INNOVATIONS IN SCIENCE:
THE CHALLENGES OF OUR TIME

Monograph
Volume 2

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CENTER FOR STRATEGIC INITIATIVES AND PROGRESSIVE DEVELOPMENT (UKRAINE)

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The collective monograph is devoted to the actual issues concerning the modern development of education and science. In particular, the monograph examines the theoretical, applied and practical aspects of various spheres of the science, as a commitment to development in civic society.

Recommended for scholars, researchers, postgraduates and students of higher education institutions, as well as for all those interested innovative development of various fields of fundamental and applied science.

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Welcoming words to the participants in the IV International Scientific and Practical Forum "Innovations in Science: Challenges of our time"

Petur Hristov,
Rector of Varna Free University «Chernorizets Hrabar» (Bulgaria),
Doctor of Science, Professor

The world is passing through a period of irreversible transformation. The fourth industrial revolution, which began ten years ago, erases the boundaries between the digital, industrial and biological spheres.

The opportunities that the digital environment offers for individual choice between many new and different presets and perspectives stimulate the development and expression of each individual person. Expanding the range of self-education increases the diversity and ease of establishing social contacts and the formation of various human communities.

But the coin has two sides, the information environment can also be viewed from the opposite point of view - as a factor that involves the alienation of a person from his inner world, restricts the freedom of self-formation and leads to the segregation of people based on their identity and, ultimately, the polarization of human communities.

Undoubtedly, the world based on digital technologies is also changing the fundamental properties of reality, which were reflected as principles in ontology, ethics, aesthetics, epistemology, etc. This implies not only changes, but also a significant diversification of the possible future structure of the human personality.

Without fundamental changes in the organization of scientific and educational activities, these processes can get out of control. In this sense, innovation in university education is not an alternative. This collection is a successful step in this direction.

Serhiy Shkarlet,
Rector of Chernihiv National
University of Technology,
Honoured Worker of Science and
Technology of Ukraine,
Doctor of Economics, professor

Nowadays we are living in the world that is developing so fast, that it is difficult to predict what it will be like even in five years, not speaking of a longer period. New challenges are arising every minute, while the old ones often acquire new features and context. Therefore, we can hardly overestimate the importance of scientific and academic collaboration of the world community to face the changes.

The intensification of cooperation between the scientific community of different countries, the exchange of best international practices and establishment of interpersonal links between the leading researchers and practitioners can contribute to the development of new ways and methods of dealing with the upcoming issues, using benefits of the interdisciplinary approach with a strong practical focus.

In this regard, the IV International scientific and practical forum "Innovations in science: the challenges of our time" plays a very important role in bringing together the representatives of academic communities from various universities and countries. It represents the importance of communication on questions of joint interest from different perspectives: law, economics, management, technology, ecology, culture etc. I believe this is the key to successful and sustainable development of our societies, based on mutual understanding and support.

On behalf of the entire team of students, PhD students and scientific-educational workers of Chernihiv National University of Technology, I would like to congratulate all participants of the Forum and wish you fruitful work, inspiration in implementing professional interests and outstanding scientific achievements for our common future.

Maryna Dei,
Candidate of Juridical Sciences,
Associate Professor,
Director of the Center for Strategic Initiatives
and Progressive Development

The constant changes in the world are the new normal. Increasing of the population, wars on the planet, the Artificial Intelligence (AI) creation, which is more efficient than the humans' brain, the population have almost used the biopotential of Earth.

Today's world is one of "VUCA" (Volatility, Uncertainty, Complexity, and Ambiguity).
Therefore, all humanity intuitively feels that education must change radically.

The main trend in modern education is increasingly implementing the model of life long learning, which allows a person to adapt and develop the competences and professional skills in line with rapid changes in the economy, technology, and labor markets. Today, consumers of educational services prefer to decide by themselves what, when, and how they want to learn. The motives for personal growth are increasing in education.

The challenges of modern education and science cannot be overcome without going beyond the old educational models, without the development and implementation of innovative forms of education.

The growing diversity of human personal requests, on the one hand, and the dynamics of the labor market driven by the acceleration of socio-economic changes, on the other hand, cannot be satisfied within the existing forms of traditional education. The problem of inconsistency of the formed education system with the new needs of society and people is aggravated. In these circumstances, we need a new perspective on the role and importance of education, that will meet current educational needs thanks to the widespread introduction of educational innovations. Today, for Ukraine it is actual and possible to implement the life-learning educational model, which requires the state to support and develop subsystems of this model: non-formal and informal education, online education, blended learning models. Lifelong learning at the national level should be defined as a full-fledged educational field with due regard for quality control and quality assurance with the recognition of various forms of education. In this context for four years now, representatives of the scientific elite of Ukraine and the EU Member States have been gathering at the Varna Free University to discuss and solve problems of innovation in science and education. The result of this Forum is a collective monograph prepared by representatives from Ukraine, Georgia, Slovakia, Bulgaria, Poland and the United States of America.

