j.still.2019.104432.

[9] Svechnikov P G and Troyanovskaya I P 2019 Tractor plough designing with specified tillage quality. Conference on Innovations in Agricultural and Rural development IOP Conf. Series: Earth and Environmental Science 341 012119 IOP Publishing doi:10.1088/1755-1315/341/1/012119.

[10] Andrea Formato Domenico Ianniello Francesco Villecco Tony Luigi Leopoldo Lenza Domenico Guida 2017 Design optimization of the plough working surface by computerized mathematical model Emirates Journal of Food and Agriculture 29(1) pp 36-44 doi: 10.9755/eqfa. 2015-10-918 http://www.eqfa.me/.

[11] Lysych M N 2019 Review of numerical methods for modeling the interaction of soil environments with the tools of soil tillage machines Journal of Physics: Conference Series 1399 DOI: 10.1088/1742-6596/1399/4/044014

[12] Asaf Z Rubinstein D and Shmulevich I 2007 Determination of discrete element model parameters required for soil tillage Soil and Tillage Research Volume 92 Issues 1–2 January pp 227-242 https://doi.org/10.1016/j.still.2006.03.006.

[13] Ovsyanko V Petrovsky A 2014 The computer modeling of interaction between share moldboard surface of plough and soil J Res Appl Agric Eng 59 100-3

[14] James Barr Jack Desbiolles Mustafa Ucgul John M.Fielke 2020 Bent leg furrow opener performance analysis using the discrete element method Biosystems Engineering Vol 189 January pp 99-115 https://doi.org/10.1016/j.biosystemseng. 11.008. 2019.

[15] Voloshinov D V 2010 Theory of automatization of objects and processes design on the basis of constructive geometric modeling methods Abstract of DSc dissertation thesis SPb SPbPU p 33

[16] Voloshinov D V 2010 Constructive Geometric Modeling Theory Application Automation Monograph (Lambert Academic Publishing Saarbrucken) p 355

[17] Juraev T Kh 2017 Conceptual Designing of Mould Board’s Surface by Geometrical Modeling American Journal of Mechanics and Applications Vol 5 No 4 pp 28-33. doi: 10.11648/j.ajma.20170504.11. ISSN: 2376-6115 (Print); ISSN: 2376-6131 (Online). http://www.ajmechanics.org/archive/621/6210504 .

[18] Juraev T Kh 2017 Geometric modeling for organizing innovative cluster on designing in agricultural machinery industry Proceedings of the international conference on integrated innovative development of Zarafshan region: achievements, challenges and prospects. Volume II 26-27 October (NSMI Navoi Uzbekistan) pp 248-251

[19] Juraev T Kh 2017 Creating the Geometric Database for Product Lifecycle Management System in Agricultural Engineering International Conference on Information Science and Communications Technologies ICI SCT 2017 Applications Trends and Opportunities. 2-4 November (TUIT Tashkent Uzbekistan) IEEE Catalog Part Number: CFP17H74-CDR, ISBN:978-1-5386-2167-7. https://www.researchgate.net/publication/321821311.

[20] Juraev T Kh 2020 Decision Maintenance Management Problems in Agriculture Engineering by Constructive Geometric Modeling Methods. Maintenance Management Edited by Fausto Pedro Garcia Márquez and Mayorkinos Papaelias (London United Kingdom) pp 23-37
https://mts.intechopen.com/storage/books/8623/authors_book/

[21] Juraev T Kh Murodov N Naimov S T 2019 Application the Geometric Modeling Methods and Systems in Design Engineering and Manufacturing on Example of Agriculture Engineering Design Engineering and Manufacturing Submitted: March 25th 2019 Reviewed: September 30th Published: December 10th 2019 DOI: http://dx.doi.org/10.5772/intechopen.89974.