REPUBLIC OF AZERBAIJAN

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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

AUTOMATION OF THE DESIGN OF THE WORKING BODY FOR THE CLEANING OF CHANNELS AND DITCHES

Specialty:	3338.01 - Systems analysis, control, and information processing (modeling and control)
Field of science:	Technical sciences
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The work was performed at the department of "Information technologies and systems" of the Azerbaijan University of Architecture and Construction.

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GENERAL CHARACTERISTICS OF THE WORK

Relevance of the topic and degree of elaboration.

In the modern era, the fundamental and comprehensive development of road infrastructure and agriculture, which is one of the leading directions of the republic, requires, along with other areas, the reconstruction and efficient use of systems intended for irrigation and protection of road surfaces. The adoption of a new concept of agricultural development in the republic has made it necessary to increase attention to this area. For this purpose, the proper use and exploitation of existing melioration irrigation systems is emerging as the most urgent issue of the day.

The majority of agricultural products in our republic are produced in areas with extensive irrigation systems. In this regard, the use of existing irrigation systems, collector-drainage networks, and the cleaning and repair of channels are important issues.

Since the drainage networks of existing channel consist of a large number of mechatronic dynamic components, the application of modern CAD/CAM automated design systems for the development of their new designs, preparation of technological reports, selection of electronic parts, design of precise measurement, regulation, control and execution mechanisms, and determination of functional characteristics can be very important in solving this problem.

Unlike earthen channels, certain technical problems arise in the process of cleaning concrete channels. Currently, concrete channels in the republic are cleaned with a single-bucket excavator or by using manual labor. The use of single-bucket excavators damages and destroys concrete covers, while the use of manual labor reduces productivity.

Object and subject of the research. The dissertation work is dedicated to the design process of the control system for the working mechanism that cleans the channels and ditches used in irrigation systems, specifically for the drainage of water, which is applied in the republic’s agricultural and road infrastructure development. The goal is the development of automated design tools for the regulating components of the working mechanism that cleans the channels and ditches.

Purpose and objectives of the research. The purpose of the work is the development of automated design tools for the improvement of the structural, technological, and design characteristics of the regulating components of the working mechanisms that clean the channels and ditches in the fields of road infrastructure and agriculture.

Research methods. Based on the topic of the work, literature sources and internet resources were searched and studied; the information, mathematical, and design-oriented tools of automated design systems were analyzed, and algorithmic and mathematical calculations were carried out using CAD/CAM, MATLAB, Solid Edge, and SolidWorks 3D software tools, with their practical results obtained through comparison.

Research methods. Based on the topic of the work, the search and study of literature sources and internet resources, the analysis of information, mathematical, and design-oriented tools of automated design systems, and algorithmic and mathematical calculations were carried out using CAD/CAM, MATLAB, Solid Edge, SolidWorks 3D software tools, with their practical results obtained through comparison

Main provisions submitted for defense:

1. Setting the overall purpose of the work and defining research tasks based on the analysis of automated design tools for the regulating device of the working mechanism that cleans channels and ditches for road infrastructure and agriculture;

2. Development of information, mathematical, and software tools based on the automated design stages of the regulating device of the working mechanism that cleans channels and ditches for various road infrastructure and agricultural areas;

3. Development of the general architecture of support tools for automating the design process of the regulating device of the working mechanism that cleans channels and ditches for road infrastructure and agriculture, based on the principles of universality and transparency;

4. Development of algorithmic support for analyzing the design stages of the regulating device of the working mechanism that cleans channels and ditches for agriculture and road infrastructure;

5. Development of algorithmic and mathematical support tools to study the technological and functional characteristics of the regulating device of the working mechanism that cleans channels and ditches;

6. Development of information support and its tool algorithms to ensure the automation of the design process of the regulating device of the working mechanism that cleans channels and ditches for agriculture and road infrastructure;

7. Development of general software, consisting of design, simulation, and animation program modules, to automate the design of the regulating device of the working mechanism that cleans channels and ditches.

Scientific novelty of the research

Scientific novelty of the dissertation work include:

1. Models of the database of data and knowledge were developed for the automation of the design of the regulating device of the working mechanism that cleans channels and ditches installed in agricultural fields;

2. Technological and design sketch projects of the application object were developed for the automation of the design of the regulating device of the working mechanism that cleans channels and ditches installed in agricultural fields;

3. Algorithmic and mathematical support tools were developed for the functional analysis of the regulating device of the working mechanism that cleans channels and ditches installed in agricultural fields;

4. A design modeling tool was developed for the regulating device of the working mechanism that cleans channels and ditches installed in agricultural fields.

Theoretical and practical significance of the research. The information, algorithmic, mathematical, and software tools of the proposed automated design system for regulating the working mechanism that cleans channels and ditches used in various types of agricultural fields are based on the principles of intelligence, universality, and transparency. The proposed automated design tools are included in a comprehensive managed software structure and are suitable for application in the development of the regulating device of the working mechanism that cleans channels and ditches in different agricultural systems.

Approbation and application. The main results of the work have been published in the materials of the following conferences: Building Innovations-2018, I International Azerbaijan-Ukraine Conference (Poltava, May 24–25, 2018); International Scientific-Practical Conference on the Application Opportunities and Prospects of Information Technologies and Systems in Construction (Baku, January 12–14, 2018); Republican Scientific Conference on Artificial Intelligence and Its Application Areas (Sumgayit, December 18–19, 2023); LXI International Scientific-Practical Conference "Advances in Science and Technology" (Moscow, June 1–2, 2024); and International Scientific Conference “Artificial Intelligence: From Theory to Practice” held at Nakhchivan State University (Nakhchivan, September 17–18, 2024).

Name of the organization where the dissertation work was carried out. The dissertation was carried out at the department of Information technologies and systems of the Azerbaijan University of Architecture and Construction.

Volume and structure of the dissertation work. The total volume of the dissertation is 177,336 characters (title, table of contents, and introduction – 34,511 characters; Chapter 1 – 37,498 characters; Chapter 2 – 34,327 characters; Chapter 3 – 29,767 characters; Chapter 4 – 41,233 characters). The dissertation consists of an introduction, four chapters, a conclusion, a list of 155 references, and appendices. The dissertation includes 169 pages of text and 33 figures.

CONTENTS OF THE WORK

In the introduction, based on the topic of the dissertation work, the relevance of the scientific problem was determined, the purpose and main tasks of the work were defined, the scientific innovations, practical significance, main provisions submitted for defense, and a brief summary of the issues considered in each chapter of the dissertation work were presented.

In the first chapter, the current state of literature sources on the development of information, mathematical, algorithmic, and software tools for the automated design of the regulating device of the working mechanism that cleans channels and ditches was analyzed; the research tasks were determined and the main purpose of the work was defined based on a comparative analysis of existing methods and tools[1].

The second chapter is devoted to the study of the design stages of the working mechanism of the device that cleans channels and ditches and the development of information support. In the automated design stages of the regulating device of the working mechanism that cleans channels and ditches, the study of specific procedures and operations was carried out, and the general structure of the design process was determined. This chapter also addresses the issue of creating and applying the main support tools during the design stages[2].

The issues of analysis, search, and selection of comprehensive automated design systems, from the selection of elements of channels and ditches that supply water to agricultural fields to their testing in the water supply environment, were examined. The main strategy and new requirements for the creation and implementation of the

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[1] Əmirbəyova, N. S. Kanal və küvetləri təmizləyən işçi orqanın tənzimləyən vasitənin funksiyalarının modelləşdirilməsi və kompüter eksperimentləri ilə tədqiqi / N.S. Əmirbəyova // Elmi xəbərlər. Təbiət və Texniki Elmlər Bölməsi. – 2024. – Vol. 24, No. 2. – P. 82-90. – DOI 10.54758/16801245_2024_24_2_82. – EDN ULCHMV. https://elibrary.ru/item.asp?id=71240198

[2] Амирбаева, Н.С. Вопрос создания информационного обеспечения для проектирования каналов водоснабжения и их очистительных устройств // «Advances in Science and Technology» LXI Международная научно-практическая конференция. –Москва, –15 июня, –2024. –с. 91-94.

automated design system (ADS) were determined. At these stages, the development of mathematical models and logical algorithms, the programming of design projects, and the conduct of experiments in a computer environment were addressed.

At the sketch design stage, the formulation of design tasks, determination of solutions, and the mathematical analysis of the development of the required devices and equipment, as well as their modern control systems, to ensure the water supply and cleaning of agricultural fields were carried out.