In the process of preparing the collective monograph, the scientists conducted a comprehensive analysis of the issues of the education system, lifelong learning, education management, the impact of science and education on various sectors of the economy have been identified and analyzed, the ways of building education and science are determined. For the successful implementation of the process of education reform, it is essential that the experience of innovation activities of universities in different countries of the world.

The proposed collective monograph is a collaborative international effort that will be of benefit to anyone interested in innovation because modern science and education must be the lifeblood of the entire civilized world. And all the knowledge embedded in a person must work to solve the problems that a person faces.

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Computer simulation of agricultural machinery parts

In the concept of the development of agricultural machinery, it is planned to create a combined, universal and unified machinery of the new generation [1], which provide high performance at minimum resource costs and perform in a single pass of the unit several technological operations without reducing the performance of the tools and the reliability of machinery at the level of modern foreign analogues [2]. To solve the problems, it is necessary to create precise mathematical models of soil tillage systems for the purpose of further computer simulation of their operation.

Analysis of recent publications on the issues and allocation of previously unsolved parts of the general problem. Any farm machine is a complex mechanical system. When choosing a calculation scheme, first of all, the issue of the number of recognized degrees of freedom – the number of independent coordinates of the mechanical system which fully determine the position of all its points is solved. The real mechanical system consists of an infinite number of material points. Since the connections between them are not absolutely rigid, the number of degrees of freedom of such a system is infinitely large. However, depending on the concrete problem to be solved, it is possible to determine the finite number of degrees of freedom without loss of accuracy. Experimental studies of agricultural machinery in laboratory and field conditions have shown that in many cases they can be represented as a mechanical system with 1, 2 or 3 degrees of freedom, which greatly simplifies the solution of dynamic tasks.

It's possible to specify three ways of generating finite-dimensional models [3, 4]. The first method is that relatively less massive parts of the system are completely deprived of mass and are presented as inertial elements, and the most rigid parts of the design are taken for absolutely solid bodies with a finite mass. In accordance with the second method, the properties of the compliance are distributed throughout the system volume in the finite number of points. In this case, the system is represented as a set of elastically joint rigid elements. The third method is based on some a priori assumptions about changing the configuration of the system in the process of oscillation (oscillation forms). If the form is given, the position of all points of the system is determined, therefore, one degree of freedom is recognized in the system. This idea of the reduction to a system with one degree of freedom lies at the basis of approximate methods for determining the dynamic characteristics of mechanical systems (Rayleigh method) [5].

Formulation of research goals. The aim of the research is to develop a mathematical model of soil cultivation system with subsequent

program realization with the help of modern mathematical packages. To achieve this goal, the following main tasks need to be solved: create a mathematical model, reproduce the model in the software environment, and verify the adequacy of the model.

Principal layouts and their justification. In the process of soil cultivation, cultivation is one of the important technological operations, which involves the use of working bodies for weeding and loosening the surface layer of the soil. When changing the physical and mechanical properties of the soil and the physical composition of plants, it is necessary to take into account the design features of the working bodies of cultivators and their modes of operation. In order to use of tractor engine power effectively, it is necessary to determine the optimal parameters that ensure the maximum productivity of the aggregate at different values of the depth of tillage and the specific resistance of the soil, as well as the features of structural materials and their profiles for the manufacture of operating devices.

The computer simulation of the mathematical models of the work of soil treatment systems in order to establish their parameters is one of the necessary stages in the creation of new operating devices [5, 6].

The modern process of mathematical modeling can't be realized without computers or embedded controllers. Various tools and environments (MathCad, MatLab, Mathematica, Maple, Derive, VisSim, Genius, Exel, and others) are used for this purpose, which considerably simplifies the process of mathematical modeling. Modern mathematical packages can be used as means to simplify expressions when solving any mathematical problems, and as generators of graphics or even sound. The tools for interacting with the Internet, by generating HTML pages directly in the computation process also became standard. A skilled researcher who has sufficient knowledge of one of the modern programming languages (C++, Java, Pascal, etc.) can independently create a separate program or a set of programs that will allow him to implement the algorithm of his task on a PC. However, such an approach requires, as a rule, large labor costs for programming, debugging and testing of each program. Therefore, in order to reduce the programming time, the said application software packages were created, the areas of which are largely overlapping. For the most effective use of computing equipment, it is necessary to choose the right software package at the very early stage of the application. After all, the real goal is to solve certain problems, and calculations are just an intermediate step on the way to this solution.

