INTERNATIONAL SCIENTIFIC JOURNAL

MECHANIZATION IN AGRICULTURE & CONSERVING OF THE RESOURCES

Issue 1
2017

Year LXIII, ISSN print 0861-9638, ISSN web 2534-8450

SCIENTIFIC TECHNICAL UNION OF MECHANICAL ENGINEERING INDUSTRY-4.0
BULGARIAN ASSOCIATION OF MECHANIZATION IN AGRICULTURE

PUBLISHERS

SCIENTIFIC-TECHNICAL UNION OF MECHANICAL ENGINEERING “INDUSTRY-4.0”
BUGLARINA ASSOTIOATION OF AGRICULTURAL MACHINERY

ISSN (PRINT) 0861-9638, ISSN (WEB) 2534-8450

YEAR LXIII ISSUE 1 / 2017

DITORIAL BOARD

Chief Editor: Prof. Dr. eng Miho Mihov
Responsible secretary: Corresp. Memb. Prof. D.Sc. Hristo Beloev

MEMBERS:
Acad. D.Sc. Jemal Katsitadze – Georgia
Acad. D.Sc. Sayaкhat Nukeshev - Kazakhstan
Acad. D.Sc. Volodymyr Bulgakov – Ukraine
Acad. D.Sc.Valeriy Adamchuk – Ukraine
Prof. Abdullah Sessiz - Turkey
Prof. Abdulrahman Al-soqeer - Saudi Arabia
Prof. Alexander Tokarev - Russia
Prof. Alexey Vassilev - Russia
Assoc.Prof. Angel Trifonov - Bulgaria
Prof. Anupam Kumar Nema - India
Prof. Ayrat Valiev - Russia
Prof. Barbro Ulén - Sweden
Prof. Carmen Puia - Romania
Prof. Cheslav Vashkievich - Poland
Prof.Cumhur Aydinalp - Turkey
Prof. Daisuke Higaki - Japan
Prof. Davor Romic - Croatia
Prof. Domenico Pessina - Italy
Dr. Finn Plauborg - Denmark
Assoc.Prof. Ganka Baeva - Bulgaria
Assoc.Prof. Georgi Mitev - Bulgaria
Prof. Georgi Tassev - Bulgaria
Prof. Haiyan Huang - China

MEMBERS:
Prof. Hoang Thai Dai - Vietnam
Prof. Iliya Malinov - Bulgaria
Assoc.Prof. Ivan Ivanov - Bulgaria
Prof. Jan Szczepaniak - Poland
Prof. Komil Muminov - Uzbekistan
Prof. Krassimira Georgieva - Bulgaria
Prof. Maja Manojlović - Serbia
Prof. Mihail Iliev - Bulgaria
Prof. Mohammad Salem Al-Hwaiti - Jordan
Prof. Papamichail Dimitris - Greece
Prof. Pavel Tlustos - Czech Republic
Prof. Plamen Kangalov - Bulgaria
Prof. Ralph Meissner - Germany
Prof. Rossen Ivanov - Bulgaria
Prof. Svetla Rousseva - Bulgaria
Prof. Tadeusz Pawłowski - Poland
Prof. Tamara Persikova - Belarus
Prof. Valentina Kundius - Russia
Prof. Wojciech Tanaś - Poland
Prof. Yerbol Sarkynov - Kazakhstan
Prof. Zdenko Tkach - Slovakia
Prof. Zinta Gaile - Latvia
Prof. Zivko Davchev - Macedonia

The journal “Mechanization in agriculture” is continuer of the journals “Mechanized farming” (1948-1957), “Mechanization and electrification of agriculture” (1959-1980) and “Mechanization of agriculture ” (1981-1991)

108, Rakovski Str., 1000 Sofia, Bulgaria
tel. (+359 2) 987 72 90, tel./fax (+359 2) 986 22 40,
office@stumejournals.com
WWW.STUMEJOURNALS.COM

C O N T E N T S

MECHANIZATION IN AGRICULTURE

CONSERVING OF THE RESOURCES

MATHEMATICAL MODEL OF COMPLEX MOVEMENT OF A MATERIAL POINT ON A SURFACE OF AGRICULTURAL MACHINE WORKING BODY

DrSc., prof. Bulgakov V.[1], DrSc., prof. Adamchuk V.[2], DrSc., prof. Nozdrovicky L.[3], DrSc., prof. Krocko V.[3], DrSc., prof. Korenko M.[3], DrSc., prof. Kyurchev V.[4], Eng. Ihnatiev Ye.[4]

[1]National University of Life and Environmental Sciences of Ukraine, 15, Heroyiv Oborony Str., Kyiv, 03041, Ukraine;
[2]National Scientific Centre “Institute for Agricultural Engineering and Electrification”
11, Vokzalna Str., Glevaкha-1, Vasylkiv District, Kiev Region, 08631, Ukraine;
[3]Slovak University of Agriculture in Nitra, Trieda Andreja Hlinku 2, 949 76 Nitra, Slovak Republic;
[4]Tavria State Agrotechnological University of Ukraine, 18, B. Khmelnytsky Ave., Melitopol, 72310, Zaporizhia Region, Ukraine

Abstract. *In theoretical study of most of agricultural machines working bodies there is a need of the modeling of material particles (material points) motion on their working surfaces. Questions of such modeling in cases when the specified surfaces are give to material points movement with difficult trajectories are especially difficult. Objective of this research is to develop the basic provisions of complex movement theory of material point. When carrying out research methods of modeling theory, theoretical mechanics, higher mathematics, in particular differential geometry, methods of drawing up programs and numerical calculations on the personal computer are used. As a result of the conducted theoretical research the complex movement of material point which relative movement happens in a moving trihedron of curve which is defined by the natural equations is considered. The figurative movement of a trihedron is defined by differential characteristics of curve. Competency of use of Frenet formulas for finding absolute speed and point acceleration in projections on unit vectors of the moving trihedron is proved. As a result of numerical calculations on the personal computer there were found absolute trajectories of material point movement and qualitative assessment of received results was carried out.*
KEYWORDS: *TRIHEDRON, COMPLEX MOVEMENT, MATERIAL POINT, ABSOLUTE SPEED, ACCELERATION, THEORY*

1. Introduction

The motion of the material point along the plane (the gravitational surface, the rough plane, etc.) has been the subject of research of many scientists, with a worldwide reputation ranging from Galileo, Huygens, Newton, Euler, Ostrogradsky and others.As a most fundamental studies of the motion of a material particle on frictional surfaces of agricultural machines should be considered the works of academician Vasilenko P.M [1] and other domestic scientists academicians Zaika P. M, Berg B. A, and also Grigorieva S. M., Melnikov S. V. and others. A considerable number of analytical problems in the theory of agricultural machines still need the application of the theory of motion of a material point (particle) or a solid body over surfaces that are used in the design of new structures.

2. Preconditions and means for resolving the problem

2.1. Formulation of the problem

The theory of the complex motion of a material point has a completed form and does not even need any refinement. It is based on the fact that the motion of a point is investigated simultaneously with respect to two coordinate systems. One of them (the main one) is assumed to be fixed, and the second one is providing relative motion according to a given law in relation to the fixed point. Generally, the relative motion of the material point is carried out in the relative movement of the coordinate system. The sum of these movements (relative and portable) creates the absolute motion of the material point with respect to the basic coordinate system. In this case, the movements (both portable and relative) are usually given by the dependencies in the time function.

There is also known the natural way of specifying the motion of a material point, in which the velocity and acceleration are considered in the projections onto the units of the accompanying trihedron of the trajectory (the Frenet trihedron). However, in the available literature it is not possible to find the application of the Frenet trihedron as a moving coordinate system in which the material point is moving relatively. The development of the theory of the complex motion of a material point along the horizontal plane with the use of the Frenet trihedron is the subject of our investigation

2.2. Analysis of recent research and publications

The natural way of specifying the motion of a material point is considered quite well known and is widely used in studies on many issues in the field of mechanization of agriculture and the theory of agricultural machines. In this case, the vast majority of simple motion of material points is considered. There are known the examples with the use of a trihedron and Frenet formulas when considering the motion of a rigid body in its system, for example, an aircraft [2]. The kinematics of the motion of the accompanying trihedron of a helical line is considered in [3]. In the latest scientific and educational publications, the kinematics of the accompanying trihedron of a trajectory as a rigid body are either not considered at all, or are considered with reference to earlier studies and publications [4, 7, 8]. Meanwhile, as shown in [5, 9, 10, 11], the trihedron and Frenet's formulas can be successfully used in problems of kinematics and the dynamics of the complex motion of a material point, in particular when considering issues that are related to the study of agricultural machines.

2.3. Purpose of the study

As a main aim of our study is the further development of the theory of the complex motion of a material point along the plane with the application of the accompanying trihedron of the curve and the Frenet formulas.

3. Results and Discussion

At any point of the curve, three mutually perpendicular directions can be constructed. Single units along them (tangent, principal normal and binormal) form the accompanying (natural) trihedron of the curve or the triaxial Frenet. For a planar curve, the unit vectors u are in the plane of the curve, and the unit vector is perpendicular to it (see Fig. 1, a).

If you move the trihedron at a given speed V_A along the curve, you can determine the velocity and acceleration of any point of the trihedron, the magnitude and direction of which will depend on the curvature of the curve. The velocity of point of the trihedron will consist of velocity of pole (the origin of coordinates *A*) and velocity of this point in the rotational motion of trihedra around the instantaneous rotation axis, which coincides with the binormal hort

$\bar{b}$. During a certain period of time Δt, the trihedron moves along the curve to a new position, due to displacement to a distance Δs and rotation through an angle $\Delta\alpha$ (Fig. 1, b).

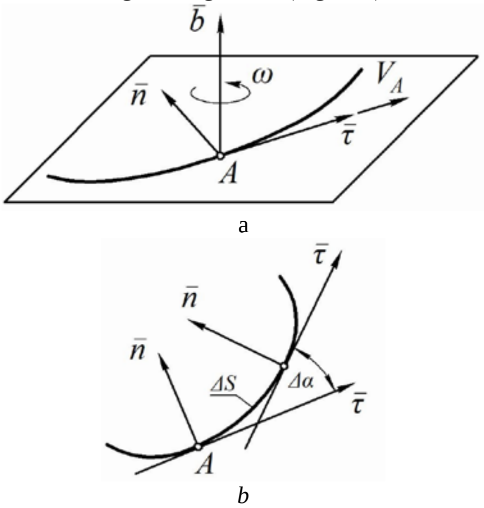


Fig. 1. *– Accompanying trihedron of the Frenet curve: a) position of the vector of the instantaneous rotation axis; b) to determine the angle of rotation $\Delta\alpha$ when the trihedron is moved along the curve by a distance Δs (the binormal $\bar{b}$ is projected to a point)*

The magnitude of the angular velocity ω can be defined as the limiting ratio of the increment of the angle to the increase in time:

$$\omega = \lim_{\Delta t \to 0} \frac{\Delta\alpha}{\Delta t} = \frac{d\alpha}{dt}. \tag{1}$$

We pass from the time parameter t to the arc coordinate s (paths along the arc):

$$\omega = \frac{d\alpha}{dt} = \frac{d\alpha}{ds}\frac{ds}{dt} = V_A \frac{d\alpha}{ds} = V_A k, \tag{2}$$

where k – curvature of the curve at the current point A.

Thus, the magnitude of the angular velocity of the trihedron depends on the speed of its motion along the curve and the curvature of the curve itself at the point where the vertex of the trihedron is located.

We fix the point B rigidly in the trihedron system and we find its velocity. The radius-vector $\bar{r}_B$ that determines the position of the point B relative to the fixed coordinate system Oxy (Fig. 2) can be specified with the help of two vectors: $\bar{r}_A$, which determines the position of the vertex of the trihedron in the coordinate system Oxy, and $\bar{\rho}$, which determines the position of point B in the trihedron system. The value of the radius vector $\bar{r}_B$ will be:

$$\bar{r}_B = \bar{r}_A + \bar{\rho}\,. \tag{3}$$

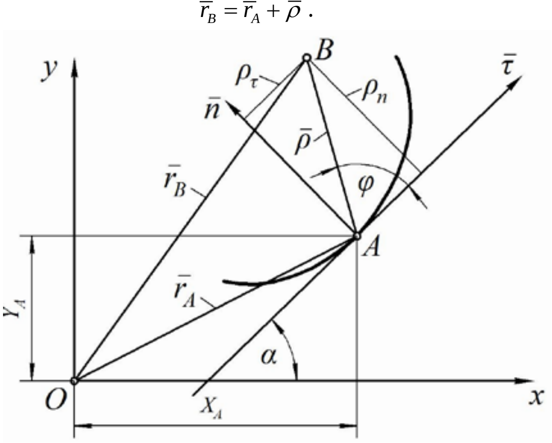


Fig. 2. *– Position of the point B in two coordinate systems: the immovable Oxy and the movable trihedron of the curve $\bar{\tau}\bar{n}\bar{b}$*

Let the point B in the system of the accompanying trihedron will be given by a vector $\rho = const$ whose components in the projections on unit vectors (orthes) have the value ρ_τ and ρ_n (Fig. 2).

We write the vector sum (3) in the projections on the axis of the fixed coordinate system Oxy. We will have:

$$\begin{aligned} x_B &= x_A + \rho_\tau \cos\alpha - \rho_n \sin\alpha; \\ y_B &= y_A + \rho_\tau \sin\alpha + \rho_n \cos\alpha. \end{aligned} \tag{4}$$

Differentiating (4) with respect to time t, we find the projection of the velocity of point B on the coordinate axes of the immovable system:

$$\begin{aligned} \frac{dx_B}{dt} &= \frac{dx_B}{ds}\frac{ds}{dt} = V_A \frac{dx_B}{ds} = V_A\left(x'_A - \rho_\tau \alpha' \sin\alpha - \rho_n \alpha' \cos\alpha\right); \\ \frac{dy_B}{dt} &= \frac{dy_B}{ds}\frac{ds}{dt} = V_A \frac{dy_B}{ds} = V_A\left(y'_A + \rho_\tau \alpha' \cos\alpha - \rho_n \alpha' \sin\alpha\right). \end{aligned} \tag{5}$$

In expressions (5) there was done the transition from the time parameter t to the arc coordinate s – the arc length of the curve. In this case, the components of expressions (5) acquire a geometric content [7]:

$$x'_A = \cos\alpha; \quad y'_A = \sin\alpha; \quad \alpha' = k. \tag{6}$$

Taking into account (6), the projections of the absolute velocity of the point B in (5) on the axis of the immovable coordinate system are written as follows:

$$\begin{aligned} V_{Bx} &= x'_B = V_A\left[(1 - k\rho_n)\cos\alpha - k\rho_\tau \sin\alpha\right]; \\ V_{By} &= y'_B = V_A\left[(1 - k\rho_n)\sin\alpha + k\rho_\tau \cos\alpha\right]. \end{aligned} \tag{7}$$

The result (7) can also be obtained from the well-known formula [4]:

$$\overline{V_B} = \overline{V_A} + \bar{\omega} \times \bar{\rho}, \tag{8}$$

where the first component $\overline{V_A}$ is the velocity of the pole A, and the second $\bar{\omega} \times \bar{\rho}$ is the speed of the point B around the pole. Accordingly they can be found in this way:

$$\begin{aligned} V_{Ax} &= \frac{dx_A}{dt} = \frac{dx_A}{ds}\frac{ds}{dt} = V_A \frac{dx_A}{ds} = V_A x'_A = V_A \cos\alpha; \\ V_{Ay} &= \frac{dy_A}{dt} = \frac{dy_A}{ds}\frac{ds}{dt} = V_A \frac{dy_A}{ds} = V_A y'_A = V_A \sin\alpha. \end{aligned} \tag{9}$$

$$\bar{\omega} \times \bar{\rho} = \begin{vmatrix} x & y & z \\ 0 & 0 & V_A k \\ \rho_\tau \cos\alpha - \rho_n \sin\alpha & \rho_\tau \sin\alpha + \rho_n \cos\alpha & 0 \end{vmatrix},$$

from where:

$$\bar{\omega} \times \bar{\rho} = \left\{ -V_A k\left(\rho_\tau \sin\alpha + \rho_n \cos\alpha\right); V_A k\left(\rho_\tau \cos\alpha - \rho_n \sin\alpha\right) \right\}. \tag{10}$$

Having added the components of the projections (9) and (10) to the corresponding coordinate axes, we obtain the already known result (7).

And now we show how it is not very difficult to find the absolute velocity of the point B in the projections onto the unit vectors of the accompanying trihedron of the curve. For comparison, we first do this using formula (8), and then applying Frenet formulas. We find the vector $\overline{\omega} \times \overline{\rho}$ in the projections onto the unit vectors of the trihedron:

$$\overline{\omega} \times \overline{\rho} = \begin{vmatrix} \bar{\tau} & \bar{n} & \bar{b} \\ 0 & 0 & V_A k \\ \rho_\tau & \rho_n & 0 \end{vmatrix} = -\bar{\tau} V_A k \rho_n + \bar{n} V_A k \rho_\tau\,. \tag{11}$$

Considering the fact that the speed of pole A in direction coincides with the orthom $\bar{\tau}$, ie. $\overline{V_A} = V_A \bar{\tau}$, we rewrite expression (8) with regard to (11):

$$\overline{V_B} = V_A\left[\bar{\tau}(1 - k\rho_n) + \bar{n} k \rho_\tau\right]. \tag{12}$$

The geometric sum of the components (7) and (12) will give the same result:

$$V_B = V_A \sqrt{(1 - k\rho_n)^2 + k^2 \rho_\tau^{\,2}}\,. \tag{13}$$

Now we consider an alternative with the using of Frenet formulas. The vector equation (3) in the system of the accompanying trihedron will be written as follows:

$$\overline{R_B} = \overline{r_A} + \overline{\tau}\rho_\tau + \overline{n}\rho_n. \qquad (14)$$

If we assume that the coordinates ρ_τ and ρ_n do not change along the curve when the trihedron moves, that is, the point *B* is fixed in the trihedron, then its absolute velocity can be found by differentiating expression (14) with respect to time *t*. However, the position of the trihedron on the curve depends on the arc coordinate *s*, so when differentiating (14), it is necessary to go from the independent variable t to the arc s:

$$\frac{d\overline{R_B}}{dt} = \frac{d\overline{R_B}}{ds}\cdot\frac{ds}{dt} = V_A\frac{d\overline{R_B}}{ds} = V_A\left[\frac{d\overline{r_A}}{ds} + \frac{d\overline{\tau}}{ds}\rho_\tau + \frac{d\overline{n}}{ds}\rho_n\right]. \qquad (15)$$

In expression (15), the derivative $\frac{d\overline{r_A}}{ds} = \overline{\tau}$, i.e. this is a single unit of the tangent. The remaining derivatives – $\frac{d\overline{\tau}}{ds}$ and $\frac{d\overline{n}}{ds}$ – are known Frenet formulas, which have a kinematic interpretation [6]. They are the basic formulas of differential geometry, in which the independent coordinate is the arc coordinate S (we give a simplified version for a plane curve):

$$\overline{\tau}' = k\overline{n}; \quad \overline{n}' = -k\overline{\tau}, \qquad (16)$$

where k – the curvature of the curve, which is given by the natural equation $k = k(s)$.

The Frenet formulas (16) make it possible to quickly and easily obtain derivatives with respect to the arc coordinate s from the unit vectors $\overline{\tau}$ and $\overline{n}$ in the projection on these units. In the kinematic interpretation, the derivatives (16) are projections of the velocities of the ends of unit vectors $\overline{\tau}$ and $\overline{n}$ on these units in the rotational motion of the trihedron [6]. Taking (16) into account, expression (15) assumes exactly the same form as it was obtained in (12). Thus, the application of the Frenet formulas (16) makes it very easy to find the velocity of the point *B* in the rotational motion around the pole *A*, which in the other case must be found as a vector product (11). Even more effectively, they work when finding the absolute speed of point *B* in a complex motion, to the consideration of which we proceed further.

Now we assume that the point *B* moves in the system of the accompanying trihedron, i.e. ector $\overline{\rho}$ is a function of time: $\overline{\rho} = \overline{\rho}(t)$. In this case, the absolute velocity of the point *B* will be determined as the sum of the transport velocity, which can be found from formula (12), and the relative velocity, which we obtain by differentiating the vector $\overline{\rho}$ with respect to time t. However, the portable speed is a function of the arc coordinate S, so the relative speed must also be related to this independent variable:

$$\overline{V_r} = \frac{d\overline{\rho}}{dt} = \frac{d\overline{\rho}}{ds}\frac{ds}{dt} = V_A\frac{d\overline{\rho}}{ds}. \qquad (17)$$

Let us write the vector equation (17), which determines the relative velocity in the trihedron system, into two components along the directing vectors $\overline{\tau}$, $\overline{n}$ and we add to the transport velocity (12). After grouping the terms and taking the pole velocity V_A off the brackets, the absolute velocity of the point *B* in the projections onto the vertices of the trihedron can be written as follows:

$$\overline{V}_B = V_A\left[\overline{\tau}\left(1 - k\rho_n + \rho'_\tau\right) + \overline{n}\left(k\rho_\tau + \rho'_n\right)\right]. \qquad (18)$$

Now we can show how it is easy to obtain the result (18) with the help of the Frenet formulas. To do this, we differentiate expression (14) under the condition that the coordinates ρ_τ and ρ_n are the functions of the arc coordinate s:

$$\overline{R'_B} = \overline{\tau} + \overline{\tau}'\rho_\tau + \overline{\tau}\rho'_\tau + \overline{n}'\rho_n + \overline{n}\rho'_n. \qquad (19)$$

Substituting in (19) the expressions for the orthonormal derivatives of the trihedron from the Frenet formulas (16), we obtain:

$$\begin{aligned}\overline{R'_B} &= \overline{\tau} + nk\rho_\tau + \tau\rho'_\tau - \tau k\rho_n + \overline{n}\rho'_n = \\ &= \overline{\tau}(1 - k\rho_n + \rho'_\tau) + \overline{n}(k\rho_\tau + \rho'_n).\end{aligned} \qquad (20)$$

Comparing equations (18) and (20), we can conclude that the differentiation of equation (14) with the use of Frenet's formulas gives the absolute velocity of the point given in the trihedron system by a removable distance $\overline{\rho} = \overline{\rho}(s)$ in the projections onto the trihedron orbits at the velocity of the trihedron along the curve V_A = 1 m·s^{-1}. In the case where the speed V_A differs from one, each projection must be multiplied by an amount V_A. So, we can formulate the following rule:

If the point in the system of the mobile accompanying trihedron of the curve is given by the radius vector in the form (14), then in order to find its absolute velocity in the projections onto the units of the same trihedron, it is necessary to differentiate equation (14) along the arc coordinate of the curve S using Frenet formulas and to multiply obtained result by the velocity of the vertex of the trihedron along the curve.

The position of the point *B* in the system of the accompanying trihedron of the curve can also be specified in the polar coordinate system – by the distance $\overline{\rho}$ and the angle φ, the count of which is taken from the orbit $\overline{\tau}$ (Fig. 2). In this case, the position of point *B* in the trihedron system in vector form will be written as follows:

$$\overline{R}_B = \overline{r}_A + \overline{\tau}\rho\cos\varphi + \overline{n}p\sin\varphi.$$

To obtain the absolute velocity of the point *B*, we need to differentiate the equation (21) along the arc coordinate s [using the Frenet formula (16) taking into account that $\rho = \rho\ (s)$ and $\varphi = \varphi\ (s)$], and multiply the result by the speed of motion v_A of the top of the trihedron:

$$\begin{aligned}\overline{V}_B = \overline{V}_A\{&\overline{\tau}\left[1 + \rho'\cos\varphi - \rho(k + \varphi')\sin\varphi\right] + \\ &+ \overline{n}\left[\rho'\sin\varphi + \rho(k + \varphi')\cos\varphi\right]\}.\end{aligned} \qquad (22)$$

The absolute velocity modulus of the point *B* for formulas (18) and (22) respectively, will be written as follows:

$$V_B = V_A\sqrt{\left(1 - k\rho_n + \rho'_\tau\right)^2 + \left(k\rho_\tau + \rho'_n\right)^2}; \qquad (23)$$

$$V_B = V_A\sqrt{\left(\rho' + \cos\varphi\right)^2 + \left[\sin\varphi - \rho\left(k + \varphi'\right)\right]^2}. \qquad (24)$$

Now we turn to finding the absolute trajectory of point *B*, i.e. trajectory in the fixed coordinate system *Oxy*. The dependencies $\rho_\tau = \rho_\tau(s)$, $\rho_n = \rho_n(s)$ or $\rho = \rho(s)$, $\varphi = \varphi(s)$ specify the trajectory of motion in the system of the accompanying trihedron, i.e. a trajectory of relative motion. The sum of the relative and movable motions of point *B* will give the trajectory of its absolute motion. After all, we need to go from the vector equations (14) or (21) to their coordinate recording in the projection on the axis of the fixed coordinate system. Due to the motion of the trihedron, the position of its vertex $A(x_A, y_A)$ in the *Oxy* system will vary depending on the arc coordinate s. The coordinates of vertex *A* in the projections on the axis of the fixed system *Oxy* can be found if there is known the dependence $k = k(s)$ – the so-called natural equation of the curve. The transition formulas have the form [7]:

$$x_A = \int\cos\ \alpha\ ds; \qquad y_A = \int\sin\alpha\ ds, \qquad (25)$$

where $\alpha = \alpha(s)$ – the regularity of the angle α change (Fig. 2) when the vertex *A* moves along the curve and which is also determined from the dependence $k = k(s)$ [7]:

$$\alpha = \int kds. \qquad (26)$$

The absolute trajectory of the point *B* in the coordinate system *Oxy* is obtained by parallel transfer of the vertex *A* along the axes on the parameters (25) and by the simultaneous transition from the coordinates of the point *B* (ρ_τ, ρ_n or $\rho\cos\varphi$, $\rho\sin\varphi$) in the trihedron system to the coordinates of the point $B(x_B, y_B)$ in the fixed coordinate system. To do this, we combine their axes by turning the trihedron around the binormal by an angle $\alpha = \alpha(s)$.

After the rotation, summation and substitution (26) in (25), the vector equation (14) is written in the projections on the axis of the fixed coordinate system:

$$x_B = \rho_\tau \cos\left(\int k ds\right) - \rho_n \sin\left(\int k ds\right) + \int \cos\left(\int k ds\right) ds;$$
$$y_B = \rho_\tau \sin\left(\int k ds\right) + \rho_n \cos\left(\int k ds\right) + \int \sin\left(\int k ds\right) ds. \qquad (27)$$

Since the parametric equations (27) describe the absolute trajectory, their differentiation with respect to a parameter s can be used to find the components and the modulus of the absolute velocity of point B as a function of s:

$$x_B' = (1 - k\rho_n + \rho_\tau')\cos\left(\int k ds\right) - (k\rho_\tau + \rho_n')\sin\left(\int k ds\right);$$
$$y_B' = (1 - k\rho_n + \rho_\tau')\sin\left(\int k ds\right) + (k\rho_\tau + \rho_n')\cos\left(\int k ds\right); \qquad (28)$$
$$V_B(s) = \sqrt{x_B'^2 + y_B'^2} = \sqrt{(1 - k\rho_n + \rho_\tau')^2 + (k\rho_\tau + \rho_n')^2}.$$

Comparing the last expression (28) and expression (23), we conclude that they are similar. For a complete analogy, the last expression (28) needs to be multiplied by the speed V_A, since in this case we will move from the equation $V_B = V_B(s)$ to the equation $V_B = V_B(t)$.

