Chapter

Decision Maintenance Management Problems in Agriculture Engineering by Constructive Geometric Modeling Methods

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Abstract

Extension of functional possibilities of tools is one of the main ways to increase the maintenance property of technical means. It especially actually in modern agricultural production, based on precision agriculture technologies, where using technical means must provide: reduction of cost, conservation of ground fertility, saving energy-resources, improvement labor conditions, and increase machines capacity. One of efficient way to solve these problems is using geometric modeling methods and systems in designing technical means. Geometric modeling, as one of the varieties of the synthetic methods of design, is a theoretical base for different technologies of these methods, like industrial design and CAD technologies. In this chapter, as examples, the following case studies will be considered: development of multifunctional mold board by geometric modeling, for increasing its maintenance property; integration role of CAD technologies in PLM, including in maintenance management; and visualization of production design process of technical means according to maintenance criterions.

Keywords: geometric modeling, production design, CAD technologies, product life cycle, multifunctionality, mold board's surface, maintenance criterions and properties

1. Introduction

Extension of functional possibilities of tools is one of the main ways to increase the maintenance property of technical means. It particularly actually in modern agricultural production, based on precision agriculture technologies, where using technical means must provide: reduction of cost, conservation of ground fertility, saving energy-resources, improvement labor conditions, and increase machines capacity. One efficient way to solve these problems is using geometric modeling in designing technical means. Geometric modeling, as one of the varieties of the synthetic methods of design, is a theoretical base for different technologies of these methods, like production design and CAD technologies. In this chapter, as examples, the following case studies will be considered: development of multifunctional mold board by geometric modeling, for increasing its maintenance property; integration role of CAD technologies in PLM, including in maintenance management; and visualization of production design process of technical means according to maintenance criterions. In recent years, increased variety of applicable machines and technologies has come to exist in the world in all spheres of human activity, especially in planning their functional possibilities. So development of tools that increase their functional possibilities is one of the most important problems of modern engineering and design activity. Expanding the functional possibilities of these tools will not only increase their capacity but also reduce specific consumptions of materials. These aspects are actually in creation resource and energy saving technical facilities, that is, main engineering activity, key direction in which is considered production design. This problem is considered in the same way actual and in condition of the strategic development of the Republic of Uzbekistan [1]. The solution to these problems is directly connected with the geometric modeling, which is based on the modern problems of the production design [2–4].

2. Development of bulldozer's multifunctional mold board by geometric modeling, for increasing its maintenance property

2.1 Designing the types of mold board's working surface

We shall consider the problem in moldboard-type tools as an example. It is well known that mold boards, as the main tool in plows, bulldozers, graders, and other specific machines, are intended for performing the preparing works in agriculture and melioration, ground works in road construction and engineering preparation of territory, as well as in municipal sphere and etc. In the classical variant bulldozer, the mold board is a frontally located cylindrical working surface, which moves earth or other mass, prism lug of the ground in the required direction and amount [5, 6]. For expansion functional possibilities of mold board, there are also development in different constructive variant, with changing location working organ and different working surface (**Table 1**). But these developments are basically directed at the expansion of their maintenance (functional) possibilities, for executing work of certain nature [5, 7]. The solution to these problems is directly connected to the geometric modeling, which is based on modern problems of the industrial design [2–4]. The result of the using the production design at development of mold board type tools on base of constructive geometric modeling is a "design-development" mold board, which possible produce in three types of working surface design. We shall consider the design-development working surface of mold board consists of pieces of surface. For the base of the models, we take multifunction surface consisting of linear surfaces, which are broadly used for designing mold boards (**Table 2**).

The design-development to construct a geometric model of a mold board's working surface applicable for work execution of the different nature raises: technical, technological and economical factors of the designed technology, allows more flexible control its functional possibility, solving constructive problems [2, 8, 9].

The analysis of existing mold board designs and studies on their improvement shows that creating a new design that can increase their functional possibilities, using constructive geometric modeling method, has a broad prospect [5, 7, 8, 10, 11]. The constructive geometric design of mold board's working surfaces can possibly be divided into three types: (1) design consisting of unbroken surface (**Figure 1**); (2) design consisting of surface pieces (the sections) (**Figure 2**); and (3) design consisting of surface elements (the plates) (**Figure 3**). Herewith possible creating away the prospects of the primary using these design on example:

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No	Mold board construction	Surface type	№	Mold board construction	Surface type
1		Cylindrical (Poland)	4		Combined (Czech)
2		Conidial (Finland))	5		Cylindroid (Sweden)
3		Conical (USA)	6		Planar (France)

Table 1.
Using linear surfaces in bulldozers' mold board types.