The use of computer simulation in the creation of modern technical objects has become widespread, automated design systems now provide not only the possibility of developing design documentation, but also the engineering calculations on the created solid-state models. This allows to solve a lot of issues related to the interaction of parts of the mechanism, their mutual location, and to visualize the project most clearly both in the interactive mode on the computer screen, as well as on paper, using a variety of types and sections, at the stage of design. At this stage, the primary task is to determine the choice of the most suitable automated design system. Recently, the tendency of expanding the range of CAE product users (Computer Aided Engineering – applications for engineering calculations), which are distributed based on geometric CAD systems (Computer Aided Design – automated design) is clearly outlined. This leads to the emergence of geometric modeling and calculation software tools. Therefore, when choosing CAD systems, it is necessary to immediately analyze the CAE products that can make calculations based on the generated models. One of the most advanced solid-state modeling systems is SolidWorks with the integrated COSMOS engineering package. The COSMOSWorks application is intended to solve the problems of mechanics of a deformed solid by a finite element method. The program uses a geometric model of a part or assembly to form a calculation model. Integration with SolidWorks makes it possible to minimize the operations associated with specific features of the finite-element approximation. This provides the solution of such tasks as the calculation of static strength and stability in linear and nonlinear formulation, allocation of own frequencies, optimization of the shape of parts and assemblies in linear formulation, analysis of fatigue and structural behavior at the impact. COSMOSWorks can accept the results of the dynamic analysis obtained in COSMOSMotion [7].

In the study of systems of automatic control, computational mathematical problems, the Matlab software system with a wide range of object-oriented libraries (toolbox) and Simulink visual simulation tool is the most effective. MatLab also has extensive programming capabilities. Its C Math library (MatLab compiler) is object-oriented and contains over 300 data processing procedures in C. Inside the package, both MatLab's own procedures and standard C language procedures can be used, making this tool the most powerful helper in the development of applications (using the compiler C Math, it's possible to embed any MatLab procedures in the ready-made applications). To visualize the simulation, the MatLab system has the Image Processing Toolbox library which provides a wide range of functions that support the visualization of computations performed directly from the MatLab environment, increasing and the analysis, and the ability to develop image processing algorithms. The MatLab system can be used to process images by constructing its own algorithms that will work with graphic arrays like with data matrices. As the MatLab language is optimized for matrix manipulation, the result is ease of use, high speed and cost-effective operation of images. System Identification Toolbox, a set of tools for creating mathematical models of dynamic systems based on observed input / output data, can also be noted among other MatLab libraries. A flexible user interface that allows organizing data and models is distinctive feature of this tool. The System Identification Toolbox supports both parametric and non-parametric methods. The system interface facilitates preliminary processing

of data, work with the iterative process of creating models for obtaining estimates and the allocation of the most significant data. As far as mathematical calculations are concerned, MatLab provides access to a huge number of subroutines contained in NAG Foundation Library by Numerical Algorithms Group Ltd (the tool has hundreds of functions in various fields of Mathematics, and many of these programs have been developed by well-known experts worldwide). This is a unique collection of implementations of modern numerical methods of computer mathematics, created over the past three decades. Only a large amount of documentation added to the system can be considered as a fundamental multi-volume electronic directory on mathematical support. VisSim software package is more convenient for visual simulation and simulation in combination with real hardware.

The reduction of energy consumption in achieving the established agrotechnical requirements for the quality of soil (depth of tillage, regularity of loosening, the area of overlapping hoes, small soil aggregates on the surface, etc.) is the urgent task when performing pre-planting treatment of the soil. The process of changing the parameters of arrow-like hoes occurs in several stages, characterized by the degree of wear of the cutting edge and the size of the occipital chamfer. With the changes in the parameters of the occipital chamfer, the agrotechnical performance of the hoe worsens, and the traction resistance increases. At the same time, the occipital chamfer excessively densifies the seedbed (bottom furrow), thus, slowing down the process of plant development. When moving the arrow-like hoe in the soil, the greatest influence on the traction resistance is made by the occipital chamfer. However, there is no a single opinion in the direction of change in traction resistance, since there is no exact theory of the formation of the occipital chamfer. The most grounded reason for the formation of the occipital chamfer is the movement of the operating device in the soil on the complex trajectories due to the movement of the equipment in the vertical direction in depth and its translational motion.

Traction resistance of the arrow-like hoe can be decomposed into components due to the gravity of the formation of the soil layer, the force of inertia, the resistance of the soil to the compression of the occipital chamfer and the resistance of the soil deformation [8]:

$$R_X = R_{GX} + R_{FX} + R_{3X} + R_{DX}, \qquad (1)$$

where R_{GX} – resistance, caused by the gravity of the layer of soil $G_п$; R_{FX} – resistance, caused by the action of force of inertia F; R_{3X} – resistance of the soil to the compression of the occipital chamfer; R_{DX} – resistance of the soil to deformation.