Applying a similar coordinate transformation with respect to the vector equation (21), we obtain the parametric equations of the absolute trajectory of the point B:

$$x_B = \rho\cos\varphi\cos\left(\int k ds\right) - \rho\sin\varphi\sin\left(\int k ds\right) + \int \cos\left(\int k ds\right) ds;$$
$$y_B = \rho\cos\varphi\sin\left(\int k ds\right) + \rho\sin\varphi\cos\left(\int k ds\right) + \int \sin\left(\int k ds\right) ds. \qquad (29)$$

Equation (29) can be written in a more compact form by applying trigonometric formulas for the sum and difference of angles:

$$x_B = \rho\cos\left(\varphi + \int k ds\right) + \int \cos\left(\int k ds\right) ds;$$
$$y_B = \rho\sin\left(\varphi + \int k ds\right) + \int \sin\left(\int k ds\right) ds. \qquad (30)$$

Analogously to the previous case, by differentiating (30) with respect to the parameter s, we can find the absolute velocity components of the point B $V_B = V_B(s)$, multiplying which by V_A we obtain the result which was obtained earlier in (24).

We consider the following examples. In view of the directing (initial) curve along which the accompanying trihedron moves with speed V_A, we take a chain line whose natural equation has the form:

$$k = \frac{a}{a^2 + s^2}, \qquad (31)$$

where a – constant parameter.

The absolute velocity can be found from formulas (18) and (23) and an absolute trajectory according to equations (27) in the case when the relative motion in the trihedron is given by the dependences of $\rho_\tau = \rho_\tau(s)$ and $\rho_n = \rho_n(s)$. If these dependences have the form $\rho = \rho(s)$ and $\varphi = \varphi(s)$, then we must use formulas (22), (24) and (30). We will use the second variant and consider the kinematics of the point B for some dependences $\rho = \rho(s)$ and $\varphi = \varphi(s)$. After substituting (21) into (30) and by integrating, we obtain:

$$x_B = \frac{\rho}{\sqrt{a^2 + s^2}}\left(a\cos\varphi - s\sin\varphi\right) + a\,\mathrm{Arsh}\frac{s}{a};$$
$$y_B = \frac{\rho}{\sqrt{a^2 + s^2}}\left(a\sin\varphi + s\cos\varphi\right) + \sqrt{a^2 + s^2}. \qquad (32)$$

By substituting the given dependences $\rho = \rho(s)$ and $\varphi = \varphi(s)$ in (32), we obtain the parametric equations of the absolute trajectory of the point B. We find the absolute velocity in the projections onto the unit vectors of the accompanying trihedron from expression (22), and its modulus from expression (24). On Fig. 3 from the equations (32) there are constructed the absolute trajectories of the point B for different dependences of $\rho = \rho(s)$ and $\varphi = \varphi(s)$.

The value of the constant a is assumed to be a = 25, the change in the arc coordinate s occurred within the range s = 0 – 100. For ρ = 0, from equations (32) we obtain the initial curve – the chain line, which is on Fig. 3 depicted by thickened line. On Fig. 4 there are presented the graphs of the absolute velocity modulation of the point B, which are plotted as a function of the arc coordinate s, using formula (24) for V = 1 m·s^{-1} for the trajectories shown in Fig. 3c and in Fig. 3d.

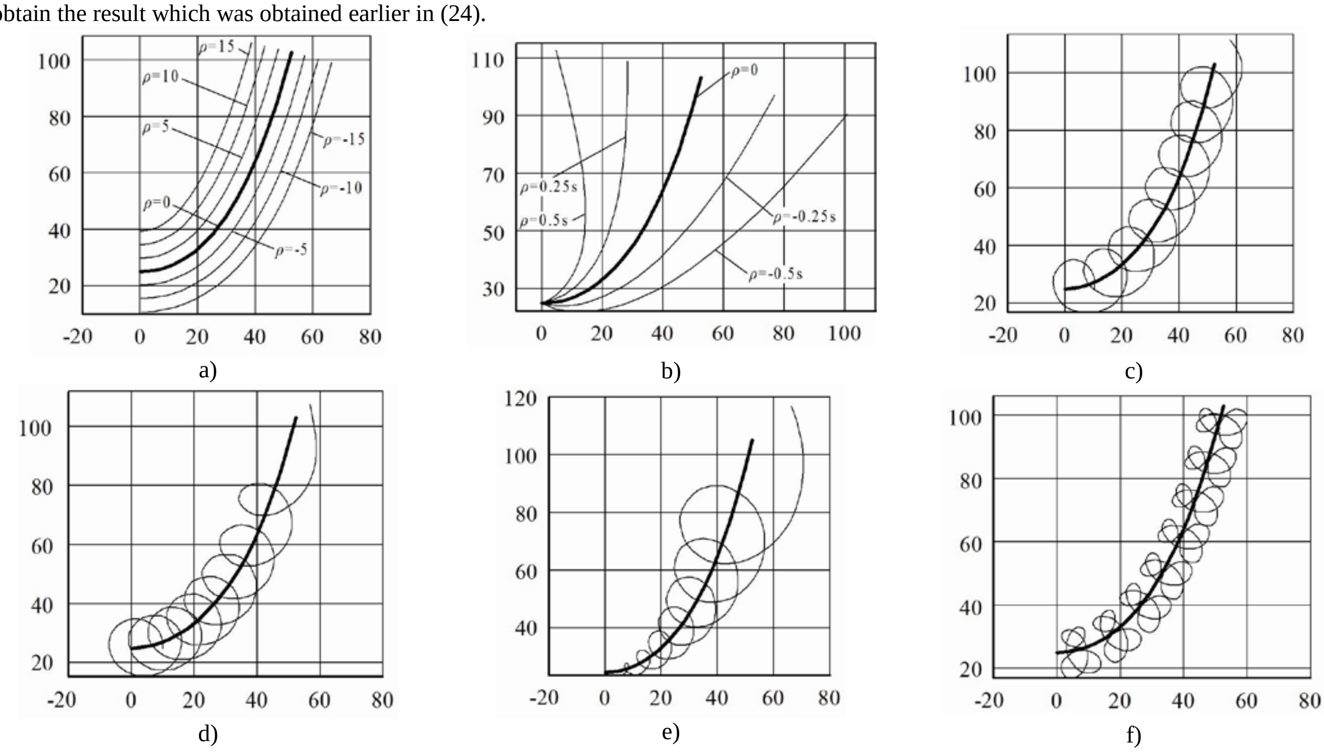
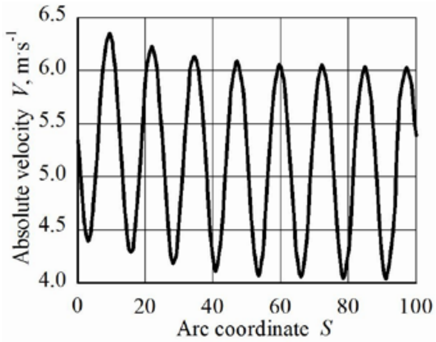
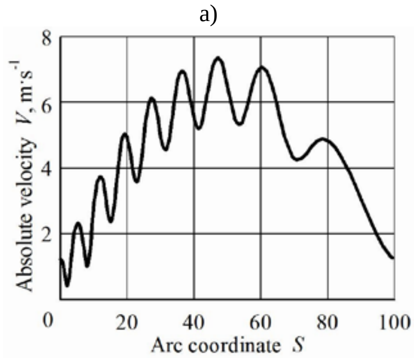


***Fig. 3**. – Absolute trajectories of the point B for different dependences $\rho = \rho(s)$ and $\varphi = \varphi(s)$, constructed from equations (32):*
a) φ = 90° – const ; ρ = const (trajectories – equidistant curves); b) φ = 90° – const ; ρ = cs – it changes linearly;
c) φ = 0,5 s ; ρ = 10 – const; d) φ = s – 0,005 s²; ρ = 10 – const; e) φ = s – 0,005 s²; ρ = 0,25 s; f) φ = 0,5 s; ρ = 10 sin s



a)



b)

***Fig. 4.** – The graphs of the changes of modulus of the absolute velocity of the point B in relation to the arc coordinate s for V = 1 m·s^{-1}: a) the graph of the changes of the velocity of the point for its absolute trajectory shown on Fig.3d; b) the graph of the change in the velocity of a point for its absolute trajectory, shown in Fig. 3e*

Let us proceed to the next stage – finding the absolute acceleration of point *B*. According to the classical theory, it is defined as the geometric sum of the three vectors:

$$\overline{w_B} = \overline{w_e} + \overline{w_r} + 2\overline{\omega} \times \overline{V_r} \ . \tag{33}$$

The first vector from (33) is called the transport acceleration and is determined by formula [4, 7]:

$$\overline{w_e} = \overline{w_A} + \overline{\varepsilon} \times \overline{\rho} + \overline{\omega} \times (\overline{\omega} \times \overline{\rho}), \tag{34}$$

where $\overline{\varepsilon}$ – vector of the angular acceleration.

We find the expressions for all the components of expression (34) and their sum. The first vector $\overline{w_A}$ of acceleration of the origin of the trihedron it is found by differentiating the corresponding velocity, while moving from the time parameter t to the arc coordinate s:

$$\begin{aligned} \overline{w_A} &= \frac{d\overline{V_A}}{dt} = \frac{d\overline{V_A}}{ds} \cdot \frac{ds}{dt} = V_A \frac{d\overline{V_A}}{ds} = \\ &= V_A \frac{d}{ds}\left(V_A \overline{\tau}\right) = v_A \left(\frac{dV_A}{ds}\overline{\tau} + V_A \frac{d\overline{\tau}}{ds} \right). \end{aligned} \tag{35}$$

The equation (35) $\dfrac{d\overline{\tau}}{ds}$ can be considered as first from the frenet formulas (16). Taking into account (16) the equation (35) can be written as follows:

$$\overline{w_A} = V_A V_A' \overline{\tau} + V_A^2 k \overline{n} \ . \tag{36}$$

In the case when $v_A = const$ the acceleration of the vertex of the trihedron will have one component directed along the principal normal $\overline{n}$, and its modulus will have a value $V_A^2 \cdot k$ or V_A^2 / r, since $k = 1/r$, where r – is the radius of curvature of the curve. This is known as the so-called normal acceleration. If the speed of motion of the trihedron is variable, then another component appears, directed along the tangent – tangential acceleration.

Thus, expression (36) is a well-known formula for determining the acceleration of a point's motion along a curve in which an arc coordinate s serves instead of a time variable. The second component of the (34) includes the angular acceleration vector $\overline{\varepsilon}$. To determine it, we differentiate the angular velocity vector $\overline{\omega}$. According to (2) we know the parameter ω: $\omega = V_A k$. Since the vector $\overline{\varepsilon}$ is directed along the binormal $\overline{b}$, the differentiation gives:

$$\begin{aligned} \overline{\varepsilon} &= \frac{d\overline{\omega}}{dt} = \frac{d\overline{\omega}}{ds}\frac{ds}{dt} = V_A \frac{d\overline{\omega}}{ds} = \\ &= V_A \frac{d}{ds}\left(\overline{b} V_A k\right) = v_A \left[\overline{b}' V_A k + \overline{b}(V_A k)'\right]. \end{aligned} \tag{37}$$

In view of the Frenet formulas (16) and after further differentiation, we obtain:

$$\overline{\varepsilon} = \overline{b} \cdot V_A \left(V_A' \cdot k + V_A \cdot k'\right). \tag{38}$$

Now we find a vector composition $\overline{\varepsilon} \times \overline{\rho}$:

$$\begin{aligned} \overline{\varepsilon} \times \overline{\rho} &= \begin{vmatrix} \overline{\tau} & \overline{n} & \overline{b} \\ 0 & 0 & V_A(V_A' \cdot k + V_A' \cdot k') \\ \rho_\tau & \rho_n & \rho_b \end{vmatrix} = \\ &= -\overline{\tau} \cdot V_A \cdot \rho_n (V_A' \cdot k + V_A \cdot k') + \overline{n} \cdot V_A \cdot \rho_\tau (V_A' \cdot k + V_A \cdot k'). \end{aligned} \tag{39}$$

The last component in expression (34) - vector composition $\overline{\omega} \times (\overline{\omega} \times \overline{\rho})$ we can find by analogous way. Below is the final result:

$$\overline{\omega} \times \overline{\rho} = -\overline{\tau} \cdot \rho_n \cdot v_A \cdot k + \overline{n} \cdot \rho_\tau \cdot v_A \cdot k. \tag{40}$$

$$\overline{\omega} \times (\overline{\omega} \times \overline{\rho}) = -\overline{\tau} \cdot V_A^2 \cdot k^2 \cdot \rho_\tau - \overline{n} \cdot V_A^2 \cdot k^2 \cdot \rho_n. \tag{41}$$

Substituting the vectors (36), (39) and (41) into (34), after grouping of the components according to corresponding directions of the unit vectors, we obtain the vector of the transport acceleration:

$$\begin{aligned} \overline{w_e} &= \overline{\tau} V_A \left[V_A' - \rho_n (V_A' k + V_A k') - V_A k^2 \rho_\tau\right] + \\ &+ \overline{n} V_A \left[V_A k + \rho_\tau (V_A' k + V_A k') - V_A k^2 \rho_n\right]. \end{aligned} \tag{42}$$

The next component in the formula (33) is called the relative acceleration, i.e. this is the acceleration of point *B* with respect to the system of the Frenet trihedron. It can be obtained by differentiating the expression for the relative velocity. The relative velocity V_r is obtained as the derivative of the radius vector $\overline{\rho}$ in the system of the accompanying trihedron:

$$\overline{V_r} = \frac{d\overline{\rho}}{dt} = \frac{d\overline{\rho}}{ds} \cdot \frac{ds}{dt} = V_A \frac{d\overline{\rho}}{ds}. \tag{43}$$

After differentiating of the expression (43), we obtain:

$$\overline{w_r} = \frac{d}{dt}\left(V_A \frac{d\overline{\rho}}{ds}\right) = \frac{ds}{dt} \cdot \frac{d}{ds}\left(V_A \frac{d\overline{\rho}}{ds}\right) = V_A (V_A' \overline{\rho}' + V_A \overline{\rho}''). \tag{44}$$

Placing the vector (44) along the directions of the unit vectors of the trihedron, we obtain:

$$\overline{w_r} = V_A \left[\overline{\tau}(V_A' \rho_\tau' + V_A \rho_\tau'') + \overline{n}(V_A' \rho_n' + V_A \rho_n'')\right].$$

Finally, the third, the last vector in the expression (33) is called the Coriolis acceleration. We find it as a doubled vector conjuction of the angular velocity vector $\overline{\omega} = \overline{b} \cdot V_A \cdot k$ and relative velocity vector V_r (43). We will have:

$$2\overline{\omega} \times \overline{V_r} = \begin{vmatrix} \overline{\tau} & \overline{n} & \overline{b} \\ 0 & 0 & V_A k \\ V_A \rho_\tau' & V_A \rho_n' & 0 \end{vmatrix} = 2V_A^2 k(-\overline{\tau}\rho_n' + \overline{n}\rho_\tau'). \tag{46}$$

Substituting (42), (45) and (46) into (33) and grouping the components of the vectors along the directions of the unit vectors of the trihedron, we finally obtain the expression for absolute acceleration of point *B*:

$$\begin{aligned} \overline{w_B} &= \overline{\tau} V_A \left[V_A'(1 - k\rho_n + \rho_\tau') + V_A(\rho_\tau'' - k'\rho_n - k^2\rho_\tau - 2k\rho_n')\right] + \\ &+ \overline{n} V_A \left[V_A'(k\rho_\tau + \rho_n') + V_A(\rho_n'' - k'\rho_\tau - k^2\rho_n + k + 2k\rho_\tau')\right]. \end{aligned} \tag{47}$$

By formula (47), we can find the absolute acceleration of point *B* in complex motion if there known the law of its motion in the contiguous plane of the trihedron $\rho_\tau = \rho_\tau(s)$, $\rho_n = \rho_n(s)$, and the trihedron itself moves with a given velocity $v = v(s)$ along a plane curve with the known natural equation $k = k(s)$. It should be emphasized that the absolute acceleration is obtained in the projections on the axis of the mobile accompanying trihedron of the curve.

Now we find the formula for the absolute acceleration of point *B* when its motion is given by equation (21), that is:

$$\rho_\tau = \rho\cos\varphi; \qquad \rho_n = \rho\sin\varphi. \tag{48}$$

Differentiating twice the equations (48), we obtain:

$$\begin{aligned}
&\rho_\tau' = \rho'\cos\varphi - \rho\varphi'\sin\varphi;\\
&\rho_n' = \rho'\sin\varphi + \rho\varphi'\cos\varphi;\\
&\rho_\tau'' = \left(\rho'' - \rho\varphi'^2\right)\cos\varphi - \left(2\rho'\varphi' + \rho\varphi''\right)\sin\varphi;\\
&\rho_n'' = \left(\rho'' - \rho\varphi'^2\right)\sin\varphi + \left(2\rho'\varphi' + \rho\varphi''\right)\cos\varphi.
\end{aligned} \tag{49}$$

Substituting (49) in (47) we obtain an expression for finding the absolute acceleration of point *B* in the case when its relative motion is specified by the distance $\rho = \rho(s)$ and angle $\varphi = \varphi(s)$:

$$\begin{aligned}
&\overline{w}_B = \overline{\tau}V_A\left\{V_A'\left[1 + \rho'\cos\varphi - \rho(k+\varphi')\sin\varphi\right] + \right.\\
&+V_A\left[\rho'' - \rho(k+\varphi')^2\right]\cos\varphi -\\
&\left.-\left[2\rho'(k+\varphi') + k'\rho + \rho\varphi''\right]\sin\varphi\right\} +\\
&+\overline{n}V_A\left\{V_A'\left[\rho'\sin\varphi + \rho(k+\varphi')\cos\varphi\right] + \right.\\
&+V_A\left[\rho'' - \rho(k+\varphi')^2\right]\sin\varphi +\\
&\left.+\left[2\rho'(k+\varphi') + k'\rho + \rho\varphi''\right]\cos\varphi + k\right\}.
\end{aligned} \tag{50}$$

The modulus of the absolute acceleration vector of the point *B* (47), which is given by the projections onto the orthograms of the trihedron, or (50), where the point *B* is given by the distance *ρ* and the angle *φ*, is defined as the geometric sum of its projections on the unit vectors $\overline{\tau}$ и $\overline{n}$:

$$w_B = \sqrt{\overline{w}_{B\tau}^{\,2} + \overline{w}_{Bn}^{\,2}}. \tag{51}$$

Formulas (47), (50) for finding of the absolute acceleration are obtained by methods of the classical theory with finding each component: transport acceleration, relative acceleration and acceleration of Coriolis.

And now we show how simply can be obtained theses formulas with the help of Frenet formulas, without dwelling on finding each individual component of absolute acceleration. This is the purpose of this study.

The determination of the vecor of an absolutte acceleration of the point *B* is carried out by differentiating the expressions (18) or (22) of the absolute velocity, since this is done in the study of ordinary motion. Anyway, it must be differentiated along the arc coordinate s, since the expressions (18), (22) are its functions. We differentiate, for example, expressions (18) in detail using the Frenet formulas (16):

$$\begin{aligned}
\overline{V_B'} &= V_A'\left[\overline{\tau}(1 - k\rho_n + \rho_\tau') + \overline{n}(k\rho_\tau + \rho_n')\right] +\\
&+V_A\left[\overline{\tau}(1 - k\rho_n + \rho_\tau') + \overline{n}(k\rho_\tau + \rho_n')\right]' =\\
&= V_A'\left[\overline{\tau}(1 - k\rho_n + \rho_\tau') + \overline{n}(k\rho_\tau + \rho_n')\right] +\\
&+V_A\Big[\overline{\tau}'(1 - k\rho_n + \rho_\tau') + \overline{\tau}(1 - k\rho_n + \rho_\tau')' +\\
&+\overline{n}'(k\rho_\tau + \rho_n') + \overline{n}(k\rho_\tau + \rho_n')'\Big] =\\
&= V_A'\left[\overline{\tau}(1 - k\rho_n + \rho_\tau') + \overline{n}(k\rho_\tau + \rho_n')\right]\\
&+V_A\left[\overline{n}k(1 - k\rho_n + \rho_\tau') + \overline{\tau}(-k'\rho_n - k\rho_n' + \rho_\tau'') - \right.\\
&\left.-\overline{\tau}k(k\rho_\tau + \rho_n') + \overline{n}(k'\rho_\tau + k\rho_\tau' + \rho_n'')\right].
\end{aligned} \tag{52}$$

Grouping in the expression (52) the components along the directions of the unit vectors $\overline{\tau}$ and $\overline{n}$, we obtain:

$$\begin{aligned}
\overline{V_B'} &= \overline{\tau}\left[V_A'(1 - k\rho_n + \rho_\tau') + V_A(\rho_\tau'' - k'\rho_n - k^2\rho_\tau - 2k\rho_n')\right] +\\
&+\overline{n}\left[V_A'(k\rho_\tau + \rho_n') + V_A(\rho_n'' + k'\rho_\tau - k^2\rho_n + k + 2k\rho_\tau')\right].
\end{aligned}$$

Comparing the expressions (47) and (53), we see that they differ only by multiplier V_A. This is understandable, since we have differentiated the expression (18) along the arc coordinate s. When differentiating with respect to time t, as it is necessary to do in order to find the acceleration, we obtain

$$\overline{w}_B = \frac{d\overline{V}_B}{dt} = \frac{d\overline{V}_B}{ds}\frac{ds}{dt} = V_A\frac{d\overline{V}_B}{ds}, \tag{54}$$

i.e. from (54) it is clear that the result (53) obtained must be multiplied by the velocity V_A. After this, expression (53) will be analogous to expression (47). In the same way, by differentiating expressions (22) one can obtain an expression (50).

So, it was shown how simply is to find the absolute acceleration vector of point *B* in complex motion with the application of the accompanying trihedron of the portable trajectory and the Frenet formulas. The obtained result can be formulated in the form of the following rule:

If the material point in the system of the mobile accompanying trihedron of the curve is given by the radius vector in the form (14), in order to find its absolute acceleration in the projections onto the units of the same trihedron, it is necessary to differentiate the expression of the absolute velocity (18) along the arc coordinate s using the Frenet formulas and the obtained result to multiply by the velocity of the vertex of the trihedron along the curve.

The formulated rule also applies to formula (21), when the material point in the contiguous plane of the trihedron is described as a polar coordinate system, i.e. it is necessary to differentiate expression (22) and obtained result to multiply by the velocity of the vertex of the trihedron along the curve.

Let us consider an example that explains the dynamics of the motion of a material point in a complex motion.

A tractor trailer that contains a flat cargo moves at a constant speed V_A along a curve, which is a chain line given by the natural equation (31). At a certain point of time, as the curvature of the curve increases, it comes into motion relative to the trailer. To find the relative and absolute trajectories of cargo movement, as well as its speed, if the location of the cargo in the trailer at the beginning of the slip and the coefficient of friction *f* are known.

Neglecting the size of the cargo, we take it for the material point, which is in the front left corner of the trailer along the tractor movement. This angle is taken as the vertex of the trihedron, which is rigidly tied to the trailer, and the ort $\overline{\tau}$ is directed along the tangent to the chain line along which the indicated point of the trailer moves, and the unit vector $\overline{n}$ – to the center of curvature of the curve. The parametric equations of the chain line after the transition from the natural equation to the parametric equations according to (25), (26) take the following form:

$$x = a\,\mathrm{Arsh}\frac{s}{a}; \qquad y = \sqrt{a^2 + s^2}. \tag{55}$$

This curve has an axis of symmetry that passes through the vertex (at $s = 0$), in which the curvature is the largest and takes the value $k = 1 / a$. When the trihedron moves along a curve with a constant velocity in the direction of the vertex, the curvature of the chain line will increase, like the centrifugal force. In this case, the moment may come when the frictional force will be overcome and the relative movement of the load in the trihedron (or trailer) system will begin.

To compose the equation of motion in the form $m\overline{w_B} = \overline{F}$, we must find the expression for the absolute acceleration of the particle *B*. We obtain it from (47) for $V_A' = 0$. Since the applied friction force $F = f\,mg$ acts in the direction opposite to the relative velocity, it is necessary to find the projections of the unit tangent vector to the relative trajectory. Its projection on the unit vectors $\overline{\tau}$ and will $\overline{n}$ have the same ratio, which is the components of the relative velocity ρ'_τ и ρ'_n т.е.:

$$\frac{\rho'_\tau}{\sqrt{\rho_\tau'^2+\rho_n'^2}} \quad \text{and.} \quad \frac{\rho'_n}{\sqrt{\rho_\tau'^2+\rho_n'^2}} \tag{56}$$

Let us write down the vector equation $m\overline{w_B} = \overline{F}$ in the projections onto the unit vectors of the trihedron, taking (50) and (56) into account, and also that $V = const$. After reducing to the mass *m* particles, we obtain a system of two differential equations in the form:

$$\begin{aligned} V_A^2(\rho''_\tau - k'\rho_n - k^2\rho_\tau - 2k\rho'_n) &= -fg\cdot\frac{\rho'_\tau}{\sqrt{\rho_\tau'^2+\rho_n'^2}}; \\ V_A^2(\rho''_n + k + k'\rho_\tau - k^2\rho_n + 2k\rho'_\tau) &= -fg\cdot\frac{\rho'_n}{\sqrt{\rho_\tau'^2+\rho_n'^2}}, \end{aligned} \tag{57}$$

where $k = \dfrac{a}{a^2+s^2}$; $k' = -\dfrac{2as}{\left(a^2+s^2\right)^2}$.

A graphical presentation of the results of numerical integration of the system (57) is shown in Fig. 5. Integration was carried out by changing the arc coordinate *s* from –80º to +80º. The value of the constants is: a = 25; f = 0.35; V = 10 m·s^{-1}.

From Fig. 5a, it is seen that the relative movement of the load began at approximately $s \approx -10$º and it is ended at $s \approx 25$º, with the maximum relative velocity reaching $V_r \approx 0.8$ m·s^{-1}.

The value of the arc coordinate *s*, at which the relative motion began, can also be determined analytically. Relative motion will begin when the centrifugal force at the vertex of the trihedron (i.e., with $\rho_\tau = \rho_n = 0$) exceeds the frictional force $F_m = f\,mg$. Equating these forces and substituting the expression $k = k(s)$, we obtain an equation with an unknown value of the arc coordinate *s* of the form:

$$\frac{m\,V_A^2\,a}{a^2+s^2} = f\,mg\ ,$$

from where

$$s = \sqrt{\frac{a}{fg}\left(V_A^2 - afg\right)}\ . \tag{58}$$

The solution of equation (58) for conditions of the indicated constants shows that the relative movement of the load begins at s > –10.15°. Having passed the way to the symmetrical point at s = 10.15º, the cargo continues to move along the body, but with a slowdown, since the values of the centrifugal force are not sufficient to continue this movement.

The graph of the relative motion trajectory (Figure 5, b) shows that the load in the trailer will move approximately 1.5 ° towards the opposite side and approximately 0.2 ° in the direction opposite to the tractor's direction of travel.