No	Geometry of surface	Using in tools
1.	Frontal planar surface	Moldboard of channel defogger
2.	Inclined planar surface	Bush cutting mold board of bulldozer
3.	Frontal cylindrical surface	Frontal mold board of bulldozer
4.	Inclined cylindrical surface	Bucket mold board of scraper
5.	Frontal conical surface	Moldboard of grader
6.	Inclined conical surface	Frontal plow's mold board
7.	Cylindroid surface	Universal plow's mold board
8.	Conidial surface	High-speed plow's mold board
9.	Hyperbolic-parabolic surface	Hyperbolic body plow's mold board
10.	Helicoid surface	Helicoid body plow's mold board
11.	Torsos surface	Cultural plow's mold board
12.	Combined surface	Combined body plow's mold board

Table 2.
Using linear surfaces in mold board-type tools.

(1) unbroken design for production of polymeric mold boards; (2) sectional design for expansion of the functional possibilities and increasing the ease of manufacturing production mold boards; and (3) plate design for the best management production and functional, working, and other quality mold boards. Developmening the working surface of mold boards that can be applied in different industries needs to consider the technical, economical, and technological factors of the designed machines. So, design-development of constructive geometric model of mold board's working surface, though exist in the designs of the considered machines, will allow more flexible control of the functional possibility of the mold board and solve the above delivered constructive problem [2, 8, 9].

2.2 Geometrical modeling of mold board's transformed surfaces

There is giving formative line—$\boldsymbol{l}$ of cylindrical surface—$\boldsymbol{\Phi}$ horizontally, and $\boldsymbol{P}$—plane of directory curve—$\boldsymbol{m}$ dispose perpendicular to these formatives on medium them. This plane crossing with working surface—$\boldsymbol{\Phi}$ is divided into two equal parts, $\boldsymbol{\Phi_a}$ and $\boldsymbol{\Phi_b}$, simultaneously being the symmetrical plane to these working surfaces. We shall choose line $\boldsymbol{k}$ on symmetrical plane, which will possibly conduct the bunch of the planes. These planes crossing with working surfaces $\boldsymbol{\Phi_a}$ and $\boldsymbol{\Phi_b}$ form curves of intersection. We shall mark these planes on both sides of the symmetrical plane $\boldsymbol{P}$ accordingly $\boldsymbol{P_1, P_2, \ldots, P_n}$ and $\boldsymbol{P_1', P_2', \ldots, P_n'}$, as well as curves of the intersection on working surfaces $\boldsymbol{\Phi_a}$ and $\boldsymbol{\Phi_b}$ accordingly $\boldsymbol{m_1, m_2, \ldots, m_n}$ and $\boldsymbol{m_1', m_2', \ldots, m_n'}$. At

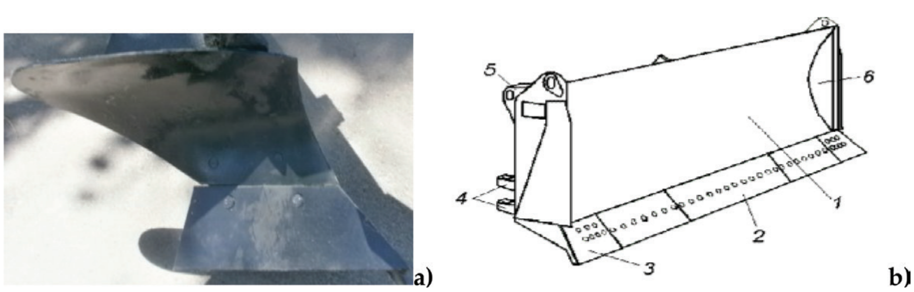

Figure 1.
Traditional construction of plow (a) and bulldozer (b) mold board.

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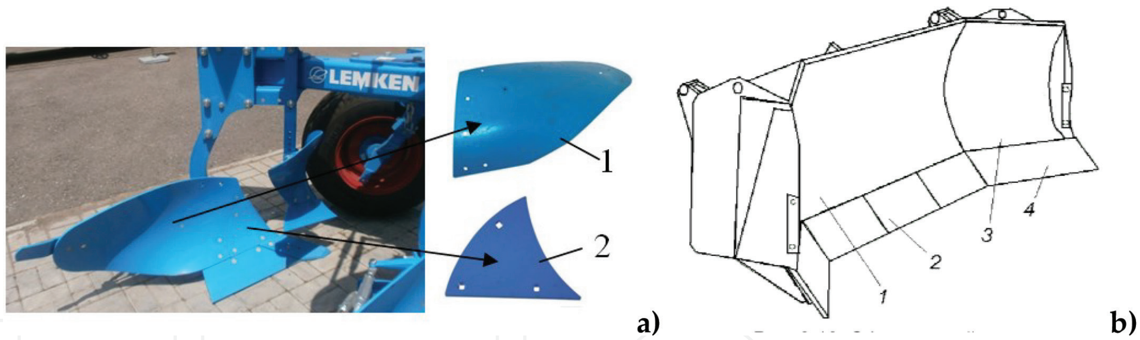

Figure 2.
Sectional construction of plow (a) and bulldozer (b) mold board: "1—wing" and "2—breast" of plow's body; "3—frontal" and "4—side" sections of spherical mold board of bulldozer.