The components of the traction resistance are determined as:

$$R_{GX} = a \cdot b \cdot l \cdot \gamma_{об} \cdot \frac{\sin\varepsilon + f \cdot (\cos\gamma \cdot \cot\gamma + \sin\gamma \cdot \cos\varepsilon)}{\cos\varepsilon - f \cdot \sin\gamma \cdot \sin\varepsilon}, \qquad (2)$$

where a – depth of soil tillage; b – the width of the capture of the hoe; l – width of the hoe wing in the direction of movement; f – the coefficient of friction of the soil on the surface of the hoe; $\gamma_{об}$ – volumetric weight of soil.

$$R_{FX} = \frac{a \cdot b \cdot l \cdot \gamma_{об} \cdot V^2 \cdot (\sin\gamma)^2 \cdot [\sin\varepsilon + f \cdot \sin\gamma \cdot ((\cot\gamma)^2 + \cos\varepsilon)]}{g \cdot (\cot\varepsilon - f \cdot \sin\gamma)}, \quad (3)$$

where V – speed of movement of the hoe; g – free fall acceleration.

$$R_{3X} \leq \lambda \cdot G_M \cdot \frac{\sin\gamma \cdot \sin\varepsilon 3 + f \cdot (\cos\varepsilon 3 \cdot (\sin\gamma)^2 + (\cos\gamma)^2)}{\cos\varepsilon 3 - f \cdot \sin\gamma \cdot \sin\varepsilon 3}, \quad (4)$$

where G_M – the gravity of a machine that falls on one hoe; λ – coefficient determining the permissible value of resistance arising from a blunt blade (λ = 0,3...0,4); ε_3 – the angle formed by the occipital chamfer with the bottom of the furrow.

This does not take into account the resistance from the shank of the arrow-like hoe R_c. At the same time, analyzing the components of the traction resistance, which is influenced by the change in the parameters of the hoes, we conclude that among the forces that determine the traction resistance, one of the main forces will be the one spent on separating the layer of soil with the blade.

Let's consider the forces and reactions that arise when moving the arrow-like hoe in the soil. When the traction effort is applied to the rack and the movement of the hoe in the soil on it, the forces arising from the friction of the ground on the foot of the paw will affect it, the force of inertia as a result of vertical lifting of the cut the layer of soil and force, is spent on the plunging of the hoe into the soil and the destruction of the roots. Let's make a scheme of forces acting on the arrow-like hoe (Fig. 1).

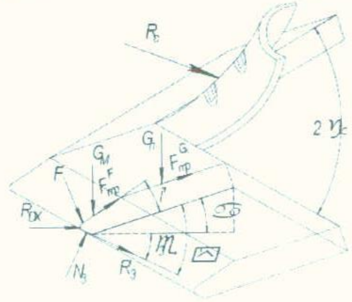

Figure 1 – Scheme of the forces acting on the arrow-like hoe when moving in the soil

Without taking into account the influence of blunt blade, with the constant depth of tillage and the speed of movement of the hoe in the soil, to change the traction resistance, the main effect will be produced by the friction force of the blade on the bottom of the furrow. The analysis of expressions (2), (3) shows that when the width of the wing of the hoe (the height of lifting of the soil layer) decreases, the traction resistance is reduced. Thus, the greatest influence on the change of traction resistance will be provided by the processes occurring at the interface between the blade and the bottom of the furrow.

The reaction N_3 is assumed to be proportional to the hardness of the soil:

$$N_3 = k \cdot \tau \cdot S, \quad (5)$$

where k – the coefficient of proportionality; τ – the hardness of the soil; S – the area of the occipital chamfer.

The reaction N_3 will determine the strength of the soil friction on the lower edge of the blade (or on the occipital chamfer after its formation):

$$R_3' = N_3 \cdot f. \quad (6)$$

Regardless of the nature of the formation of occipital chamfer, from the physical point of view, it is formed at an angle determined by the direction of movement of the soil relative to the cutting edge. Taking into account that the angle of the occipital chamfer vary with operating life, the horizontal component of the friction force will also change R_{3X}':

$$R_{3X}' = N_3 \cdot f \cdot \cos\varepsilon_3' = k \cdot \tau \cdot S \cdot f \cdot \cos\varepsilon_3'. \quad (7)$$

The area S of the occipital chamfer depends on the angle of its inclination and the degree of the blade wear, as the blade has a sharpening area at an angle i.

The dependence of the width of the occipital chamfer on its angle and the linear wear of the U-wing on the sharpened area is determined by the solution of the triangles:

$$\begin{cases} b_ф = \frac{t + U \cdot \tan i}{\sin\psi}, with\ 0 < U < \frac{T-t}{\tan i} \\ b_ф = \frac{T}{\sin\psi}, with\ U \geq \frac{T-t}{\tan i} \end{cases}, \quad (8)$$

where T – the thickness of the wing; t – the thickness of the blade of the new hoe.