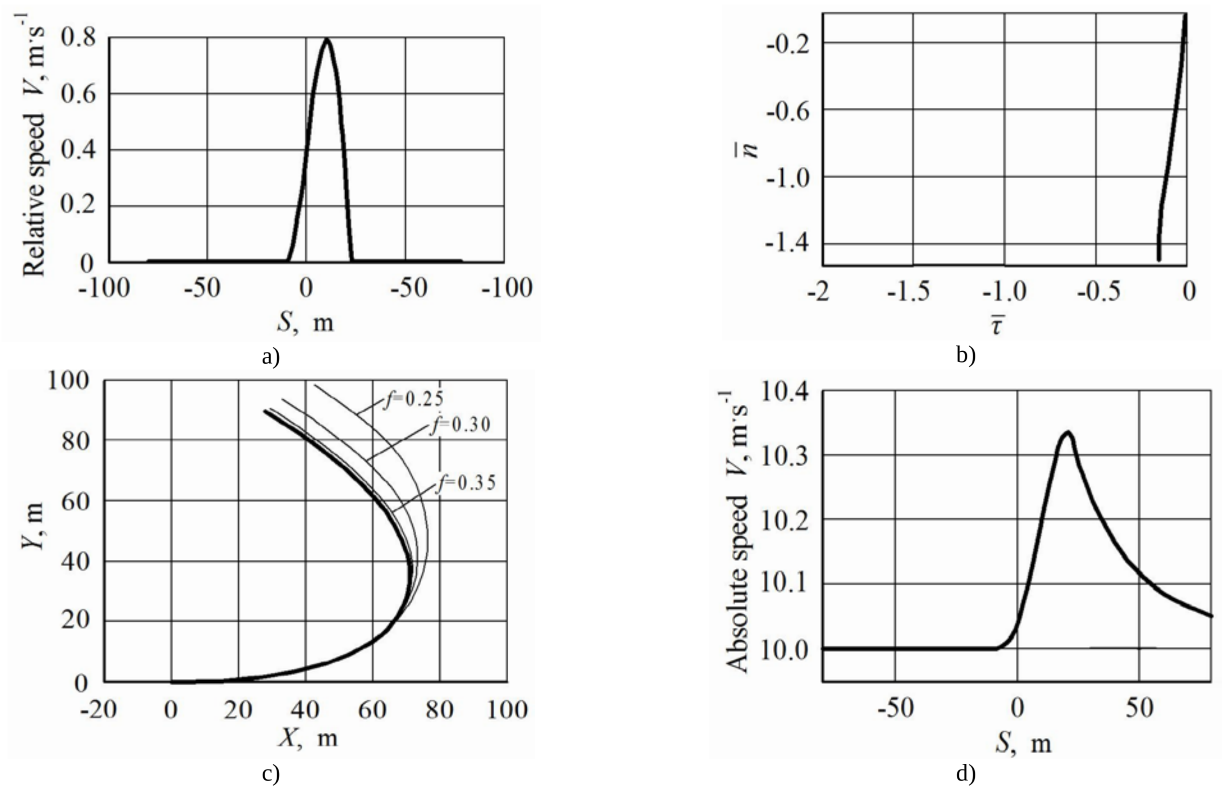


Fig. 5. *Graphs of dependencies obtained as a result of integration of the system (57): a) graph of the change of relative speed; b) the trajectory of relative motion in the trihedron system; c) a chain line and absolute trajectories of motion (additionally shown for f = 0.3 and f = 0.25); d) graph of absolute speed changes*

The graphs of the absolute trajectory (Figure 5, c) show that for different coefficients of friction the relative movement of cargo in the trailer starts from different points of the chain line. After the discontinuance of the relative movement, the absolute path of the load obtains the form of a curve parallel to the chain line.

From the graph of the change in absolute velocity (Figure 5, d) it can be seen that after the discontinuance of a relative movement, the absolute speed of the load will be greater than it was before it, since it occupies another position in the trihedron system.

There are possible also other examples of similar processes.

4. Conclusions

The application of the accompanying trihedron of a plane curve as a moving coordinate system relative to which a relative motion of the point is carried out is quite possible when investigating the complex motion of a material point along the plane. The Frenet formulas make it possible to quickly and easily find the absolute velocity of a material point in its complex motion in the projections onto the orthograms of the trihedron and to find the absolute trajectory in a fixed coordinate system.

In this case, it is much easier to find the absolute acceleration of a point in a complex motion in the projections onto the orthogonal faces of the trihedron, which automatically includes all three of its components. This allows us to solve, on a new scale, the problems of the dynamics of a material point in the moving system of the Frenet trihedron. A method which is developed considerably simplifies the solution of problems of complex motion of a material point, which determines its further development and effective application.

4. References

1. Vasilenko P.M. Teoriya dvizheniya chastitsyi po sherohovatyim poverhnostyam selskohozyaystvennyih mashin. – K.: Izd-vo Ukr. akad. selsk. nauk, 1960. – 283 p.

2. Lure A.I. Analiticheskaya mehanika. – M.: FM, 1961. – 823 p.

3. Loytsyanskiy L.G., Lure A.I. Kurs teoreticheskoy mehaniki. V dvuh tomah – T. 1: Statika i kinematika. – M.: GITTL, 1954. – 379 p.

4 Butenin N.V., Lunts Ya.L., Merkin D.R. Kurs teoreticheskoy mehaniki. V dvuh tomah – T. 1: Statika i kinematika. – 4-e izd., ispravlennoe – M.: Nauka, 1985. – 240 p.

5. Pylypaka S.F. Kinematychna interpretatsiia rukhu suprovidnykh tryhrannykiv Frene i Darbu cherez vnutrishni parametry kryvykh // Nauk. visnyk Nats. ahrar. un-tu : Zb. nauk. pr. – 1998. – Vyp. 4. – P. 143-146.

6. Milinskiy V.I. Differentsialnaya geometriya. – L.: KUBUCh, 1934. – 332 p.

7. Pylypaka S. Bending of screw surfaces in the surface of revolution // Proceedings fifth international conference “New leading-edge technologies in machine building”. – Kharkov-Rybachie, 1996. – P. 134.

8. Pogorelov A. V. Differentsialnaya geometriya. Izdanie 6-e, stereotipnoe. – M.: Nauka, 1974. 176 p.

9. Rashevskiy P. K. Kurs differentsialnoy geometrii. Izdanie 3-e, pererabotannoe. –M.-L.: Gosizdat tehniko-teoreticheskoy literaturyi, 1950. 428 p.

10 Pylypaka S. F. Doslidzhennia rukhu materialnoi chastynky po horyzontalnomu dysku, yakyi obertaietsia navkolo vertykalnoi osi, za dopomohoiu rukhomoho naturalnoho tryhrannyka i formul Frene // Mekhanizatsiia ta elektryfikatsiia silskoho hospodarstva. Mizhvidomchyi tematychnyi naukovyi zbirnyk. – Hlevakha, 2005. – Vyp. 89. – pp. 49-60.

11. Zakharova T. M. Konstruiuvannia ploskykh kryvykh, shcho opysuiutsia rivnianniamy u funktsii dovzhyny duhy, za dopomohoiu suprovidnoho tryhrannyka vykhidnoi kryvoi/ T. M. Zakharova // Pratsi Tavriiskoho derzhavnoho ahrotekhnolohichnoho universytetu. – Vyp.4. Prykl. geometriia ta inzh. grafika. – Vol. 53. – Melitopol: TDATU, 2012. – pp. 57-65.

INVESTMENT OF AGRICULTURAL MACHINERY IN AGRICULTURAL PRODUCTION OF UKRAINE

ИНВЕСТИРОВАНИЕ ТЕХНИЧЕСКОГО ОСНАЩЕНИЯ АГРАРНОГО ПРОИЗВОДСТВА УКРАИНЫ

Prof. doc. eng. Didur V. PhD, Doc. eng. Gritsaienko H. PhD, Doc. eng. Gritsaienko I. PhD
Tavria State Agrotechnological University
18, Khmelnytskiy av., Melitopol, 72312, Zaporozhye region, Ukraine
E-mail: didurva@mail.ru

Abstract. *The article examines the current state and investment of supplying the agriculture with the main types of agricultural machinery. The availability and capacity of combine harvesters and tractors of all brands at agricultural enterprises and households has been analyzed. The issues of agricultural machinery renovation, including the expense of imports, are considered. In order to justify the most effective external funding the investments in agricultural machinery, a comparative analysis of financial leasing conditions and bank lending for purchasing a new tractor and a combine harvester. The prospects for further research have identified the justification for the rational composition and structure of the material and technical basis for the intensification of agriculture in the region.*
KEYWORDS*: LOGISTICS, FINANCE INVESTMENTS, FINANCIAL LEASING, BANK CREDIT, TRACTORS OF ALL BRANDS, COMBINE HARVESTERS*

1. Introduction

Overcoming the crisis in agriculture, the development of market economy, food security is not possible without a corresponding development of logistics and effective investment in technical equipment of agricultural production.

2. Analysis of recent researches and publications

The issue of technical equipment of agricultural production covered in the scientific work of scholars such as Y.K. Bilousko [1, 11] O.V. Vishnevetska [1], A.S. Danilenko [2] O.V. Zaharchuk [4] A.M. Karpenko [2], V.E. Skotsyk [7-9], and many others. However, the complexity and diversity of the mentioned problems requires further comprehensive study of what is due relevance of the chosen topic.

3. Formulation of the problem

The object of the article is to study the current state of agriculture equipment agricultural machinery and to identify effective ways to invest.

4. Results and discussion

Among the factors intensifying agricultural mechanization is a priority. According to the World Bank [6], in terms of provision of agricultural machinery, tractors per 100 square km of arable land Ukraine lags far behind the developed European countries. Thus, among the considered 31 European countries in 2000 (the most comprehensive data analysis) together with Bulgaria Ukraine with the index 98 units occupied 28-29 position, just ahead of the Russian Federation (60 units) and Croatia (27 units). At the same time the three leaders entered Slovenia, Switzerland and Italy with indicators respectively 6600, 2654 and 1938 units, exceeding the national average, respectively 67, 27 and 20 times. During 2000-2008 in Bulgaria the number of agricultural machinery and tractors per 100 square km of arable land increased by 75.5% to 172 units, but in Ukraine during the same period it increased only by 5.1%.

According to the State Statistics Service of Ukraine, the dynamics of the current number of agricultural machinery at agricultural enterprises and households in 2000-2015 has shown a negative trend (Table 1).

So, for 2000-2015 years the number of tractors of all brands (excluding tractors, are mounted on the machine) as a whole declined by nearly one fifth of and made in 2015 309.7 thousand. Units combine harvesters - under 16, 4% to 56.3 thousand units. Based on the analysis of the trend can be concluded that over the period the number of tractors decreased annually on average by 3.8 thousand. Units combine harvesters - by 1.0 thousand Units (Table 2).

Table 1. *Dynamics of agricultural machinery availability at agricultural enterprises and households of Ukraine*

Years	Tractors of all brands (excluding tractors, are mounted on the machine), total units	including		Combine harvesters, total units	including	
		agricultural enterprises	households		agricultural enterprises	households
2000	382628	281650	100978	67366	65240	2126
2005	331457	196080	135377	59937	47150	12787
2006	325505	182552	142953	59174	44252	14922
2007	320034	169953	150081	57503	41032	16471
2008	319872	161800	158072	57435	39091	18344
2009	318788	153791	164997	56580	36783	19797
2010	310248	137757	172491	53531	32750	20781
2011	313480	134554	178926	54074	32062	22012
2012	322209	137958	184251	54651	31997	22654
2013	315261	129341	185920	52065	29364	22701
2014	309111	120638	188473	50019	27196	22823
2015	309716	127852	181864	56328	37537	18791
2015 in % by 2000	80,9	45,4	180,1	83,6	57,5	by 8,8x

Source: compiled according to the State Statistics Service of Ukraine

In the provision of equipment and farm households observed the opposite trend (Table. 1, 2). So, for 2000-2015 years the total number of tractors of all brands (excluding tractors, which are mounted on the machine) in agricultural enterprises decreased by 54.6%, while in households by contrast, increased by 80.1%. Accordingly, the number of harvesters at agricultural enterprises has decreased by 42.5% and at households - increased by 8.8 times.

Table 2. *Trends in the availability of agricultural machinery in agricultural enterprises and farms Ukraine in 2000-2015*

Indexes	The equation of the trend line	Ratios of correlation (R), determination (D)
Tractors of all brands (excluding tractors, are mounted on the machine), total units	y = -3817,1x + 348004	R = 0,6919 D = 0,4787
including: agricultural enterprises	y = -10493x + 229365	R = 0,8482 D = 0,7194
households	y = 6675,8x + 118639	R = 0,9205 D = 0,8474
Combine harvesters, total units	y = -1006,4x + 63097	R = 0,8138 D = 0,6623
including: agricultural enterprises	y = -2303,6x + 53678	R = 0,8084 D = 0,6535
households	y = 1297,2x + 9419	R = 0,79 D = 0,6241

Source: compiled according to the State Statistics Service of Ukraine

With settlements established inverse relationship between the number of tractors of all brands (excluding tractors, which are mounted on the machine) in agricultural enterprises (in) and farms (x):

$$y = -1{,}6656x + 431036; R = 0{,}9764; D = 0{,}9534.$$

That is, increasing the number of tractors in farms 10 units accompanied by a decrease in their agricultural enterprises by 17 units. The correlation coefficient R indicates a close relationship, close to the function.

A similar situation is observed for combine harvesters:

$$y = -1{,}7222x + 69448; R = 0{,}9924; D = 0{,}9848.$$

Increasing the number of tractors at households by 10 units is accompanied by their reduction at agricultural enterprises by 17 units. Impact factors are not taken into account in the model - 1.52% (coefficient of determination equal to 0.9848).

Loading agricultural machinery in Ukraine (tab. 3) times higher than corresponding figures in developed countries, hindering the necessary process operations on time and leads to yield losses.

The load on the tractor in the whole Ukraine with 82 hectares of arable land in 2000 increased by almost a third, amounting in 2015 105 hectares (for comparison: in the US - 28 hectares in France - 14 ha per tractor [9]). In this figure farms of 69 hectares in 2000 increased to 152 hectares, or 2.2 times, while in farms from 104 hectares in 2000 it was reduced to 64 hectares in 2015, or at 38.6%.

The load on the combine harvester in general in Ukraine with 203 hectares of grain and leguminous crops in 2000 increased to 262 hectares in 2015, or 29.2% (for comparison: in the US, France and Germany to combine load of about 55 hectares [9]). In the farms, the figure of 184 ha in 2000 increased by 55.6% and amounted to 2015 286 hectares of private households - according to 786 hectares in 2000 decreased by 72.8% and amounted to 214 ha in 2015.

Table 3. *Dynamics of load indicators at agricultural enterprises and farms of Ukraine*

Years	The area of arable land per tractor 1, hectares	including: agricultural enterprises	including: households	Area grains and legumes per 1 processor, ha	including: agricultural enterprises	including: households
2000	82	69	104	203	184	786
2005	98	102	80	250	244	273
2006	100	106	80	245	252	225
2007	101	114	76	263	285	207
2008	102	121	72	272	310	192
2009	102	126	70	280	330	186
2010	105	140	68	282	344	183
2011	104	143	66	291	366	181
2012	101	141	63	283	358	177
2013	103	148	64	301	394	181
2014	105	160	62	296	391	183
2015	105	152	64	262	286	214
2015 in % to 2000	127,9	221,6	61,4	129,2	155,6	27,2

Source: compiled according to the State Statistics Service of Ukraine

Analysis of trends in the burden on the technique proves (Table 4), for 2000-2015 arable land area per 1 tractor average in Ukraine increased annually by 1.2 hectares. In the agricultural enterprises of the increase annually by 6.8 hectares, while at households - on the contrary, decreased by 2.8 hectares respectively. Area grains and legumes per 1 combine harvester on average in Ukraine for 2000-2015 increased annually by 5.6 hectares, including households 13.9 ha. Increasing the number of harvesters in households led to an annual reduction of the burden on them in accordance with an average of 26.6 hectares.

Table 4. *Trends stress on technique in agricultural enterprises and farms of Ukraine in 2000-2015.*

Indexes	Trend equation	Ratios of correlation (R), determination (D)
The area of arable land per 1 tractor, hectares	y = 1,2227x + 92,655	R = 0,7085 D = 0,502
including: agricultural enterprises	y = 6,8156x + 82,476	R = 0,945 D = 0,893
households	y = -2,822x + 90,861	R = 0,8525 D = 0,7267
Area grains and legumes per 1 combine, total, ha	y = 5,6222x + 232,4	R = 0,7456 D = 0,5559
including: agricultural enterprises	y = 13,922x + 221,56	R = 0,7806 D = 0,6094
households	y = -26,586x + 421,77	R = 0,5593 D = 0,3128

Source: compiled according to the State Statistics Service of Ukraine

The analysis of the movement of agricultural equipment indicates that negative trend observed excess of that which is left out during the year to that received (Fig. 1).

Thus, in 2008-2010. Number of tractors and combine harvesters, who dropped out for a year and a half to two times higher than that which came respectively. Lowest in years 2008-2015. This ratio was in 2011-2012. (104.1% and 81.5% for tractors, 93.1% and 103.3% for combine harvesters, respectively).

State Program realization of technical policy in the agricultural sector for the period up to 2015 [3] included in the 2015 production of competitive tractors at 9.5 thousand units, combines - 1.5 thousand units. Total state support for agricultural production technical support provided funding in the amount of 134.23 billion UAH. Increased technical support of agricultural production in 2015 was 7.6% help reduce the losses of agricultural production as a result of timely and quality of the mechanized operations by 30%. Unfortunately, starting from 2012 funding of this program is not the case. According to calculations [8], a garden tractor is now 45% of the needs of agriculture, combine harvesters - 48%, other types of equipment - from 35 to 60%.

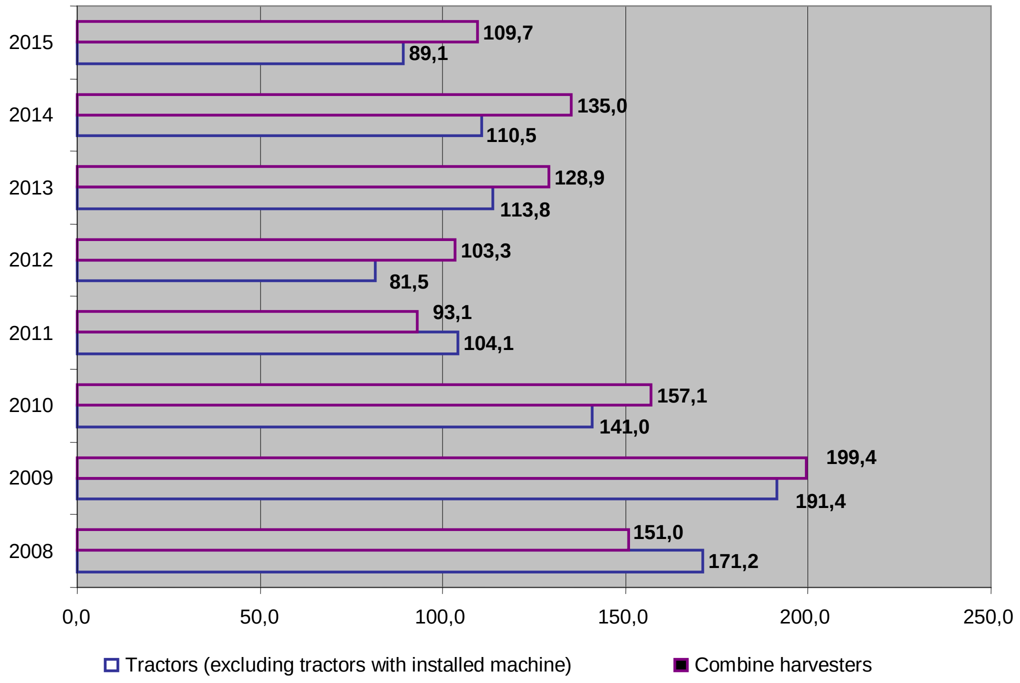


Fig.1. *Ratio of technology in agricultural enterprises, which for the year dropped to one that came, in %*
(Source: compiled according to the State Statistics Service of Ukraine)

Average rate of deterioration of agricultural machinery is 70%, including 78% of tractors, harvesters - 71%.

Dynamics buying farms Ukraine new tractors and combine harvesters for 2011-2015 presented in Table 5.

Analysis of the data of Table 5 shows the reduction in the number and simultaneous substantial increase in cost of purchases of tractors and combines as a result of price increases. The average annual growth rate of average prices for all kinds of tractors for 2010-2015 is amounted to 129.8% and harvesters - 124.6%, respectively.

Despite the fact that domestic appliances cheaper agricultural producers prefer imported counterparts, whose share is more than 80% of the total value of funds spent on the purchase of technical support. Foreign technique works longer without repair, fuel spends more economical, less harmful to the environment, can significantly save human resources [7].

Table 5. *Dynamics of purchasing new tractors and combine harvesters by agricultural enterprises of Ukraine*

Years	Tractors of all types				Combine harvesters			
	number, units.	total cost, UAH.	average price		number, units.	total cost, million UAH.	average price	
			UAH, per unit.	% by previous year			UAH, per unit.	% by previous year
2011	2983	1352,4	453374	133,1	804	1140,3	1418244	129,3
2012	3010	1471,9	488997	107,8	541	802,3	1482984	104,6
2013	2788	1512,7	542566	111,0	524	806,2	1538600	103,8
2014	1822	1305,5	716533	132,0	336	673,6	2004757	130,4
2015	2095	2627,4	1254125,2	175,0	479	1573,7	3285475,0	163,9
2015 in % by 2011	70,2	194,3	276,6	x	59,6	138,0	231,7	x

Source: compiled according to the State Statistics Service of Ukraine

**Excluding the temporarily occupied territory of the Autonomous Republic of Crimea, Sevastopol and the zone of the antiterrorist operation*

But the high cost of imported machinery is a deterrent to the modernization and renewal of technical machinery in agricultural production. Table 6 shows the data on the dynamics of the number and value of import tractors and combine harvesters.

According to Table 6 during 2011-2015 there can be observed a significant reduction in imports of machinery. Thus, the number of tractors of all brands, imported to the country fell by more than two-thirds harvesters - almost half. The value of the purchased tractors fell by 59%, combine tractors - by 60.8%.

According to the Ministry of Agrarian Policy of Ukraine, the minimum scientifically justified annual update of tractor fleet to the technological needs of the prices prevailing at the beginning of 2016 is 35 bln UAH, including about 40 thousand tractors (15 bln UAH) and nearly 7 thousand combine harvesters (10,5 bln UAH) [5]. In conditions of severe shortage of agricultural enterprises owning funds to upgrade agricultural machinery is needed to find the most effective external financing investment in technical support of agriculture. Among the most common can be identified financial leasing and bank lending.

Table 6. *Dynamics of import of tractors and combine harvesters*

Years	Tractors		Combine harvesters	
	number, thousands, units.	million, USD	number, units.	million, USD
2011	146,4	559,1	2619	272,2
2012	104,9	564,8	1647	187,3
2013	156,0	562,6	1570	183,3
2014	108,8	273,7	935	95,5
2015	39,7	229,3	1285	106,6
2015 in % to 2011	27,1	41,0	49,1	39,2

Source: compiled according to the State Statistics Service of Ukraine

We conducted a comparative analysis of financial leasing and bank loans for the purchase of new agricultural machinery in accordance with NAK "Ukragroleasing" and Ukreximbank. NJSC "Ukragroleasing" with an annual interest rate of 11% provides a choice of term loans (3, 5 and 7 years), options of debt settlement (payment every month, once every 3 or 6 months), and the size of the down payment (10, 15 or 30%). In Ukreximbank with an annual interest rate for the purchase of new agricultural machinery and 22% for loans up to 5 years, monthly or quarterly repayment of debt, the size of the down payment of 15%. The analysis shows that the conditions of financial leasing are more attractive than bank lending. Rise in credit services NAK "Ukragroleasing" depending on the selected size of the down payment is respectively 23.5% (down payment of 15%) and 24.3% (down payment of 10%). At the same time the rise in credit Ukreximbank services is 52.6%, more than twice as much.

The shortage of own financial resources, special attention should be given opportunities of foreign investment. Unfortunately, in the ranking of the degree of ease of doing business, characterizing investment attractiveness of Ukraine in 2016 took only 83 among 189 countries. Among the components of the ranking (Fig. 2) is the most problematic "Resolving Insolvency", "Obtaining construction permits" and "Connecting to power supply" - Ukraine's place these criteria in 2016 amounted to 141, 140 and 137 positions.

The highest places in the ranking in 2016 Ukraine ranked according to criteria "Getting credit" and "starting a business" - respectively 19 and 30 positions. To improve the situation, the relevant areas developed 43 objectives, the implementation of which will not only facilitate the business environment, but also improving the investment climate in Ukraine as a whole.

5. Conclusion

Thus, we can conclude that to strengthen the competitive position in the markets of agro-food production and sustainable development of the domestic agricultural sector is an urgent need for increasing investment in technical support for agricultural producers. However, its level for a long time tends to decrease as a result of many factors, chief among which consider the lack of sufficient own funds to upgrade the machine-tractor fleet. As an effective source of funding the investment in agricultural machinery is offered more extensive use of financial leasing.

Prospects for further research this issue is the rational study the composition and structure of logistics for the intensification of agriculture in the region.

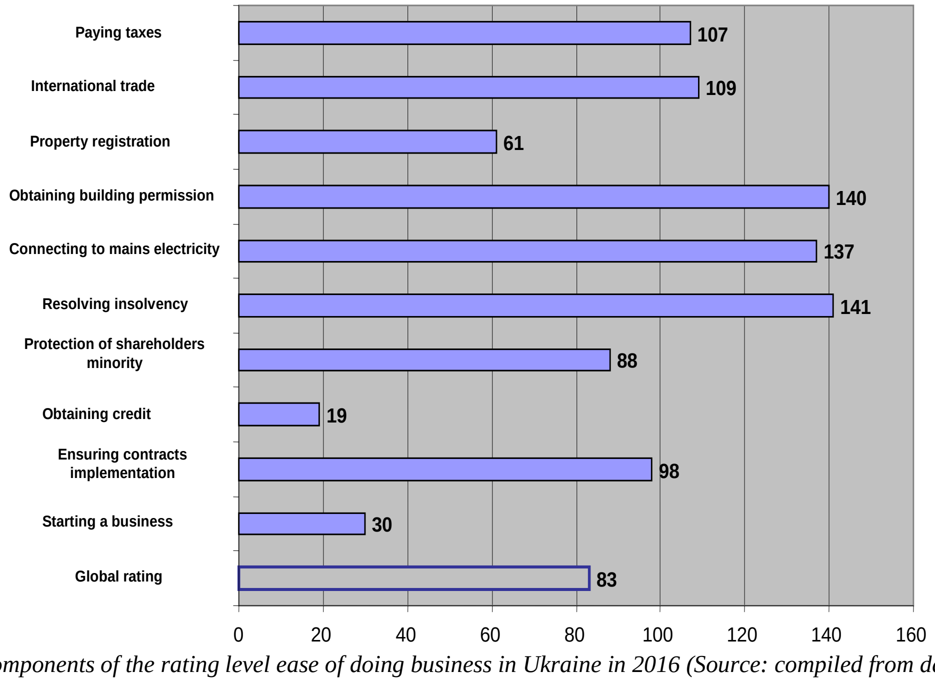


Fig. 2. *Components of the rating level ease of doing business in Ukraine in 2016 (Source: compiled from data [6])*

6. References

1. Vishnevetska O.V. Tehnichne pereosnaschennya agrarnoyi galuzs v konteksts efektivnostI lizingovih sistem / O.V. Vishnevetska, Ya.K. Bilousko // Visnik Odeskogo natssonalnogo unIversitetu. EkonomIka. – 2013. – Vol. 18, Isue. 1(1). – pp. 53-57.

2. Danilenko A.S. Problemi materialno-tehnichnogo zabezpechennya virobnitstva produktsiyi v silskogospodarskih pidpriemstvah / A.S. Danilenko, A.M. Karpenko // Ekonomika ta upravlinnya APK. – 2014. – №1. – pp. 71-76.

3. Derzhavna tsilova programa realizatsiyi tehnichnoyi politiki v agropromislovomu kompleksi na period do 2015 roku // Zatverdzhena postanovoyu Kabinetu Ministriv Ukrayini vid 30 travnya 2007 roku # 785 [Elektronniy resurs]. – Rezhim dostupu: http://zakon3.rada.gov.ua/laws/show/785-2007-%D0%BF

4. Zaharchuk O.V. Problemi materialno-tehnichnogo zabezpechennya silskogospodarskih pidpriemstv Ukrayini / O.V. Zaharchuk // Ekonomika APK. – 2014. – №7. – pp. 92-99.

5. Ofitsiyniy veb-portal Ministerstva agrarnoyi politiki Ukrayini [Elektronniy resurs] – Rezhim dostupu : http://minagro.gov.ua/

6. Ofitsiyniy sayt Vsesvitnogo Banku [Elektronniy resurs] – Rezhim dostupu: http://databank.worldbank.org/data/reports.aspx ?source=world-development-indicators#

7. Skotsik V.E. Kontseptualni zasadi rozvitku rinku silskogospodarskoyi tehniki v UkrayinI / V.E. Skotsik // Ekonomika ta upravlinnya APK. – 2014. – №2. – pp. 114-118.

