

## **INDUSTRIAL DESIGN IN AGRICULTURE ENGINEERING BY GEOMETRIC MODELING**

TOJIDDIN JURAEV<sup>1,2,\*</sup>, SHAVKAT IMOMOV<sup>1</sup>, YULI PANCA<sup>2</sup>,  
RUSTAM XUJAKULOV<sup>3</sup>, TULKIN ABDUKARIMOV<sup>1</sup>

<sup>1</sup>Bukhara Institute of Natural Resources Management, 32, Gazli, 200107, Bukhara, Uzbekistan

<sup>2</sup>INTI International University, Persiaran Perdana BBN Putra, 71800, Nilai, Malaysia

<sup>3</sup>Karshi Engineering Economics Institute, 225, Mustaqillik, 180100, Karshi, Uzbekistan

Corresponding Author: tojiddin\_1968@mail.ru

### **Abstract**

As it knows, moldboard type working bodies are the most common and complex among the working bodies of agricultural machines and equipment from a geometric view point. Therefore, the use of geometric modeling methods in the development of such working bodies are decisive importance. This article discusses applications of geometric modeling methods in product development using the example of a plow's moldboard with a combined work surface. The article solves the problem of designing moldboards based on their geometric models. To solve this problem, the use of a combined surface consisting of pieces of cylindrical and conical surfaces as a working surface is theoretically justified. A concept of moldboard with a combined working surface is proposed. Acceptable models of the moldboard for plough been obtained based on the results of concept selection method. A sketch model of a moldboard with a geometrically combined working surface has been developed. The contours of the moldboard were determined based on the methods of projective geometry. Based on these developments, a patent was obtained for a utility model for moldboard with a geometrically combined working surface.

Keywords: Agriculture, Combined surface, Conceptual design, Concept selection, Geometric model, Moldboard's surface.

## 1. Introduction

Nowadays special attention is paid to the design process of agro machinery equipment (AME), based on Geometric Modeling (GM), which is widely used in industrialized countries. At the same time, the development of geometric models and algorithms, as well as methods for their implementation in the design process of AME, is one of the important tasks of this field. Improving existing and creating new models of AME are the main factors of reducing energy and material costs, improving labour productivity and the quality of agro processing, as well as improving economic efficiency [1-3].

But nowadays traditionally used analytical and experimental methods for developing the new models are insufficient [4, 5]. Currently design process of AME requires a quick change of their modification and the creation of more advanced, where geometric parameters play a major role. It is considered necessary to use GM methods in this process because their geometric parameters are of particular importance, and this requires the development of corresponding models and algorithms, as well as methods for their implementation in computer modeling and design systems [6, 7].

In Uzbekistan, as well as in other agrarian developing countries, they began to pay great attention to the application of modern design methods and systems in the R&D of high-performance AME. Therefore, the use of synthetic design methods and tools, as one of the modern ones based on graphical information, in R&D is an urgent task. This research study will focus on the application of GM in the development of AME.

In particular, moldboard surfaces are considered since they are the most complex from a geometric view point and are widely used. Therefore, research works are universal and innovative in nature, which increases the significance of this work, since they are applicable not only in agricultural engineering, but also in mechanical engineering in general. The main agricultural and land reclamation work consists of preparation and tillage.

Therefore, most AME are used by machines that affect the soil, which shows the importance of AME research with a moldboard surface. For example, in the Republic of Uzbekistan, when cultivating agricultural crops, up to 25% of labour and about 40% of energy costs are spent annually on basic tillage alone [8]. The main share of reclamation equipment such as: ploughs, check formatters, ditch diggers, furrow cutters, as well as bulldozers, planers, and graders, among others have moldboard surfaces that affect the soil.

These once again show the importance of using synthetic methods in the development the moldboard surfaces of AME, which makes it possible to more effectively solve the current problems of agricultural production at the state level, for example, improving the land reclamation status [9]. AME with moldboard surfaces occupy a special place in terms of geometric parameters. These parameters, i.e., the shapes, sizes and relative positions of their elements in space, play a major role in the agro technological processes when they are exposed to the soil. For example, ploughs' moldboards have a complex geometric shape associated with their function. Therefore, their design and manufacturing processes are also complex.