Taking different values of the angle of the occipital chamfer, the equation can be represented graphically. Since the width of the occipital chamfer determines its area (taking the length of the perimeter of the edge of the blade L unchanged when other parameters are changed), the expression (7) can be written as:

$$\begin{cases} R'_{3X} = \frac{k \cdot T \cdot L \cdot (t + U \cdot \tan i) \cdot f \cdot \cos \varepsilon'_3}{\sin \psi}, \; with \; 0 < U < \frac{T-t}{\tan i} \\ R'_{3X} = \frac{k \cdot T \cdot L \cdot T \cdot f \cdot \cos \varepsilon'_3}{\sin \psi}, \; with \; U \geq \frac{T-t}{\tan i} \end{cases} \quad ,(9)$$

The angle ε'_3 of the inclination of the occipital chamfer to the direction of motion is defined as the angle difference $(\psi' - \alpha)$. Then:

$$R'_{3X} = \frac{k \cdot T \cdot L \cdot (t + U \cdot \tan i) \cdot f \cdot \cos(\psi' - \alpha)}{\sin \psi}, \quad (10)$$

where α – the incidence of the hoe.

The vertical reaction R_{3z}, affecting the occipital blade edge, can be determined by the formula:

$$R_{3z} = \lambda \cdot G_{M}, \quad (11)$$

The coefficient λ, as it was already mentioned above, can't exceed the values of 0.3...0.4. Thus, the vertical reaction can't exceed 0.3...0.4 of the weight of the machine, which falls on one operating device. Consequently, the value of the coefficient k in the formula (10) is a variable magnitude.

Assuming, with some assumption, the value of R_{DX} unchanged with the wear of the blade, the coefficient of proportionality k varies from 0.43 to 0.60. Solving the expression (10) with different wear of the wings of the hoe in width, we obtain the theoretical graphical dependence of the change in friction force, and, respectively, and the traction resistance, from the angle of the occipital chamfer (Fig. 2).

According to this dependence (Fig. 3), with the decrease of the angle of inclination of the occipital chamfer to the bottom of the furrow, the horizontal component of the traction resistance increases. This change also depends on the width of the wings of the hoe. In real conditions, the formation of the chamfer and the change in the width of the wing occur simultaneously. Hence the conclusion arises: if the angle of inclination of the occipital chamfer decreases, then its area increases. This leads to an increase in the part of the weight of the equipment, transmitted by the chamfer to the soil, as the soil is

more difficult to deform with the increase in the support area, and the growth of traction resistance. But at the same time the width of the wing decreases, and, correspondingly, so does the depth of tillage, which leads to some reduction in traction resistance.

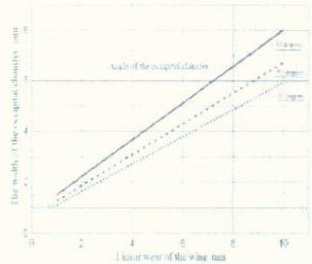

Figure 2 – Dependence of the width of the occipital chamfer from the linear wear of the wing on its angle

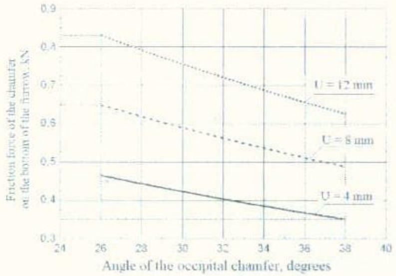

Figure 3 – Dependence of the friction force of the occipital chamfer on the bottom of the furrow of the occipital chamfer on the linear wear of the wing from its angle

Thus, the task of computer modeling is to determine the degree of impact on the traction resistance of the width of the wings of the hoe.

Let's consider how the depth of the soil tillage changes with the uneven movement of the hoes. We assume that at a certain moment of time all hoes of the equipment (or at least two adjacent ones) deviated by the same magnitude. In this case, the depth of tillage will be reduced due to the turn of the leg by the value of $h_{в}$, due to the turn of the hoe and the formation of the ridge bottom of the furrow by the value of $h_{л}$:

$$\Delta h = h_{в} + h_{л} = 2R_1 \cdot \left(\sin\frac{\delta}{2}\right)^2 + \frac{B-c}{2\tan\gamma} \cdot \sin\delta, \quad (12)$$

where c – the area of the intersection between the adjacent hoes.

In addition to the size of the recess Δh, the hoe is deepened due to the presence of the occipital chamfer and uneven distribution of hardness of the soil massif. As a result, with the increase in wear, the area of the occipital chamfer increases, which complicates the plunging of the operating device into the soil. Therefore, the largest value of the recess should consist of Δh and the recess from the action of the occipital chamfer, with the latter providing the greater effect on the uneven depth of tillage, which requires an experimental verification.