8. Skotsik V.E. Problemi vidtvorennya tehnichnih zasobiv, yak osnovi intensifikatsiyi virobnitstva silskogospodarskoyi produktsiyi / V.E. Skotsik // Staliy rozvitok ekonomiki. – 2013. – № 4. – pp. 229-233.

9. Skotsik V.E. Tehnichne zabezpechennya silskogospodarskih tovarovirobnikiv: suchasniy stan ta problemi virishennya / V.E. Skotsik // Ekonomika ta upravlinnya APK. – 2013. – Vol. 10. – pp. 56-60.

THE STUDY WIDE SPAN TRACTOR (VEHICLES) FOR CONTROLLED TRAFFIC FARMING

ИССЛЕДОВАНИЯ СПЕЦИАЛИЗИРОВАННОГО ШИРОКОКОЛЕЙНОГО АГРОСРЕДСТВА ДЛЯ КОЛЕЙНОЙ СИСТЕМЫ ЗЕМЛЕДЕЛИЯ

Assoc. Prof. Eng., PhD. Kuvachov V.

Tavria State Agrotechnological University
18, Khmelnytskiy av., Melitopol, 72312, Zaporozhye region, Ukraine
E-mail: tdatu-mvz@yandex.ru, kuvachoff@mail.ru

Abstract: *Promising energy technology means for controlled traffic farming are wide span tractor (vehicles). The effectiveness of the practical use of wide span tractor (vehicles) depends on a sound scientific base or theoretical frameworks, concerning the study of their technological properties. The article presents the theoretical basis of the dynamics of plane-parallel movement wide span tractor (vehicles) in the horizontal and vertical plane as well as its cornering. Developed the theory of plane-parallel movement wide span tractor (vehicle) allows for the justification of new schemes, design parameters and operating modes with acceptable controllability and stability of motion in the horizontal plane. Ride wide span tractor (vehicles), as a dynamical system, moving through the traces of permanent tramlines significantly depends on the characteristics of the irregularities of the longitudinal profile. The desired character of the internal structure of the longitudinal profile laid tramlines is almost possible to obtain the appropriate technology for its formation. Quality testing of dynamic system input perturbations, which are irregularities of the longitudinal profile permanent tramlines and the unevenness of the traction resistance of the soil, depends on the scheme and the constructive and other settings wide span tractor (vehicles). A significant impact on the smoothness of the latter renders the rigidity of the tire support wheels, the magnitude of which can be influenced, within certain limits, by changing the air pressure in them. Improve driving dynamics the technological part of the wide span tractor (vehicles) is observed by increasing the rigidity of the tire its supporting wheels and operating mass. The offered new scheme of the turn of a wide span tractor (vehicle) for controlled traffic farming on the turning strip by turning the undercarriage, using the steerable wheels from its one board around the turning centre arranged in the centre of the space between the wheels from the other board, allows shifting of the tractor, simultaneously with the turn, to the next operating position with better kinematic parameters. In addition to it, the improvement of the turnability characteristics is achieved at such a design embodiment of the wide span tractor (vehicle) when the relation of its wheelbase to the width of the wheeltrack is as small as possible.*

KEYWORDS: CONTROLLED TRAFFIC FARMING, WIDE SPAN TRACTOR (VEHICLES), AGRICULTURE, MOVEMENT IN THE HORIZONTAL AND VERTICAL PLANE, TURN.

1. Introduction

A promising direction for further stable development of the world agriculture is the introduction of innovative technologies, which should include controlled traffic farming [1-8]. Its application provides the basis for automation of most technological processes in crop production, ensures the effective implementation of "precision" agriculture and provides other significant advantages.

Promising in this respect is the use of wide span wide span tractor ore vehicles [3-11]. The use of a wide span tractor (vehicles) allows to obtain the maximum efficiency (technological, social, environmental, economic) in the processes of tillage and maintenance of crop plants [3-12].

The effectiveness of the practical use of wide span tractor (vehicles) depends on a sound scientific base and theoretical framework for the study of their technological properties. Constructive-technological features of these wide span tractor (vehicles) require the development of a fundamentally new system for their operation and use. The question in this respect, scientists have studied not enough, and the effective practical realisation of the potential of technological properties of wide span tractor (vehicles) are currently missing. Therefore, from the perspective of the solution of the food problem in the world, as well as the development of resource-saving technologies, which are based on the principles of a track system of agriculture, in accordance with the trends of scientific and technological progress in the mechanization − improving the functioning of the technical means at the expense of complex mechanization, electrification, automation and robotics − this area of research is very important.

2. Preconditions and means for resolving the problem

2.1. Analysis of recent research and publications

All known studies on this issue aimed at the study of the dynamics of tractor units based on traditional tractors, and do not relate to the solution of the specified problem. The accumulated scientific and practical experience in the use of traditional machine-tractor units in controlled traffic farming is allowed to justify certain requirements on the parameters of permanent tramlines and energy resources. However, these requirements do not take into account the atypical layout scheme wide span tractor (vehicles), specific mounting and operating conditions [13,14], therefore, needs to be clarified. At the same time, the now famous methodology of choice of constructive schemes, parameters and modes of operation of machine and tractor aggregates cannot be used to study the dynamics of movement wide span tractor (vehicles). Therefore, from the perspective of effective use of wide span tractor (vehicles), there are unresolved issues relating to the study of conditions that are imposed on their design and other parameters.

2.2. Purpose of the study

The purpose of researches is the increase of efficiency of functioning and the use of wide span tractor (vehicles) by study schemes, technological, etc. parameters.

3. Results and discussion

Wide span tractor (vehicles) is a rather complex dynamic system. This complexity is determined by its multi-dimensionality, high order differential equations of motion and especially the presence of nonlinear relationships between its individual coordinates. Therefore, at this stage of the study of the dynamics of wide span tractor (vehicles) it is advisable to consider it a simplified diagram in the form of stationary linear model. This idealization of the system in many cases is quite effective for complex agricultural units and their control systems, the dynamics of which is still insufficiently studied.

In the study of movement wide span tractor (vehicles) in the longitudinal-horizontal plane of the dynamic system has two degrees of freedom (fig. 1), which correspond to two generalized coordinates: the heading angle φ and the displacement of the abscissa X_S of the center of mass it S_t.

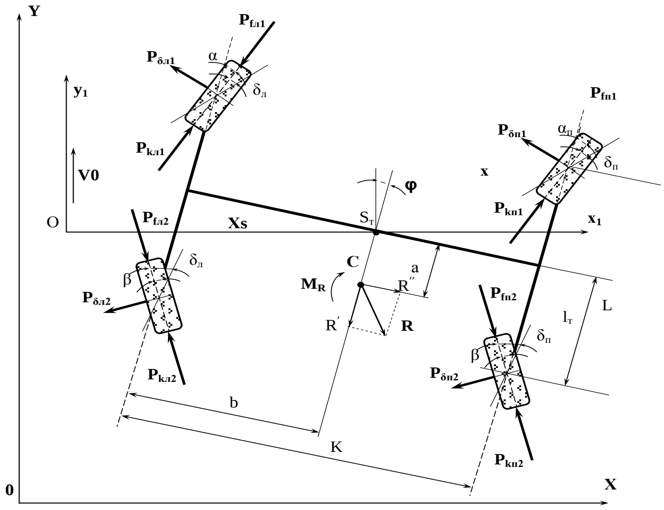


Fig. 1. *Scheme of the forces acting on wide span tractor (vehicles) in a horizontal plane when the kinematics method of its control (wheel rotation)*

Analysis of amplitude and phase frequency characteristics of the influence of circuit and parameters of a wide span tractor (vehicles) on its handling and stability of motion [15-17] have shown a significant dependence on speed. At low speeds (1m/s) have a significant nedouregulirovannymi in a dynamic system the control action (rotation angle α of the front wheels). In this case, the desired frequency of oscillation of the angle of the front wheels is at the level of 0.5 s^{-1}, where the gain value of the input control action is close to 1. However, the increasing speed, wide span tractor (vehicles) to 2 and 3 m/s at low frequencies ($\omega < 1{,}3\ s^{-1}$) contributes to the overshoot of the dynamic system, at frequencies $\omega > 1{,}3\ s^{-1}$ on the contrary - brings characteristics to the ideal. As for the phase shift of mining, dynamic system control, when the increase of working speeds wide span tractor (vehicles) up to 3 m/s the phase-frequency characteristic closest to the ideal.

The main perturbations that cause vertical movement of the wide span tractor (vehicles) in a longitudinal vertical plane, there are irregularities of the longitudinal profile of the traces of permanent tramlines, the fluctuations of the traction resistance of agricultural implements (R_x and R_z) and the main moment of resistance (M_R) (fig. 2).

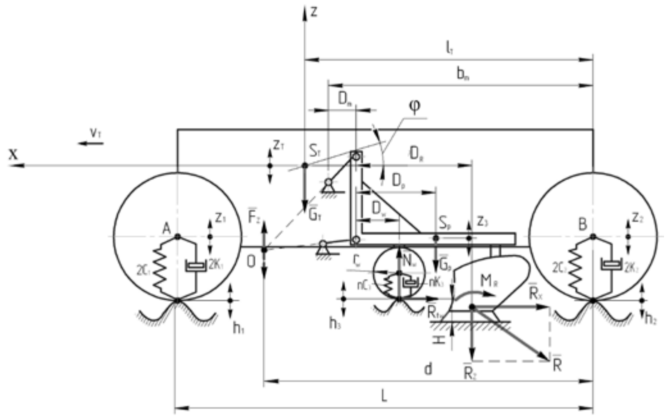


Fig. 2. *The scheme is equivalent to a dynamic system of movement wide span tractor (vehicles) in a longitudinal vertical plane*

As a result of mathematical modeling of the dynamics of plane-parallel movement wide span tractor (vehicles) in a longitudinal vertical plane established [18] that, from the point of view of the desired testing dynamic system perturbations, a significant increase in the stiffness coefficient of the tire to its supporting wheels is effective only in the case when the variances of the fluctuations of the roughness profile permanent tramlines are concentrated in the frequency range 0...8 s^{-1} and 16…20 s^{-1}. Consider a dynamic system almost does not respond to the outrage, if the main range of the variances of roughness permanent tramlines is concentrated in the frequency range of 13-15 s^{-1}. Practically this can be achieved by the appropriate technology of formation of traces of permanent tramlines or change in the stiffness of the pneumatic tire by adjusting this air pressure in it, which would ensure minimum response of a dynamic system to an input disturbance. If the variance of roughness profile permanent tramlines are concentrated in the range of lower frequencies, reducing the rigidity of the tire wheel wide span tractor (vehicles) is effective.

Theoretically established, if the main range of the dispersions of the irregularities of the permanent tramlines will be concentrated in the high frequency range of 13-15 s^{-1}, the coefficient of stiffness of the tires of the supporting wheels of the technological part of the wide span tractor (vehicles) must not be more than 25 kN/m, or at least 200 kN/m. Also found that the operational weight of the technological part worsens the dynamics of its motion in the vertical plane. Informed that the character of mining oscillations of the traction resistance of wide span tractor (vehicles) essentially depends on the position of the hinged mechanism. It is established that the displacement of the hinged mechanism of the position of rear mounting in the central – worsens the dynamics of its motion in the vertical plane. From a practical point of view the unsatisfactory result of the latter can compensate for the change in the stiffness of the pneumatic tire by adjusting this air pressure, which would ensure minimal dynamic response of the system to irregularities of the profile of permanent tramlines.

The offered new scheme of the turn of a wide span tractor (vehicle) for controlled traffic farming on the turning strip by turning the undercarriage, using the steerable wheels from its one board around the turning centre arranged in the centre of the space between the wheels from the other board, allows shifting of the tractor, simultaneously with the turn, to the next operating position with better kinematic parameters. In addition to it, the improvement of the turnability characteristics is achieved at such a design embodiment of the wide span tractor (vehicle) when the relation of its wheelbase to the width of the wheeltrack is as small as possible (fig. 3) and (fig. 4) [19].

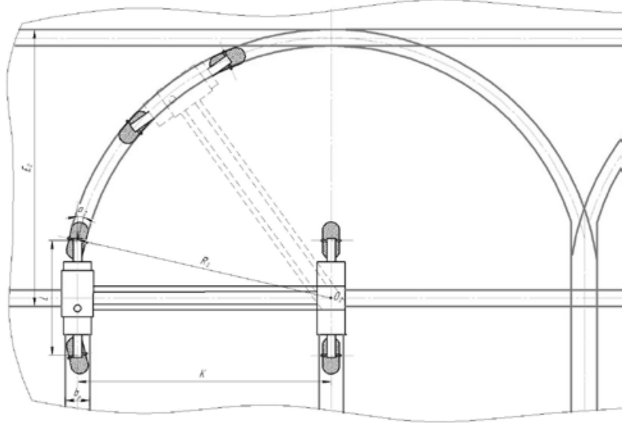


Fig. 3. *Schemes of the turn of a wide span tractor (vehicle) around the turning in the centre of the space between the wheels of one of the boards*

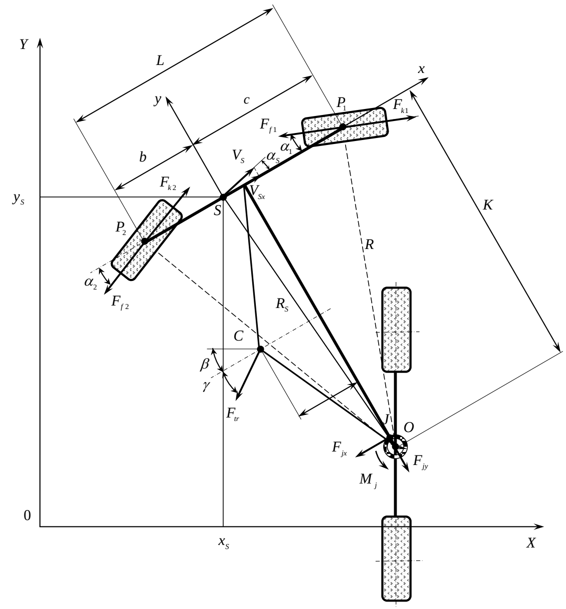


Fig. 4. *An equivalent scheme of the turn of a wide span tractor (vehicle) with steerable wheels of the left board*

4. Conclusion

1. Developed the theory of plane-parallel movement wide span tractor (vehicle) allows for the justification of new schemes, design parameters and operating modes with acceptable controllability and stability of motion in the horizontal plane.

2. Ride wide span tractor (vehicles), as a dynamical system, moving through the traces of permanent tramlines significantly depends on the characteristics of the irregularities of the longitudinal profile. The desired character of the internal structure of the longitudinal profile laid tramlines is almost possible to obtain the appropriate technology for its formation. Quality testing of dynamic system input perturbations, which are irregularities of the longitudinal profile permanent tramlines and the unevenness of the traction resistance of the soil depends on the scheme and the constructive and other settings wide span tractor (vehicles). A significant impact on the smoothness of the latter renders the rigidity of the tire support wheels, the magnitude of which can be influenced, within certain limits, by changing the air pressure in them. Improve driving dynamics the technological part of the wide span tractor (vehicles) is observed by increasing the rigidity of the tire its supporting wheels and operating mass.

3. The offered new scheme of the turn of a wide span tractor (vehicle) for controlled traffic farming on the turning strip by turning the undercarriage, using the steerable wheels from its one board around the turning centre arranged in the centre of the space between the wheels from the other board, allows shifting of the tractor, simultaneously with the turn, to the next operating position with better kinematic parameters. In addition to it, the improvement of the turnability characteristics is achieved at such a design embodiment of the wide span tractor (vehicle) when the relation of its wheelbase to the width of the wheeltrack is as small as possible.

5. Literature

1. Chamen T. Controlled traffic farming – from world wide research to adoption in europe and its future prospects // Acta Technologica Agriculturae Nitra. – 2015. –№3. – P. 64–73.

2. Kingwell R., Fuchsbichler A. The whole-farm benefits of controlled traffic farming: An Australian appraisal // In Agricultural Systems. – 2011. – vol. 104, № 7. – P. 513–521.

3. Chamen W.C.T. Assessment of a Wide Span Vehicle (Gantry), and Soil and Cereal Crop Responses to Its Use in a Zero Traffic Regime // Soil & Tillage Research. – 1992. – №24(4). – P. 359-380.

4. Chamen W.C.T. Design, Operation and Performance of a Gantry System: Experience in Arable Cropping // Journal of Agricultural Engineering Research. – 1994.– №59(1). – P. 45-60.

5. Onal I. Controlled Traffic farming and Wide span tractors // Journal of Agricultural Machinery Science. – 2012. – №8(4). – P. 353-364.

6. Pedersen, H.H. Harvest Capacity Model for a Wide Span Onion Bunker Harvester // In Automation and System Technology in Plant Production / CIGR section V & NJF section VII conference, 30 June - 2 July 2011.

7. Chamen W.C.T. A New Methodology For Weed Control And Cereal Crop Production Based On Wide Span Vehicles And Precision Guidance: Biotrac // 4th EWRS Workshop on Physical Weed Control, Elspeet, The Netherlands, 20-22 March 2000. - P.51-55.

8. Pedersen H.H., Sørensen C. G., Oudshoorn F.W., McPhee J.E. User requirements for a Wide Span Tractor for Controlled Traffic Farming. International Commission of Agricultural and Biological Engineers, Section V. CIOSTA XXXV Conference “From Effective to Intelligent Agriculture and Forestry”, Billund, Denmark, 3-5 July 2013.

9. Kuvachov V.P. Specialized vehicle for the trip of agriculture (In Ukrainian language) // Bulletin of HNTUA. – 2014. – № 148. – P. 63–69.

10. Kuvachov V.P., Kutsenko S.M., Kovalev V.V. Electric agricultural vehicle is an efficient solution to the problems of mechanization of agricultural production (In Ukrainian language) // Papers TSAU. – 2012. – Is. 12, v. 2. – P. 86-92.

11. Kuvachov V.P. Bridge agriculture on the basis of sprinkling machines (In Ukrainian language) // Scientific Bulletin TSAU. – 2012. – Is. 2, v. 5. – P. 15-23.

12. Kuvachov V.P. Land use in the regeneration field for working energy tools bridge type (In Ukrainian language) // Scientific Bulletin TSAU.– 2013. – Is.1, v.3. – P.116-126.

13. Kuvachov V.P. Justification of energy saturation specialized self-propelled energy means of the bridge type (In Ukrainian language) // Scientific Bulletin TSAU.– 2014. – Is.4, v.2. – C. 124-131.

14. Kuvachov V.P. Justification of energy saturation of the self-propelled energy means of the bridge type (In Russian language) // Actual problems of scientific-technical progress in the agro-industrial complex: collection of scientific articles on materials of VIII International scientific-practical conference "Resource - and energy saving in the agricultural sector. Alternative fuels". – Stavropol: AGRUS of Stavropol state agrarian University, 2013.- P.101-110.

15. Kuvachov V.P. Evaluation of stability of motion the broad-gauge of the power and process of mechanization of agricultural production (In Ukrainian language) // Papers TSAU. – 2015. – Is. 15, v.3.- C. 204-210.

16. Nadykta, V.T., Kuvachov V.P. Assessment of the manageability of the traffic the broad gauge of the power and process of mechanization of agricultural production (In Ukrainian language) // Scientific Bulletin TSAU. – 2016. – Is. 6., v.1. – P. 99-110.

17. Kuvachov V. Modeling of plane-parallel movement in the horizontal plane broad-gauge means in the kinematic method of its control (In Russian language) // Motrol. – 2015. – Vol. 17, № 9. – P. 49–54.

18. Kuvachov V., Mitkov V., Shulga O. Modelling of plane-parallel movement in a vertical plane of means for broad-gauge track system of agriculture (In Russian language) // Motrol. – 2016. – Vol.18, №1. – P. 3-12.

19. Kuvachov V.P. The kinematics of the rotation the broad-gauge mechanization of agricultural production for the track system of agriculture (In Ukrainian language) // Bulletin Sumy state University. – 2016. – Is. 10/2 (30). – P. 46-49.

RATIONALE OF PARAMETERS OF TECHNICAL SUPPORT CROP PRODUCTION

ОБОСНОВАНИЕ ПАРАМЕТРОВ ТЕХНИЧЕСКОГО ОБЕСПЕЧЕНИЯ РАСТЕНИЕВОДСТВА

PhD, s.r.o. Kudrynetskyy R. B.
National Scientific Centre “Institute for Agricultural Engineering and Electrification”, 11, Vokzalna Str., Glevaкha-1, Vasylkiv District, Kiev Region, 08631, Ukraine
E-mail: kudsl@ukr.net

Abstract: *Reveals the scientific and methodological principles of determining the needs of farmers in the technical means to perform mechanized processes of agriculture. The parameters of technological systems in different technologies in crop production and the volume of work that match agricultural requirements the quality and timeliness of work.*
KEYWORDS: *HARDWARE, PARAMETERS, PLANNING OF MECHANIZED OPERATIONS, QUALITY, PERFORMANCE, NOLOSSES.*

1. Introduction

Modern agricultural production processes are characterized by a high level of mechanization and automation and are aimed at creating favorable living conditions of plants and soil microorganisms. Technology used for mechanization of the process is knowledge-intensive, its cost is growing because there is a problem in the rational use of its mechanized processes that can reduce operating costs for agricultural production.

The high level of technology in agricultural production, technical excellence and high cost of equipment requiring a high level of management of the technical resources, finding ways to reduce the share of material and energy costs in the cost of agricultural products.

Search for sustainable solutions in the composition and use of machine-tractor fleet of agricultural enterprises - one of the most difficult tasks, because when its decision should take into account a large number of factors, the overwhelming share are probabilistic in nature and ungovernability. Effective technical means on which it is advisable to complete machine-tractor fleet management, determined on the basis of technical and economic calculations [1-9, 11-14]. For their performance the scientists developed a number of methods and computer application software based on the methods of linear or dynamic programming [9]. For optimization criterion used straight or given operating costs.

2. Preconditions and means for resolving the problem

Modern trends in technology provide the technological operations in clearly defined terms of cultivation techniques, providing favorable conditions for plant growth and development and yield formation. This is especially true for spring sowing and harvesting, as each day deviation from the optimal timing of harvest shortfall increases [15, 18, 20].

To perform all the work in the shortest possible time necessary to provide differentiated approach to each transaction and prepare for their implementation tractor units, which provide high quality work, productivity and the lowest possible fuel consumption.

Characteristics of agricultural processes are probabilistic in nature. The scope of work and terms of their performance in the economy during the year variable. In certain periods there are so-called "peak load", the largest of which is calculated quantitative need for machines and power tools.

According to research authors [4, 5, 8, 11], timely and quality execution of all work positively affects the productivity of crops. From the level of the park and farm equipment with new equipment depend on production costs. Therefore, in determining the efficiency of the machine-tractor fleet should pay great attention to the requirements of agricultural technology, scope of work and terms of operation the machine-tractor units and their service provision.

Presence of modern computers, powerful operating systems, database management systems and applications has enabled scientists to develop algorithms and software economic and mathematical modeling of agricultural production processes, planning mechanized operations, determining the need agricultural enterprises in the engineering and assembly of the basis of rational the structure of the machine-tractor fleet.

To solve the problem "Planning mechanized operations", basically use a mathematical model that solve linear programming method [8-11, 18 etc.]. Solving this problem to optimize machine-tractor fleet minimum criteria for direct exploitation or reduced costs. More and more in solving this problem, the method of dynamic programming [16, 17]. The essence of this method is that it does not require the linearity of the objective function and takes into account the cost of landscaping and expenses caused by the loss of production due to deviations from optimal deadlines.

These methods are focused on performance and average values do not include probabilistic nature of the factors of production processes, and therefore do not provide optimal solutions in terms that differ from those in the calculations.

There is also a method of optimizing machine - tractor fleet by the criterion of minimum energomachines [4]. This criterion, according to the authors provide minimum operational costs. This assumption focuses on the feasibility of acquisition machine - tractor park power means high power, use of which will increase the productivity of machine-tractor units and works fewer machines. However, this does not guarantee that the work will be done with the lowest possible operating cost.

Also widely used method of statistical simulation modeling Agricultural productions justification for the need to implement them. [3] The use of these techniques requires appropriate specialist skills, inaccessible because the vast majority of farms.

3. Results and Discussion

When manning a machine-tractor fleet of agricultural enterprises for various types of work settings agree on technical means for the width, capacity and load factor that can increase the efficiency of their use. The parameters auxiliary machinery agree with the parameters of machines to perform the main technological operation.

To determine the parameters of the machine should consider the following factors [5]:

1) requirements for quality farming operations that set the terms of farming production of the type of product and are made of steel;

2) agronomic calendar and deadlines that have grown dependent on culture, state of the field, and weather conditions are variable;

3) the cost of technical tools that determine the value of the operating costs.

Selecting units to perform manufacturing operations carried out by the criterion according to performance requirements farming appointment to the quality of the work. The composition of the unit determined by the amount of work and permissible duration of their implementation.

The scope of work that must be done by one day R_i determined by the formula:

(1) $$R_i = \frac{\sum S_{ij}}{T},$$

where S - the total amount of similar work in different cultures in the ij-th period, ha or ton; T - agrotechnical permissible duration of the work, day.

If the unit is independent of the volume of work that can be performed by this unit per day, determined by the formula [4]:

(2) $$P_i = W_{zm} \cdot t \cdot k_o \cdot k_T,$$

where R_i - the amount of work that can be performed unit per day, at a certain kind of work, ha or ton; Wzm - performance unit for a certain kind of work an hour alternating time, ha/h; t - the duration of a given operation throughout the day, hours; k_o - factor for the simple organizational reasons; k_t - factor for the time spent to perform technical maintenance and repairs.

Various authors [5, 18, 19] suggested a number of criteria for pre-selection units:

- Minimum operating costs per unit of work;
- Maximum coefficient operation;
- Maximum performance machine - tractor aggregates;
- Maximum performance per unit of power;
- Minimum labor costs;
- Minimum energy vehicles.

Limited to one of the suggested criteria is inappropriate because they do not take into account the quality and timeliness of work and cost of ownership of technology. Therefore, the choice of machines should be carried out using the eligibility criteria indicators of quality of work and productivity requirements of agricultural technology, maximum use of machines in the production and minimum necessary cost of ownership of technology. The value of the costs to own this or that machines must not be greater than the cost of production lost due to untimely and poor quality of work performed in the household during field work cycle without machines.

In terms of quality machines selected in terms of their appointment with the terms of their compliance with agricultural technology to perform a technological operation:

(3) $$Q_m \geq Q_a,$$

where Q_m - quality of work machine; Q_a - an indicator of quality requirements farming operations unit.

In terms of performance determined parameters such technical means by which the amount of work required to be done in optimal terms:

(4) $$W_q \geq \frac{\sum R_i}{P_i},$$

Number of units required for each operation, determined by the formula [3]:

(5) $$x_{is} = \frac{R_i}{p_{is}},$$

where x_{is} - number of units required for the performance of the total volume of similar works in optimal time; p_{is} - performance s-th unit in the i-th operation.

In terms machine parameters selected from the conditions that the cost of car ownership was not greater than the value of proceeds from the sale of additional products produced with the use of a car, and a variable cost was less than the value of work performed under the contract of lease:

(6) $$C_n \leq S \cdot U \cdot C,$$

where C_n - constant annual cost of the technique, UAH; S - the amount of work to be performed in the best technical means periods ha or ton; U- culture yield, t/ha; C - the price of additional products produced using machines due to the quality and timeliness of work, UAH/t.

To determine the performance of machines and technological complexes tractor fleet manned base on tractors with engine capacity of 130-140 kW and 44-60 kW has been calculated by the example of farm acreage 2700 hectares. To calculate the need for tractor fleet management adopted a 4-rotation of the fields sown areas structure (shown in Table 1) for intensive farming systems and selected tractor units to perform manufacturing operations plant production.