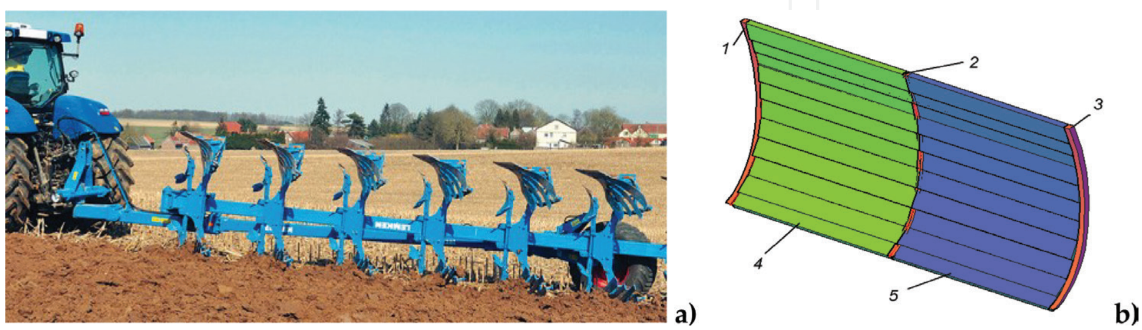

Figure 3.
Plate construction of plow (a) and bulldozer (b) mold board: 1—right, 2—middle and 3—left guiding frames, 4—right and 5—left formative plates (*construction offered by author).*

angles between planes and symmetrical plane—$\boldsymbol{P}$, we shall accordingly mark $\alpha_1, \alpha_2, \ldots, \alpha_n$. Each pair of surface intersection curve $m_1, m_1'; m_2, m_2'; \ldots; m_n, m_n'$ are formed accordingly by pair of planes $P_1, P_1'; P_2, P_2'; \ldots; P_n, P_n'$, are symmetrical, where k is an axis of the mirror image pair of curves on working surfaces Φ_a and Φ_b (**Figure 4a**). So at rotation pair planes P_i and P_i' with surfaces Φ_a and Φ_b around axis k corresponding to angle α_i, planes P_i and P_i', as well as curves m_i and m_i' belonging to them, are combined. As a result of this operation, will be formed a rib on working surface, which separates the working surface into two halves. On the basis of this model, different constructive variants of the transformed mold board can possibly be developed, allowing the conversion from one working surfaces to another.

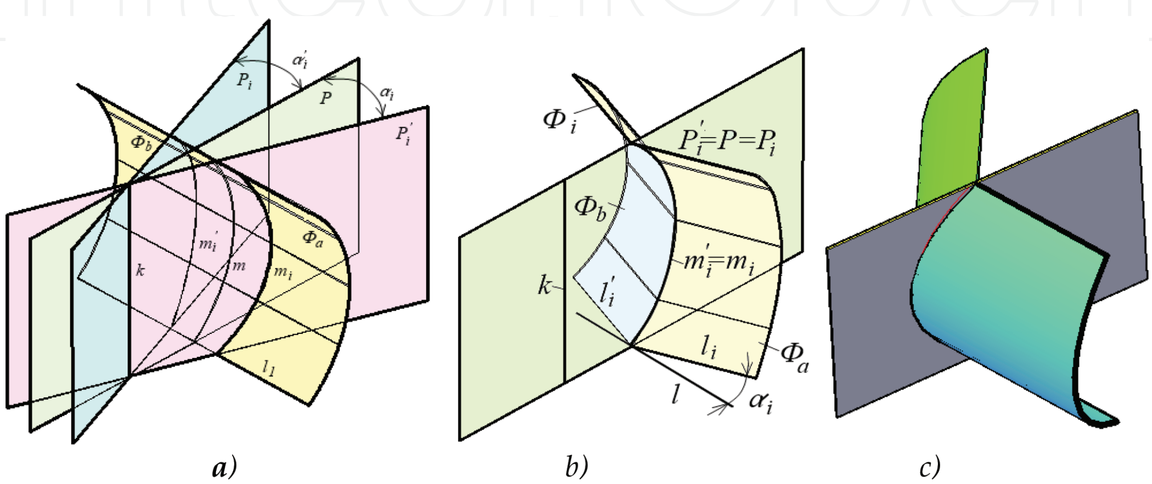

Figure 4.
Forming of moldboard's working surface with bilateral action: a) transforming sheme; b) moving ground mass to the sides; c) moving ground from the sides.