Arrow-like hoes move in the ground not horizontally (or at the small technological, pre-installed angle), but deviating back to a certain angle α and oscillation of the operating device occurs in relation to this position. The angle depends on the properties of the soil and the geometry of the hoe itself. Geometric calculations show that there is the following dependence between the angles of the reverse chamfer on the stern ψ 'and the wing ψ:

$$\psi' = \tan^{-1}[\tan(\psi - \beta) \cdot \sin\gamma] + \tan^{-1}[\tan\beta \cdot \sin\gamma], \quad (13)$$

where β – the incidence of the hoe in intersection, degrees; γ – the angle of opening the hoe wings, degrees

If the assumption made about the deviation of the operating device during the process of operation with the exceeding of the traction resistance of some value of R_{x1} and the formation of the reverse wear chamfer of the furrow parallel to the bottom is correct, then the horizontal component of the traction support for the cultivator with a restraining spring is proportional to the characteristics of its spring:

$$R_{x1} \sim F_2 = c \cdot (\Delta l_0 + \Delta l), \quad (14)$$

where c – the stiffness of the traction booster spring, N/m; Δl_0 – precompression of the spring, m; Δl – the compression of the spring in the process of operation, m

The compression of the spring in the process of operation is determined by geometric calculations when considering triangles *OO1A* and *OO1B* (Fig. 4):

$$\Delta l = l_1 - \sqrt{l_1^2 - 4 \cdot r_2 \cdot \sin\left(\Theta - \frac{\alpha}{2}\right) \cdot \sin\frac{\alpha}{2} \cdot \left[r_2 \cdot \cos\Theta + \sqrt{l_1^2 - r_2^2 \cdot (\sin\Theta)^2}\right]}, \quad (15)$$

where l_1 – the length of the spring in the mounting position, m; r_2 – the radius of turning point B around the pivot O, m; Θ – the angle between the beam of the rack OO1 and the lever OA in the mounting position of the

operating device, degrees. Then the horizontal component of the traction resistance of the operating device is:

$$R_{x2} = \frac{F_2 \cdot l_F}{l_R}, \quad (16)$$

where F_2 – the force that occurs at the safety spring compression, H; l_F and l_R – moment arm F_2 and R_2, correspondingly, m.

The expression obtained (16) allows us to determine, on the measurable experimental basis, the angle of the rear chamfer of the hoe blade, the average value of the horizontal component of the traction resistance of each operating device, which is perceived by the coupling device of the tractor. However, the equation (15) is obtained under certain assumptions that during the operation of the cultivator sower frame and the ploughshare leg are absolutely rigid. We also neglected the force of gravity and friction that arise in combinations. In fact, when working under the influence of dynamic forces there are elastic deformations in the design that give some increase to the angle α, which is very difficult to evaluate theoretically, so computer simulation is necessary to verify the assumption.

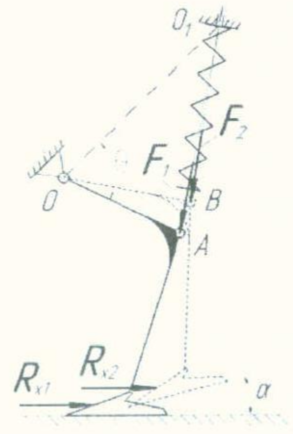

Figure 4 – Scheme of forces affecting the rack

Thus, after performing simulation, it will be possible to determine the traction resistance of specific working bodies in any soil-climatic conditions, knowing the design of the rack and exploring the geometry of the operating device.

At the stage of computer simulation, 26 simulations of the cultivator hoe operation of measurements were formed at various parameters (Tab. 1), such as ploughing depth, speed of motion, type of soil, etc. In addition, different types of soils were taken into account: I – preparation: ploughing for the winter, spring harrowing, 2 time cultivation, sowing – sunflower and corn, after sowing – 1 time inter-row treatment; II – preparation: ploughing for the winter, spring harrowing, 2 time cultivation.

As a result, data files were obtained concerning the dependence of the output voltage on the ADC from the effort on the operating device of the plough.

Table 1 – Parameters of the simulations

Type of the soil	№ (title) of the test	Number of tests	Depth of ploughing, cm	Speed of motion, km/h	Frequency measurement
I	Test 1	1	7	0.895	-
	Test 2	3	7	1.79	-
	Test 3	3	10	0.895	+
	Test 4	3	10	1.79	+
	Test 5	4	10	3.6	-
II	Test 6	3	10	0.895	+
	Test 7	1	10	7.19	-
	Test 8	4	7	0.895	-
	Test 9	1	7	7.19	-