Table 1. *Structure acreage of crops in the fields 4-rotation intensive crop production*

Agricultural crops	Area crops	
	ha	%
Winter wheat	675	25,0
Corn for grain	1350	50,0
Sunflower	405	15,0
Soy	270	10,0
Total:	2700	100,0

After the appropriate calculations, it was determined the need for technological machinery for production system of intensive agriculture, namely the need for technical equipment (Fig. 1) and their annual download; Direct operating expenses technological complex machines and their structure by growing operations.

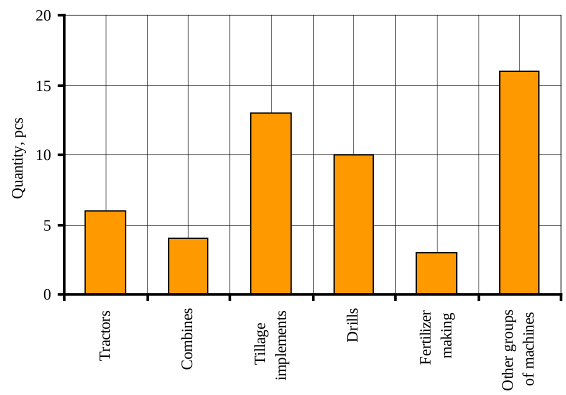


Fig. 1. *Estimated demand for technical means for completing future structure tractor fleet*

Established that the cultivation of crops for intensive technology park with a specific machine-tractor units direct operating costs in the structure of total expenses are 31% (Fig. 2).

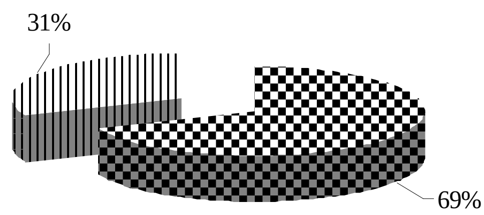


Fig. 2. *Structure of the cost of crop production for intensive technology in short rotation rotation*

- direct operating costs

- other operating costs

4. Conclusions

Using mathematical models proposed selection criteria and technical and operational parameters of means the specified volumes and crop production technologies provide choice complexes cars and manning rational structure of machine - tractor fleet management and improve the efficiency of crop production.

5. Referances

1. Адамчук, В. Система техніко-технологічного забезпечення виробництва продукції рослинництва / В.В. Адамчук, М.І. Грицишин – К.:Аграрна наука, 2012.-416 с.

2. Адамчук В.В., Булгаков В.В. Пріоритетні напрями створення сучасної сільськогосподарської техніки. Вісник аграрної науки,-2014. - №5. - С.5-10.

3. Адамчук, В., Системно-проектні підстави управління парком машин сільськогосподарських товаровиробників / В.В. Адамчук, О.В. Сидорчук, В.Г. Мироненко // Вісник аграрної науки,-2014. - №11. - С.33-40.

4. Фінн, Е. Комплектування машинно-тракторного парку колгоспів і радгоспів / Е.А. Фінн, М.Л. Варшавський, І.Є. Черватюк. К.: - Урожай, 1989, 176 с.

5. Грицишин, М. Методологічні основи комплектування МТП аграрних підприємств в умовах обмеженого ресурсного забезпечення / М.І. Грицишин // Міжвід. темат. наук. зб. Механізація та електрифікація сільського господарства. Глеваха, 2014. – Вип. 99 Т. 2.– С. 392-400.

6. Грицишин, М. Техніко-економічна оцінка технологічних комплексів машин для органічного виробництва продукції рослинництва / М.І. Грицишин, Р.Б. Кудринецький, М.Г. Цибуля та ін. // Міжвід. темат. наук. зб. Механізація та електрифікація сільського господарства. Глеваха, 2014. – Вип. 99 Т. 1.– С. 140-150.

7. Попович, В. Определение рационального состава парка машин для хозяйств / В.К. Попович, Н.И. Белоконь, Л.Г. Полянская и др. // Механизация и электрификация сельского хозяйства. – 1980. – №5 – С. 58-59.

8. Репетов, А. Оптимизация состава МТП и его работоспособность / Репетов А.Н. // Тракторы и сельхозмашины – 1984. - №2 – С. 8-10.

9. Мининзон, В. Определение оптимального состава машинно- тракторного парка в зависимости от погодных условий / В.И. Мининзон, А.В. Тюленев, Б.В. Вечернин и др. // Тракторы и сельхозмашины. - 1986. - № 3 – С.7-9.

10. Удосконалити детерміновану модель планування механізованих робіт в аграрних підприємствах, що функціонують в різних природно-виробничих умовах України. Виконати перевірку детермінованої моделі планування механізованих робіт на адекватність: звіт (проміжний): 33.01.00.01Ф/НААН; ННЦ «ІМЕСГ»; кер. М. І. Грицишин. – Глеваха, 2012. – 115 с. – Вик.: В. І. Днесь, Н. М. Перепелиця, М. Г. Цибуля, Н. В. Сергєєва, Н. М. Коньок, І. О. Недвига, Л. М. Нестеренко – № ДР 0111U006975.

11. Мельник, І. Оптимізація комплексів машин і структури машинно-тракторного парку та планування технічного сервісу / І.І. Мельник, В.Д. Гречкосій, В.В. Марченко – К.: - Видавничий центр НАУ. – 2001. – С. 5-47.

12. Сидорчук, О. Інженерія машинних систем. Монографія. / О. В. Сидорчук – Львів: Добра справа, 2007. – 263 с.

13. Сидорчук, О. Оптимальне управління розвитком машинно-тракторного парку / Сидорчук О. В., Головач І. В., Яременко В. В., Новак Я., Красовский Є. // Механізація та електрифікація сільського господарства / ННЦ «ІМЕСГ». – Глеваха, 2012. – Вип. 96. – С. 362-368.

14. Сільськогосподарська техніка. Методи економічного оцінювання техніки на етапі випробування. ДСТУ 4397:2005. Київ. Держспоживстандарт України. 2005. – 16с.

15. Методика определения экономической эффективности технологий и сельскохозяйственной техники. – М.: ГПУСЗ Минсельхозпрома России. 1998.

16. Завалишин, Ф. Основы расчета механизированных процессов в растениеводстве / Ф. С. Завалишин – М.: Колос, 1973 – 319 с.

17. Нагірний, Ю Типові задачі машиновикористання в землеробстві: Навчальний посібник. / Ю. П. Нагірний, Б. І.Затхей, В. В. Хом'як та ін. – Львів: ЛДАУ, 2001. – 180 с.

18. Нагірний, Ю. Аналіз технологічних систем і обгрунтування рішень / Ю. П. Нагірний, І. М. Бендера, С. Ф. Вольвак; за ред. Ю. П. Нагірного. – Камянець-Подільський: ФОП Сисин О. В., 2013. – 264 с.

19. Кудринецький, Р. Обгрунтування ефективних технологічних комплексів машин для виробництва продукції рослинництва в сільськогосподарських підприємствах / Р. Б. Кудринецький, М. І. Грицишин // Механізація та електрифікація сільського господарства: загальнодержавний зб. / ННЦ «ІМЕСГ». – Глеваха, 2015. – Вип. № 1(100). – С. 250-259.

20. Кудринецький, Р. Обґрунтування технологічної потреби і наявності зернозбиральної техніки в умовах Донецької області / Р. Б. Кудринецький, С. П. Степаненко, М. І. Уваров, І. І. Махмудов // Механізація та електрифікація сільського господарства. Випуск 97. Т.1 – Глеваха, 2013. – С. 489-495.

21. Рихтер Дж. CLR via C#. Программирование на платформе Microsoft.NET Framework 2.0 на языке C# (2-е издание) / Дж. Рихтер // М.: «Русская редакция»; СПб.: Питер – 2006. – 656 с.

22. Нортоп Тони. Основы разработки приложений на платформе Microsoft.NET Framework. Учебный курс Microsoft / Нортоп Тони, Уилдермьюс Шон, Равен Билл // Пер. с англ. – М.: «Русская редакция»; СПб.: Питер – 2007. – 864 стр.: ил.

23. Хабатов Р.Ш. Прогнозирование оптимальных параметров и состава машинно-тракторного парка. – К.: ВЦ Госплана УССР, 1969.

24. Галузева угода Міністерства аграрної політики та продовольства України на 2014-2016 рр. http://www.vin.gov.ua/web/upravlinnya/web_upr_apk.nsf/web_alldocs/DocHDBH6.

EXPERIMENTAL STUDY OF STRIP TILL MACHINE

Mitev[1]. G.V., Kr. Bratoev[1]

“Angel Kanchev”University of Ruse, 8 Studentska Str. 7017 Ruse, Bulgaria

Abstract: *Strips tillage machine with simultaneous fertilizing in the depth of processing is examined. The experiments were carried out by standard methods known as the theory of the experiment, at the same time is determined and the optimization task with which to establish the optimum setting of the machine. The results obtained show that the machine corresponds to all requirements, the best results are achieved at a speed of 9,0km / h and a depth of 0,25m.*

Keywords: strip till, soil productivity, agricultural machines

Introduction

It was found that as a result of the annual deep tillage of the soil, due to the structural features of the machines with which they are applied immediately below the plow layer is formed compacted horizon called. "Plow pan". This phenomenon has caused excessive compaction of the soil, to prevent the ingress of solid and becomes an obstacle difficult to overcome for the development of roots in the depth of penetration of air, water and nutrients.

Deep plowing emerged as one of the main causes of soil degradation in recent decades. More and more tangible for producers effect of decreasing soil fertility, manifested mainly in reducing organic matter content.

This requires the application of such technology for growing crops where along with maintaining high yields should be monitored and conservation of soil fertility. One of the areas is the application of technologies for production with reduced number of tillage. Wherever possible, the turning of the soil layer is replaced with subsoiling, but without inverting the layers (so scarifying the soil). The purpose of this study consists in application of a reduced number of the treated soil using deep handling of soil in strips. Regarding the objective of the study has the following main tasks:

• Study the work process of stripe working tolls.
• Optimizing the operating mode of stripe till machine.

Material and Methods

To conduct production research as experimental model used for subsoiling tillage in strips produced by the company "Unverferth", USA, Figure 1. The machine is designed for deep tillage in strips, after appropriate reorganization and introduction of solid mineral fertilizers in the depth of processing. The working width of the machine is 4,2 m. Structural width of 4.2 m is imposed by Engine Power indicators tractors. Usually this type of tillage needed 47-50 kW of power for operating authority. Used tractors with a capacity of about 280-300 kW, [2,4,6].

On the frame are six working body with them cultivators subsequent sections, and above them are volume of fertilizer regulations. The maximum working depth of tines that can handle the soil is 0,60 m. It is set by means of two pneumatic support wheels across the width at both ends of the frame.

Through parallelogram mechanism after every working body hanging cultivator section in which a pair of disks closes the groove and then moving them tines mixed and aligned and the soil surface. At the base of the hoppers for fertilizer are six fertilizer apparatus of the grooved type, that through flexible tubes bind to the solid pipes rigidly attached to the rear of steam each working body. Fertilizer equipment the machine can provide fertilizer rate to 500 kg /ha, 1,4,9].

For normal operation of the machine it needs to be aggregated with a tractor, providing 30 ÷ 45 kW of power to the working section. Joining energetic means going through the three-point lifting device mounted on the machine frame.

Conducted preliminary studies related to the choice of control factors influencing processes in basic research, but also with justification indicators (parameters optimization).

Research in the field of processed soil indicate that the mechanical and handling affect too many factors. In general they can be grouped as constructive and kinematic factors related to physical - mechanical properties of the soil.

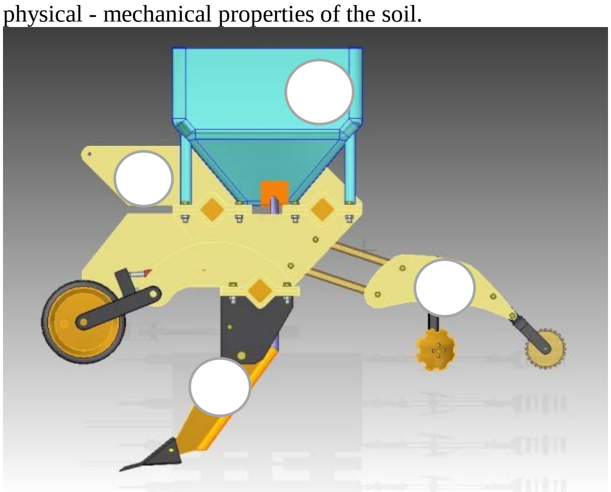


Fig. 1. Strip till machine with fertilizer system: 1 frame of the machine; 2 fertilizer regulations; 3 deep ripening working body; 4 cultivator section

The most commonly used controllable factors in machines for soil cultivation are: operating speed of the machine; the depth of processing and the angle of attack in order to break up large aggregates subsoil. The majority of the physical and mechanical properties of the soil appear random factors which are constantly modified in the course of its processing. Such factors include humidity, hardness, abrasion, organic matter content, stickiness and others. This multitude of factors acting simultaneously makes the process of probabilistic processing.

The quality of the principal tillage is judged primarily by the degree of fragmentation of soil aggregates and the degree of insertion of plant residues in the soil. So when testing machines for basic tillage, they are used as parameters of optimization, ie Y_1 - degree of plowing of crop residues and Y_2 - the amount of soil aggregates, [3,5,8,10], .

Of the numerous factors that influence these parameters with the greatest weight is the operating speed of the machine and the depth of tillage. As the study carried machine and direct import of solid mineral fertilizers is desirable to check whether the pilot process would not have filed disruptions in the flow of the main process (tillage). It follows from this that as a first control factor includes the operating speed of the machine -x_1, and as a second factor is the depth of processing -x_2. The influence of all other factors not participate as manageable in experiments reported by aggregate impact of confounding factors.

In accordance with the tasks conducted active experiment. By its nature, it is a multifactor regression analysis conducted during the field experiments.

In the fixed values of control factors x_i (i = 1,2 ..., m), by the action of the unguided (disturbing) factors W_k (k = 1,2 ..., q) each of the parameters (responses) Yj (j = 1 2 ..., p) the output will be random in nature. If controllable factors are quantitative (measurable), the general appearance of the relationship between parameters Y_j (j = 1,2 ..., p) and control factors is represented by the so-called. "Function response" [11]:

$$E[Y_j / x_1,\dots,x_m] = \varphi(x_1, x_2,\dots x_m), \quad (1)$$

where $E[Y_j / x_1, x_2,\dots x_m]$ is the conditional mean value of parameter Yj.

The equation (1) is called the regression equation, and the surface that it describes the - surface of the response. The type of function $\varphi(x_1, x_2,\dots x_m)$ depends on the nature of change of parameters Y_j in the selected area of change the factors $x_1, x_2,\dots x_m$. In carrying out the multi-factor experiments, which has the character of an optimization problem to obtain the type of the equation (1) using a polynomial model of the second level which m when the factor has the form:

$$\tilde{y} = \sum_{i=0}^{m} \beta_i x_i + \sum_{i,k=1}^{m} \beta_{ik} x_i x_k + \sum_{i=1}^{m} \beta_{ii} x_i^2, \quad (2)$$

where $\beta_0, \beta_1,\dots\beta_m$ are the parameters of the regression coefficients of the model.

It should be borne in mind that the polynomial model simply approximated with some accuracy function $\varphi(x_1, x_2,\dots x_m)$ in a small range of variation of control factors. One of the major tasks of any experimental study is seeking zoom function response based on the received experimental data. This may be a good approximation, it is necessary attempts to hold a special scheme - run the experiment. With many good properties are the plans of type Bm, [11,12,13].

Since the selected control factors were quantified, then to find a mathematical model of the research process (main tillage) using regression analysis [86, 89, 90].

Because of the possibility of error in experimental data and because of their finite number are determined not true model $\beta_0, \beta_1,\dots\beta_m$ parameters and their estimates.. Therefore, to describe the area of optimum parameters optimization separately for each expression (2) is presented in the form:

$$\hat{y} = b_0 + \sum_{i=1}^{m} b_i \overset{o}{x}_i + \sum_{i,k=1}^{m} b_{i,k} \overset{o}{x}_i \overset{o}{x}_k + \sum_{i=1}^{m} b_{ii} \overset{o}{x}{}_i^2, \quad (3)$$

To determine the optimum mode of operation of the test machine is used by the method of optimization of the desirability function [13].

For this purpose, the target function of Y_1 and Y_2 is represented by a generalized function of desirability, which is of the type [90]:

$$D = \sqrt{d_1.d_2}, \quad (4)$$

Where d_1 and d_2 are private functions desirability defined by the equation:

$$d = \exp[-\exp(-Y^{`})] \quad (5)$$

In determining the function of desirability some restrictions are used: $Y_1 \geq 90\%$ and $Y_2 \leq 25\%$. For indicator Y_1 restriction provides the necessary degree of plowing of crop residues in the field, and to limit Y_2 provides agro-technical requirements for the size of soil aggregates after treatment. For the summary function of desirability is sought after model type [21]. The summary function of desirability is determined for two series of experiments. Thus, from the values obtained for her look the most and determine the optimum values of factors. The possible values for summary function of desirability are listed in Table 1.

Table 1.

Values on the scale of desirability

Desirability	Values on the scale of desirability
Excellent	1,00
Very good	1,00-0,8
Good	0,8-0,63
Satisfied	0,63-0,4
Not satisfied	0,4-0,3
Bad	0,3-0
Very Bad	0

Essential to the reliability of the test results is the exclusion of conflicting mode of study experienced machine. Such a regime at the trials is the process of scratching deep loosening tools. Determine the length of this section are the way of the detachable machine to the linkage of the tractor and constructive set back corner of the working bodies. This mode is removed in the region corresponding to the path of scratching of deep loosening element not conducting measurements. The duration in various attempts multifactor experiment at a constant length of the test section is amended in the range of 95÷150s depending on the set speed of the unit. Within this interval, the experimental installation process strips right length as 142,8 m early not involved in measurements due to the above mentioned reasons.

Studies are conducted under real field conditions, subject to agro-technical deadlines and comply with the soil - climatic conditions for the implementation of the agricultural event.

Firld experiments are made in sections of the field, which is piled previous culture and has not carried out then treated soil. The machine is aggregated with a tractor power 265 kW, equipped with a navigation system for guiding field. This provides the necessary distance between border clubs in treated soil strips, which should be sown the seeds of the crop. The depth of working of the soil is adjusted by screw mechanisms mounted on two support wheels of the machine, taking into account their sinking into the soil, which is from 0.02 to 0.04 m.

The speed of the machine is set by the experiments conducted and regulated by mechanics, Managing tractor selects the appropriate gear from the gearbox the energy machine.

Reporting the optimization parameter Y_1 is done using a square measuring frame size of the country equal to the width of the treated strip. Initially, the framework is put in place individual attempts before treatment and defines an area covered with debris. After crossing the machine in test points in the treated areas, measuring frame is repositioned and define the areas over which remained non putted into the soil plant debris.

Reporting parameter Y_2 it using a screen classifier for soil aggregates. Take soil samples from treated areas that are weighed before placing them in the classification, and after passing through it weighed rest of the sieve fraction.

The preconditions under which the experiments were conducted are presented in Table 2. The studies were conducted in farmland ET "Renaissance". Lozenets, Municipality of Krushari, Dobrich.District.

Table 2.
Measured values of the indices immediately before conducting experiments

Indicator	Dimension	Value
Soil: Carbonite chernozem	-	-
Power of the organic horizont. Flat field, depth 0.60 -0.90 m	m	0,60 – 0,90
Mechanical structure - sandy-loam to light clay	-	-
Prticle size 0,25 -0,05 mm	%	8
Below <0.001 mm	%	15
pH	-	6,0 – 6,8
Organic matter content	%	2.4 – 1,6
Cultivated area – flat		
Direction of cultivation		
Previous Crop – Winter wheat		
Height of cutting the stems at harvest	m	0.20 – 0.25
Available crop residues	%	100
Condition of the field. Stubble, heavily padded.	t/m^3	1,65-1.75
Set up the tillage depth	m	0.25 - 0.35
Absolute Soil Moisture	%	18
Soil density before the tillage in the range of 0.01 – 0.80 m	t/m^3	1,68-1,70
Crop residue depth leave on the soil surface	m	0.07 – 0.11
Degree of Uniformity of the crop residue spread out	%	90

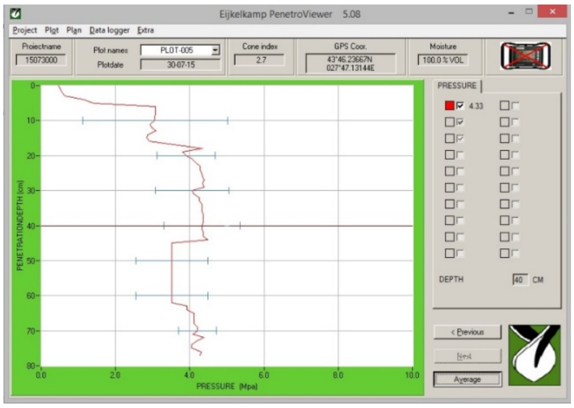


Fig. 2. Diagram hardness of the soil before switching on the machine for soil cultivation in strips

The surface layer of the soil is heavily compacted Fig. 2. The measurements made by the instrument for measuring the hardness of the soil in the range of 0 - 0.80 m, indicate that there are two levels of sealing.

The first level is in the range of 0.07 - 0.15 m. This type of seal is obtained after passage of heavy machinery on wet soil, i.e. during the retraction of the production.

In the second level, the soil is heavily compacted in depth between 0.24 - 0.43 m. This indicator shows tillage reversed layers - deep plowing, as subsoil is compacted over limits.

The analysis of these studies and determine the depth to be conducted to determine the quality of the machine for soil cultivation in strips without turning the layers. The specified working depth is 0.25 and 0.35 m.

The summarized experimental data are presented in Table 3.

Table 3.
Overall experimental data with data processing software "Statistics"

No: of the experiment	x_1 Km/h	x_2 cm	Y_1 %	Y_2 %
1	2	3	4	5
1	7	25	90.90	22.40
2	7	35	60.40	19.80
3	7	30	90.79	26.80
4	8	25	92.30	17.20
5	8	35	92.40	13.80
6	8	30	92.40	16.20
7	9	25	94.00	13.50
8	9	35	94.00	13.00
9	9	30	92.80	14.20

where
x_1 is the operating speed of the MTA, km / h;
x_2 - the depth of treatment, m;
Y_1 - the degree of plowing of crop residues%;
Y_2 - resulting yields, kg / ha;
Y_3 - soil aggregate size greater than 50 mm,%.

The results of the regression analysis are presented in Table 4.

Table 4.
Results of regression analysis of the second degree model for Y_1

N=9	Обобщение на регресионния анализ за зависима променлива. Regression Summary for Dependent variable: Y_1 R=0,98512209 R^2=0,97046553 Adjusted R^2=0,92124142 F(5,3)=19,715 p<0,01678 St. Error of estimate =0,36918					
	b^*	St. error of b^*	b	Std. Error of b	$t(3)$	$p-value$
Intersept			20,74222	20,95735	0,98974	0,395269
x_1	12,5927	2,846452	19,12833	4,32375	4,42402	0,021448
x_2	-1,6283	2,282085	-0,49467	0,69330	-0,71350	0,527034
x_1x_2	-1,8164	1,219249	-0,05500	0,03692	-1,48980	0,233048
x_1^2	-10,7334	2,751485	-1,01833	0,26105	-3,90094	0,029902
x_2^2	2,6627	2,064657	0,01347	0,01044	1,28967	0,287592

Table 4 shows that the significance level α = 0,05, are significant factors $b_1 = 19{,}128$ and $b_{11} = -1{,}01$.. This shows the strong

influence of factors x_1 on parameter Y_1. The influence of $x_2$on Y_1 is significantly less. (See p-value at which the values are greater than 0.05).
The coefficient of determination e $R^2 = 0{,}97$. I.e. 97% of cases amending Y_1 due to controllable factors and describes the model of the second degree, who include all odds model has the following specific type, equation 6.

$$Y_1 = 20{,}74 + 19{,}13x_1 - 0{,}49x_2 - 0{,}055x_1x_2 - 1{,}018x_1^2 + 0{,}0135x_2^2 \qquad (6)$$

The graphical representation of the model shown in Figure 3. The surface of the model Minimax and in-depth analysis is necessary to make a section through line at the same level figure 4.

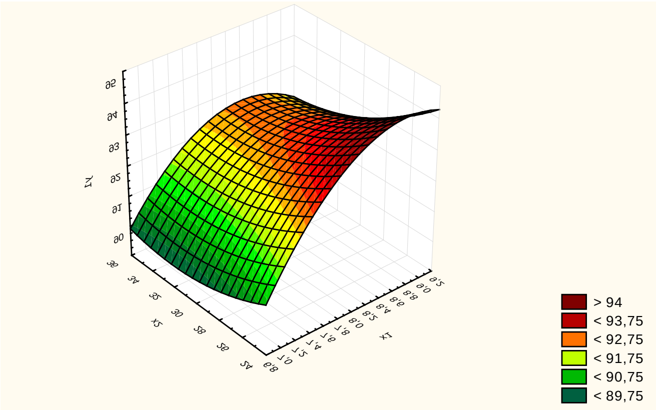


Figure 3. Surface response $Y_1 = f(x_1, x_2)$

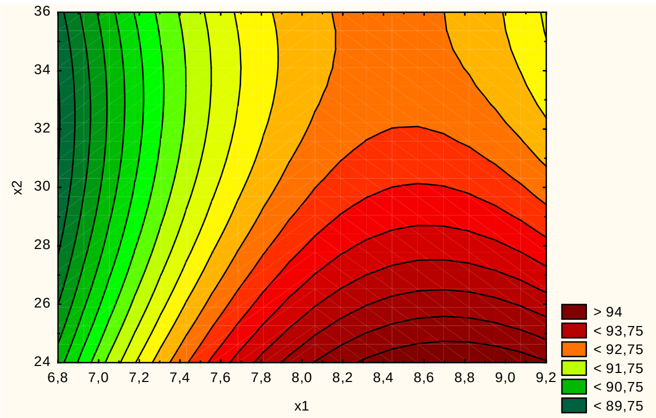


Figure. 4. Lines with the same level $Y_1 = f(x_1, x_2)$=*const*

The lines at the same level it is clear that large amounts of Y_1 are obtained at higher speeds and lower working depth of the tines.
Regression analysis parameter $\boldsymbol{Y_2}$

Table 5

Regression analysis parameter Y_2

N=9	Обобщение на регресионния анализ за зависима прменива Y_2. Regression Summary for Dependent variable: Y_2, R=0,84264071R^2=0,71004336 Adjusted R^2=2,9359,0949					
	b^*	St. error of b^*	b	Std. Error of b	$t(6)$	$p-value$
Intersept			52,200	12,025	4,340	0,0048
x_1	-0,843	0,21983	-4,583	1,1985	-3,824	0,80046
x_2	0,0580	0,21983	0,0633	0,2397	0,2642	0,80046

From Table 5 it is apparent that the influence of x_1 (operating speed) on Y_2 (size of soil aggregates) has been demonstrated. With increasing x_1 - Y_2 reduced.
It is obvious that the surface is Minimax Figure 5. The regression equation has the following full record:

$$Y_2 = 187{,}27 - 56{,}13x_1 + 4{,}78x_2 + 2{,}95x_1x_2 + 0{,}15x_1^2 - 0{,}01x_2^2 \qquad (7)$$

In this case, the best value factors, or some of them are the boundaries of the field of climate factors. This is shown by the lines of equal responses presented in Figure 6.