## 2. Materials and Methods

The linear surfaces are mainly used as the moldboard's working surface, since the soil adheres to them less and the soil mass moved on such surfaces is subjected to the least resistance. Further, the manufacture of such surfaces is considered the most technologically advanced. However, they are sometimes inferior to non-deployable surfaces in their agro technical (operational) indicators. Therefore, specialists have developed various experimental models of moldboards with a geometrically combined working surface consisting of pieces of deployable surfaces [1, 2].

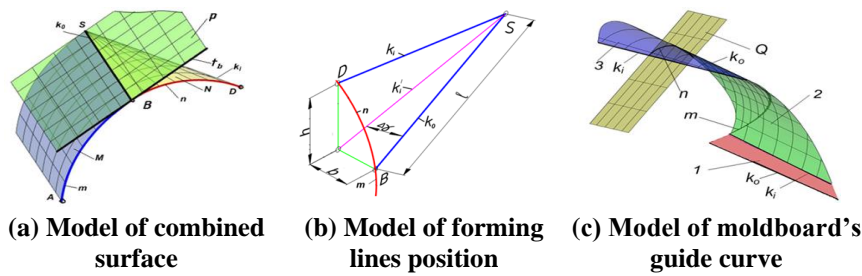
Work on the creation of such surfaces of moldboards has been carried out since the advent of the science of agriculture engineering. Despite such advantages, a long time, and the amount of work carried out on this problem, it has not yet been sufficiently solved, especially in parameterization terms of elements of the working surface, which is why they are not widely used. One of the reasons is the complexity of controlling the geometric parameters of the working surface of such moldboards. Therefore, the solution to this problem is to develop a geometrically combined working surface.

At the same time, the combination of such surfaces will consist from pieces of deployable surfaces as cylindrical and conical, which allows for easily controlling the geometric parameters of the working surface. To preserve the technological characteristics of the working surface, the approximation method is used, which approximates the geometrically combined working surface to the surface of a cylindroid, by joining the pieces of the deployable surfaces in the required position and quantity. This allows developing various options to combined working surfaces for moldboard type AME.

Consider a combined working surface consisting of two linear surfaces  $M$  and  $N$ , Fig. 1(a). One of the conditions for setting the combined working surface is to ensure its *smoothness*, especially at the junction of the components, which is achieved by setting the common tangent plane  $P$  at their junction. Since the components of the surface have the same forming lines, the line of their junction is a common forming line -  $k_0$  for them. It is also the contact line of the plane  $P$  to both components and the combined surface itself, which provides a condition for its smoothness. The intersection line of the tangent plane ( $P$ ) with the guide curve's plane ( $Q$ )  $mn$  is tangent- $t_b$  to its point  $B$ , which is also the intersection point  $k_0$  with  $Q$ .

The position of the forming line  $k_i$ , Fig. 1(b), significantly affects the characteristic of the surface, the variants of which will be considered by GM method. In traditional design, a parabola is mainly used as a guide curve, because it has variable *curvature* for giving a crumbling ability to the surface [4, 5]. The upper part of the parabola is longer to give the necessary *rotation* to the soil layer sliding from moldboard surface. This part of the guide curve with the upper forming lines, which have an angles' changing rule  $y=f(z)$  to the furrow wall, determine the formation of the moldboard's wing, Fig. 1(c).

The necessary torsion of the wing is obtained at the cylindroid surface, in contrast to the cylinder, but its disadvantage is the low manufacturability, which is characteristic of non-deployable surfaces. Therefore, to improve technological performance, deployable combined surfaces have found their application.

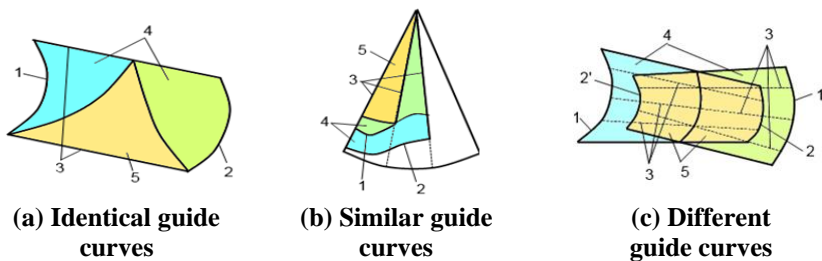


**Fig. 1. Geometrically combined working surface model and its elements.**

AME with different working surfaces can consist from single geometric surface, for example, moldboard type AME mostly has linear surfaces. If it can bring the geometric parameters of different working surfaces with the same geometric surface to a common one, then it will be able to increase the functionality of the AME. According to the provisions of moldboards surface theory [4], descriptive geometry, and preliminary studies [10-12], the following characteristics of ruled surfaces' elements can be considered, Figs. 2(a) to (c):