The graphical representation of typical files is shown in Fig. 5

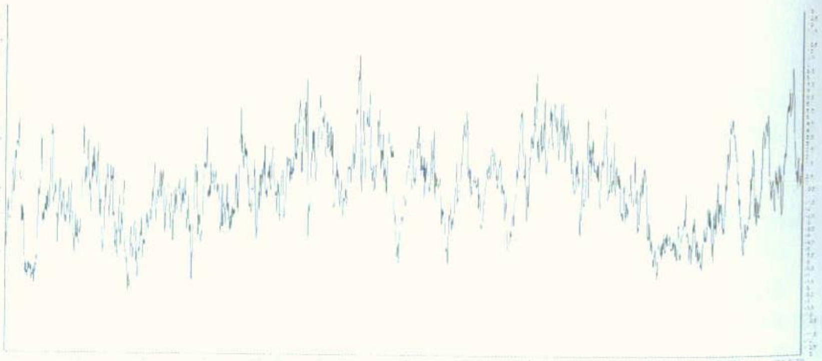

Figure 5 – The graphical representation of typical files of simulations

After the corresponding simulation, these data allow us to determine the optimal parameters for the use of the plough: the speed of motion, the thickness of the cutting tool, etc.

Using the remarkable Fourier transforms, it is possible to determine the correlation function of the random process by the magnitude of the spectral density:

$$K_x(\tau) = \int_0^{\infty} S_x(\omega)\cos\omega\tau d\omega \quad (16)$$

The inverse Fourier transform allows finding the spectral density by a known correlation function:

$$S_x(\omega) = \frac{1}{\pi}\int_0^{\infty} K_x(\tau)\cos\omega\tau d\tau.$$

Dividing the correlation function and the spectral density by dispersion, we obtain the same normalized values:

$$\rho_x(\tau) = \frac{K_x(\tau)}{D_x}$$

$$S_x(\omega) = \frac{S_x(\omega)}{D_x}$$

All the considerations above associated with the spectral analysis, belonged to the semi-period 0 – T or to the positive part of the frequency axis ω. This simplifies the calculations. Negative frequencies do not actually happen, but it turns out that it is necessary to introduce conditional and negative frequencies into consideration in the case when spectral decomposition of a random process in a complex form is carried out. Using the Euler formula for substitution we get:

$$\cos\omega\tau = \frac{e^{i\omega\tau} + e^{-i\omega\tau}}{2}. \quad (17)$$

Let's replace the expressions (4.1), (4.2) with Fourier transforms in the complex form:

$$K_x(\tau) = \int_{-\infty}^{\infty} S_x^*(\omega)e^{i\omega\tau}d\omega \quad (18)$$

$$S_x^*(\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} K_x(\tau)e^{-i\omega\tau}dt. \quad (19)$$

In the expression (19), the negative frequencies region ω is also included in the integration limit, that is, they are expanded 2-fold in comparison with the limits in formulas (16) and (17). At the same time, the spectral density function $S_x^*(\omega)$ remains even and valid. Therefore, the practical transition to spectral decomposition in a complex form is connected with the fact that in the graph of a function $S_x^*(\omega)$, except the right-hand side, in the region of positive ω there appears a left-hand symmetric side in the region of negative ω. Since the area of the graph should remain equal to Dx, then, for the corresponding frequencies, we obtain:

$$S_x^*(\omega) = \frac{1}{2} S_x(\omega). \qquad (20)$$

The discrete spectra were discussed above, which helped us to pass to the consideration of continuous spectra. In practice, both discrete and continuous spectra of dispersion can occur. The first occurs in cases where the random process consists of periodic fluctuations of one or more frequencies $\omega_k = k_{\omega_1}$ with random amplitudes. Each such fluctuation corresponds to a discrete spectrum line.

If the oscillations acquire an aperiodic 'disorderly' character, then the spectrum of the dispersion becomes continuous. As the random fluctuation increases, the spectrum graph 'is aligned' and on the boundary becomes ribbon-like, limited on the top by the horizontal line. Such a graph is called the white spectrum, and the corresponding random process is called a white noise. Any two sections of such a process are not correlated with each other, however closely they were located.

The expression of spectral density has this form:

$$S_x^*(\omega) = \frac{\alpha}{\pi} D_x \frac{\omega^2 + \alpha^2 + \beta^2}{(\omega^2 - \alpha^2 - \beta^2)^2 + 4\alpha^2\omega^2}. \qquad (21)$$

This expression of spectral density includes regions of negative and positive frequencies:

$$S_x^*(\omega) = \frac{2\alpha}{\pi} D_x \frac{\omega^2 + \alpha^2 + \beta^2}{(\omega^2 - \alpha^2 - \beta^2)^2 + 4\alpha^2\omega^2}. \qquad (21)$$

The algorithm for obtaining a correlation function [11] in MatLab program [12, 13, 14] is presented in Fig. 6.