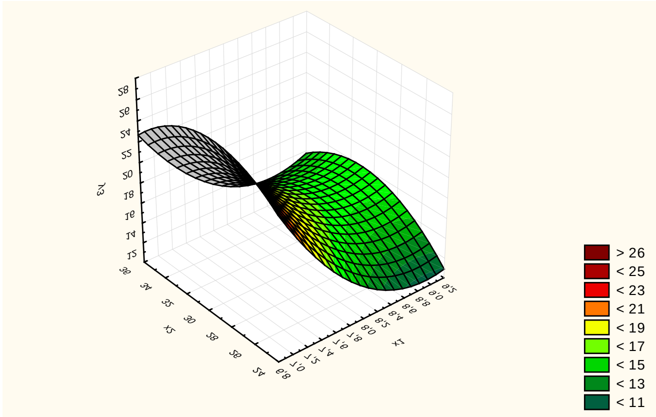


Fig. 5. surfaces of response $Y_2 = f(x_1, x_2)$

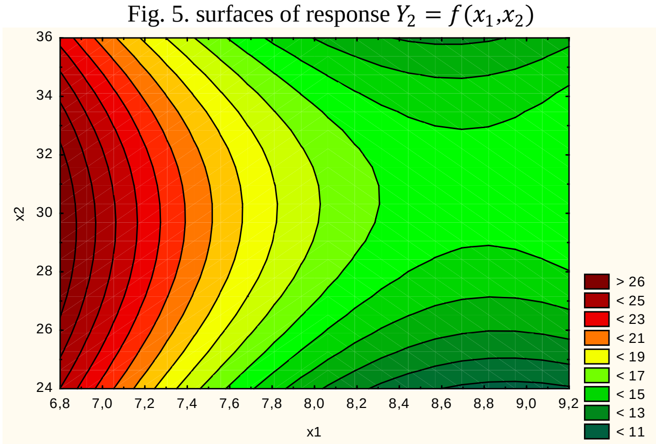


Fig. 6. Lines of uniform response $Y_2 = f(x_1, x_2)$=*const.*

On the lines of uniform response (Fig. 6) it is apparent that small values of Y_2 (i.e., greater crushing of soil components) is obtained at higher speeds and smaller working depth of the working organs.
The total extreme of the two functions is found by performing optimization of workflow summary function of desirability. Data from optimization performed are presented in Table 6 and in Figure 7.

Table 6.

Results obtained for summary function of desirability

	1 x1	2 x2	3 D
1	1	1	0,616999
2	-1	1	0,254702
3	1	-1	0,764495
4	-1	-1	0,279304
5	1	0	0,642522
6	-1	0	0,189018
7	0	1	0,559031
8	0	-1	0,770853
9	0	0	0,589063

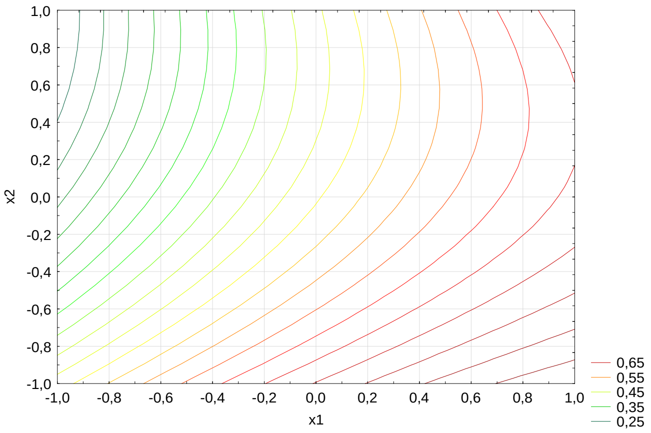


Figure 7. Lines at the same level for the function of desirability

From the data in Table 4.8 shows that in the seventh experience levels factors provide a very good function of desirability (D = 0,8), wherein the values of the parameters satisfy the constraints of the optimization: $Y_1 \geq 90\%$ and $Y_2 \leq 25\%$. Lines presented at the same level in Figure 7 shows that the optimal operation of the machine is achieved at levels of factors $x_1 = 1$ and $x_2 = -1$.. Expressed in natural units, these levels correspond to 9,0 km / h and 0,25 m. From these two factors with greater weight on achieving optimum performance of the machine is x_1, since its exclusion from the model summary function of desirability, the coefficient $R^2 = 0{,}1$, while off x_2 - $R^2 = 0{,}42$.

Conclusion

The survey indicates that the appropriate adjustments made processing machine for processing strips of soil with simultaneous application of mineral fertilizers in depth corresponds to the agricultural requirements. From the resulting regression models for the studied parameters shows that to achieve the best possible results must be preferred to work at a higher speed. This is confirmed by the conducted optimization problem, which shows good results at a speed of 9,0km / h and a depth of 0,25m.

Sources:

1. Alexandrov, V. et all, 1967. Manual for design of Agricultural Machines, Machinostroenie, Moskow, v.2
2. Daskalov, Dj., J. Demirev, Hr. Beloev, 1995. Manual for Agricultutal Machines, part I.
3. Demirev, J., Kr. Bratoev, 2012. Agricultural Machines, I., Ruse,
4. Dimitrov, P., A. Lazarov, D.Dimitrov, Hr. Beloev, P. Radulov, S. Valchinkov.2008. Antierosion technique for maize growing on slopy fields. Agricultural Academy, Ruse Press, p.59
5. Georgiev, I.,1973. Fundamentals of similarity and modeling of agricultural equipment. Zemizdat, Sofia,
6. Vagin, A. et all. 1977. Mechanization and protection of soil from water erosion I not chernozem area, Kolos, Leningrad, 1977.
7. Galushka, I., I. Ovchinnikov. 1967. Device for local injection of fertilizers in orchards. Mechanization and Electrification of the Agriculture, Urogaj, Kiev, 8:,
8. Markov, N., 1986. Study on chisel working bodies of machines for deep loosening of soil waterlogged surface. Abstract, Sofia, 1986
9. Mitev, G.V., A. Pavlikianova, Kr. Bratoew, St. Manushkov, 2011. Study of soil mixes for water holding materials. Proceedings of Scientific Publications, Ruse University "Angel Kanchev", p. 231-234.
10. Mitkov, A., D. Minkov, 1989. Statistical Methods for study and optimization of the Agricultural Machines, Ist part.
11. Mitkov, A., D. Minkov, 1989. Statistical Methods for study and optimization of the Agricultural Machines, IInd part.
12. Mitkov, A., 2011. Theory of the experiments, Dunav Press, Ruse.
13. Panov, I., V. Vetrohin, 2008. Physical fundamentals of the soil mechanics, Kiev.
14. Fishstenko, G., 1967. Mechanization of irrigation the underplough soil layers. Mechanization and Electrification of the Agriculture, Jrojai, 8:23-25
15. Srivastava ,A. K et al. 1993. Engineering principles of agricultural machines. American Society of agricultural engineers

.

POWER CONSUMPTION AT INERTIAL THRESHING OF SESAME

КОНСУМАЦИЯ МОЩНОСТИ ИНЕРЦИОННОЙ МОЛОТЬБЫ КУНЖУТА

Asist. prof. eng. Zaykov R., Assoc. prof. eng. Ishpekov S., Ph.D student eng. Naydenov N.,
Assoc. prof. eng. Triffonov A.
Department of Agricultural Mechanization, Agricultural University - Plovdiv, Bulgaria
sishpekov@abv.bg

Abstract: *The power consumption of a flow fruit detacher and classic thresher with equal nominal throughput at sesame threshing has been determined. The results show that the total power consumed by the detacher is 4.81 times smaller than by the conventional thresher. This result is due to inertial threshing which does not require destruction of capsules and deformation of stems for detaching of seeds.*
Keywords*: SESAME HARVESTING, MECHANICAL THRESHING, POWER CONSUMPTION*

1. Introduction

An experimental unit of a flow detacher with non-symmetric angular oscillations has been developed at the Agricultural University - Plovdiv, BULGARIA (Ishpekov S. et al., 2015a). It is designed for detaching of fruits and seeds from plants through inertial way. The detacher achieves the best indicators about degree of threshing, portion of impurities in the threshed mixture and mechanical damage of the seed (Ishpekov S. et al., 2016). Moreover, it threshes sesame without destruction and deformation of its capsules and stems, which is the significant difference with the classic thresher (Ishpekov S., 2013, Ishpekov S. et al., 2015b). The various ways of threshing cause a difference between their power consumption.

The aim of the study is to determine the power consumption of the flow detacher at inertial threshing of sesame and its comparison with that of the conventional thresher.

2. Experimental method

The power consumption of the detacher has been determined experimentally through the magnitude of current consumed by the drive motor. The measurement of the AC is conducted with an experimental installation presented in figure 1. It is composed of the detacher (6, 7, 8, 9), electric motor 4, frequency inverter - 3 and ammeter - 2. The detacher is driven by three-phase asynchronous motor - 4 with a nominal power of 750 *W*. It is connected under the scheme "star", which supplies 3 phases of 220 *V* to the coils, and not as a normal - three phases of 380 *V*. Therefore, the engine develops $\sqrt{3}$ times less power, i.e. 433 *W*. The speed of the electric motor is controlled by frequency inverter Schneider Electric - ATV12HU22M2 - 3 (http://www.schneider-electric.com/ww/en/).

Power consumption of the electric motor - P_k, [*W*] is calculated by the formula

$$P_k = U.I.\eta_м \cos\varphi \qquad (1)$$

where:

U is the voltage supplied to the motor, [*V*];

I - the current consumed by the three phases, [*A*];

$cos\varphi$ - the power factor of the used electric motor (cosφ=0,74);

$\eta_м$ - the mechanical efficiency of the system. Is calculated by reference (Trubilin E., 2010);

The power consumption of the detacher is determined for three operating modes that are typical for the thresher of grain harvester:

- In acceleration mode without loading with stems;
- In idling mode with constant rotation frequency of the central wheel of the pulse mechanism - 7;
- In mode with loading with stems.

An experiment according to design B_2 (Mitkov At., 1993) with three replications has been conducted for each of the three operating modes with the following controllable factors:

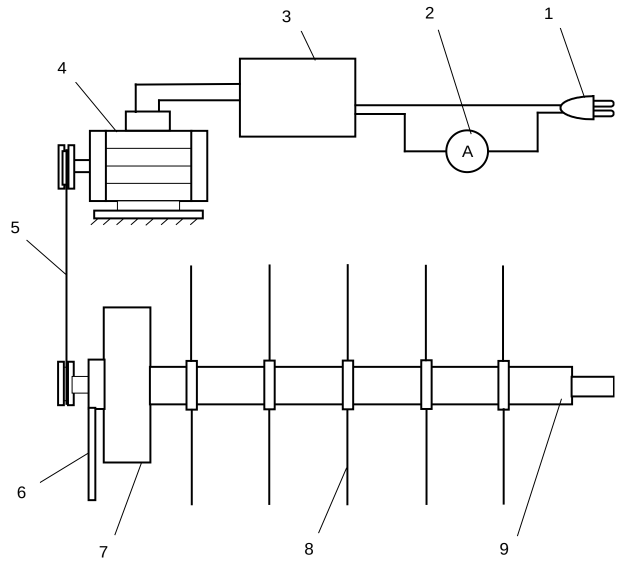


Figure 1. *Scheme of experimental installation*
1 - power supply, 2 - ammeter, 3 - frequency inverter, 4 - three-phase electric motor, 5 - belt drive, 6 - one-way clutch, 7 - pulse Chalmers mechanism, 8 - fingers, 9 - shaft.

- The rotation frequency of the central wheel of the pulse mechanism - *n*, [min^{-1}];
- Initial elastic momentum of the clutch - $M_{el\,0}$, [*N.m*].

The natural and coded values of controllable factors are presented in table 1.

The current consumed by the drive motor - *I* has been meazured and by formula 1 is calculated the power consumption of the detacher - P_k.

The power consumption of the frequency inverter has been measured and reduced from this of the electric motor in all experiments.

Table 1. Natural and coded values of controllable factors

code	*n*	$M_{el\ 0}$
	min^{-1}	*N.m*
-1	120	0
0	420	1,28
+1	720	2,56

The power consumption of the conventional thresher is analytically determined by the following relations (Ishpekov S., 2013):

$$P_0 = A\omega + B\omega^3 \qquad (2)$$

where:

$A\omega$ is the power to overcome friction in the bearings, [*W*];

$B\omega^3$ - the power to overcome air resistance, [*W*];

P_0 - the power idling, [W];

The coefficients A and B have been taken from reference book. (Ishpekov S., 2013).

$$P_{o\text{в}} = \frac{q.v_{б}^{2}}{1-f} \qquad (3)$$

where:

q is the productivity of the conventional thresher, [kg/s];

$v_б$ - the peripheral speed of the drum, [m/s];

f - the coefficient for accounting the resistance of the concave (for rim thresher f =0,65÷0,75);

$P_{oв}$ - the power for threshing, [W];

$$P = P_0 + P_{o\text{в}} \qquad (4)$$

where P it the total power consumption of the conventional thresher, [W].

The resulting power consumption translates to one kilogram threshing stems. The results are used to compare the two devices and the two working methods of threshing.

3. RESULTS

The power consumption of the detacher and of the threshing apparatus of the plot combine harvester Wintersteiger - classic (www.wintersteiger.com) have been determined and compared. The main technical data for the two devices are presented in table 2. Both have the same nominal productivity, but operate on different principles. The detacher releases sesame seeds on inertia way and threshing apparatus of the combine harvester - by rubbing and strokes.

The measured power consumption of the inverter at a constant mode is 16,3 W and at acceleration reaches 95,4 W. During acceleration up to speed of the central wheel shown in table 1 is seen an increase of power consumed by the detacher from 138,4 W to 488,4 W. At an acceleration up to n=720 min^{-1} the power consumption reaches 112,8 % compared to the nominal, which in this case is 433 W. The electric motor works with an overload of 12,8 %, which is acceptable for a short time.

In idle mode the power consumption is changed from 137,3 W to 241,5 W, which is from 31,7 % to 55,8 % of the rated (Fig. 2). The remaining power may be used for the technological process in the detacher.

Table 2. *Technical data of the investigated devices*

Parameter	Dimension	Detacher	Threshing apparatus of Wintersteiger - classic
Diameter of the drum	*m*	0,48	0,35
Width of the drum	*m*	1,3	0,785
Peripheral speed of the drum	*m/s*	1,45 - 3,05	15
Frequency of angular oscillations of the drum	*Hz*	12	-
Rated productivity	*kg/s*	1	1
Principle of threshing	-	inertial	rubbing and strokes

In mode with loading with stems, which mass is 0,87 kg for the power consumption P_k of the detacher is obtained the following regression equation -

$$P_k = 131,8415 + 0,0373n - 12,5068M_{el\_0} + 0,0002n^2 + 3,2570M_{el\_0}^2$$

with coefficient of determination R^2=0,99, Fisher criterion $F_{4,22}$=558,15, and probability $p(F)$=0,00001.

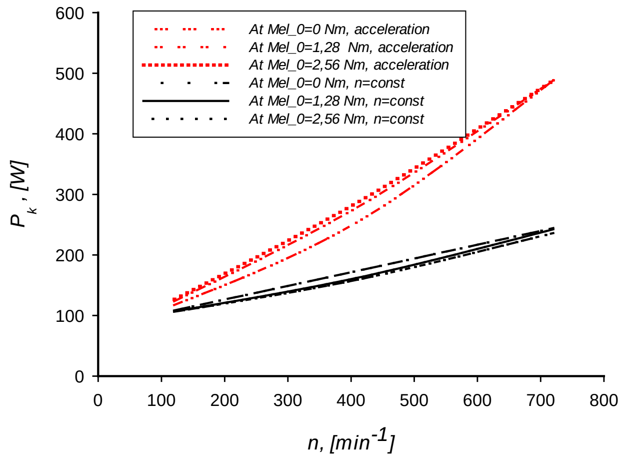


Figure 2. *Power consumption P_k of the detacher depending on the speed of the central wheel n and the initial elastic moment M_{el_0} in mode without loading with stems.*

Equal level lines for power consumption P_k in mode with loading of the detacher with stems are presented in figure 3. The power consumption is from 174,2 W to 258,8 W, which is an increase compared to idling from 36,9 W (26,6 %) to 17,3 W (7,2 %). This increase is less at high speed of the central wheel, because then the inertial forces are increased, but the proportion of torque for vibrations and movement of the stems - decreases.

The results obtained demonstrate two important facts:

- In load mode the detacher has a large supply of power to overcome temporary overloads;

- The initial elastic moment the clutch M_{el_0}, which is resistance type, has no significant impact on the power consumption of the detacher in idling and loading modes (Fig. 3). It increases the power consumed in acceleration mode only.

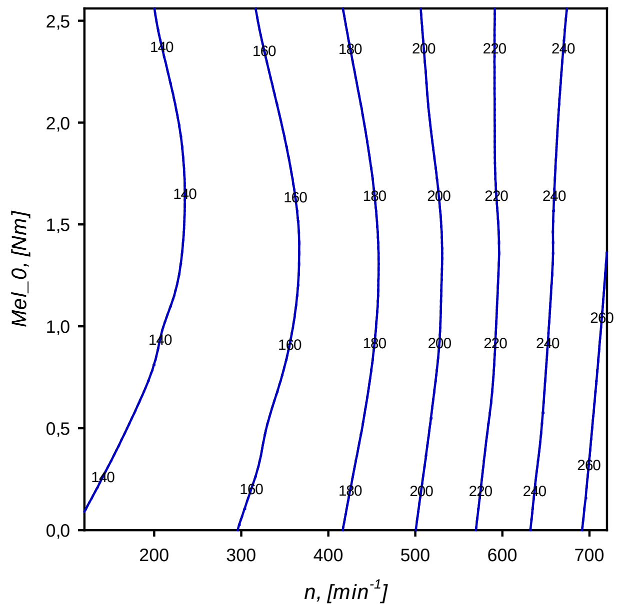


Figure 3. Equal level lines for power consumption P_k of the detacher depending on speed of the central wheel n and initial elastic moment M_{el_0} in loading mode with stems which mass is 0,87 kg.

The power consumption of both devices at threshing equal amount of stems is presented in table 3. Apparently, the detacher consumes 2,04 times less power at idle due to lack fan effect. It consumes 43,35 times less power for threshing, because it does not deform stems and capsules for removing seeds, while in classic thresher this is inevitable. Total specific power consumption of the detacher is 4,81 times smaller than of the conventional thresher with the same productivity.

Table 3. *Specific power consumption by the investigated devices [W/kg] at threshing stems with a mass 0,87 kg.*

Parameter	Detacher	Thresher of Wintersteiger - classic	Difference (times)
Specific power consumption in idling mode	277,6	567,3	2,04
Specific power consumption for threshing	19,9	862,1	43,35
Total specific power consumption	297,5	1429,4	4,81

It should take into account that the power consumption of the detacher has been determined experimentally and of the conventional thresher - analytically. Besides that, it is presumed an equality of both resistance coefficients of the concave at threshing of wheat and sesame. The value of this coefficient for sesame threshing is unknown, but probably is greater than that for wheat threshing. Therefore, it is possible the actual power for sesame threshing $P_{ов}$ by conventional thresher to be greater than analytically obtained. For this reason, it can be expected that the actual differences between power consumption of inertial and classical threshing to be larger than those obtained in this study. Those assumptions may lead to experimental error of the first kind, which does not lead in bad consequences of the results (Mitkov At., 1989).

4. CONCLUSION

The initial elastic moment of the clutch has no significant impact on the power consumption of the detacher in constant mode of operation. In idling the detacher consumes up to 48,3 % of the power that is consumed in acceleration mode. Power consumption for threshing of the detacher is up to 7,6 % in comparison with the power for its acceleration. The total power consumed by the detacher is 4.81 times smaller than by the conventional thresher with the same productivity.

5. References

Ishpekov S., (2013). Harvesting machines - I part. Book, Agricultural University - Plovdiv, ISBN 978-954-517-188-8, (Bg).

Ishpekov S., P. Petrov, D. Ruschev, R. Zaykov, 2015 a. Flow rotational fruit detacher with non-symmetric angular vibrations. Patent Application 3143 of 05.11.2015, Bulgarian Patent Office.

Ishpekov S., R. Zajkov, (2015 b). Inertial detachment of sesame seeds from non-squander genotypes, Agric Eng Int: 17, (3), p 83 - 91, (En).

Ishpekov S., R. Zajkov, P. Petrov, D. Ruschev, (2016). Indices of flow fruit detacher with angular vibrations at inertial threshing of sesame. Agric Eng Int: 18 (2):94-10;

Mitkov At., D. Minkov, 1993. Statistical methods for investigation and optimization of agricultural machinery. Zemizdat, Sofia, p 366, (Bg).

Trubilin E., V. Ablikov. Harvesters. Krasnodar, 2010 (Ru). Трубилин Е. И., В А Абликов., 2010. Машины для уборки сельскохозяйственных култур. Краснодар, 325 стр.

www.wintersteiger.com

http://www.schneider-electric.com/ww/en/

INFLUENCE OF THE SOIL PARTICLES ON THE WEAR OF PLOUGHSHARES DURING PLOUGHING

Opačak I., mag.ing.mech. [1], Putnik I., mag.ing.mech. [1], Samardžić M. [1]
Faculty of Mechanical Engineering, University of Osijek, Trg Ivane Brlić-Mažuranić 2, Slavonski Brod, Croatia [1]

iopacak@sfsb.hr, iputnik@sfsb.hr, msamardzic@sfsb.hr

Abstract: *Researchs of the influence of the soil particles were perfomed on the powder loamy soil to powder clay texture. Standard and welded ploughshares were tested. The standard ploughshares are made of steel 50Mn7. The welded ploughshares are made by applying C-Cr-Co-Ni-Si additional material on the steel 50Mn7. The ploughshares are tested on the plough roller machine. Researches were perfomed in periods of 120, 240 and 360 hours of ploughing, or 60, 120 and 180 work hours of each ploughshare. After 180 hours of work at least average reduction of the ploughshares lenght was at welded ploughshares and it amounted to 8,27 % of the initial length. At the same time reduced the average length of the top of the ploughshares with standard ploughshares amounted to 19,65 % of the initial length. It was concluded that the application of welded ploughshares can contribute to increased of the productivity.*

Keywords: *PLOUGHING, SOIL PARTICLES, WEAR OF PLOUGHSHARES, PRODUCTIVITY*

1. Introduction

While ploughing the soil certain parts of the plough wear, mostly ploughshares. The most weared parts of the surface are the top and blade. They dull during the work, causing the loss of the mass and dimension changes of the ploughshares. Standard ploughshares which are supplied while buying ploughs do not meet the requirements of sustainability. Delays which are caused by wear and dull of the ploughshares require some time to replace with new ones. It increases the costs and reduces the efficiency of the tractor. One of the possible solutions to the wear problem of the ploughshares is the surfacing hard layers to the top of the blade. Wear problems of the tools for the soil ploughing was among the first engaged by the scientist Richardson [1]. He found that the soils contain abrasive particles with a hardness greater than the hardness of ploughshares. Further examinations of the ploughshares different hardnesses author notes that the surface hardness is one of the most important characteristics of resistance to wear during operation. In the nineteen seventies experiments with the application of the hard layers of the additional material on the blades for the soil ploughing began [2]. Conclusion was that on the sustainability and wear, significant influence has humidity and mechanical composition of the soil during ploughing. Natsis and colleagues [3] investigated the influence of type and soil moisture and the sharpening of ploughshares on power consumption, performance and quality of ploughing. They conclude that on the clay and loamy soils ploughshares wear decreases with increasing soil moisture, and that on the sandy soils wear increases with increasing moisture content. They note that during the work with the worn-dull blade of the ploughshares comes to increasing the necessary traction force for 62 %, and consequently to reduce the effect of efficiency for 30 %. Banaj and colleagues [4] analyzed the arrangement of the moisture in depth and found out that, depending of the soil type, the difference between the layer of 0 to 10 cm and 20 to 30 cm is around 5 %. Top of the ploughshares first dulls, and then other cutting surfaces [4, 5]. Aim of this research is, based on the comparision of the results of the welded and standard ploughshares, to find: change the basic dimensions of ploughshares, weight loss, and that based on these parameters define which of the tested ploughshares showed the best results.

2. Ploughshares materials and research methods

Research was performed with two tractors (W_1 and W_2) power of 129 kW with drive to all four wheels and two rotational ploughs with working width of 120 cm. Two characteristic soil types were selected for the analysis.

For the analysis for the wear resistance during ploughing are selected: 1. standard ploughshares, manganese steel 50Mn7, test sample mark „A“, 2. own welded ploughshares, an optional protective layer on the base material C-Cr-Co-Ni-Si on the basic material of manganese steel 50Mn7, test sample mark „B“.

2.1. Types of soil

Research on the influence of soil to wear of the standard and welded ploughshares was performed on silty loamy and silty clay soil. Research was performed from september to december. Pre-crop on plots on which was performed research were wheat and corn. Those pre-crops, due to the much larger soil compaction than after eg. turnip, affecting soil that has a higher resistance when ploughing [6]. The soil composition and the level of current humidity were tested, middle value on the depth from 0 to 30 cm, Table 1.

Table 1: *Composition, humidity and textural mark of the soil.*

Sample number	Moisture content, %	Mechanical composition of the soil, % particle, mm					
		Big sand	Small sand	Total sand	Dust	Clay	Texture mark of soil*
		2 ÷ 0,2 mm	0,2 ÷ 0,05 mm	2 ÷ 0,05 mm	0,5 ÷ 0,02 mm	< 0,02 mm	
1	19,32	0,25	0,93	1,17	67,95	30,88	PrGI
2	26,72	0,98	1,69	2,67	74,67	22,65	PrI
3	26,28	0,80	1,40	2,20	70,84	26,96	PrI
4	35,39	0,46	1,28	1,74	67,78	30,48	PrGI
5	26,13	0,89	1,64	2,53	69,51	27,96	PrGI
6	25,72	1,08	1,39	2,47	66,46	31,07	PrGI
7	23,99	0,37	1,08	1,45	65,06	33,49	PrGI
8	24,28	1,01	1,67	2,68	68,95	28,37	PrGI
9	32,37	0,70	1,13	1,83	66,50	31,67	PrGI
10	24,25	1,09	1,28	2,36	67,77	29,86	PrGI
11	21,41	0,92	1,70	2,61	71,24	26,18	PrI
12	24,76	1,35	1,64	2,99	71,67	25,34	PrI
13	21,24	0,34	2,05	2,39	69,35	28,26	PrGI
14	23,61	0,49	2,02	2,51	70,83	26,66	PrI
15	25,08	1,16	2,00	3,16	71,90	24,94	PrI

*Soil mark: PrI - silty loam; PrGI - silty clay loam.

The smallest share of the current humidity is established on the land no. 1 (19,32 %), while the highest was on the no. 4 (35,39 %). It was found that the proportion of clay particles is in the range of 22,65 % on the land 2 to 33,49 % on the land. 7. On this lands soil is silty loam (41,17 %) to sily clay loam texture (58,83 %). Percentage of particles of clay with silty loam soil texture ranged 22,65 % on the land 2 to 26,96 % on the land 3. In silty clay soil texture percentage of clay particles ranged from 27,96 % on the land 5 to 33,49 % on the land 7. Increased share of clay particles affects a range of chemical and physical properties of soil. The main characteristic of the clay is swellable, and when the soil is dry, it is shrinking and decreasing volume. Clay particles are impermeable to water, have very high plasticity and stickiness when wet and compact and hard when dry.

2.2. Material of the ploughshare

Standard ploughs, mark „A“ are made of the manganese steel 50Mn7. On experimental steels, standard ploughs and for making your own ploughshares chemical analysis was performed. Composition of both steel meets the requirements, Table 2.