The dependency formula of the tools of the ADS, formed on the basis of design operations and procedures automated by existing methods, is expressed as follows:

$$\forall(LƏ_i \wedge LP_j) \in((\{LƏ\} \wedge \{LP\}) \exists A_k \in \{A\} \quad (1)$$

where, $i = \overline{1,n}, j = \overline{1,m}, k = \overline{1,p}\ p < n, p < m$ – are the sets of design operations, procedures, and tools, respectively.

In this case, the design operations (LƏ) and design procedures (LP) do not belong to the automated design tools (A) of the channel and ditch cleaning equipment, that is:

$$min\,\{(LƏ\ /\ A) \wedge (LP\ /\ A)\} = \{(LƏ_r\ /\ LƏ_r \in LƏ) \wedge (LP_s\ / \\ /\ LP_s \in LP)\}, \quad (2)$$

where, $r = \overline{1,t}, s = \overline{1,f}, t = n - p, f = m - p.$

During the operation of the milling thrower, it is also considered appropriate to use the SPK-207 type sensor panel for programming. This controller, based on wireless technology, operates with remote control during the work process. At the same time, Codesys software tools, which maximally comply with the MEK 61131 standard, can also be used[3].

[3] Quliyev, Z.H., Əmirbəyova, N.S., Tağıyeva, V.R. SPK-207 tipli sensorlu panel proqramlaşdırılan məntiqi kontrollerin istilik qazan qurğusunun avtomatlaşdırılmasına tətbiqi // İnşaatda informasiya texnologiyaları və sistemlərinin tətbiqi imkanları və perspektivləri Beynəlxalq elmi-praktik konfransın materialları. –Bakı, –2018. –s. 56-59.

The classic structure of an automated design tool for an application object created using a hierarchical method includes subsystems of technical, software, information, mathematical, and algorithmic support.

Based on theoretical and experimental studies, a special algorithmic control of the main, constructive, and technological parameters of the milling thrower type working mechanism for cleaning channels and ditches was carried out in MATLAB. For the first time, control and regulation of the processes performed by the working mechanism were achieved.

Depending on the speed of the technological process, it was possible to enable the milling thrower to throw the soil to the designated distance[4].

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[4] Əmirbəyova, N.S. Nişanlanmış atılma məsafəsi olan işçi orqanın idarəetmə alqoritminin qurulması // Building Innovations-2018. I Beynəlxalq Azərbaycan-Ukrayna Konfransının elmi materiallar toplusu, –24 мая, –2018. с. 34-37.

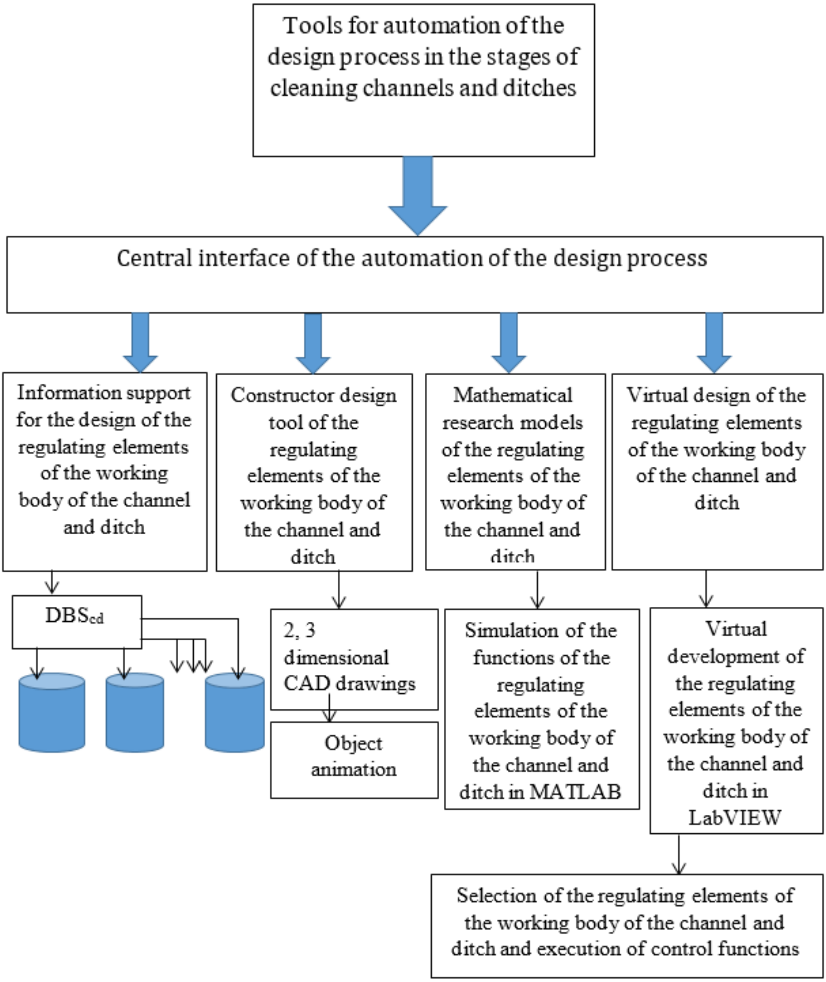


Figure 1. Structural diagram of the tools for automating the design process of the regulating elements of the working mechanism of a channel and ditch

In the second chapter, the modeling of the functions of the regulating device of the working mechanism that cleans channels and ditches and their investigation through computer experiments were examined.

In the process of designing the channel-cleaning device, particularly at the stage of developing draft projects, algorithmic research was carried out with the aim of increasing the operability of the device's parts and improving their quality, and the control process was checked through computer experiments.

In the design process of the channel-cleaning device, particularly at the stage of developing sketch designs, algorithmic research was carried out to improve the operability of the device's components and enhance quality, computer experiments were conducted to test the control process[5].

During the experimental process, the adaptation of the elastic part at the tip of the blade to the corresponding force and its effect on the quality of weed removal were extensively studied. An algorithm was proposed to ensure accurate conduct of the experimental study.

As a result, an increase in the area of the thrown mass occurs. Based on the study of indicators obtained during experimental research through computer experiments, several dependency equations were derived to determine the required power of the working mechanism more precisely.

During the research, the effect of soil moisture at various forward speeds on the power required by the working mechanism and the base machine was investigated. Based on the proposed production-type model, the information support of the control system for more efficient execution of the operations of the regulating device of the working mechanism used for cleaning channels and ditches was developed.

As the length of the rods is increased up to $l_f = 0.02$ m, due to the deformation of the elastic element of the force, an increase of the

[5] Hacıyev A.M., Feyzullayev E.N., Əmirbəyova N.S. Sement zavodunda klinkerin alınması texnoloji prosesinin idarəetmə alqoritminin işlənməsi // İnşaatda informasiya texnologiyaları və sistemlərinin tətbiqi imkanları və perspektivləri Beynəlxalq elmi-praktik konfransın materialları, Azərbaycan Memarlıq və İnşaat Universiteti, –Bakı, –2018, –№1(3000), –s. 178-180.

force up to $l_f > 0.02$ m is observed, and, by rubbing against the concrete layer, an increase is observed based on the required force.

Based on technological measurements, it was determined that the required power of the elastic element constitutes 8–11% of the total power of the cleaning device. In this case, other parameters do not change and remain constant.