- Parallel cross sections of the surface that, gives a guide curve: *identically* for cylindrical (a), *similarly* for conical (b) and *differently* for cylindroid (c) surface;
- The forming lines are *parallel* in a cylindrical surface (a), *split ends* in a conical surface (b), or *interbreeding* in a cylindroid surface (c);
- The contour piece of the surface are *inter complementary* (a), *has a common part* (b) or *mirror-reflected* (c).

The following non restrictions for pieces of surface can be distinguished: *identity, similarity, and secularity* - for a cylindrical surface; *similarity and secularity* - for a conical surface; and only *secularity* - for a cylindroid surface. There are no restrictions for cylindrical surface and can be chosen as base surface.



**Fig. 2. Setting ruled surfaces as moldboard's working surface.**

### 3.Results and Discussion

On purpose of the study is applying GM to the design of the moldboard for adaptation into manufacturing. As an example, consider the conceptual design of the plough's moldboard. Ploughs used in agricultural production have various moldboard design models based on their destination. Each model has its advantages, and isomorphic using of these advantages in another model can lead to loss some perfection of this model. In such cases, it is possible to combine the advantages of the proposed models

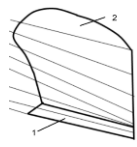
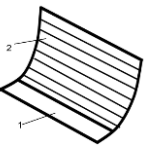
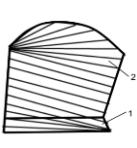
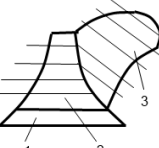
according to various evaluation criteria into one new model with necessary changes on basis of ID principle "Concept selection" [6].

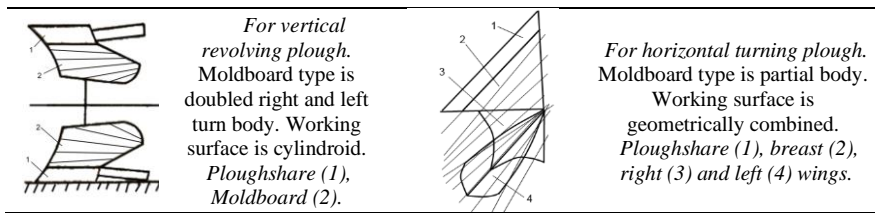
Moldboards have a complex technical surface and a universal geometric model. These factors allow for ID in development of moldboards by geometric characteristics that affect their technical and technological characteristics. It can be consider improving and creating directions of plough's moldboards. There considered visual analysing of moldboard models in Table 1. This analysis shows that the main reason for improvement is to analyse advantages and disadvantages of different geometric designs of the moldboard's working surface. The analysis depends on geometric parameters, metal quantity of construction, manufacturability of moldboard, and functional working quality.

Evaluation of criteria for each basic design model appears in Table 2. Geometric characteristics of each model are evaluated by their advantages (+) and disadvantages (-) in relation to the basic model. The characteristics that are not clearly distinguished conditionally evaluated neutrally (0), because they do not particularly affect to the models design.

The qualitative assessment and analysis of characteristics as visualized in Table 2 supports the combination of models' construction according to the models' advantages. However, although the development of a model based on the principle of "Concept selection" is in the initial design stage and subject to further development, it reduces the previously mentioned design costs. For the next stage of development, design models that had a rating placement of 1-3 in Table 2 were analysed again. On the basis of analysing models, a new generated model direction "G" can be proposed by GM. Variants of proposed design models "G1", "G2", and "G3" appear in Table 3, showing geometrically combined working surfaces that consist of separate parts and double-acting operation.