Table 2: *Chemical composition of the basic material and standard and own ploughshares.*

Steel mark 50Mn7 EN 10025-2: 2004	Chemical composition of the basic material, %									
	C	Si	Mn	S	P	Cr	Ni	Mo	Cu	N
Standard ploughshares „A“	0, 45	0, 33	1, 78	0, 029	0, 024	0, 22	0, 13	0, 04	0, 02	0, 007
Own welded ploughshares „B“	0, 55	0, 25	1, 63	0, 027	0, 030	0, 29	0, 12	0, 09	0, 03	0, 008

Top of the ploughshare is part of plough is most exposed to reducing the dimensions during ploughing [6]. Except top, wear is exposed to the back part of the ploughshare blade. For the continuation of studies were selected: - to weld the top of the ploughshare with electrode C-Cr-Co-Ni-Si, with hand-arc process, - to secure back part with inductive melted powder C-Cr-Co-Ni-Si. Hand-arc process is chosen because of complicated "the pointed" shape top of ploughshares (top triangle should be welded from the back side). The outer pard of the ploughshare is welded first, shaped in the letter „V“, and then fills the top of the triangle (dimensions ≈ 150 mm down part, b ≈ 120 mm upper part in shape of „V“). Back part of the ploughshare blade is welded with the inductive melted powder. Weld width is 20 mm, thickness is 3 mm. First, inductive device is welding the blade, and then with the hand-arc procedure is welded top from the front and the back side. The length of both sides of the top of ploughshares has the shape of a triangle side (≈ 50 mm). Inductive procedure is selected because of the possibility of achieving evenly distributed layer, evenly thickness and the speed of the melting procedure on such large lenghts (over 500 mm). Chemical composition of the additional material is shown in Table 3.

Table 3: *Chemical composition of the electrode and metal powder of the additional material.*

Chemical composition, %						
C	Si	Mn	Cr	Ni	Mo	Co
3,30	1,49	0,43	24,32	3,13	0,10	3,20

Analysis is performed with spectrometric method on the device SPECTRUMAT - 750 GDS. Characteristic dimensions of ploughshares are marked on Figure 1. By controlling the dimensions before, during and after the ploughing their wear will be followed. Measuring of the ploughshares „a“, „b“, „c“ and „d“ was performed with the caliper, measuring range 0 ÷ 200 mm with the accuracy of measurement (± 0,01 mm).

Mass of the tested ploughshares will be determined by weighing on an electronic scale with measuring range to 6000 g and accuracy ± 1 g.

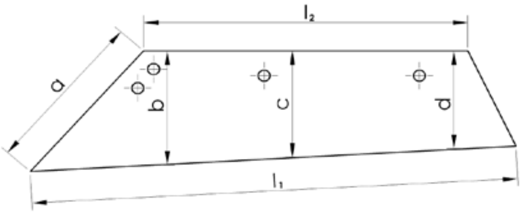


Figure 1 *The characteristic of ploughshares dimensional control: a - the length of the top of the ploughshare; b - hight of the ploughshare on front part ; c - hight of the ploughshare on middle part; d - hight of the ploughshare on back part; l_1 - lenght of back part of blade; l_2 - lenght of upper part of ploughshare.*

2.3. Making of test ploughshares

For the purposes of this research are purchased/constructed two sets of ploughshares, 8 ploughshares on every plough. Total of 16 ploughshares. One set of standard ploughshares was purchased (mark „A“) and one set of own ploughshares with the surface layer of the additional material „B“ was made, with same dimensional characteristics like standard one. Standard ploughshares are purchased from suppliers and on them were performed tests of the chemical composition, hardness, dimensional and mass control. With hand arc procedure top of the ploughshare was welded, and with inductive melting powder procedure back part of the ploughshare was surfaced. Surface preparation was performed before welding procedure. In arc welding process: sanding and degreasing, and in inductive process: milling of the surface prior to welding. For inductive welding of the ploughshare metal powder was used, and for arc welding the diameter of the electrode was ø 4,5 mm. Thickness of the additional material is around 3 mm. Average surface hardness of the standard ploughshares „A“ is 44 HRC, while on the welded ploughshares „B“ average hardness is around 46 HRC. The characteristic appearance of standard ploughshares „A“ is showed in Figure 2, own welded „B“ in Figure 3.

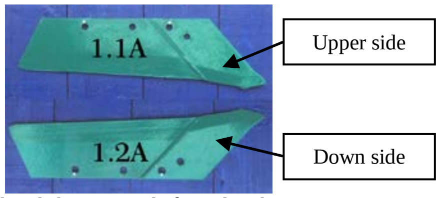


Figure 2 *Standard ploughshares „A“ before ploughing.*

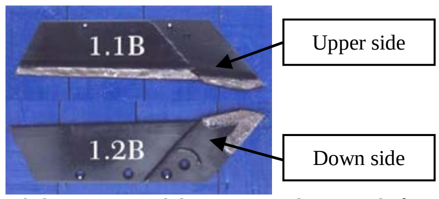


Figure 3 *Welded ploughshares „B“ with basic material 50Mn7, before ploughing.*

3. Test results

Researchs were performed on both sets of the ploughshares, 8 ploughshares on every plough. During the reasearch roller ploughs were used. Average start lenght of the top „a“ of standard ploughshares „A“ was 198,50 mm, width „b“ 142,13 mm, „c“ 127,63 mm, „d“ 121,25 mm, while the average lenght of the top „a“ of welded ploughshares „B“ was 199,63 mm, width „b“ 143,75 mm, „c“ 132,13 mm and „d“ 125,63 mm. Control of dimension change and mass loss of the ploughshare „A“ and „B“ was performed in three periods: 120, 240 and 360 working hours.

So, the roller plough was used, every ploughshare is controlled after 60, 120 and 180 hours of work. Before starting and in any defined time of the research measurement was performed in order to determine size and weight. Results of change of characteristic dimension are shown in Table 4, and results of weight loss in Table 5. Figure 4 and 5 show ploughshares after testing/ploughing.

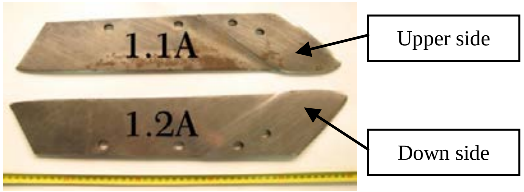


Figure 4 *Standard ploughshares „A“ after ploughing.*

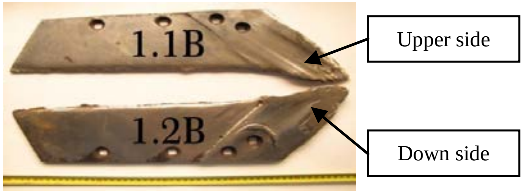


Figure 5 *Welded ploughshares „B“ on basic material 50Mn7, after ploughing.*

Table 4: *Average dimension reduce of 8 ploughshares during ploughing.*

Average reduction of characteristic dimensions						
Ploughshares type	After 60 hours of work		After 120 hours of work		After 180hours of work	
	Nominal dimension *a*					
	Wear		Wear		Wear	
	mm	%	mm	%	mm	%
Standard „A“	16,13	8,12	27,38	13,79	39	19,65
Welded „B“	6,25	3,14	12,13	6,07	16,5	8,27
	Nominal dimension *b*					
Standard „A“	5,63	3,97	9,25	6,51	13,63	9,59
Welded „B“	3,13	2,18	6	4,18	8,13	5,66
	Nominal dimension *c*					
Standard „A“	6,88	5,39	10,5	8,23	14,13	11,07
Welded „B“	5,75	4,35	8,75	6,63	10,75	8,14
	Nominal dimension *d*					
Standard „A“	6,13	5,04	10,25	8,35	14,38	11,85
Welded „B“	5,13	4,08	8,25	6,57	10	7,95

Table 5: *Average weight reduce of standard and welded ploughshares.*

Ploughshares type	After 60 hours		After 120 hours		After 180 hours	
	Weight loss		Weight loss		Weight loss	
	g	%	g	%	g	%
Standard „A“	355	9,04	678,75	17,29	1.032,50	26,29
Welded „B“	381,25	8,82	708,75	16,39	971,25	22,45

During research average speed of all tractors was monitored with chronometer in lenght of 100 m. In all tests the speed of the tractor is set to 7 km/h. The optimal speed is selected to obtain a good turn of the furrows. („that the ridges along as sheets of the book“), and to obtain appropriate tempo of ploughing. In the event of an increase in the occurrence of resistance of soil sensor in the transmission registers it. The automatic transmission shifts gears in the lower level of the movement, and has avoided the manual gear changes. The monitoring has found that during the experiment speed of tractors ranged from 6,8 to 7,2 km/h. The controller of high pressure pump adjusts engine speed and in terms of the major resistance it increased to a maximum of 200 r/min. Size of treated surface is measured with the measuring tape, and work hours of tractor are measured with the chronometer, Table 6.

Table 6: *Size of treated surface and work hours of tractor.*

Work time, h	Treated surface, ha	Time of tractors clean work, h
	Standard ploughshares „A“	
120	119,23	120
240	110,23	120
360	101,79	120
	Welded ploughshares „B“	
120	127,36	120
240	113,92	120
360	107,60	120

Plough depth (h_o) was determined with depth sonar, while the plough width (b_o) was determined with measure tape, Table 7. Measures are in both cases performed 30 times with 3 repeats (total of 90), and it determined the average of depth and width of plough.

Table 7: *Middle values of the depth and width of ploughing.*

Tractor’s work time, h	Depth and width of plough, cm			
	Standard ploughshares “A”		Welded ploughshares “B”	
	h_o	b_o	h_o	b_o
120	29,17	163,68	29,67	163,90
240	29,11	163,43	29,57	163,30
360	29,03	163,41	29,93	163,09

4. Analysis of the results and conclusion

Average depth of plough with the standard ploughshares is 29,10 cm. For welded ploughshares „B" average depth of ploughing was 29,71 cm. Analysis of the average reduction of ploughshares on characteristic parts (Table 4) determined significantly higher reduction of average dimension of standard ploughshares „A“ in comparision with the welded ploughshares „B“. The average weight of standard ploughshares „A“ before starting the work was 3.927,50 g, and welded ploughshares „B“ 4.330,00 g. Average reduction of weight on standard ploughshares „A“ and welded ploughshares „B“ after 60, 120 and 180 hours was shown in Table 5. On welded ploughshares „B“ whose surfaces were welded with combined technique of welding, there was less wear compared with the standard ploughshares „A“. Wear of ploughshares in sandy clay PrI is higher than in silty clay loam PrGI. This is consistent with the results [7] where is stated that the weight reduction of ploughshares in sandy soil was 30 to 150 g/ha, while the weight loss of ploughshares in clay soil was 5 to 30 g/ha. The intensity of the wear of ploughshares during ploughing increases with increasing the share of sand in the soil and ranges from 90 to 210 g/ha [8, 9].

Table 8: *Treated surface, working time and coefficient of utilization of working time.*

Tractor's working time, h	Treated surface, ha	Time of tractors clean work, h	Loss of tractor's working time, h	Total working time, h	Utilization of working time, %
Standard ploughshares „A“					
120	119,23	120	78,39	198,39	0,60
240	110,23	120	74,70	194,70	0,62
360	101,79	120	93,10	213,10	0,56
Welded ploughshares „B“					
120	127,36	120	50,17	170,17	0,71
240	113,29	120	47,54	167,54	0,72
360	107,60	120	51,74	171,74	0,70

Natsis and colleagues [3] indicate that the ploughing performance is decreased for 30 % when the thickness of the ploughshare on blade during wear increases from 1 mm to 6 mm.

Longer life of ploughing tools increases the performance and the productivity. One of the reasons is less loss of work time due to frequent changes of the ploughshares [10]. Coefficient of utilization of working time with standard ploughshares „A“ was 0,60 %, 0,62 % and 0,56 %. When ploughing with welded ploughshares „B“ coefficient of utilization of working time (at all measures 120, 240 and 360 hours) was 0,71 %, 0,72 %, 0,70 %, Table 8. Based on these preliminary results, an advantage in the application should be given to the welded ploughshares. Continuation of research through analysis of relations of influence of the structure of surface layers of ploughshares should point out the ratio of carbide in dull core, in order to get higher performance. We should not leave out either the economic effects that include not only the direct costs of development/acquisition of new ploughshares, but also possible indirect tribological "losses".

5. References

[1] Richardson, R. C. D.: *The wear of metallic materials by soil - Practical phenomena,* Journal of Agricultural Engineering Research 12 (1967) 1, 22-39.

[2] Xiaogang, Z.; Zebing, X.: *Abrasive wear resistance property of surfacing cladding hard alloy on tillage components,* Agricultural Equipment & Vehicle Engineering, 5 (2014).

[3] Natsis, A.; Papadakis, G.; Pitsilis, J.: *The influence of soil type, soil water and share sharpness of a mouldboard plough on energy consumption, rate of work and tillage quality,* Journal of Agricultural Engineering Research, 72 (1999) 2, 171-176.

[4] Banaj, Đ.; Duvnjak, V.; Tadić, V.; Kanisek, J.; Turkalj, D.: *Tehničko-tehnološki aspekti primjene novih oblika lemeša pluga,* Poljoprivreda, 14 (2008) 1, 1-8.

[5] Filipović, D.; Banaj, Đ.; Košutić, S.; Josipović, M.; Šimić, B.: *Comparison of the protected and unprotected plough share wear by the abrasion of the soil particles,* Strojarstvo, 45 (2003) 1-3, 17-23.

[6] Owsiak, Z.: *Wear of symmetrical wedge-shaped tillage tools,* Soil Tillage Res., 43 (1997) 3-4, 295-308.

[7] Miloš, B.; Pintarić, A.; Buljan, G.: *Abrasive wear of agricultural machinery parts,* Proceedings of the International conference „Tribology in Agriculture“, 1993., 44-48.

[8] Bobobee, E. Y. H.; Sraku-Lartey, K.; Fialor, S. C.; Canacoo, E. A.; Agodzo, S. K.; Yawson, A.: *Wear rate of animal-drawn ploughshares in selected Ghanaian soils,* Soil Tillage Res., 93 (2007) 2, 299-308.

[9] Bayhan, Y.: *Reduction of wear wia hardfacing of chisel ploughshare,* Tribol. Int., 39 (2006) 6, 570-574.

[10] Ferguson, S. A.; Fielke, J. M.; Riley, T. W.: *Wear of cultivator shares in abrasive South Australin soils,* Journal of Agricultural Engineering Research, 69 (1998) 2, 99-105.

RESEARCH OF THE NEW GENERATION CHISEL PLOW

ИССЛЕДОВАНИЕ ЧИЗЕЛЯ НОВОГО ПОКОЛЕНИЯ

Associate professor of the department of machine repair and materials science, PhD, associate professor Tverdokhlebov S.A.[1],
leading researcher of the department of field crop cultivation and mechanization, PhD, Parkhomenko G.G.[2]
Kuban State Agrarian University[1], North-Caucasian Scientific Research Institute of Mechanization and Electrification of Agriculture[2],
RUSSIA

Abstract: *The article presents the chisel plow of the new generation developed on the basis of the systematic approach and adaptability of technological impacts from soil-climatic and agro landscape conditions. The principle of the use of the alternating movement of working elements for the destruction of the layer in the so-called lines of the least connections was built into the basis of the chisel plow construction. The chisel plow is multipurpose: it performs the present technological process of soil processing of fields on different depth and spaces between rows of perennial plants on the depth which is differentially changed distancing from the bole due to the architectonics of the root system disposition. Working elements of the chisel plow contain the fastened clutches on hinges, the angle of the mounting is determined by the action of soil resistance forces but the destruction of the layer is executed by differently directed deformations. Researches showed that the chisel plow qualitatively fulfills the present technological process and corresponds to agro-technical demands. The amount of agronomically valuable aggregates increases in the arable layer under the processing of soil by the chisel plow. The chisel plow is fairly aggregated with the T-150K according to energetic indexes. The decrease in traction resistance (by 12.27%) and specific energy consumption (1.14%) when using the working elements with self-centered clutches have been observed. There was set the reasonability of the application of the type without clutches at the deeper tillage, and it is necessary to use the chisel plow with self-centered clutches under the soil treatment on small and medium depth. To treat soil in arid conditions there was developed the construction of the combined chisel plow presenting the combination of the chisel plow with a roller. The comparative analysis of technological process indexes testifies increasing the quality under function of the chisel plow with a roller and unimportant increase of power inputs in normal ranges. According to the acceptance tests on the South-Caucasian MIS chisel plow is recommended to the application in agricultural production.*

KEYWORDS*: CHISEL, SOIL, WORKING ELEMENTS, DEFORMATION, TECHNOLOGICAL PROCESS, TRACTION RESISTANCE*

1. Introduction

Modern trend of mechanization of agricultural production provides for the creation of a new generation of machines and aggregates to treat soil developed on the basis of the systemic approach and adaptability of technological effects from soil-climatic and agro-landscape conditions. The solution of the present problem must be based on the analysis of interaction of working elements with soil, the choice of optimal parameters and regimes of functioning allowing us to execute the present technological process with required qualitative rates under the least power inputs.

2. The problem of the discussion

Under designing the soil-cultivating machines it is necessary not only to eliminate fluctuations leading to the loss of stability but to use the alternating movements of working elements to destruct the layer by the so-called lines of the least links. This method is based on the principle of operation of working elements of the chisel plow (CDA-3,6) which is versatile, it executes the specified technological process of field soil tillage at different depths and between rows of perennial plants in the depth which is differentially varying as the distance from a tree (shrub) respectively to architectonics of the root system disposition.

The working elements of the chisel plow contain the hinged fastened clutches whose angle of mounting, relatively to the bay with chisel in cross-vertical plane, is determined by the action of soil resistance forces but the destruction of the layer is implemented by differently directed deformations at the expense of alternating movable elements (clutches). The hinged assembly of clutches with the bay promotes fluctuations of a working element not worsening the stability of a machine.

The object of researches is the technological process of soil tillage by the chisel plow with options of working elements: clutches are fixed in position "flat cutter"; clutches are not fixed and self-mounted in the cross-vertical plane under the action of soil resistance forces transforming the "flat cutter" into the "chisel"; clutches are absent (Figure 1).

Figure 1 *– Chisel plow with options of a working element*
1 – the chisel plow of the new generation; 2 – position "flat cutter";3 – position "chisel".

3. Purpose and methods of research

It is known that the energy consumption for basic soil processing can be around 40% of the total costs on the cultivation of a crop. That is, these studies are to examine the possibility of reducing the traction resistance of a machine, and hence the energy costs of tillage. The reduction of energy inputs is possible with the impact on soil by differently directed movement of working elements when the layer is destructed along lines of the least links. All possible options (in general type) of working elements for deeper tillage: transforming with full range of change of the mounting angle (0-90^0) of its movable elements (clutches) in the cross-vertical plane as well as the flat-cut (mounting angle of clutches 0^0) and chisel (mounting angle of clutches 90^0 or their absence) are exposed to the comparative analysis on results of agro-technical, energetic and dynamic assessments.

4. Results of researches

The chisel plow effectively carries out the present technological process (Table 1) and corresponds to agro-technical requirements.

The deviation of the depth from given one (2,03-2,16 cm) is in normal range (to 3cm). Some overstated irregularity at depth 19 cm (11% at admitted to 10%) is conditioned to multifocal uptakes of the upper layer of soil. With increasing depth to 26.7-33.8 cm the unevenness is reduced to 8 and 6% respectively and is within the tolerance (10%).

It can also explain the high percentage of ridge from the depth 19cm (28,8%), which however does not exceed the limits (up to 30% agricultural demands).

***Table 1** – Agrotechnical indexes of the chisel plow*

Index title	Value of working element option			
	Clutches are not fixed		Clutches are fixed	Clutches are absent
Technological operation	Subsurface tillage with slight cut of layer in the depth of coverage (chisel plowing)			
Depth of treatment: - average, cm - average square deviation, ± cm - coefficient of variation, %	19,0 2,09 11	26,7 2,14 8	27,0 2,16 8	33,8 2,03 6
Ridging of surface, cm	5,5	5,5	5,4	5,5
Percentage of ridge from the depth, %	28,8	20,6	20,0	16,3
Coverage, m	3,2±1%	3,2±1 %	3,2±1%	3,2±1%
Stubble preservation, %	60…70	60…7 0	60…70	60…70
Degree of weed trimming, %	100	100	100	100
Crumbling of the layer in fractions, mm, %: - above 50 - less 50	35 65	35 65	34 66	40 60
Blocking **%**	8	9	9	8
Sealing and blockage of working elements	not observed			

Ridging with the increase of depth treatment practically is not changed (5,4-5,5 cm). The absolute value of ridging slightly exceeds the norm (to 4 cm), but the relative value determining in percentage from the depth of treatment is within the tolerance. 60-70% of plant residues (stubble) at admitted 60% and more remain on field surface after soil treatment by the chisel plow. Weeds were cut entirely.

The chisel plow provides the stable depth of coverage with irregularity 1% at admitted 2%.

In the treated layer of soil the fractions with diameter up to 50mm (60-66%) with the required 60 or more prevail, and their number with increasing depth decreases slightly. At the maximum depth (33.8 cm) some reduction of content in the treated layer the fractions with diameter up to 50 mm (60%, and on smaller and medium depth of 65 and 66%, respectively) is conditioned to the density of the low soil layers and as well as the method of cultivation of the layer by working elements at a given depth (in the absence of flat-cutting clutches).

Blocking is within normal range, amount of clots in diameter more 100 mm in treated layer does not exceed 8-9% at admitted to 20%.

The fixation of clutches in position "Flat-cutting" does not influence significantly the change of agro-technical indexes characterizing the quality of technological process of the chisel plow. At all models of the working element (fixed, non-fixed and absent clutches) the chisel plow effectively makes the subsurface tillage with slight cut of the layer in coverage and corresponds to agro-technical requirements.

Data of comparative analysis of the structural soil content before and after chisel processing with different models of working elements (Table 2) testify to the increase of agronomically valuable aggregate content in layers 5-15 cm and 15-25 cm on 8,2-8,6% using the working element with non-fixed clutches.

***Table 2** – Data of structural content of soil*

Depth of sampling, cm	Content of fraction in % from absolutely dry soil							<0,25mm	Agronomically valuable aggregates, 0,25-10mm
	>10mm	10-5mm	5-3mm	3-2mm	2-1mm	1-0,5mm	0,5-0,25mm		
Black soils simple weak humus vigorous light-clayey on loess-like clays									
Before treatment									
5-15	17,7	6,7	1,5	8,4	4,6	0,4	10,4	10,3	72,0
15-25	32,9	8,1	6,8	7,5	6,7	3,4	2,4	2,2	64,9
25-35	21,6	7,9	8,8	9,5	0,0	5,2	3,6	3,4	75,0
Clutches are not fixed (depth 27 cm)									
5-15	11,5	17,4	16,7	12,1	16,1	9,5	8,8	7,9	80,6
15-25	21,0	4,0	4,5	8,6	1,2	8,2	6,6	5,9	73,1
25-35	31,3	23,0	12,4	7,5	9,4	6,2	5,4	4,8	63,9
Clutches are missing (depth 34 cm)									
5-15	53,1	9,5	5,6	4,9	8,4	6,7	5,9	5,9	41,0
15-25	25,8	20,6	11,4	7,6	11,1	8,4	7,8	7,3	66,9
25-35	11,8	29,6	19,0	11,0	11,8	6,9	5,1	4,8	83,4

At soil treatment by chisel plow with missing clutches, on the contrary, in the layer of 5-15 cm a sharp decrease in the content of agronomically valuable aggregates (from 72,0 to 41.0%) takes place, in the layer of 15-25 cm – it remains the same (and 64.9 and 66.9%), and increases by 8.4% in the layer of 25-35 cm at the depth of the chisel plow's passage.

So, it can be marked the increase of amount of agronomically valuable aggregates in layers 5-15 cm and 15-25 cm under treatment by the chisel plow with non-fixed clutches in the layer 25-35 cm – at missing clutches.

Therefore, it is advisable to use the option with missing clutches at the deepest tillage, and to use a chisel plow with non-fixed clutches at the tillage on small and medium depth.

The experimental studies of energy rates of the chisel plow are shown in Table 3, calculated on the basis of experimental values of traction resistance.

The analysis of data testifies to the increase of traction resistance consumed output and specific power intensity with increase of depth treatment [1, 2, 3].

It follows that from the analysis:

– increasing the speed of the aggregate from 6,67km/h (1st gear of the tractor T-150K) to 8,57km/h (3rd gear) traction resistance increases in 1,5 times;

– traction resistance with the increase of depth increases more intensively than with the increase of speed. So, with the increase of soil treatment depth in 1,4 times by the chisel plow with non-fixed clutches the traction resistance increases in 1,7 times.

At soil treatment depth in 27 cm and the option of working on with non-fixed clutches the traction resistance of the chisel plow is close to the nominal traction force of the tractor of traction class 3T, which indicates to the rational consumption of power with specified operation mode.

In the result of researches there was determined that the traction resistance of the chisel plow with non-fixed clutches on the depth in 34 cm with clutches insufficient to the capacity of the tractor T-150K. So, the way of soil treatment with option of a working element without clutches is rational to use at the deeper tillage (34 cm and more).

On the depth in 19 cm the traction resistance of the chisel plow is quite less than at 27 cm, the consumed power is lower, the speed is 6,67; 7,35 and 8,57km/h on 1, 2 и 3 gears, that corresponds to the norm at maximum traction capacity of the tractor of the traction class 3T.

Based on the foregoing, we can conclude that the traction resistance of the chisel plow satisfactorily is aggregated with the tractor T-150K.

The comparison of energy characteristics of the chisel plow (Table 4) indicates to the decline of traction resistance (by 12.27%) and decrease of specific energy intensity (1.14%) when using the working elements with non-fixed clutches, it supports the hypothesis that the destruction of the layer along the path of the least resistance by self- mounting of clutches at the angle of natural soil cleavage. The increase of traction resistance is conditioned by the increase of pressure of the soil layer on the surface of working elements in the option with fixed clutches [4].

Table 4 *– Comparative assessment of chisel plow energy rates*

Rate title	Value for option of working element	
	non-fixed clutches	fixed clutches
Work rate: - speed, km/h - depth, cm	6,10 27	6,10 27
Traction resistance, kN	32,52±3,2	37,07±3,8
Decrease of traction resistance, %	12,27	–
Specific energy intensity, kWt·h/ha	33,21	37,76
Decrease of specific energy intensity, time	1,14	–

So, the angle of soil deformation on the sides of the chisel plow, under which the clutches are mounted to loosen the layer, is determined by the physico-mechanical properties of the treated medium (humidity, hardness, etc.), we can assume that under other circumstances, the reduction of traction resistance, and, consequently, specific energy consumption in the process is more important than the results of field experiments.

Analyzing the obtained deviation of traction resistance from the average one (Table 3), it follows to note the decrease of irregularity with the increase of treatment depth conditioned by the miter of dynamic influences of the top layer of soil. So the coefficient of variation of traction resistance at the depth of 19 cm in average amounts for 14.06%, at the depth of 27 cm – 10,02%, at the depth of 33-34 cm – 8,67%. In this case the average deviation of traction resistance is not practically changed from speed, depth, and type of a working element of the garden chisel plow and is in the limits of tolerance (in average about ±3 kN).

Despite the fact that the great cut plant residues remain on the surface, the topsoil does not have sufficient erosion resistance, as plant residues are badly crushed, there are areas with large clots of soil, thereby mulch surface I not provided. These disadvantages can be eliminated by means of application in the construction of disk working elements to crumble the plant residues and adjustments to improve the soil crumbling (rollers). It is necessary to apply the compaction of the top treated layer by the roller in arid areas, because the blowing of fertile soil is decreased and moisture is preserved better because of decrease of intensity of convection-diffusion flow of vaporous water, the intensity of which will be higher in loose soil. In combination with disks the rollers create the insulating layer on the soil surface decreasing the moisture evaporation.

On the basis of researches there was worked out the construction of the combined chisel plow presenting the combination of the chisel plow with a roller, whose general form is presented on the fig.2.

The technological process of the chisel plow with a roller is implemented in the following way: during the moving of the aggregate across the field the clutches with a bit cut soil on a given depth, which is crumbled and then is subjected to additional tillage and crumbling of large soil clots by a roller-ripper with simultaneous leveling of surface.

Agro-technical indices of the chisel plow with a roller were obtained [5] at tillage of black soils along stubble of winter wheat. Relief and microrelief of fields are smooth. Humidity and soil solidity on the background 2 is in normal range, the background 1 is characterized by increased solidity and low soil humidity in a treated layer (Report №11-64-12 (1010032) North-Caucasian MIS).