It is known that when designing the complexity technical forms, considered surface mentally differs on "geometric" and "working" surfaces and from one surface possible to get different working surfaces [4, 7]. So by means of the proposed model, as a result of rotation working surfaces Φ_a and Φ_b around axis k to angle α_i, a new working surface Φ_i is formed. Though given Φ and newly formed Φ_i cylindrical surfaces, they have a different working surface with different functional quality, where α enters as controlling parameter in the formation of Φ_i. Unlike the given surfaces Φ, a new working surface Φ_i promotes the improvement of directing actions of the moveable mass to the sides (**Figure 4b**) and from the sides (**Figure 4c**).

2.3 Giving the rotation axis of mold board's working surface

The process of the formation required working surface—Φ_i possible to control, except parameter α, as well as position of k. In considering that the model rotation axis k is located vertically and has determined distance comparatively to Φ_i. However, change the position k greatly influences upon formation Φ_i. Here possible consider two parameters of k: change the distance—f, defined between fixed point k and m, for instance base k and sock m on horizontal plane; as well as change of the slopping angle—β to horizontal plane. Under one and same angle α_i and the form of directory curve m_i, change f will bring about change the mutual location pair of directory curves m_i and m_i' that will bring and to change constructive parameter of mold board with working surface—Φ_i. From considered by author, acceptable variants (**Figure 5**) for given problems are chose variants (*b*) a chord—AB and (*d*) a tangent in point—C, with the result that possible neglect the parameter f that simplifies the problem. Though the other variants too have such working surface, they can bring about complication in the constructive parameter of the mold board. However, when forming the surface Φ_i, in variant (*d*) rotation is produced in inverse direction than in variant (*b*). With the importance of the rotation angle α, we choose within $0 < \alpha < \alpha_{max}$, with the condition that planes P_i and P_i' must cross all forming surfaces Φ_i, where α_{max} is on $tg\alpha = (1/2)/b$, and overhang of curve b.

2.4 Parameters of designing working surface's directory curve

It is necessary to note the parameters on the form and position directory curve m of surface Φ. On condition of the problem form of directory curve—m is flat and fluent, with determined by curvature and concave side onward. Since these characteristic directory curves remain low-lying during the transformation of the surfaces, they shall select as topological parameters of curve, defining its

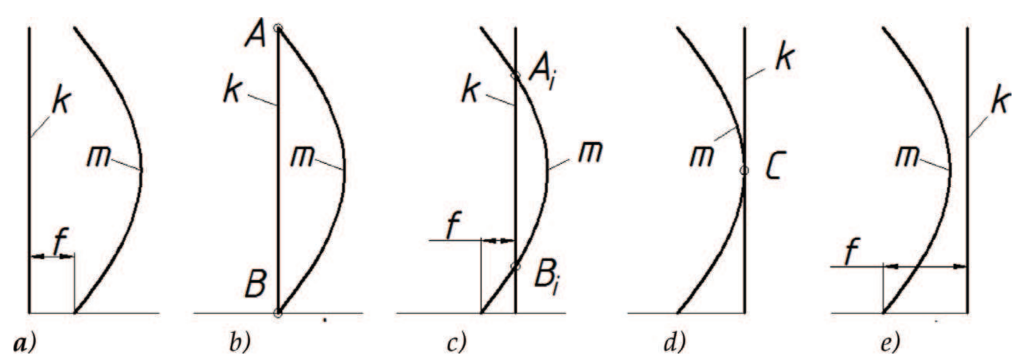

Figure 5.
Position variants of rotating axis k comparatively to m.

form. Consequently, such parameters of surfaces, as their type and curvature also remain low-lying and when forming the new surface Φ_i. The position of curve is assigned two parameters: overhang b and height h of curve. They shall be marked as constructive parameters, since they define the design of the mold board. The following variants possibly select the relative position constructive parameters of m, defined by typical point positions (**Figure 6**): lower (A) and upper (B) points define h, and extreme left and right (the pair from points A, B, C) points define b. These variants directory curves are possible to choose when designing the mold board depending on execution of its work. When changing f, in the vertical position of k, the dimension height of mold board h' in the same way remains low-lying. The parameter $\delta b_{max} = b_i\text{-}b$ derived after forming rib of surfaces Φ_i is situated opposite, for points, on which pass the rotation axis k (*right/left*—on bosom or *upper/lower*—on carrying).

