Parametric Modeling in CAD Programs for Plow Design

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Abstract: This article provides a brief analysis of research and development in agricultural engineering, including parametric modeling. The main advantages of parametric modeling are indicated, promising methods for designing plows in the conditions of Uzbekistan are analyzed. Parametric modeling of plows is considered with the aim of optimizing their design to create more efficient, adaptable and productive plows. An analysis of the role of automated design systems in the fast and high-quality production of a new product is given. The factors influencing the increase in design efficiency and acceleration of product manufacturing time are analyzed. The problem of designing plow bodies, which are the main working parts of the plow and have a complex working surface, is considered. The main dependencies are presented that describe the radius and the height of the center of the circle, the radius of the guide curve, as well as intermediate values of the angles of the generatrixes with the wall of the furrow. Parameters such as the working width of the plow body, the working depth, the angles of inclination of the forming furrows to the furrow wall, and the angle of installation of the plowshare blade to the bottom of the furrow were analyzed. Using CAD software, a flowchart was drawn up for the parametric modeling of the plow body. By changing the input parameters, it is possible to construct a furrow profile, a frontal contour and a horizontal projection of the plowshare and blade, and a graph of changes in the angles of the generatrixes with the wall of the furrow. A graphic image was obtained - a 3D model of plow bodies of various designs, such as universal and cultural. It is possible to obtain preliminary data on the mass of the plow body, the area of the working surface, and the coordinates of the plow body center of gravity. It is shown that this method of construction and mathematical calculations are easily amenable to automatic calculation and drawing in educational and research processes. In addition, the presented modular system will significantly improve the production and adaptability of plows, providing the ability to readjust them for specific working conditions.

1 INTRODUCTION

The most important solution to the problems of creating and improving soil cultivation tools is to substantiate the rational forms of their working surfaces. In this direction, conducting targeted research on creating forms of working surfaces of tillage implements that carry out high-quality implementation of the technological process in accordance with agrotechnical requirements with minimal energy costs is an urgent task and requires a practical solution. According to the existing practice of designing soil-cultivating implements, there is usually no justification for the geometric parameters of the surfaces of their working bodies. The working surface is taken from the number of ready-made analogue surfaces. Graphic-analytical methods for designing surfaces require a lot of computational and graphic work and do not make it possible to justify surface parameters, both from the point of view of meeting agrotechnical requirements and energy costs. It is possible to improve the agrotechnical and energy performance of the created working bodies through the use of computer modeling methods and tools. Modeling the surface of the working body of a tillage implement will allow you to: describe the geometry of the surface and its changes when varying parameters; identify connections between the

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geometric parameters of the surface and the agrotechnical and energy characteristics of the working body; evaluate options for working surface geometry at the design stage.

Let's consider parametric modeling, i.e. modeling using the parameters of model elements and the relationships between these parameters. This allows you to examine various design schemes in a short time by changing parameters or geometric relationships and avoid fundamental errors (Maslov, 2019; Azimov et al., 2020). Parametric modeling differs significantly from conventional 2D drawing or 3D modeling. In the case of parametric design, the designer creates a mathematical model of objects with parameters, when changing which changes the configuration of the part, mutual movements of parts in the assembly, etc.

There are 2D parametric modeling and 3D parametric modeling. Parameterization of 2D drawings is usually available in medium and heavy-duty CAD systems. However, these systems rely on three-dimensional design technology, and the possibility of parameterizing two-dimensional drawings is practically not used. 3D parametric modeling is a much more effective (but also more complex) tool than 2D parametric modeling. The existence of a parametric description of an object is the basis for the entire design process1 (Jagtap et al., 2021).

Parametric modeling plays a very important role in creating and automatically updating high-quality models in product design. Using this method, the production process can be analyzed and optimized. Parametric modeling can be briefly explained in the following areas:

1. Process modeling. Parametric modeling allows you to accurately describe production processes. Using parameters, you can model different stages of the process and connect them with each other. For example, you can analyze the process by parameters such as hardness, temperature, time, pressure.

2. Optimization. With parametric modeling, parameters can be changed to improve process efficiency. This helps achieve goals such as increasing production speed, reducing costs or improving quality.

3. Simulation. Simulation can be used to simulate how a process operates under different conditions. This helps to identify problems that may arise in the production process in advance and create a plan to solve them.