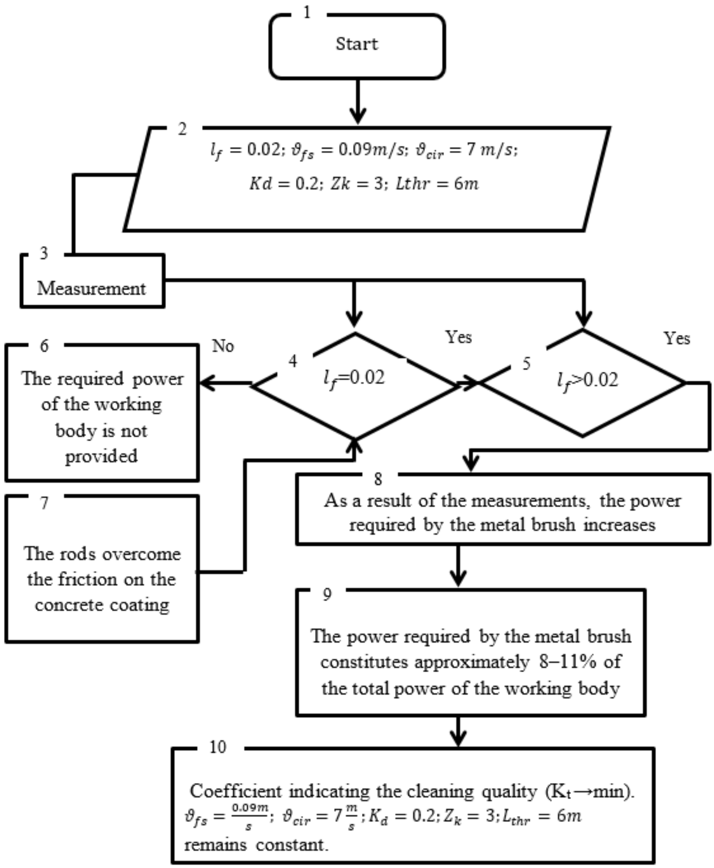
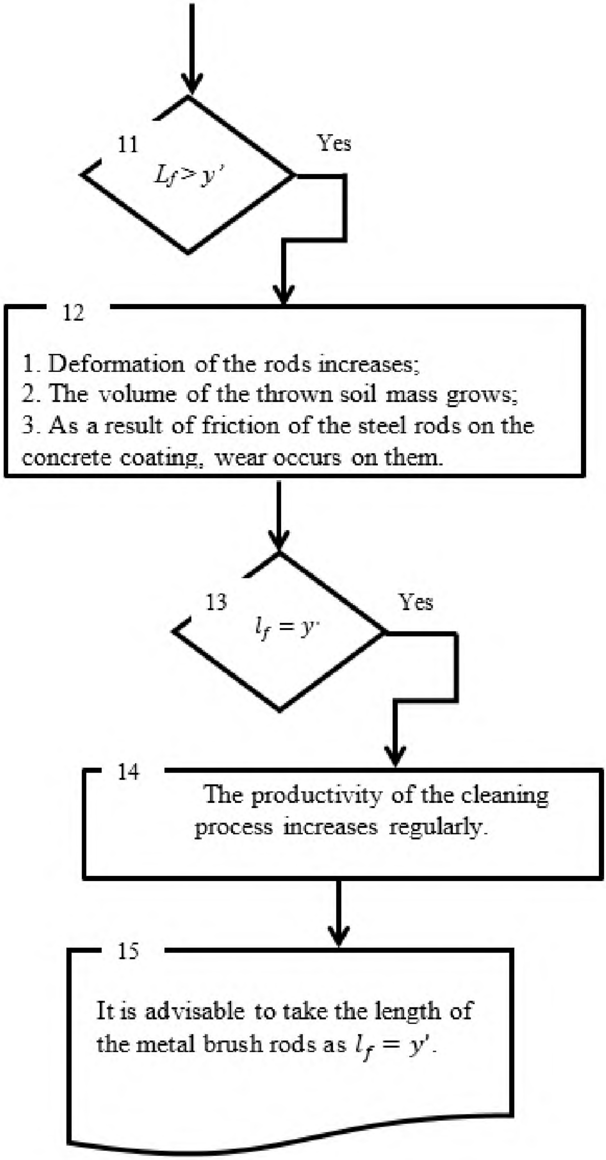


Figure 2. Algorithm for selecting the length of the steel rods of the metal brush affecting productivity and the quality of channel cleaning



Continuation of Figure 2

As a result of the research, it was determined that the variation in the length of the steel rods significantly affects the quality of channel cleaning. The length of the rods is accepted as up to l_f=0.02 m. The dependency indicators based on the length of the metal brush rods are determined with the following values:

$$\vartheta_{fs} = 0.09m/s; \quad \vartheta_{cir} = 7\ m/s;$$

$$K_d = 0.2;\ Z_k = 3;\ L_{thr} = 6m$$

As a result of studying the indicators obtained during experimental research through computer experiments, several dependency equations were derived to determine the required power of the working mechanism more accurately.

The dependence of the required power for the working mechanism on the forward speed of the machine is determined by the following indicators:

$$\vartheta_{cir} = 7\ m/s;$$

$$Z_k = 3;$$

$$b_d = 0.4m;$$

$$H_k = 0.6m;\ a = 45;\ b = 18.76\%\ ;$$

$$z = 1515\ kq/m^3;\ k = 180000\ H/m^3;\ m^2 K_d = 0.2\ ;\ N = 0.3725.$$

To study experimentally the effect of soil moisture on the power required by the working mechanism during the cleaning of concrete-lined irrigation channels with a milling thrower, the analysis of the following initial data is required:

a - the overall condition of the cleaning process;

b – the condition of the channel after cleaning.

During the research, the effect of soil moisture on the power required by the working mechanism and the base machine at different forward speeds was studied. The initial data at different forward speeds are entered in the following implication form[6]:

[6] Qasımov A.F., Əmirbəyova N.S. Beton örtüklü kanalları lildən təmizləmək üçün işçi orqanın əsas konstruktiv parametrlərinin təyin olunması // Ümummilli lider Heydər Əliyevin anadan olmasının 87-ci ildönümünə həsr olunmuş Tələbə və magistrantların XXXII elmi konfransının materialları, II hissə, Azərbaycan Memarlıq və İnşaat Universiteti, –Bakı. –10 may, –2010 –№1(2000), –s.19

Production 1

IF $\upsilon_{fs} = 0.05\, m/s$ *and* $\upsilon_{fs2} = 0.09\, m/s$ *soil moisture changes occur,*

THEN the power acting on the machine's actuating element becomes variable.

ADDITIONALLY, IF the soil water balance is less than 14%,

THEN the shear resistance for its strength indicator increases

AND the power required by the working mechanism increases.

IF the moisture exceeds 19%,

THEN adhesion of soil to the blades of the milling thrower occurs.

This primarily worsens soil cutting and, at the same time, its free accumulation on the blades of the milling thrower. Therefore, the required power also increases. The minimum power required by the working mechanism occurs when soil moisture is in the 14...19% range.

Accordingly

IF soil moisture is in the 14...19% interval,

THEN adhesion of soil to the blades of the milling thrower does not occur during the operation,

AND the working mechanism is not subjected to additional load.

As soil moisture increases, its stickiness and friction coefficient increase up to a maximum limit. With further increase in moisture, these factors gradually decrease due to the formation of a free water layer on the soil surface. This water layer acts as a sliding interface between the surfaces in contact. Therefore, the soil moisture (J_n) during the cleaning of the ditch is represented as follows:

$$14 \leq J_n \leq 19\%$$

IF $(J^n\_max = 19\%) \leq \{20, 21, \ldots\}$*,*

THEN during the operation of the cutter and thrower, contamination of the ditch and surrounding areas occurs due to the throwing of wet soil to the edges.

As a result of changing the number of revolutions (n_f) of the milling thrower's actuating mechanism, the energy indicator affects the distance and dispersion of the thrown soil. During experimental research, it was found that changing the number of revolutions of the milling thrower affects its productivity. As the number of revolutions of the milling thrower increases, the throwing distance of the soil also increases. Then, the production model is written as follows:

Production 2

IF the number of revolutions n_{f1} *= 130 rev/min,*

THEN the soil throwing distance $L_{thr} = 4.2m$.

IF the number of revolutions n_{f2}*=260 rev/min,*

THEN the soil throwing distance $L_{thr} = 8.7\ m$.

From this, we can conclude that as the number of revolutions of the milling thrower increases regularly, the soil throwing distance increases more rapidly.

As a result of throwing wet soil, uneven distribution of the soil occurs. Small particles of the thrown soil are thrown to the nearby area of the channel, while large particles are thrown to distant areas.

During the operation of the cutting tool, due to the low number of revolutions of the actuating mechanism, certain particles of the thrown wet soil are scattered to the edge of the channel. In this case, the decision-making algorithm of the control system is written as follows:

IF the number of revolutions $n_{f3} = 155$ *rev/min,*

THEN the soil throwing distance is $4.7 \leq L_{thr} \leq 6.5\ m$.

IF the number of revolutions $n_{f4} = 260$ *rev/min,*

THEN the soil throwing distance is $L_{thr} = 8.7\ m$.