2.5 Parameters of designing working surface's formatives

The criterions of the choice variant relative position of typical point of directory curve m on h and b, when designing mold board possible to explain, linking these points with typical positions of formatives l. For example, we shall select the following position formatives l, getting through typical points m on width b in respect to h, upper, lower, front, back, as well as average (on h or on b), and define their influence upon nature of the moving the moveable mass on working surface of the mold board (**Table 3**). From given table, it can be understood that the nature of the moveable mass on working surface is possible to control, having changed relations h and b, by changing the slopping angle β to axis k. Unlike vertical position, the slopping k on angle β onward or will back add the working surface except improvements of the shift of the moveable mass aside under its horizontal trimming (**Figure 7a**), as well as perfects the functional quality on shaping tilted lowering (**Figure 7b**) and ascent (**Figure 7c**) from moveable mass. This is the positions reached by change forming l, which present as well as plowshare, for horizontal plane on angle—φ, after forming Φ_i. The angle φ possible define by projection model, on base of descriptive geometry rules [12], using joining method (**Figure 7d**). Turning the horizontal plane on 90°, to joint it with frontal projection

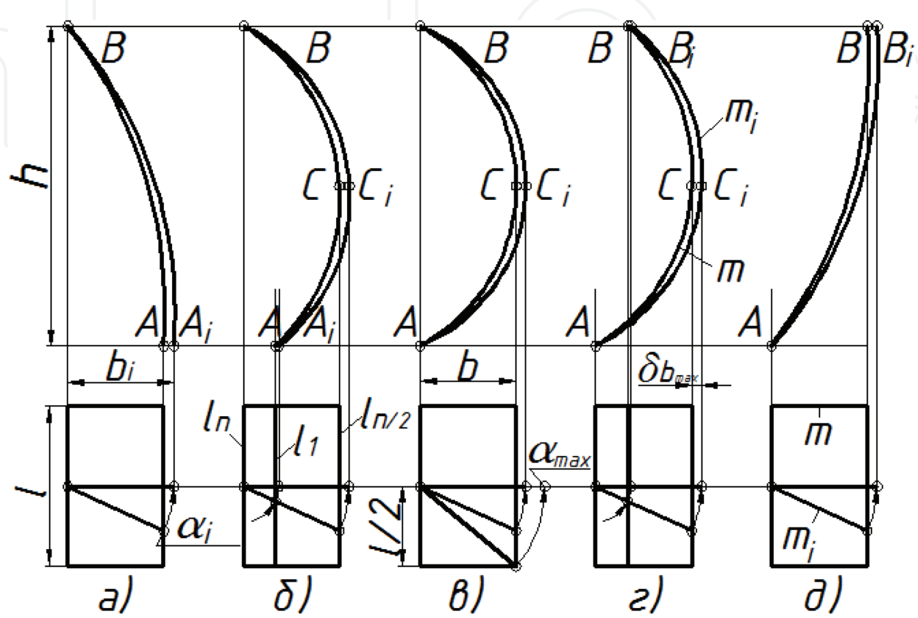

Figure 6.
Relative position variants of directory curve's constructive parameters.

No	On width *b*, in respect to *h* and through points			Nature of moving the moveable mass on worker of the surfaces
	Anterior	Average	Posterior	
1.	Superior—***B***	Not available	Interior—***A***	Powerfully postponed in before.
2.	Superior—***B***	Interior—***A***	Average—***C***	Partly is taken on breast and powerfully postponed in before.
3.	Superior/interior—***B***/***A***	Not available	Average—***C***	Completely taken on breast and powerfully postponed in before.
4.	Interior—***A***	Superior—***B***	Average—***C***	Completely taken on breast and weakly postponed in before.
5.	Interior—***A***	Not available	Superior—***B***	Completely taken on bosom.

Table 3.
Positions of formatives and their influence to working surface nature.