4. Decision Making: Parametric modeling can be used to predict the impact of decisions made during a manufacturing process. This allows you to analyze the results of decisions and choose the best option.

5. Process monitoring and analysis. Process changes can be monitored and analyzed using parametric modeling. This is useful for quickly responding to changes and ensuring process stability.

Through parametric modeling, manufacturing processes become more efficient and easier to manage, which improves overall production quality and efficiency. Parametric models provide ease of automated changes, instant updates, and optimized design. The main goal of this method is to simplify the geometric shape of the product, conduct comparative control of properties and optimize the system (Blednykh and Khudyakov, 1989; Makarova, 2000).

Modern engineering production is characterized by the complexity of product design and rapid change of products, as well as short production times. In such conditions, it is necessary to speed up production and increase its efficiency, as well as ensure the competitiveness of products (Hedau et al., 2023). The design stage is a complex, labor-intensive stage in the production of a new product. The main time and material costs when introducing a new product into production are spent on the design process. Therefore, the role of automated design systems in the fast and high-quality production of a new product when automating the design process is invaluable (Juraev et al., 2019).

2 MATERIALS AND METHODS

Parametric modeling in CAD programs is important in the development of various new equipment designs in agricultural engineering. The complex surface of the working bodies when cultivating the soil determines the quality of the work process (Alimova, 2023). For example, the process of designing the working surface of a plow body is a complex and time-consuming process.

For parametric modeling when designing the plow body, the method of graphically constructing working surfaces using one guide curve and a given law of changing the angle of the generatrices with the field side was used. This method was developed for the design of cylindrical working surfaces of plough-bodies (GOST 65-62). Graphic techniques are based on the theory of working surfaces of plow bodies and basic relationships established experimentally. Analytical design of a working surface according to given agrotechnical indicators is associated with great difficulties, since they require studying the relationship between the geometric parameters of the surface and the quantitative characteristics of the resulting treatment.

The general procedure for designing all mouldboards is the same, only some values taken at the beginning of the calculation differ. First, construct a frontal projection of the plough-body contour and projections of the generatrices on it, then horizontal projections of the generatrices and plough-body contour, projections of vertical sections of the plough-body surface perpendicular to the direction of movement when plowing, and vertical sections perpendicular to the ploughshare blade. The initial data for constructing the working surface of any type of mouldboard are the plowing depth and the width of the layer (Primkulov et al., 2022; Alimova et al., 2024).

In addition, based on existing data developed by practice, parameters characterizing the installation of the ploughshare are specified, i.e. angle θ_0 of installation of the ploughshare to the wall of the furrow, angle ɣ of installation of the ploughshare to the bottom of the furrow, as well as angles θ_{min} and θ_{max}. We consider the given agrotechnical parameters of the plow body design to be variable.

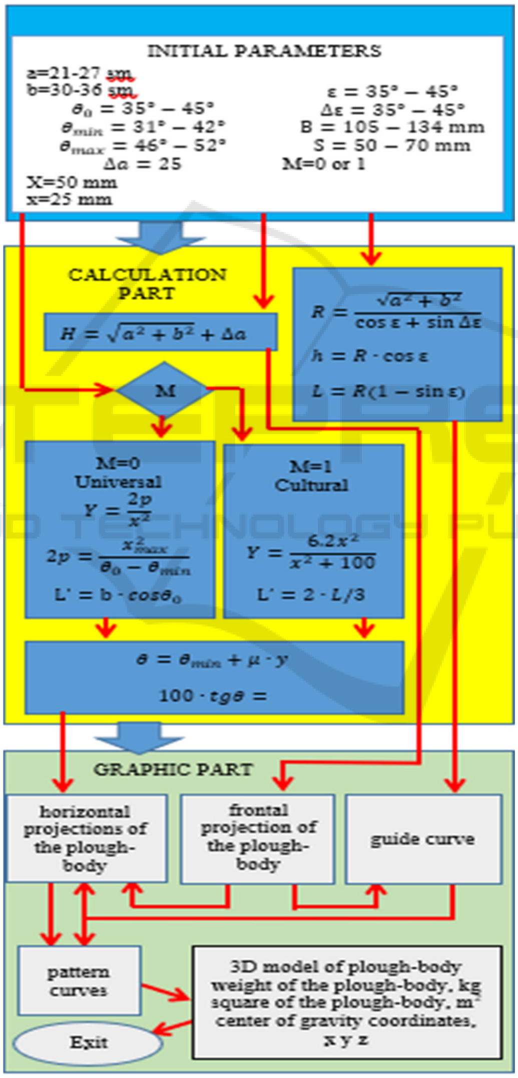


Figure 1: Block diagram of algorithm for parametric modeling of the plough-body.