**Table 1. Visual analysis of moldboard models.**

Basic model "A"	Considered model "D"
 <p data-bbox="395 1160 630 1305"><i>For one side turning plough. Moldboard type is classic body. Working surface is cylindroid. Ploughshare (1), Moldboard (2).</i></p>	 <p data-bbox="818 1160 1101 1305"><i>For horizontal turning plough. Moldboard type is double action body. Working surface is cylindrical. Ploughshare (1), Moldboard (2).</i></p>
Considered model "B"	Considered model "E"
 <p data-bbox="395 1379 630 1547"><i>Plough for one side turning. Moldboard type is experimental body. Working surface is geometrically combined. Ploughshare (1), Moldboard (2).</i></p>	 <p data-bbox="818 1379 1101 1547"><i>Plough for one side turning. Moldboard type is partial body. Working surface is geometrically combined. Ploughshare (1), breast (2), wing (3).</i></p>
Considered model "C"	Considered model "F"



**Table 2. Evaluation of moldboard’s criteria by geometric characteristics**

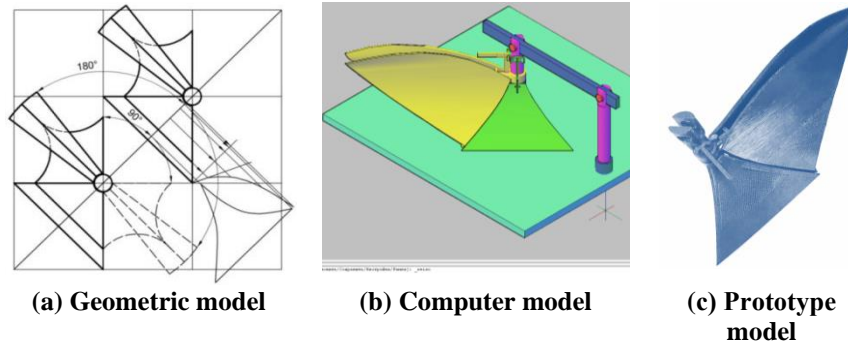
№	Influence of geometric characteristics to technical and technological characteristics	Design models of moldboards						
		A	B	C	D	E	F	G1, G2, G3
1.	Influence of layer’s trajectory	0	+	0	-	0	0	take on “B”
2.	Influence of plough’s material quantity	+	+	-	0	+	-	take on “BE”
3.	Influence of plowing’s operation quality	0	+	0	-	0	0	take on “B”
4.	Influence of plow’s smoothness	-	-	+	+	-	+	take on “CDF”
5.	Influence of plowing’s functionality	-	-	-	-	+	+	take on “EF”
6.	Influence of moldboard’s manufacturability	-	-	-	+	0	0	take on “D”
7.	Influence of complexity of construction	+	+	0	0	0	-	take on “B”
	Number of disadvantages “-”		3	3	3	1	2	
	Number of advantages “+”	Basic model	4	1	2	2	2	Proposed models
	Summarized amount		1	-2	-1	1	0	
	Rating placement		1	4	3	1	2	

**Table 3. Description of the proposed design models of moldboards**

Proposed model <i>G1</i> generated by <i>B</i> and <i>D</i> models	Proposed model <i>G2</i> generated by <i>B</i> and <i>E</i> models	Proposed model <i>G3</i> generated by <i>B</i> and <i>F</i> models
<i>Plough for one side turning. Moldboard type is partial body. Working surface is geometrical combined. Ploughshare (1), breast (2), wing (3).</i>	<i>For horizontal turn plough. Moldboard type is partial body. Working surface is geometrical combined. Ploughshare (1), breast (2), right (3) and left (4) wings.</i>	<i>For horizontal turn plough. Moldboard type is partial body. Working surface is geometrical combined. Ploughshare (1), main breast (2), right (3) and left (4) ancillary breast, right (5) and left (6) wings.</i>

Amongst the main evaluation criteria of the plough, depending from its geometric parameters it can be note lower material quantity of construction, high-tech manufacturability of the moldboard, as well as quality of the functionality. But

connect all these quality together is problematic that is connected with complex designing process of construction. Based on author researches, based on GM, CAD and ID, proposed models *G1* and *G2* were patented and adapted to production conditions [10-12]. The geometric, Fig. 3(a), three dimensional, Fig. 3(b) and prototype models of the double sided moldboard body for horizontal rotary ploughs are developed based on *G3* model by author.