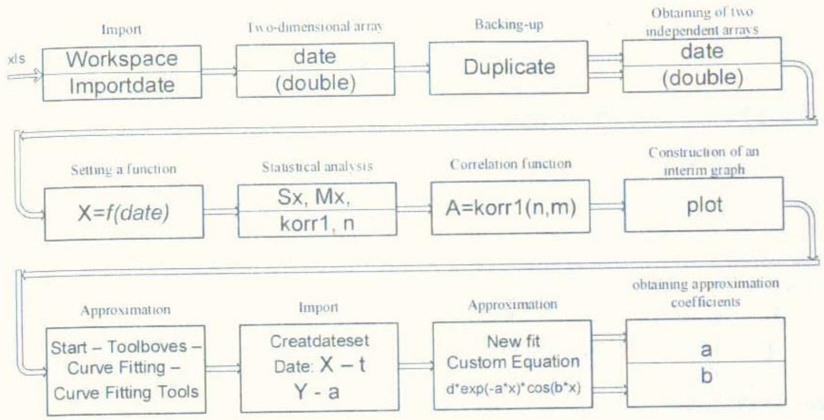

Figure 6 – The algorithm for obtaining a correlation function

Fig. 7 shows screenshots of the digital signal filtering.

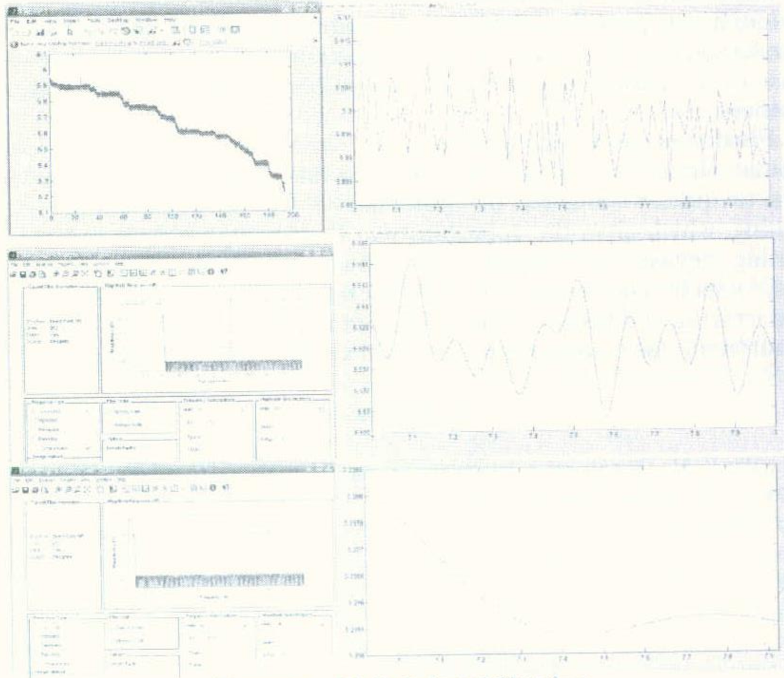

Figure 7 – Digital signal filtering

Fig. 8 shows the results of computer simulation in the form of correlation and spectral functions.

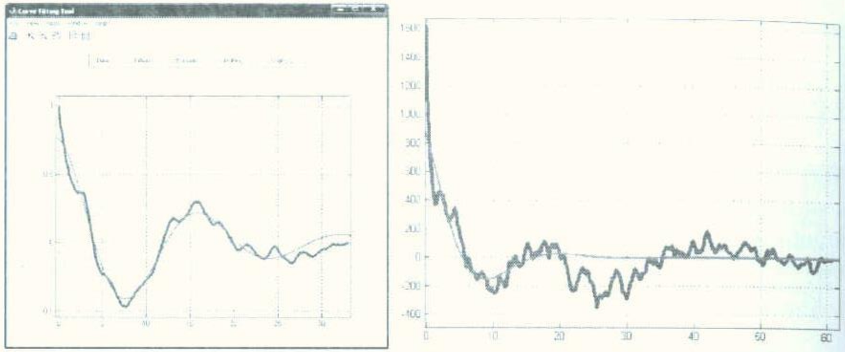

Figure 8 – Screenshots of construction of correlation and spectral functions

Thus, computer simulation of the parameters of the operating devices of the plough can provide complete information for amplitude-frequency and spectral analysis. These data allow us to determine the optimal parameters for the use of the plough: the speed of motion, the thickness of the cutting tool and others.

Findings and perspectives of further research. The use of computer simulation of the cultivator operation with different parameters allows to quickly visualize the potential of the research on the stage of designing, which gives the opportunity to find the optimal parameters of the operating devices and significantly reduces the probability of structural errors, which otherwise could only manifest itself at the stage of manufacturing and testing of research samples. In the future, it is planned to fully automate the simulation process and visualize the cultivator's modeling.

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Collective monograph

Volume 2

Edited by

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Maryna Dei, PhD, Associate Professor
Olga Rudenko , Dr.Sc in PA, Professor
Vitalii Lunov, PhD, Associate Professor

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