IF the number of revolutions $n_{ft} \geq \{n_{f1}, n_{f2}, n_{f3}, n_{f4}\}$,

THEN the power $N_{t.un}$ *spent on throwing the soil increases.*

The circumferential speed of the milling thrower (ϑ_{cir}) is determined according to the required throwing distance of the soil, provided that it has low energy consumption during the cleaning process:

Production 3

IF the number of revolutions $n_{f5} = 100\ rev/min$,

THEN the power of the working mechanism $N_{t.un} = 3.38\ kW$ *is required.*

IF the number of revolutions $n_{f5} = 200\ rev/min$, *THEN the power of the working mechanism* $N_{t.un} = 4.61\ kW$ *is required.*

IF the number of revolutions is – $2\ n_f$,

THEN the power of the working mechanism $N_{t.un}$ *→ min increases.*

IF despite the increase of the number of revolutions in $2\ n_f$,

AND $\vartheta_{fs} = 0.09\ m/s$

AND $K_d = 0.2$ *AND the number of blades of the milling thrower* $Z_k = 3$

THEN the productivity approaches →0.

THEN the energy indicator of the milling thrower increases significantly.

For the automated design of the regulating device of the working mechanism of the channel and ditch, a database management system (DBMS) has been created based on the information support databases.

Based on the technological and design features of the application object, and on the characteristics of functional, design, and material technologies, a knowledge base from expert knowledge for the decision-making of the working mechanism's regulating process has been created.

The third chapter is devoted to the creation of the mathematical support for the functional and technological design of the working mechanism of the device that cleans channels and ditches.

Based on the analysis of concrete-coated channels and their cleaning issues, solutions to the problem have been identified. At the initial stage, new forms of channel construction are designed, with the upper surface of the channels covered with reinforced concrete and the framework built with reinforcements.

The depth of the channel varies in the range of 0,6÷1,6 m[7]. The top coverings are installed in the inclined layers of the irrigation

[7] Muradağayev M.S., Əmirbəyova N.S. Ağır mineral qruntlarda ensiz xəndəkli drenaj qazan maşının əsas parametrlərinin təyini // Ümummilli lider Heydər Əliyevin anadan olmasının 87-ci ildönümünə həsr olunmuş Tələbə və magistrantların XXXII elmi konfransının materialları, II hissə, Azərbaycan Memarlıq və İnşaat Universiteti, –Bakı, –10 may, –2010, –№1 (2000), –s.17-18.

channels using DN500 H775 grade concrete slabs. The technical characteristics of the concrete (compressive strength, impermeability, frost resistance, etc.) make it possible to produce a durable and long-lasting coating.

As a result of the application of concrete-coated channel, irrigation of the agricultural lands in nearby areas does not exceed the norm, and water flooding is reduced.

During the design of the concrete-coated channel, the condition of the water flow and its distribution into the agricultural fields has been determined. The full restoration period of the intended service life of the concrete coatings is approximately 40...50 years, while the service life of the coatings themselves is 15...20 years.

For the automation of the process of selecting the main dimensions and carrying out the design of the concrete-coated channel, an algorithm in the form of a block diagram is proposed (Figure 3)[8].

[8] Əmirbəyova N.S., Əmirbəyov B.R. İnşaat armaturlarının tikinti konstruksiyalarında dartılmaya davamlılığının işlənilməsi və hesablama metodikası // Tikinti istehsalında texnoloji maşınların istifadəsinin müasir problemləri mövzusunda respublika elmi-praktiki konfransı, Azərbaycan Memarlıq və İnşaat Universiteti, –Bakı, –2019, –№1(8000), –s.45-48.

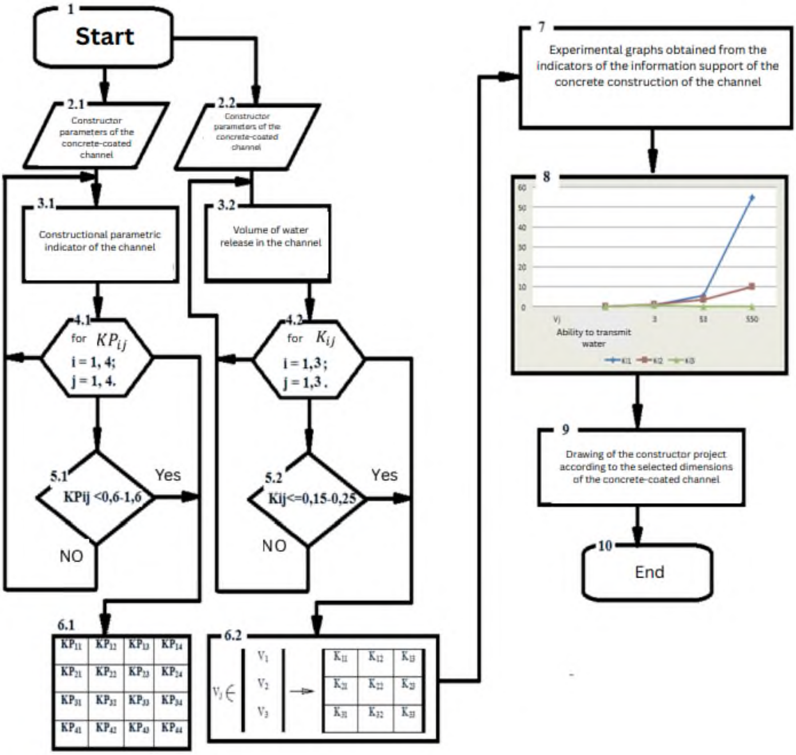


Figure 3. Block diagram for the automation of the process of selecting the main dimensions and construction design of the concrete-coated channel

During the operation of the cleaning device, since overloads act on the milling-cutting tool, the effect of the total power must be taken into account. In this regard, the indicator of the total power required for channel cleaning is calculated by the following formula:

$$N' = N_g + N_{tot} + N_{add} \tag{3}$$

Where,

$N_{tot} + N_{add} = N'$; N'– consists of the sum of the total power required by the milling thrower and the power required to overcome the additional load.

During the measurements, the movement speed of the diagram tape was taken as 5400 mm/hour in accordance with the standard. From equality (3), we can also write analogously:

$$N_{tot} = N - N_{add}$$
$$N_{add} = N - N_{tot}$$

The experimental studies were carried out in various variants by changing one of the values of the factors affecting the productivity, the required power, and the energy capacity of the milling thrower — ϑ_ir=0.01 ...0.07 m/s; Zk=2 ...6; t =10.5 ...26.2 s; nf=100 ...250 rev/min; l_f=0.02 ... 0.04 m; Hl=0.1 ... 0.6 m — while keeping the others constant. Based on these values, experiments were carried out affecting the power and energy capacity of the milling thrower.

Table 1.

Experimental database of values affecting the power and energy consumption of the milling thrower (number of blades of the milling cutter Z_k=*const*)

Parameter	1st indicator	2nd indicator	3rd indicator
ϑ_{ir}	0,02	0,04	0,06
Z_k	3	3	3
t	12	15	20
n_f	100	150	200
l_f	0,02	0,03	0,04
H_l	0,3	0,4	0,5

In the irrigation systems applied in agricultural fields, a technological analysis of the cleaning device in the channels was carried out, and it was determined that the efficient removal of polluted water from the channel, as well as the elimination of weeds and algae, depends on the configuration of the working mechanism's milling-cutting tool, the regulation of the mill's rotational speed, the machine's forward speed, and the power of the actuator.

To ensure these principles, a mathematical method was used in the design process of the cleaning device's working mechanism. The rotational speed of the mill, considered the cutting tool of the working mechanism of the channel and ditch cleaning device, is determined according to its peripheral speed.

The clay layers cut from the bottom and slope sections of the channel accumulate on the blades of the milling thrower until reaching the discharge boundary, i.e., the special window provided in the coating, and the discharge process is ensured. As the thickness of the channel's clay layer increases, the input parameters of power N_1 are increased, and the graphical characteristics of the experiment are constructed (Figure 4).