**Fig. 3. Modeling and prototyping the proposed *G3* model of the moldboard.**

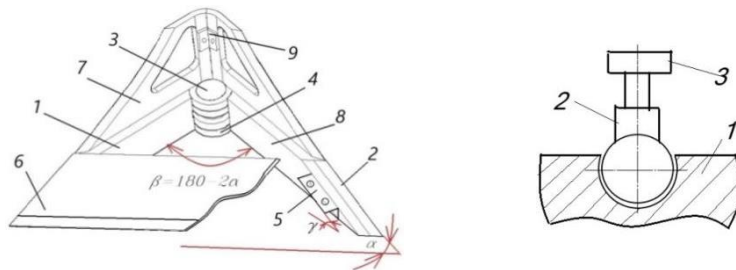
Efficiency of the *G3* model compared with the existing scheme of plough bodies design is as follows: application of geometrically combined working surface allows to develop various variants of double sided moldboard body significantly reducing metal quantity of horizontal rotary ploughs' construction relative to reversible turnover ploughs with doubled moldboard bodies. The proposed methodology is also applicable for the design of other moldboard type AME, such as the moldboards of bulldozers, scrapers and graders, as well as the moldboards of ditch diggers and furrow cutters.

Currently, a common design scheme for the execution of plow housings is being used, in which the principle of a *disposable geometric model* is applied. In such models, the quantitative and qualitative values of the geometric parameters are constant, i.e. for each design development of the housing designed for specific soil conditions; the dimensions of its parts are individual. However, for other soil conditions, a new development of the plow body is required, the parts of which have other dimensions. With this development approach, in addition to design costs, additional costs are required for the production and operation of this equipment.

To reduce such costs, the author conducted a number of studies in which the analysis was carried out and the essential geometric parameters of the moldboard's surfaces were determined [10-12]. Based on this, the author proposed a design scheme for the execution of the plow housings for the *G3* model, in which the principle of a *reusable geometric model* is applied. With this use of the design, it becomes possible to change the quantitative and qualitative values of geometric parameters. Based on this, the design of a shoe consisting of a double-sided plowshare, right (1) and left (2) field boards, as well as a right (7) and left (8) saddle are proposed.

The angle  $\gamma$  of the blade of the plowshare (6) to the furrow wall determines the positions of the forming cylindrical surface of the chest of the blade, which can be controlled by the use of a swivel joint (3,4) of the rear ends of the right (1) and

left (2) field boards. The attachment of the double-sided ploughshare (6) to the front ends of the right (1) and left (2) field boards, by means of lugs (5) that regulate the position of the ploughshare (6), allows controlling the angle  $\alpha$  of entry of the ploughshare (6) into the soil. The right (7) and left (8) saddles of the blade chest, attached to the upper faces of the right (1) and left (2) field boards with the lower ends and attached to each other with an eye (9) that regulates the angle between them, have ribs whose curved profile repeats the shape of the guide curve, Fig. 4(a). The arrangement of connecting bolts (3) attached by spherical hinges (2) along the curved profile (1) allows to control the curvature of the cylindrical working surface, Fig. 4(b).



(a) Reusable model of the shoe (b) Bolt for controlling curvature

Fig. 4. Reusable geometric model of the moldboard's shoe for G3 model.

#### 4. Conclusions

The results of preliminary theoretical research supports the proposed hypothesis, that of using geometrically combined working surfaces in the development of moldboard type AME is advantageous. The models are theoretical and serve as a basis for the development of prototypes for various moldboard types. Final confirmation of the proposed hypothesis requires further applied research, funding, and technical conditions. A comparison of the results of previous and current research on the development and application of geometrically combined working surfaces for moldboards shows the following similarities and differences. The similarity is that in previous and current researches cylindrical and conical surfaces are used as a combination. The difference is that in previous research, geometric models were not used, and according to these studies, geometric models and algorithms for elements of a geometrically combined working surface of moldboards were developed. This confirms the advantages of these studies as tools for designing moldboards resulting in reduced costs, time, and labour in developing moldboards. The solution to these problems makes it possible to produce import-substituting products and, in the future, export-oriented products. Results of synthetic design methods can be use also for other engineering fields.

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continue this research in 2023 at the Soil Machine Dynamics Laboratory with scientists from the Iowa State University (Ames, Iowa, USA).

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