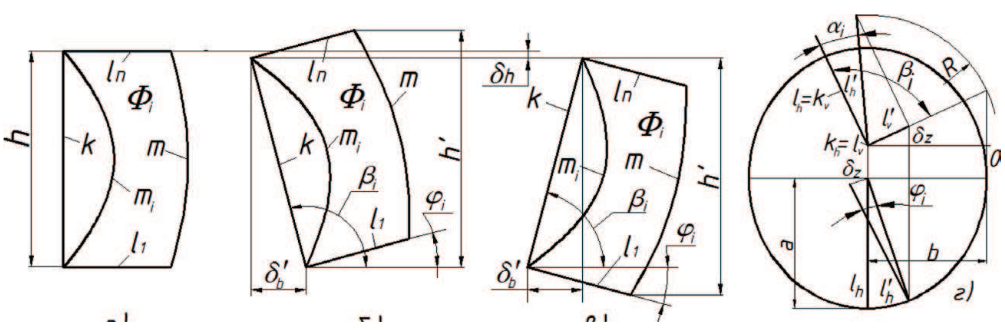

Figure 7.
Determination of inclined working surface geometric parameters.

combine the projections ***k*** and ***l***. Rotating ***l*** on angle αi, marked its ***l'***, easy find the frontal projection l_v'. Since ***l*** revolves on frontal projection plane, perpendicular to ***k***, circle of the rotation ***l*** projects on the horizontal plane as an ellipse. By means of projection beams, find l_h' and define φ angle of the slopping ***l*** on horizontal plane using the square-wave triangle, also considered as the corner of the slopping of the plowshare. After transformation working surface Φ on Φ_i under inclined ***k***, will increase the height dimension h' of mold board though h decreasing on δh. At, the higher part rib bends over onward or for lower part back, daring on distance $\delta b'$. As a result of transformation, working surface changes the lengths corresponding to forming l_i within $0 < \delta b < \delta b_{max}$, offset end forming belonging to rib to surfaces. In point, on which pass the rotation axis ***k***, length l_i is equal $\delta b = 0$, but in nose (*upper* or *lower*) of a part it is equal $\delta b = \delta b_{max}$.

2.6 Sections of designing working surface

The definable parameters got Φ_i on two variants, and on positions of the descriptive geometry, make sure that α_i parameters and Φ_i are alike, but are mutually negative (**Figure 8a** and **b**) [12]. This allows to combine two variants in one design and as a result enlarges the functional possibilities of the designed mold board (**Figure 8c**). We can select five compartments of working surfaces on intersection lines. Alternate switching-on or switching-off of corresponding compartments will enable the mold board to work in three modes: moving the mass

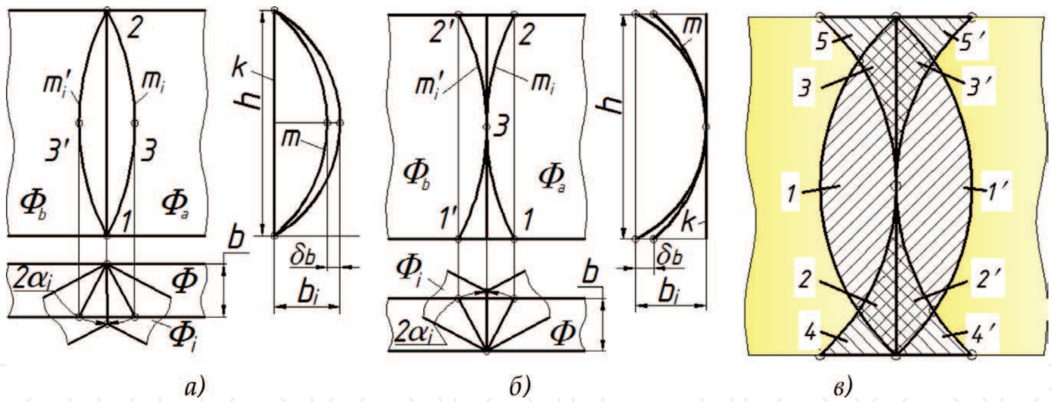

Figure 8.
Forming of working surface with bilateral action.

frontal, moving ground mass to the sides, or from the sides. The proposed device of geometric modeling-transformed working surface allows to develop a constructive geometric model of a multifunctional mold board. This development is intended for organizations to produce specific machines. Parameterization of mold board's working surface relieves designers' work, increases the choice a variant under development mold board's working surface, and allows effectively to solve the constructive problems.

3. Integration role of CAD technologies in PLM, including in maintenance management

The modern production is founded on using information science and communication technologies as CALS-technology (continuous acquisition and lifecycle support) or PLM-technology (information support of the product lifecycle management processes). PLM is an approach to designing and producing high-tech and scientifically based product, using information science and computer technology at all stages of the product life cycle [13].

This aspect actual in condition of developing countries, like Uzbekistan, where using these technologies is innovative process in production. One of the problems in this process is adapting them in production, that is, translating the engineering data to PLM system, by way of integrating PLM and CAD/CAE/CAM systems, using the product's engineering database at the base of PDM-technology (product data management).