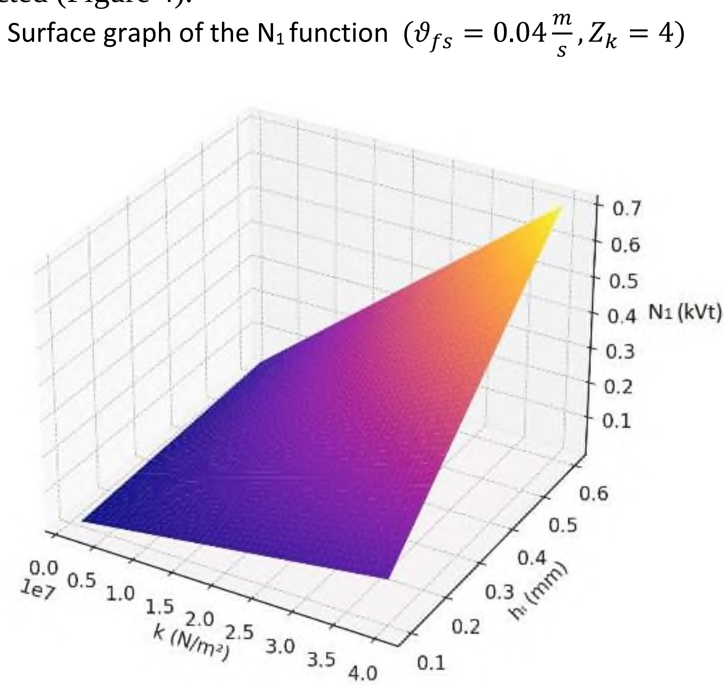


Figure 4. Graphical characteristics of the experiment with an increase in the input parameters of power N_1

To determine the power required to overcome the friction of the metal brush bristles on the concrete coating, it is first necessary to determine the force *P* pressing the bristles of the metal brush against the concrete surface.

Due to the influence of various factors, theoretically determining the force P is very complex; therefore, it can be more accurately established primarily through experimental methods. The factors affecting the force pressing the metal brush bristles against the concrete coating include, in particular, the diameter of the bristles, the modulus of elasticity of the bristles, their number, the resistance of the soil acting on them, the physical and mechanical composition of the soil being cleaned, the length of the bristles, their stiffness, the normal and tangential forces acting on the metal brush, the sliding–friction coefficient of the bristles on the concrete coating, the bending moment of the steel bristles, and so on. The total power N_{tot} can be determined as follows:

$$N_{tot} = \frac{(k \cdot h_l \cdot \vartheta_{fs} \cdot \pi \cdot R_f)}{5 \cdot 10^2 \cdot Z_k \cdot \eta} + \frac{P_t^f \cdot \varphi_0 \cdot g(2R_f + \text{У}' - \frac{1}{4} H_k)}{3{,}6 \cdot 10^6 \eta} + \frac{P_t^f \cdot f_0 \cdot \vartheta_{cir}^2}{7{,}2 \cdot 10^6 \eta} + \frac{P_t^f \cdot \Upsilon_0 \cdot f_0 [(R_f + l_f) - r_0] \alpha_1 \cdot \omega \cdot 0{,}3756}{1 \cdot 0{,}8 \cdot 10^6 \eta} + \frac{P_t^f \cdot \Upsilon_0 \cdot (R_f + l_f)^2 \cdot \left((0{,}67 + 0{,}33) \frac{r_0}{(R_f + l_f)}) \right) \cdot \omega^2 \cdot \Upsilon_0 \cdot \varphi_0 \cdot E_0}{3{,}6 \cdot 10^6 \eta} + \frac{P_t^f \ (\vartheta_{fs} + \vartheta_f)}{1000 \cdot \eta} \quad (4)$$

The fourth chapter is devoted to the development of software for the automated design of the channel and ditch cleaning device[9].

In Chapters 2 and 3, the task of developing general and special-purpose software tools for the automation of the information and mathematical support of the mechatronic components of the cleaning device was set. The structure of the software for the automated design of the mechatronic components of the cleaning device has been proposed.

[9] Əmirbəyova N.S. Kanal və küvetlərin təmizlənməsi üçün işçi orqanın idarəetmə sisteminin proqram təminatının layihələndirilməsi // “Süni İntellekt:nəzəriyyədən praktikaya” beynəlxalq elmi konfrans. Naxçıvan Dövlət Universiteti, –Naxçıvan – 17-18 sentyabr, –2024.

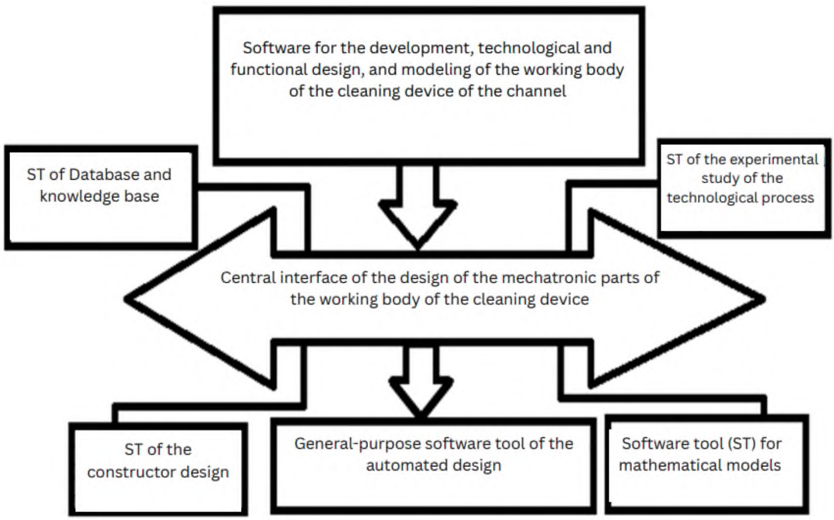


Figure 5. General structure of the software for the automated design of the mechatronic components of the channel cleaning device's working mechanism

Using specialized mathematical software tools for programming mathematical models, computer experiments were conducted in the MATLAB system, and the results of solving the following tasks were obtained:

In the first mode, the graphical characteristics of computer experiments of the mathematical model for regulating the number of revolutions and the power required for cutting soil with the working mechanism's milling-cutting tools were constructed;

In the second mode, an experimental graphical characteristic of the results of the mathematical model of regulating the power and number of revolutions expended for raising the working body with milling-cutting tools up to the level of loosening the soil has been constructed;

In the third mode, the experimental graphical characteristics of the mathematical model for regulating the number of revolutions and the power required for throwing the soil with the working mechanism's milling-cutting tools were constructed;

In the fourth mode, the experimental graphical characteristics of the mathematical model for regulating the number of revolutions and the power required to overcome the friction resistance of soil on the mill’s blades with the working mechanism’s milling-cutting tools were constructed;

In the fifth mode, the experimental graphical characteristics of the mathematical model for regulating the number of revolutions and the power required to overcome the friction force of soil on the mill’s coating with the working mechanism’s milling-cutting tools were constructed;

In the sixth mode, the experimental graphical characteristics of the mathematical model for regulating the number of revolutions and the power required to overcome the friction of the metal brush bristles on the concrete coating with the working mechanism’s milling-cutting tools were constructed.

Based on the mathematical modeling of the regulation process, software modules for managing the technological process of the application object were developed and proposed as the general structure of the software for regulating the working mechanism[10].

A set of input data for the information support of the working mechanism’s mechatronic components was formed using a relational method to create the database of the cleaning device’s working mechanism.

The types and technical specifications of the transmitter and motor, which respectively ensure the information-measurement and actuation of the working mechanism, are presented in tabular form as follows[11]:

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[10] Quliyev, Z.H., Əmirbəyova, N.S. Oduncaq lif plitələri (OLP) istehsalında elektrik enerjisinin xüsusi sərfinin və plitənin fiziki-mexaniki göstəricilərinin defibratorda oduncaq kütləsinin üyüdülmə dərəcəsindən asılılıqlarının modellərinin qurulması/ Z.H. Quliyev, N.S. Əmirbəyova //AzMİU Elmi əsərlər, - Bakı, -2018. № 2, –s. 62-67.

[11] Амирбекова Н.С. Экспериментальное исследование процесса регулирования степени сжатия двигателя внутреннего сгорания // Материалы конференции «Искусственный интеллект и области его применения». Республиканская Научная Конференция. № 7, – Сумгаит, – 07-08 декабря.– 2023. – с. 81-83.

Table 2.

Types and technical specifications of the transmitter and motor, which respectively ensure the information-measurement and actuation of the working mechanism

Transmitter type	Output type	Electric voltage	Measurement range	Accuracy	Measurement interval
1	**2**	**3**	**4**	**5**	**6**
Modbus, ModBUS RTU	Analog	24 V	Max –100% Min – 0 %	2÷3 %	80 ÷ -40^{0}C
Capacitive transmitter Water Scout	Analog	6÷12 V	Max – 50 % Min – 0 %	1÷2 %	40 ÷ -10^{0}C
SoilClik	Analog	6÷8 V	Max – 30 % Min – 0 %	3÷4 %	40 ÷ -10^{0}C
FC28	Analog	3÷5 V	Max – 36 % Min – 5 %	1÷2 %	35 ÷ -5^{0}C

Table 3.