3 RESULTS AND DISCUSSION

To create an automatic design program for the plough-body, we can use the KOMPAS 3D program, which is part of the CAD software.

Sequence of creating an automatic design program

1. The parametric mode command is launched in the drawing section of the KOMPAS 3D program;

2. Using the change command in the drawings section of the KOMPAS 3D program, enter the specified parameters and formulas used in the design (Fig. 1). In the drawings section of the KOMPAS;

3D program, the dimensions of each line used in the design of the plough-body are entered into functional connections using specified parameters or directly specified parameters;

4. We create new working documentation through the “Create” department for the design of the plough-body in the KOMPAS 3D program;

5. To create the plough-body, use the commands in the Frame and surfaces section;

6. This command creates parallel planes by entering the distance between the planes;

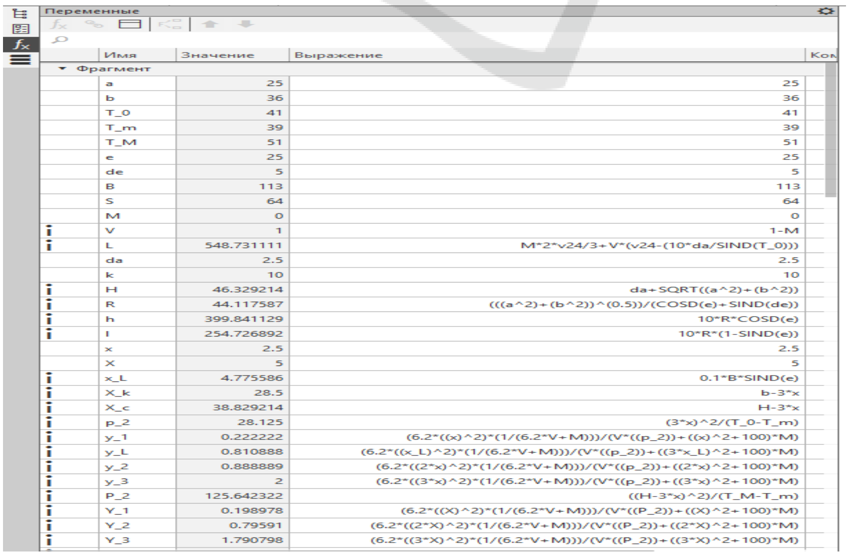
7. In the process of designing a plough-body based on design rules, we use pattern curves, where each pattern curves is placed on parallel planes;

8. At the next stage, we connect the curves of the model using the commands “Surface truncation” and “Surface along a network of curves” and create the working surface of the plow body.

9. The thickness of the surface is added to the resulting working surface using the Fiberboard Add Thickness command and a 3D model of the plow body is created.

Table 1: Table of entered and received results.

Initial parameters		
Mouldboard type	Cultural	Universal
Working width	0.36 metr	0.32 metr
Plowing depth	0.25 metr	0.22 metr
Θ_0	37º	41º
Obtained parameters		
Weight	10.067 kg	13.098 kg
Square	0.375 m^2	0.495 m2
Center of gravity coordinates	x=127.564 mm y=484.109 mm z=99.684 mm	x=167.564 mm y=514.109 mm z=130.684 mm