The product's engineering data are possibly divided into three groups: structural (constructional), functional, and technological. Let me present to you the structural data, which we can call the geometric data, that are necessary for integrating CAD and PDM systems. The product's geometric data are used not only in enterprise where they are produced but at all stages of the product life cycle from designing to maintenance. So, creating the geometric database, using different forms of the geometric data (**Figure 9a**), is very important in the product life cycle.

As is well known, the product lifecycle includes the period from origin necessity for creating the product up to its liquidations in consequent exhaustion of consumer characteristic. Primary stages of product life cycle are selecting four main stages: designing, producing, maintaining, and utilizing.

Though life cycles of old and new products always form the unceasing cycle, because of brightly not images, traditionally life cycles of each product were considered separately, which during the initial stage was designing but finally cutting. However, author, founding on his conducting researches, offers to consider that

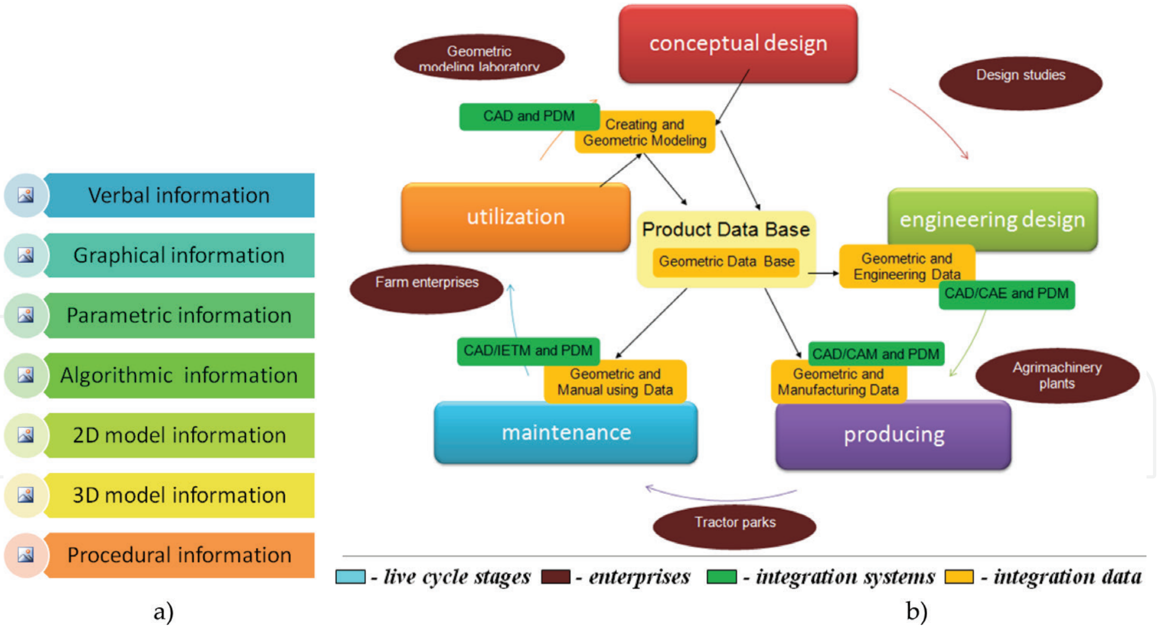

Figure 9.
Types and levels of geometric data (a). Integration role of geometrical modeling system in PLM (b).

that beginning of PLM is from creation an instrument from stone, bones and wood by primitive man. Since no one can reject that the base of modern industrial robot is an instrument of the stone age, the end of "old" product is a beginning of "new" product. It is possible to say that the beginning and the end of PLM connect with beginning and end of mankind on land. The present production conditions, in which production design steel play one of solving roles, relationship between "old" and "new" product lifecycle become reveals itself all more brighter. Coming from author's offers separate stage of the designing on two: conceptual and engineering design. Conceptual design stage is founded on the basis of geometric modeling and it is the closing stage of the product life cycle, having a causal relationship between "maintenance-utilizing" and "designing" stages. Nowadays, producing geometric modeling has become a primary method, facilitating designing. In this stage, the product will be designed on the basis of the relationships between exhaustion of consumer characteristic of old product and necessity for creating the new (innovative) product.

The need for geometric data arises at all stages of the product life cycle, particularly in the initial stage—"conceptual design" stage, when it is very high. Created at this stage, geometric database is directly or indirectly used also in the other stages of the product life cycle, by integrating CAD and PDM systems. It is necessary to note that the need to create a "new product" is basically formed in the maintenance of "old" product. Since it at this stage is not only used Geometric data of "old" product in maintenance but arises Geometric data of "new" product in designing.