Types and technical specifications of the actuating mechanism of the cleaning device's working mechanism

Motor type	**Speed** (rev/min)	**Electric voltage** (V)	**Flange Diameter** d_f (mm)	**Power** (Kw)
Siemens 1LE1502-2AC43-4	1000	400	350	90
AIP 250 S2	2100	350	270	75
AIP80	270	300	40	3,5

The software for regulating the rotation speed of the milling-thrower according to the number of revolutions is built based on the following algorithm:

IF the number of revolutions n_{f1} *= 130 rev/min,*

THEN the soil throwing distance L_{thr}*=4.2 m.*

IF the number of revolutions n_{f2}*=260 rev/min,*

THEN the soil throwing distance L_{thr}*= 8.7 m.*

At low rotation speeds of the milling thrower, a portion of the soil falls on the edge of the channel. In this case, the decision-making algorithm software is built based on the following algorithm:

IF the number of revolutions n_{f3} *= 155 rev/min,*

THEN the soil throwing distance $4.7 \leq L_{thr} \leq 6.5$ *m.*

IF the number of revolutions n_{f4}*=260 rev/min,*

THEN the soil throwing distance L_{thr}*= 8.7 m.*

IF the number of revolutions $n_{fi} \geq \{n_{f1}, n_{f2}, n_{f3}, n_{f4}\}$,

THEN the power $N_{t.un}$ spent on soil throwing increases.

The number of revolutions of the milling tool integral ensuring the efficient operation of the milling–thrower should vary between 150...200 rev/min. At this number of revolutions, the operating mode of the milling thrower becomes more stable and consistent.

In this paragraph, the goal is to address the following programming tasks that ensure the automation of the design process of a milling-type active working body for the efficient cleaning of sludge and weeds from small and medium-sized concrete-covered channels:

1. Creation of a complex structural scheme that ensures the automation of the design process of the milling-type active working body for channel cleaning[12];

2. Modeling of the 3D design procedures of the working body cleaning channels and gutters using Solid Edge software.

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[12] Асланов Т.И., Влияние алмазного выглаживания на чувствительность к концентрации напряжений / Т.И.Асланов, А.Ф.Гасымов, Н.С.Амирбекова // Elmi əsərlər jurnalı. –Bakı: Azərbaycan Memarlıq və İnşaat Universiteti, –2015, №1, –s.59-61. İSSN-2222-5013

To increase the efficiency of the design process of the working body of the cleaning device (CDWB), 2D and 3D computer graphics systems in Solid Edge software were used. For the automation of the sketch design operations, a general structural scheme was proposed for the joint operation of drawing, certification, building a graphic database, and animation of the CDWB in 2 and 3 dimensions.

Based on the program interface of the automated design, the 3D frontal, horizontal, and vertical drawing procedures of the constructive design were carried out step by step, determining the dimensions of individual mechanical parts, the material and its processing degree, as well as drawing and editing the CDWB in construction design operations.

The application of Solid Edge 2D and 3D software environment is formed from automated design in 2D and 3D drawing and animation operations of the object's graphic-mode software procedures. The mentioned complex design and information support is organized in the architecture of the automated design system. For the efficient organization of the automated design system architecture of CDWB, the following design functions were implemented:

1. Activation of the Solid Edge 2D, 3D system and naming of the drawing object;

2. Drawing of the generalized line of CDWB in Solid Edge 2D. Selecting a 2D coordinate system for drawing the object and boundary lines, assigning an A1 corner stamp and corresponding drawing scale;

3. Determining the working drawing and geometric shape, internal and external dimensions of the 2D generalized representation of the selected prototype design during the technical proposal stage of CDWB, as well as selecting the material type on it;

4. Providing additional views according to the complexity of the application object in accordance with the 2D generalized representation and creating a specification database;

5. Determining the main overall dimensions of the drawing and coding each mechanical part based on standard scale dimensions depending on the real dimensions of CDWB;

6. Searching and selecting input data for the main query, managing the database of the specification table, corner stamp, geometric figures, positional coordinates, material types, etc., and storing graphic data based on the names of the included mechanical parts.

The program procedures used for the automated design of the cleaning working body of the channel and gutter cleaning device ensure the 2D and 3D construction design process with logical operations for search, selection, and drawing functions[13].

The operations performed during the cleaning of the newly proposed construction channel, as designed by the project-constructor, are ensured through the following sequence:

query – search – selection – editing

To draw the generalized contour of the application object, procedures such as subdividing mechanical parts into elements, coding them, and determining their coordinates are modeled step by step. CDWB s divided into standard and non-standard elements in its 2D drawing. Standard elements consist of mechanical parts defined by the state standard, which involve the following design procedures:

P1: CDWBB→ CDWB *body (B) or element_1 (standard element);*

P2: BA → Body assembly (BA) or element_2 (standard element);

P3: CDWBS → CDWB *shaft (S) or element_3 (standard element);*

P4: SE→ Shaft extension (SE) or element_4 (standard element)

P5: CDWBMC→ CDWB *milling cutter (MC) or element_5 (non-standard element).*

Based on the logical combination of selected standard and non-standard elements from the CDWB mechanical parts database, the generalized drawing of the device is formed. To perform this combination logic operation, the Zade operator is used:

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[13] Amirbayova, N.S. Constructor design of the regulating working element of the Channel cleaning equipment / N.S.Amirbayova, S.A.Akhmadova, // İnternational journal of Computing, № 2, Vol. 23. –2024, –p. 476-485.

$$\mu_{A \cup B} = MAX(\mu_A, \mu_B) \tag{5}$$

For selecting mechanical parts of CDWB from the certified database:

Using

$$M_{part\ 1 \cup element\_2 \cup \ldots \cup .\ element\_5} = MAX(\mu_{element1}, \mu_{element2}, \ldots, \mu_{element5})$$

operator, the 3D linear model of the CDWB is generated.

The elements of the created 3D CDWB are drawn step by step to form the device’s representation. The 3D geometric figures of the used element_i are combined in the following sequence, resulting in the generalized drawing of the CDWB (Figure 6):

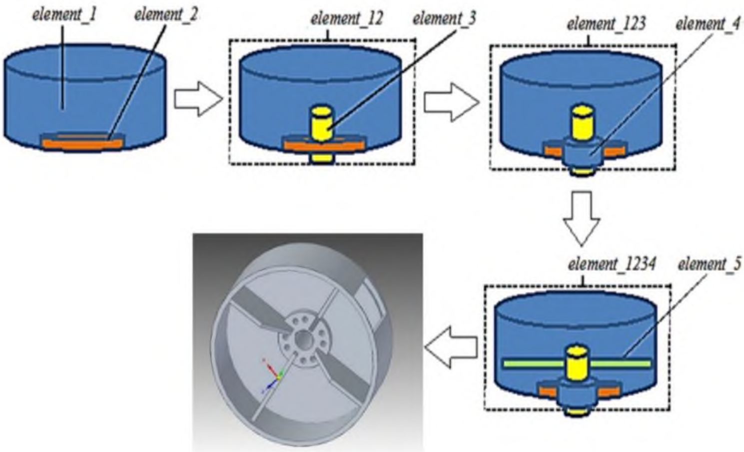

Figure 6. General block diagram of the CDWB constructed based on logical combination

<u>Procedure 1 (P1)</u>

*((CDWB*B *∪BA)↔(element_1∪element_2)) → element_12*

<u>Procedure 2 (P2)</u>

((element_12 ∪ CDWBS) ↔ (element_12∪ element_3))→ element_123

Procedure 3 (P3)

((element_123 ∪ SE)↔(element_123 ∪ element_4)) → element_1234

Procedure 4 (P4)

((element_1234∪ CDWBMC)↔(element_1234 ∪ element_5)) →element_12345

All these procedures are modeled step by step to ensure the efficiency and accuracy of the design. The use of CAD/CAM systems allows simulation of mechanical parts and functional testing. Through modeling, the performance of the mechanical system, interactions, and potential issues are analyzed in advance, enabling project optimization.

To check the dimensions of individual parts of the CDWB working unit, input data for dimensions are adjusted during the drawing of mechanical parts in A3 and A4 formats. By changing input data, the speed of the moving milling thrower is regulated. When the 2D drawing of the CDWB shaft is created, the overall body shape, the precise dimensions of the coupling and shaft, and the types of springs mounted on the shaft are selected (Figure 7).