Переменные

Имя	Значение	Выражение
Фрагмент		
a	25	25
b	36	36
T_0	41	41
T_m	39	39
T_M	51	51
e	25	25
de	5	5
B	113	113
S	64	64
M	0	0
V	1	1-M
L	548.731111	M*2*v24/3+V*(v24-(10*da/SIND(T_0)))
da	2.5	2.5
k	10	10
H	46.329214	da+SQRT((a^2)+(b^2))
R	44.117587	(((a^2)+(b^2))^(0.5))/(COSD(e)+SIND(de))
h	399.841129	10*R*COSD(e)
l	254.726892	10*R*(1-SIND(e))
x	2.5	2.5
X	5	5
x_L	4.775586	0.1*B*SIND(e)
X_k	28.5	b-3*x
X_c	38.829214	H-3*x
p_2	28.125	(3*x)^2/(T_0-T_m)
y_1	0.222222	(6.2*((x)^2)*(1/(6.2*V+M)))/(V*((p_2))+((x)^2+100)*M)
y_L	0.810888	(6.2*((x_L)^2)*(1/(6.2*V+M)))/(V*((p_2))+((3*x_L)^2+100)*M)
y_2	0.888889	(6.2*((2*x)^2)*(1/(6.2*V+M)))/(V*((p_2))+((2*x)^2+100)*M)
y_3	2	(6.2*((3*x)^2)*(1/(6.2*V+M)))/(V*((p_2))+((3*x)^2+100)*M)
P_2	125.642322	((H-3*x)^2)/(T_M-T_m)
Y_1	0.198978	(6.2*((X)^2)*(1/(6.2*V+M)))/(V*((P_2))+((X)^2+100)*M)
Y_2	0.79591	(6.2*((2*X)^2)*(1/(6.2*V+M)))/(V*((P_2))+((2*X)^2+100)*M)
Y_3	1.790798	(6.2*((3*X)^2)*(1/(6.2*V+M)))/(V*((P_2))+((3*X)^2+100)*M)

Figure 2: Entering parameters using the variables command.

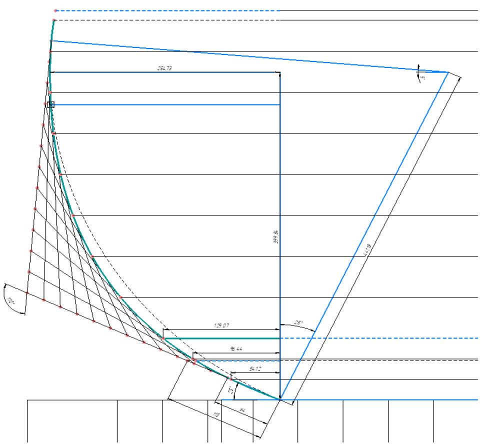


Figure 3: Construct of guide curve.

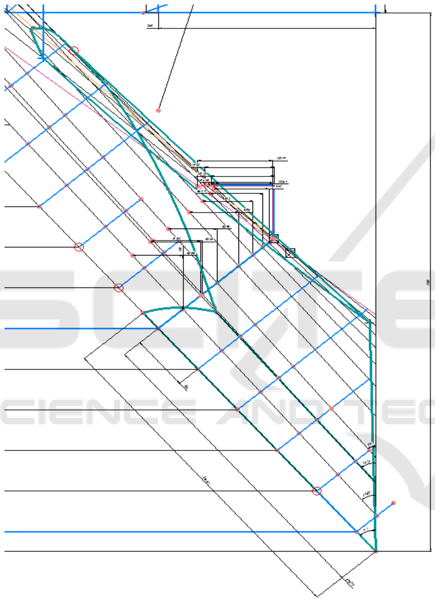


Figure 4: Construct of horizontal projection of mould board when M=0.

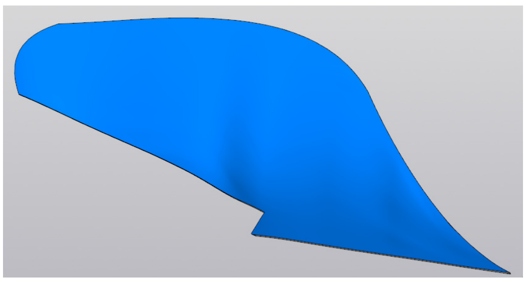


Figure 5: Model of the plough-body obtained as a result of using a computer-aided design program.

4 CONCLUSIONS

By learning deeply about computer-aided design systems, other types of functionally related design processes can be easily automated.

Through an in-depth study of parametric modeling in CAD programs, it is possible to automate complex design processes with other types of functional connections, determine metal consumption in advance and select the appropriate type of production for the project.

As parametric modeling becomes more important in the latest CAD programs, this method remains an important part of the design editor with advanced features for design acceleration, automatic updates and feature monitoring.References

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