As example, we shall consider creating the agricultural machinery tools' geometric database, which is necessary to enterprises that participate in these products life cycle [14]. Creating this database needs the review, classification, and analysis of appropriate information about agricultural machinery tools from a geometric standpoint. This will allow us to reveal general and individual geometric features of these tools that assist in an efficient management of product data for all participating enterprises in this process (**Figure 9b**). At present, the author is the leading researcher on development of theoretical bases and applying aspects of the geometric modeling of agricultural machinery tools. With the results from research, models, algorithms, and methods of designing these tools with mold board surface by geometric modeling were worked out.

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	Influence of geometry on technical and technological characteristics	Considered constructions						Proposed design on advantage
		A	**B**	**C**	**D**	**E**	**F**	
1.	Influence on earth layer trajectory	0	+	0	–	0	0	**B**
2.	Influence on material quantity	+	+	–	0	+	–	**BE**
3.	Influence on process quality	0	+	0	–	0	0	**B**
4.	Influence on flat plugging	–	–	+	+	–	+	**CDF**
5.	Influence on multifunctionality	–	–	–	–	+	+	**EF**
6.	Influence on manufacturability	–	–	–	+	0	0	**D**
7.	Influence on complexity of construction	+	+	0	0	0	–	**B**
	Amount of disadvantages "–"		3	3	3	1	2	Advantages
	Amount of advantages "+"		4	1	2	2	2	
	Total score		1	–2	–1	1	0	
	Rating place		1	4	3	1	2	

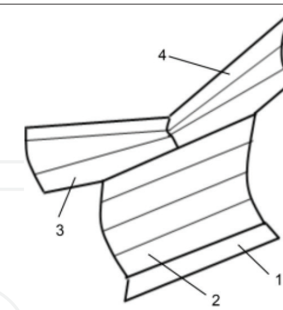

Table 4.
Screening of model selection process for designing mold board.

As a result, information sufficient for creating the geometric database in different forms was accumulated. We shall select the following forms of geometric data: verbal, graphical, parametric, algorithmic, 2D and 3D model, and methodical (that may include all geometric data forms). All elaborations are executed in *AutoCAD 2013* system.

4. Visualization of designing process of technical means according to maintenance criterion

The present pace of industry development requires the development and introduction in production innovation designing technologies. Using the methods of the production design gives the essential result in the process of developing technical object on different criterions engineers play one of key role in this, since saving to energy and resource, improvement to ease of manufacturing and functionality, as well as capacity, mainly depend on under development them technology and technical facilities [15]. Using of these methods require from constructors revealing the problems, which decisions are connected with geometrical modeling, on which is founded production design, as well as way of their decision. We shall consider using one of the methods of the production design—"*Concept selection,*" choosing the models to design. The moldboard have a complex technical form, long period of change on improvement their design, and have a universal geometric model. These factors allow using the production design in development mold board on geometric features, influencing on technician-technological features. As is well known, application in agricultural production plows has a different mold board constructions in accordance with their destination. The combination, on advantage of different criterions, considered constrictions in one new constriction, with necessary changes, by screening-method of "Concept selection" will allow to choose the models for development. The development conducting on the main types design moldboard plows, in which is taken into account row of the main criterion of the choice to models on geometric features (based on geometric data and parameters), presented by requirements of the producers and consumers (**Table 4**). As base, at estimations of the criterion, is chose design $\boldsymbol{A}$. Geometric features are valued upon their advantage (+) and defect (−). The features design, obviously not by specialists as advantage or defect, are conditionally evaluated neutral (0), coming from that considerations that they specifically do not influence upon these features. The visualization of the qualitative estimation and analysis of the features in such a way allow to choose the directions of modeling of designs on advantage, and then to combination of design. They are hereinafter offered development of the models, on basic model, occupied 1–3 places with provision for their advantage.

5. Conclusions

The proposed constructive geometric model of mold board's working surface allows to develop the multifunctional tools applicable in agricultural, engineering, road building, mining, and municipal service industries and in other branches of machinery use. Parameterization of mold board's working surface relieves designers' work, increases the variants choice under developing mold board's working surface, and allows effectively to solve the constructive problems. The integration of geometric modeling systems (CAD) and methods allows the efficient use not only in designing process and but also in production and maintenance processes of the technical facilities. Creating the product's geometric database by CAD technologies became one of the necessary tasks of production, particularly engineering products. In contemporary conditions of using CALS technologies, "conceptual design" stage of innovative product by methods and facilities of geometric modeling is the defining stage of the product life cycle. The visualization of the design-development process allows to develop a new product according to maintenance criterions. Efficient use of this method reduces design process time, labor, and material costs during the development of a new product.

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