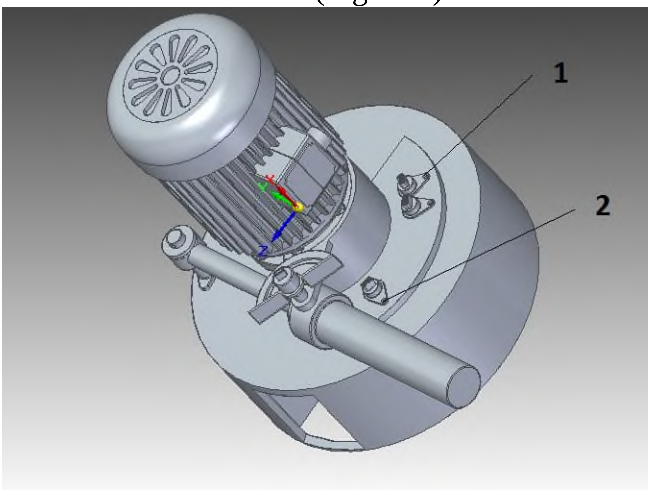

Figure 7. 3D representation and animation of the CDWB milling thrower in the Solid Edge 3D system

The use of the GMT Suite software optimizes the performance of throwers and other logistics equipment. The integration between the software's various components (Figure 8) enhances process accuracy, supports environmental protection, and improves the efficiency of logistics operations.

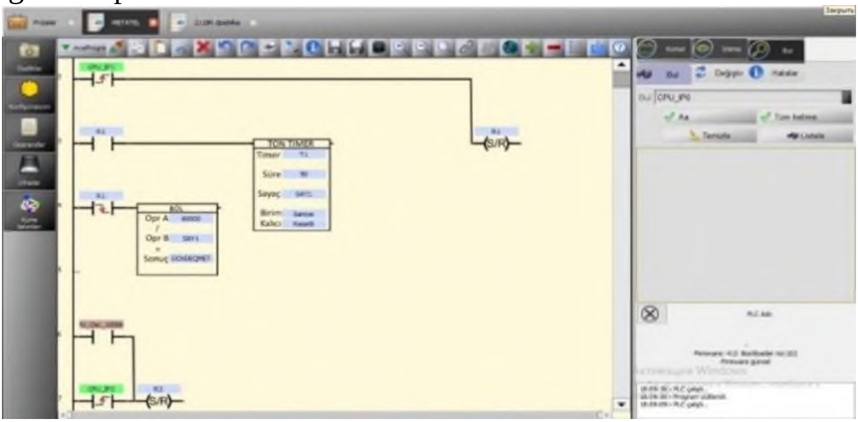

Figure 8. Visualization of the optimization algorithm for the milling cutter-thrower element in the GMT Suite software environment

To develop the control algorithm for the technical system, it is first necessary to analyze the technological process and gather expert knowledge in the field of land reclamation.

Accordingly, based on parameters such as the machine's forward speed, the thrower's rotational speed, and the soil moisture affecting the designated throw distance of the working body, the design of a fuzzy logic algorithm is considered using the Fuzzy Toolbox in the MATLAB environment. In this case, the following linguistic variables are used as inputs to the automated regulation system's controlling controller[14]:

1. Controller inputs (input variables):

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[14] Amirbayova, N.S. Automation of the design of the working body and control system for regulating the cleaning of channels and ditches / N.S.Amirbayova, // Lecture Notes in Networks and Systems, Springer, Cham, Vol. 1622. -2025, -p.13.

1.1. Machine forward speed;
1.2. Thrower rotational speed;
1.3. Soil moisture.
2. Controller outputs (output variables).
2.1. Designated throw distance;
2.2. Direction of the milling thrower’s cover;

Based on machine forward speed, the following linguistic terms are defined:

MİHS_1 → forward speed ***below normal*** *(0.01 0.02 0.32 (m/s));*
MİHS _2 → forward speed ***normal*** *(0.042 0.09 0.45 0.99 (m/s));*
MİHS _3 → forward speed ***slightly increased*** *(0.84 1.15 1.34 1.59 (m/s));*
MİHS _4 → forward speed ***increased*** *(1.48 1.63 1.75 1.86 (m/s));*
MİHS _5 → forward speed ***greatly increased*** *(1.79 1.92 2.15 2.38 (m/s)).*

Based on thrower rotational speed, the following linguistic terms are defined:

TDS_1 → rotational speed ***much below normal*** *(125 137 149 159 (rev/min));*
TDS_2 → rotational speed ***below normal*** *(157 163 172 180 (rev/min));*
TDS_3 → rotational speed ***normal*** *(173 188 197 202 (rev/min));*
TDS_4 → rotational speed ***above normal*** *(200 205 207 209 (rev/min));*
TDS_5→ rotational speed ***much above normal*** *(208 210 212 215 (rev/min));*

Based on soil moisture, the following linguistic terms are defined:

QN_1→ soil moisture ***low*** *(10 12 13 14 (%));*
QN _2 → soil moisture ***normal*** *(13.5 14.8 16.5 17.4 (%));*
QN _3 → soil moisture ***slightly high*** *(16 18 19 20.5 (%));*
QN _4 → soil moisture ***high*** *(19 21.35 22 23.6 (%));*
QN _5 → soil moisture **very high** *(23 24.75 26 28 (%)).*

Based on the cover orientation angle of the milling thrower, the following linguistic terms are defined for the designated throw distance:

*İOÖİB_$_1$ → cover orientation **<u>does not reach designated distance</u>** (-120 -110 -103 - 99(angle));*
*İOÖİB_$_2$ → cover orientation **<u>reaches designated short distance</u>** (-95 -90 -83 -79 (angle));*
*İOÖİB_$_3$ → cover orientation **<u>reaches designated distance</u>** (-64 -25 30 60 (angle));*
*İOÖİB_$_4$ → cover orientation **<u>goes beyond designated distance</u>** (60 70 80 95 (angle));*
İOÖİB_$_5$ → cover orientation **<u>goes far beyond designated distance</u>** (91 100 120 142 (angle))[15].

Based on the fuzzy linguistic terms of the machine's forward speed, thrower rotational speed, and soil moisture, the control algorithm for the milling thrower type working body is constructed as follows:

IF "machine forward speed is ***<u>below normal</u>***";
AND "thrower rotational speed is ***<u>below normal</u>***"
AND "soil moisture is ***<u>below normal</u>***";
THEN "Excavated soil will fall into the channel or ditch";
IF "machine forward speed is ***<u>below normal</u>***";
AND "thrower rotational speed is ***<u>below normal</u>***"
AND "soil moisture is ***<u>normal</u>***";
THEN "Excavated soil will almost fall into the channel or ditch";
IF "machine forward speed is ***<u>normal</u>***";
AND "thrower rotational speed is ***<u>normal</u>***"
AND "soil moisture is ***<u>normal</u>***";
THEN "Excavated soil will fall to the designated throw distance";
IF "machine forward speed is ***<u>slightly above normal</u>***";
AND "thrower rotational speed is ***<u>above normal</u>***"
AND "soil moisture is ***<u>slightly above normal</u>***";
THEN "Excavated soil will fall to the designated throw distance and partially to the edges";
IF "machine forward speed is ***<u>above normal</u>***";
AND "thrower rotational speed is ***<u>much above normal</u>***"

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[15] Amirbayova, N.S. Mathematical basis for the design of the working body of a channel cleaning device / N.S.Amirbayova, // Azərbaycan Ali Texniki Məktəblərinin Xəbərləri, № 2, Vol. 27. –2025, –p. 78-90.

AND "soil moisture is ***above normal***";
THEN "A small portion of the excavated soil will fall to the designated throw distance";
IF "machine forward speed is ***greatly above normal***";
AND "thrower rotational speed is ***excessively above normal***"
AND "soil moisture is ***very high***";
THEN "Excavated soil will pass over the designated throw distance and fall outside".

The logical algorithm, developed based on the adjustable movement speed of the milling cutter working body, has been studied through computer experiments, and as a result, using MATLAB with the Fuzzy Toolbox, the following program graphs are constructed. [16].

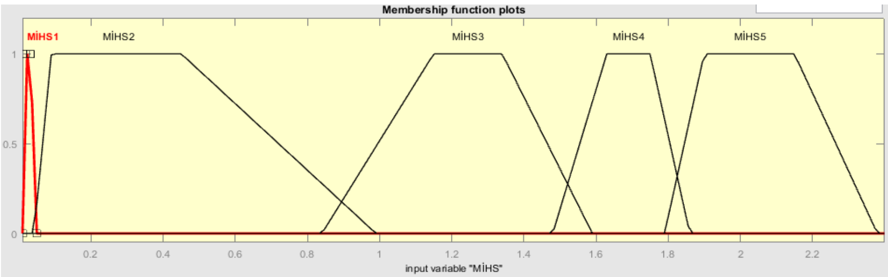

Figure 9. Program graph obtained based on the machine's forward speed indicators and the accepted terms with their corresponding range values

[16] Qasımov A.F., Əmirbəyova N.S. Drenaj maşın növlərinin müqayisəsi və onların inkişaf istiqamətləri // Ümummilli lider Heydər Əliyevin anadan olmasının 86-cı ildönümünə həsr olunmuş Tələbə və magistrantların XXXI elmi konfransının materialları, Azərbaycan Memarlıq və İnşaat Universiteti, –Bakı. –10 may, –2009, –№1, –s. 261-262

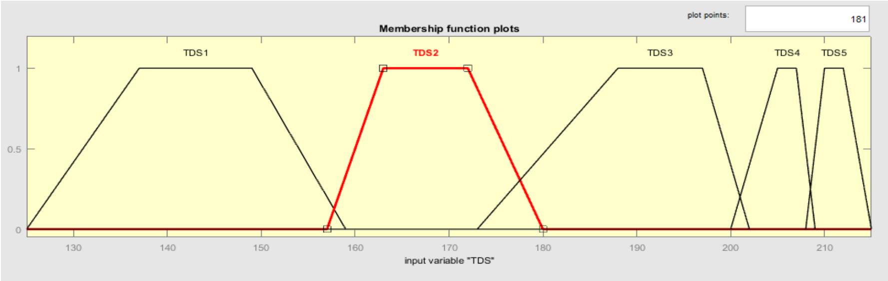

Figure 10. Program graph obtained based on the thrower's rotational speed and the accepted terms with their corresponding range values

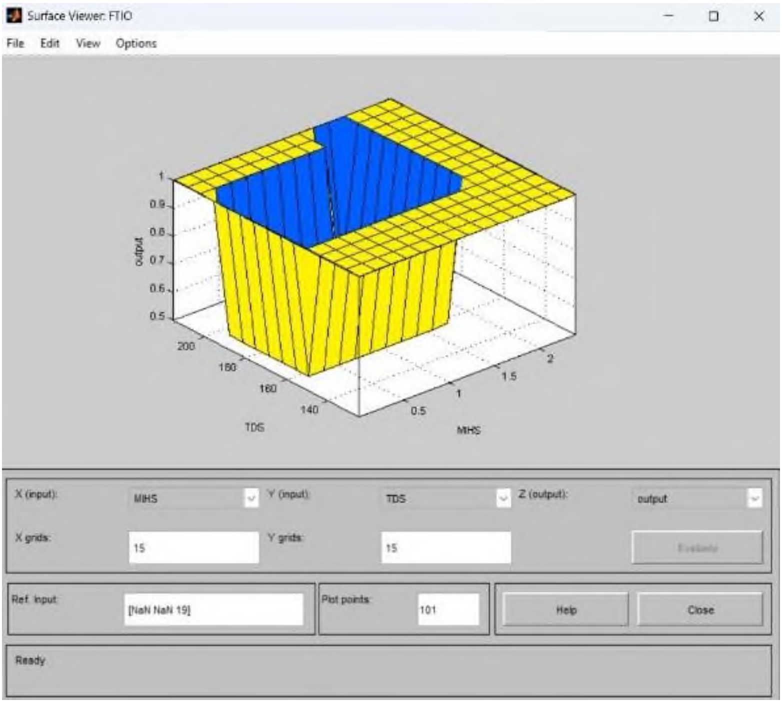

Figure 11. 3D representation of the fuzzy control algorithm for determining the automated working body's targeted throw distance

MAIN CONCLUSIONS OF THE DISSERTATION

1. The structure of the development stages of devices for cleaning channels and ditches has been proposed, and the automated design process has been modeled.

2. An information support system has been developed based on a database created from the technological characteristics of existing cleaning devices for the selection and design of regulating elements of the working body for cleaning channels and ditches.

3. The functions of the regulating mechanism of the working body for cleaning channels and ditches have been modeled and studied through computer experiments.

4. An algorithm for regulating the speed of the execution mechanism of the milling-cutting tool of the cleaning device of the channel using the production method has been developed, and the types and technical characteristics of the applied information-measuring sensors have been determined.

5. The analysis of the structures of the channels used for irrigation of agricultural areas has been carried out, and the information support of the main technical indicators has been created.

6. A mathematical model has been developed for the functional design of the device that cleans the silt layer of channels and ditches, based on parameters affecting the productivity, power, and energy consumption of the milling thrower, and it has been studied using computer experiments.

7. Mathematical models for selecting the power of the working body of the device for cleaning channels and ditches according to work modes have been developed and studied using computer experiments.

8. For the automated design of the device that cleans channels and ditches, the structure of the software has been proposed, the functions of the subprogram modules have been determined, and the software has been developed in the corresponding software environment.

9. Design programming procedures have been developed for the elaboration of the sketch design of the automated design of the cleaning device.

LIST OF PUBLISHED SCIENTIFIC WORKS ON THE TOPIC OF THE DISSERTATION

1. Əmirbəyova, N. S. Kanal və küvetləri təmizləyən işçi orqanın tənzimləyən vasitənin funksiyalarının modelləşdirilməsi və kompüter eksperimentləri ilə tədqiqi / N.S. Əmirbəyova // Elmi xəbərlər. Təbiət və Texniki Elmlər Bölməsi. – 2024. – Vol. 24, No. 2. – P. 82-90. – DOI 10.54758/16801245_2024_24_2_82. – EDN ULCHMV. https://elibrary.ru/item.asp?id=71240198
2. Амирбаева, Н.С. Вопрос создания информационного обеспечения для проектирования каналов водоснабжения и их очистительных устройств // «Advances in Science and Technology» LXI Международная научно-практическая конференция. – Москва, –15 июня, –2024. –с. 91-94.
3. Quliyev, Z.H., Əmirbəyova, N.S., Tağıyeva, V.R. SPK-207 tipli sensorlu panel proqramlaşdırılan məntiqi kontrollerin istilik qazan qurğusunun avtomatlaşdırılmasına tətbiqi // İnşaatda informasiya texnologiyaları və sistemlərinin tətbiqi imkanları və perspektivləri Beynəlxalq elmi-praktik konfransın materialları. –Bakı, –2018. –s. 56-59.
4. Əmirbəyova, N.S. Nişanlanmış atılma məsafəsi olan işçi orqanın idarəetmə alqoritminin qurulması // Building Innovations-2018. I Beynəlxalq Azərbaycan-Ukrayna Konfransının elmi materiallar toplusu, –24 мая, –2018. с. 34-37.
5. Hacıyev A.M., Feyzullayev E.N., Əmirbəyova N.S. Sement zavodunda klinkerin alınması texnoloji prosesinin idarəetmə alqoritminin işlənməsi // İnşaatda informasiya texnologiyaları və sistemlərinin tətbiqi imkanları və perspektivləri Beynəlxalq elmi-praktik konfransın materialları, Azərbaycan Memarlıq və İnşaat Universiteti, –Bakı, –2018, –№1(3000), –s. 178-180.

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Personal contribution of the applicant in joint works with co-authors:

[1] Analysis for determining the main parameters of the soil thrown during the operation of the milling thrower;

[2] Idea author, method of problem solving and analysis of results;

[3] Formulation of the issue concerning the study of the information-measuring elements of the working body's control system;

[4] Development of an algorithm for proper control of the targeted throwing distance;

[5] Development of the technological process control algorithm;

[6] Development of software for the SPK-207 type sensor panel programmable logic controller during the control of the milling thrower;

[7] Analysis of the condition of modern models of drainage networks;

[8] Determination of tensile strength in the study of the construction of the channel and ditch;

[9] Obtaining the construction of the working body using Solid Edge software;

[10] Problem solving method, development of dependency models;

[11] Problem formulation, method of solution and analysis of results;

[12] Analysis of the process of polishing the paddles of the milling thrower's working body with diamond;

[13] Problem formulation, method of solution and computer simulation;

[14] Problem formulation, method of solution and analysis of results;

[15] Problem formulation, method of solution and analysis of results;

[16] Investigation of multiple mechatronic dynamic parts of drainage networks, analysis of the condition of modern models;

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