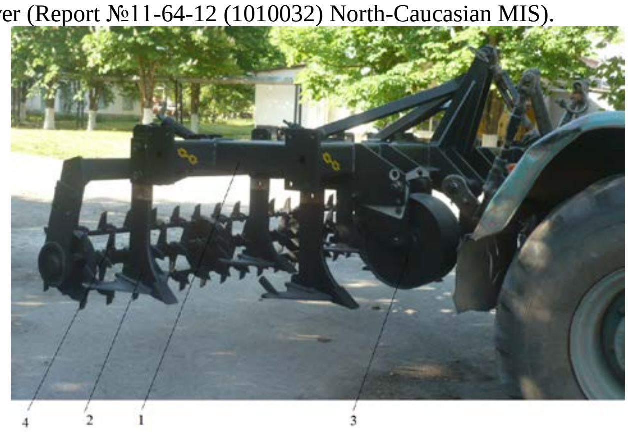


Figure 2 *– Chisel plow with a roller:*
1 – frame; 2 – supporting wheel; 3 – working element; 4 – roller-ripper

Agro-technical indices obtained at working elements with clutches on the depth 13; 20 and 27 cm and without clutches on the depth 27 and 30 cm. The unit runs steadily by the depth of soil treatment (deviation of 1.3...3.0 cm).

Agro-technical indices of the chisel plow with a roller are presented in the Table 1.

Table 5 *– Agro-technical indices of the chisel – plow with a roller*

Rate title	Value of rate for a working element				
	with clutches (background 1)			without clutches (background 2)	
Depth of treatment: -average, cm - deviation, ±cm - coefficient of variation, %	12,24 1,30 14,79	19,10 1,76 9,28	27,56 2,16 7,88	26,42 1,30 4,92	29,49 3,00 10,50
Soil crumbling, %: - size of fractions to 50 mm - size of fractions more 50 mm	76,49 23,51	63,88 36,12	57,51 42,49	71,91 28,06	61,44 38,56
Ridging of soil surface, cm	3,25	4,50	5,03	5,79	5,88
Stubble preservation, %	50,52	47,42	43,30	85,58	85,12
Change of erosion-hazardous soil particles in the layer of 0...5 cm, ±%	- 2,40	- 2,76	- 4,04	- 5,14	- 5,19

The quality of soil crumbling is good, the number of fractions up to 50 mm made of 57.51...76,49%, which meets the agronomic requirements (not less than 25% in fallow field). During almost at all operation modes the number of fractions up to 50 mm accounted for more than 60% with the exception of the variant with clutches on the depth 27,56 cm (of 57.51%), due to the increased soil hardness in the treated layer on the given background.

Blocking of soil layer amounted for 3,25…5,88 cm, it meets the requirements (not more than 30% from depth of treatment).

The preservation of stubble on the background of normal moisture and solidity meets the agro-technical requirements (not less 85%) and amounted for 85,12…85,88%. However, this rate does not exceed 50,52% on the background of increased solidity and low moisture, as far as the stubble got spilled in the crack between dry soil clots.

After the passage of the aggregate the amount of erosion-hazardous particles in the top soil layer decreased to 2,40…5,19%, it corresponds to agro-technical requirements (it must not increase).

So, at soil tillage by the chisel plow with a roller without options of working elements on all regimes the aggregate's work on all agro-technical characteristic corresponds to requirements excluding the preservation of stubble with increased solidity and low humidity that is connected with arid soil-climatic conditions [5].

The analysis of energetic characteristic testifies to the increase of speed and depth of treatment the traction resistance consumed the capacity and specific power inputs are increased

The most traction resistance 41,7 kN at 6,67 km/h and depth 27 cm is explained by the increased soil solidity of the background 1 and by low soil humidity of treated layers that led to the remultiplex of the layer.

The analysis shows that the chisel plow with a roller due to traction and capacity rates is satisfactorily aggregated with the tractor T-150K.

During the operation of the chisel plow with a roller the soil tillage technological process damages (blockage and sticking) were not noticed on all regimes, it testifies to the stability of technological process operation, the coefficient of reliability is 1,0, and it meets standard requirements (not less 0,99).

5. Conclusion

Researches show that the chisel plow with a roller meets the requirements due to rates of technological process of soil treatment and is recommended to the application in agricultural production on the results of tests on North-Caucasian MIS.

The comparative analysis of agro-technical rates testifies to increase the quality of crumbling and decreasing of height of ridges on the surface of treated soil under functioning the chisel plow with a roller (Table 1 and Table 5), that is the power inputs will slightly increase (Table 3 and Table 6) and are in normal range. From above mentioned we make conclusions on reasonability of the chisel plow modernization.

6. References

1. Parkhomenko, G.G. Change of traction resistance of the garden chisel plow in the process of working element transformation /G.G. Parkhomenko, S.A. Tverdokhlebov // Condition and prospects of agricultural engineering industry: Materials of 5th international scientific-practical conference (29 February-1March 2012). On 15th international agro-industrial exhibition "Interagromash-2012" – Rostov-on-Don, 2012. – p. 49-51.
2. Parkhomenko, G.G. Comparative assessment of power rates of the garden chisel plow with different types of working elements/ G.G. Parkhomenko, S.A. Tverdokhlebov // Vestnik of MichSAU. – №3. – 2012. – p. 152-156.
3. Parkhomenko, G.G. Experimental research of a deep ripper to treat soil in spaces between rows of perennial plantations /Parkhomenko G.G., Medovik A.N., Tverdokhlebov S.A. // International technical-economic journal. – 2011. – №3. – p. 76-80.
4. Parkhomenko, G.G. Experimental determination of influence of operation regimes and parameters of working organs on qualitative and energetic rates of the garden chisel plow/ G.G. Parkhomenko, S.A.Tverdokhlebov, V.A. Maksimenko // Collection of scientific works of NCSRIMEA "Agro-engineering science in the sphere of AIC" 7th international scientific-practical conference "Agro-engineering science in increasing of AIC energy effectiveness" (11-12 April 2012, Zernograd) – Zernograd. – 2012. – p. 24-34.
5. Parkhomenko, G.G. Analysis of rates of the technological process of the chisel plow with a roller/ G.G. Parkhomenko, A.V. Gromakov, V.V.Skidelo // Working out of innovation technologies and technical means for AIC: Collection of scientific works "Innovation developments for AIC"Agro-engineering science in the sphere of AIC" in 8th international scientific-practical conference (28-29 March 2013). Part I. Zernograd NCSRIMEA. – p. 21-25.

SCIENTIFIC-PRACTICAL PROBLEMS OF DEVELOPMENT RURAL AREAS AGRARIAN SECTOR AS ECOSYSTEM KNOWLEDGE ECONOMY

Науково-практичні проблеми розвитку сільських територій аграрної сфери як екосистеми економіки знань

Doctor of Economic Sciences, Professor, Zhavoronkova G., PhD (Economics), Associate Professor, Zhavoronkov V.
National Aviation University, Kyiv,
PhD (Economics), Associate Professor National University of horticulture, Melnyk L., Uman, Ukraine.
zhavor@ukr.net

Abstract: In the article the essence and content of the concept "rural areas". Investigated the current state and problems of development of rural areas, identifies the main factors: economic, social and environmental that prevent their development, and the prospects of their development.
KEYWORDS: RURAL TERRITORIES, DEVELOPMENT, AGRARIAN SECTOR, KNOWLEDGE ECONOMY, ECOSYSTEM.

1. Introduction

Today in the developed world are formed and develop models of the information society. Economically developed countries have recognized the priority of development of science and education as the guarantor of the progressive movement in the future, building a competitive economy, to meet the constantly growing needs of the people. So there is a smooth transition to a new level of understanding of reality that is characterized by the formation of "knowledge economy". Ukraine is also moving in that direction.

Since Ukraine is an agro-industrial state, the development of rural areas is one of the main priorities of the state policy of Ukraine aimed at improving the living standards of rural population, growth of efficiency of functioning of agricultural production, improve the environment and improve the quality of life of the rural population.

The state policy of development of rural areas aims to ensure the formation of favorable institutional, organizational and economic environment at national and regional levels, to encourage the establishment of effective mechanisms for attracting domestic and foreign investment into the country and to create comfortable conditions for living and work residents of the Ukrainian village.

In the socio-economic life of the country rural areas hold a special place. Are home to 31.1% of the population of our state and accounts for about 90% of its area. The importance of these territories is enhanced by their exceptional contribution in establishing food security and increasing export potential of the country. These and other levers make the development of rural areas one of the main priorities of the state policy of Ukraine aimed at improving the living standards of rural population, growth of efficiency of functioning of agricultural production, improve the environment and improve the quality of the human population. Improving the efficiency of agricultural production under condition of preservation of the environment, overcoming the economic and financial crisis and social revival of the village – the processes are organically related. Reform of the agricultural sector will have positive results in their social direction, improving living standards in rural areas.

For a long time Ukraine was considered to be a rural country, even now, despite our achievements in rocket and aircraft construction, agriculture is an important sector of the economy and the rural population remains a real reserve of the Ukrainian society. In Europe there is no country where agriculture is in the state's economy of more than 3.5 % of GDP. But in Ukraine, the agricultural sector generates about 11 % [11].

Using the methodology of systemic-structural approach allows us to consider the national economy as an economic system, i.e. as a set of subsystems and their elements, which is formed from separate relatively independent elements, the interaction between which determines the occurrence of the common qualities and characteristics of a holistic organic unity, is not inherent in its individual elements . Consider the example of research on the sectoral structure of the national economy, which reflects the interaction of the main economic activities in the country (table. 1).

Table 1 *The dynamics of the employed population on branches of economy of Ukraine, %*

Indicators	2010	2011	2012	2013	2014
Industry	15,0	14,6	14,5	13,8	13,8
Agriculture	4,0	3,6	3,6	3,2	3,4
Information and telecommunications	1,3	1,4	1,5	1,5	1,6
Services	79,7	80,4	80,4	81,5	81,2
Services/manufacturing	4,2	4,4	4,4	4,8	4,7
Services/ agriculture	19,9	22,3	22,3	25,5	23,9
Services/ information	61,3	57,4	53,6	54,3	50,8
Agriculture / information	3,1	2,6	2,4	2,1	2,1

It is worth noting that the share of employed population in services and information between 2010 and 2014 each year increases, which indicates the dominance of the sphere of information products and services, i.e. information and knowledge become important factors that affect the competitiveness of the economy. The share of employment in agriculture of Ukraine on the average for 2010-2014 was 3.6 %. The share of employment in services in 2014 is 24 times higher than the share of employment in agriculture.

2. Status and problems of development of rural territories of Ukraine

Recently, the concept of "rural area" is widely used in the scientific literature, but also to determine the nature and content yet dominated by highly specialized approach, namely the "rural areas" is:

- economical-ecological category, regional-territorial unit with the specific climatic, socio-economic conditions where economically and environmentally balanced and energy are interrelated the various resources (natural, labour, material, energy, information, financial, etc.) to create the total social product of a particular territory and a full-fledged living environment for present and future generations [5];
- country area specific natural, economic, administrative-territorial parts of the country;
- the resource base for agriculture;
- two-component concept that reflects the characteristics of the empirical object, has a significant number of features with complex internal structure;
- the combination of production and economic, political, social, and natural components that are subject to local

governments, public authorities and the regulatory impact local communities, businesses and the public;

- the physical territory within which are the representatives of the flora, fauna and man as a biosocial creature;

- rural part of the territory, within the space [2].

The study of literature and own research allows to allocate the following factors influencing the development of rural territories of Ukraine: economic, social and environmental. Identified the key problems of development of rural territories of Ukraine, which is represented in Fig. 1

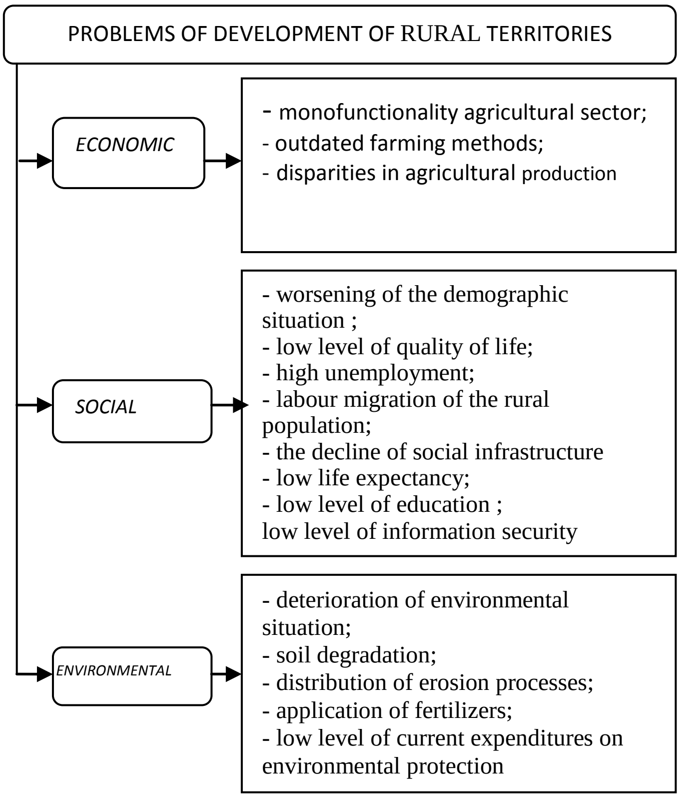


Fig. 1. *Problems of development of rural territories of Ukraine (compiled by the author)*

2.1. Economic aspects of the study of development of rural territories

The current state of development of rural territories of Ukraine reflect the macroeconomic indicators for 2010-2014 (table. 2).

Table 2

Main economic indicators of development of rural territories of Ukraine

Indicators	2010	2011	2012	2013	2014
Agricultural production, bln.	194,9	233,7	223,3	252,9	251,4
The GDP share of agriculture in total GDP, %	7,4	8,1	7,8	8,7	10,2
Agricultural GDP per capita, thousand UAH.	301,1	368,8	357,8	434,3	477,4
The index of selling prices of agricultural enterprises, % to the previous year	130,0	113,6	106,8	97,1	214,3
The rate of growth of production of agricultural products, % to the previous year	98,5	119,9	95,5	113,3	99,4

2.2. Social development of rural areas

Particularly acute today is the issue of social development of rural areas for social welfare of rural people depends on the further development of rural areas. For the analysis of the social component of the knowledge economy rural areas need to consider the following indicators: demographic, infrastructure, security, living standards, security of human and intellectual resources. The current state of social condition of the village is given in table. 3

Table 3 *The main indicators of social development of rural territories of Ukraine*

Indicators	2010	2011	2012	2013	2014
The share of rural population in total population, %	31,3	3,2	31,3	31,1	31,0
The life expectancy of the rural population	69,02	69,76	69,75	69,88	69,72
The number of preschool education institutions, thousand units	8,5	9,0	9,2	9,4	9,3
The enrolment of children in institutions (percent of number of children of appropriate age)	33	35	37	41	40
The unemployment rate of the working population in rural areas %	7,1	7,5	7,4	7,3	9,5
The gap between the money income of 20 % most and 20% least well-off population of rural areas, since	3,6	3,5	3,3	3,2	3,2
The share of rural population with monetary incomes below the subsistence minimum, %	26,5	24,4	24,2	21,4	20,2
The share of rural population with monetary incomes below the subsistence minimum, %	26,5	24,4	24,2	21,4	20,2
The presence of the housing stock in average per person living in rural area, m2	26,4	26,8	27,2	27,5	27,6
Average monthly nominal wages of agricultural workers, RS.	1472	1853	2086	2340	2556
The share of employed population in agriculture in total employment, %	4,0	3,6	3,6	3,2	3,4
The level of education of personnel, %	26,5	26,7	29,2	30,0	30,6

Having considered the indicators of social development of rural territories of Ukraine, it is worth noting that the rural population over the period 2010-2014 decreased by 2.5 %, the birth rate remains approximately at the same level, while the mortality rate greatly exceeds. Population decline is a consequence of the continuous outflow of economic active sectors of the rural population, which in turn caused weak development of rural areas.

In rural Ukraine there is a low security network of rural educational institutions. During 2010-2014 in the villages was the number of schools was reduced by 8% due to the reduction of school-age children in the village.

The deterioration of the situation in the village is also associated, in particular, low quality of health services and unequal access of different segments of the population. Acute problems are a shortage of medical facilities, trained medical personnel, low level of equipment of medical institutions, lack of ambulances and the quality of the roads.

A characteristic feature of Ukraine at the present stage is the growing poverty among the working population. On average, 23.3% of the farmers have incomes below the subsistence minimum. Also the ratio of incomes between the richest and the poorest peasants in the Ukraine is extremely high and an average of 3.4 times.

Negative trend of formation of labor potential of agriculture is a gradual reduction in the numbers employed in her youth. In 2010-2014, the number of employed in agricultural production has declined by 11.3 thousand persons, or 8.9%. The employment rate of young people in the region on average was 0.24.

Social infrastructure of the village is to satisfy the vital needs of a leading productive force of society – the person, and thereby contribute to the development of rural economy. The absence of important structural elements of the social sphere is the cause of a mass outflow of labor force from rural areas and decline of rural areas.

2.3. Environmental factors of development of rural territories

From the point of view of ecology, sustainable development of rural areas should ensure the integrity of biological and physical natural systems, their viability depends on the global stability of the biosphere. Of particular importance is the ability of such systems simultaneously and adapt to various changes, instead of storing in a static condition or degradation and loss of biological diversity.

In Ukraine in the agricultural turnover is about 80% of the arable land, whereas in countries with intensive development of agriculture is much lower (Germany: 67%, France 61%, United States – 43%, UK 35%). The high proportion of tilled soil is a negative phenomenon for our country, for two reasons: first, it promotes the loss of humus; second, the evidence predominantly extensive agriculture and low level of culture of agricultural production .

Brought ecologically valid ratio of the area of arable land, natural grassland, forest and water areas that adversely affect the sustainability of the agricultural landscape, causing the degradation of soil and is a real threat to economic security in the agricultural sector.

Evaluation of indicators of ecological safety of development of rural territories of Ukraine in 2010-2014 is shown in table. 4.

Table 4 *Indices of ecological safety of rural territories of Ukraine*

Figure	2010	2011	2012	2013	2014
The coefficient of ecological stability of land use, points	0,40	0,40	0,40	0,40	0,39
Coefficient of anthropogenic load	3,53	3,53	3,52	3,52	3,53
Coefficient of atmospheric pollution	8,10	8,20	8,70	8,00	7,70
Level the plowed farmland	0,78	0,78	0,78	0,78	0,78
The ratio of capital expenditures on environmental protection	0,64	0,51	0,57	0,24	0,35
The ratio of current expenditures on environmental protection	0,36	0,49	0,43	0,76	0,65
The ratio of costs for air protection	0,004	0,01	0,01	0,02	0,01
Number of employees industry agriculture, working in conditions not meeting sanitary-hygienic norms, thousand people	47,7	47,7	42,5	42,5	36,9
% to the account of payroll employees in the industry	8,3	8,3	8,7	8,7	8,7

Ukraine is the poorest of the water resources of Europe and is one of the regions with significant anthropogenic pressures on water sources and lack of sufficient fresh water. The coefficient of purity of the water used in agriculture is very low – 0,01. The coefficient of water use efficiency is also low, at 0.1, besides, tends to decrease. Under the influence of chemicals in agricultural production, land drainage, water resources are undergoing significant changes.

Now most countries are trying to reduce the negative environmental impacts of farming, translating agricultural production on organic principles of growing of crop production. Ukraine has also introduced organic farming.

3. Directions of improvement and development of rural territories of Ukraine

Also a significant problem of rural development of the agrarian sphere as ecosystems of knowledge economy is the lack of financial resources. However, even existing resources are not always effective and are not earmarked in the development of rural areas. To solve problems and improve the condition of rural areas requires the following actions Fig. 2.

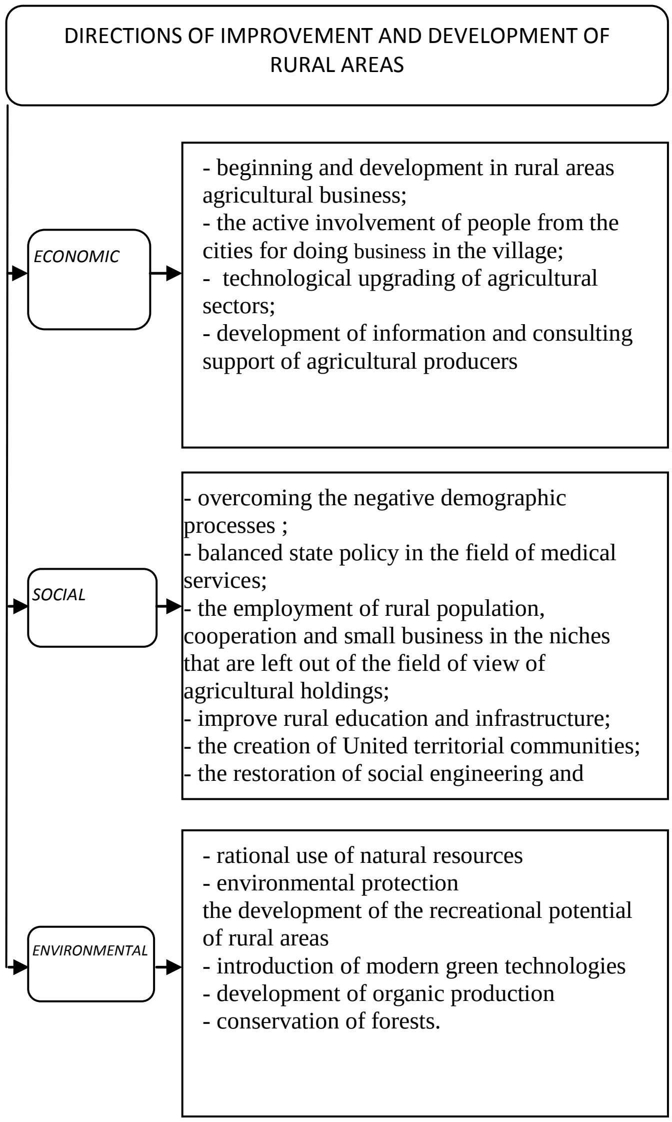


Fig. 2. *Directions of improvement and development of rural territories of Ukraine (compiled by the author)*

The above steps will help form a favorable climate and ensure the development of rural territories of Ukraine. For rural development, Ukraine should pay attention to the European counterparts, namely, interest (motivation) of employers in the transfer of production capacity of enterprises in rural and peripheral areas. The impetus for the development of the village is the construction of new and rehabilitation of existing roads. Should also work on implementation while promoting the development of rural areas of advanced models of self-organization and training for distribution business as it was carried out during the reform of rural areas of the Nordic countries.

References

1. Economic encyclopedia : in 3 t. T. 3 / Ed. edited by S. K. Mocherniy. – K. : Academy, 2002. – P. 384.
2. Magiovich R. I. Status, problems and prospects of development of rural territories of the Western region of Ukraine. Available from Internet: http://nauka.kushnir.mk.ua/?p=75015.
3. Klyuchnik A.V. Formation and development of the economic potential of rural territories of Ukraine: Monograph. – Nikolaev: Design and printing, 2011. – 468 p.
4. Zalizko V. D. Scientific and practical aspects of the formation the structure and of the targets of socio-economic development of rural areas in modern condition / Efficient economy. – 2015. - № 2.
5. Problems and prospects of development of rural territories (on the example of Carpathian region): of Sciences.analit. report. – Lviv: Institute of regional studies, 2011. – 60 p.
6. Strategic directions of development of agriculture of Ukraine for the period until 2020. Under the editorship of J. A. Lupenko, V. J. Mesel-Veseljak.- K.: NSC "IAE", 2012. – 182 p.
7. Smyntyna N.V. Strategic planning of socio-economic development at the meso-level: theory, methodology, practice: monograph / N. V. Smyntyna. – Odessa: Atlanta, 2015 – 365 p.
8. Slavkova E. P. Development of rural areas: theory, methodology, practice / E. P. Slavkova. – Sumy: Sumy national agrarian University. – 2010. – 330 p.
9. Stehnei M.I. Current trends in maintenance of sustainable development for rural territories: European experience and Ukrainian realia / M. I. Stehnei // Actual problems of economics. – 2013. - № 3.
10. Statistical yearbook of Ukraine for 2014. – K.: State statistics service of Ukraine, 2015. – 586 p.
11. Tkachuk A. Rural areas in the period of change. New features ?! / A. Tkachuk . Available from Internet: http://www.csi.org.ua/silski-terytoriyi-u-period-zmin-novi-mozhlyvosti/
12. Ulianchenko A. V. Formation and use of the resource potential in the agricultural sector : monograph. / A. V. Ulyanchenko / KNAU im. V.V. Dokuchaev. – Kh., 2009. – 357p.

EXPERT APPROACH IN ANALYZING THE NECESSITY OF IMPROVING THE PLANT GROWING TECHNIQUES IN DRYING UP AND WATER SCARCITY CONDITIONS

Mitev G.V.

ЕКСПЕРТЕН ПОДХОД ПРИ АНАЛИЗ НА НЕОБХОДИМОСТТА ОТ УСЪВЪРШЕНСТВАНЕ НА ТЕХНОЛОГИЧНИТЕ ПРОЦЕСИ В УСЛОВИЯТА НА ЗАСУШАВАНЕ И ВОДЕН ДЕФИЦИТ

Митев, Г.В.

Abstract: The production of agricultural products in the conditions of droughtdrying up and water scarcity is accompanied by the use of insufficiently complete and reliable information. In doing so, problems arise that are not well structured, have many outbound links, and virtually do not lend themselves to algorithmization. The production of agricultural produce requires the possession of complex knowledge and skills, compliance with a number of environmental conditions and market conditions. For these reasons, justifying the need to improve technological processes from a technological point of view is an important step towards validating innovative solutions. An expert group was set up to assess the efficiency of applying advanced technological processes to the cultivation of trenches.

***KEYWORDS**: TECHNOLOGY, EXPERTS, AGRICULTURAL LAND, EVALUATION CRITERIA*

Introduction

The production of agricultural produce in drying up and water deficit is accompanied by the use of insufficiently complete and reliable information. In doing so, problems arise that are not well structured, have many outbound links, and virtually do not lend themselves to algorithmization. In the studied technological processes, the alternatives are the following:

1. Maintain the application of the technological processes of soil tillage, sowing and use of water for the needs of plants at the level of their classical performance. This includes:
   a. Spreading of mineral and / or organic fertilizers on the soil surface;
   b. Yearly deep plowing, mainly in the direction of the slope;
   c. Using classic seed drills for precise sowing, seeding the seeds in one row;
   d. Using water for plant needs according to falling rainfall and / or after applying some of the types of irrigation - where possible by sprinkling, gravity, improved gravity, drip, subsoil but without improving storage conditions.
2. Partial replacement of machines in existing complex technological lines (KTL) for soil treatment, sowing and water use for plant needs (irrigation);
3. Complete renovation of the KTL for the aforementioned technological processes, meeting the requirements for protection of the soil and water resources, preservation of the soil fertility and increase of the yields.

The application of modern technologies for agricultural production requires the possession of complex knowledge and skills, compliance with a number of environmental conditions and market conditions. For these reasons, justifying the need to improve technological processes from a technological point of view is an important step towards validating innovative solutions.

The selected criteria allow for an overall assessment of all the essential aspects of the alternatives by meeting the following requirements:

Clear and accurate formulation of selected indicators that provide a clear understanding of all members of the expert group, provided they work fully independently of each other;

Mutual independence of the criteria;

Minimum number of criteria that can assess alternatives with sufficient accuracy for the study, Table 1. The final number of criteria is determined after determining the weight ratios, R_{cp}, [2,10,11,12].

The technological processes of soil cultivation, sowing and use of water for plant needs can be formalized with a number of factors whose levels form an ever-increasing set of factors. This division is conditional, as some of the factors can be considered as continuous or discreet.

Таблица 1. Критерии за оценяване на алтернативите

Criteria No:	Descrfiption		Criteria content (Criteria content (explanation)
1	2	3	4
1	Scale of application (volume of production)	Q	The area of arable land that can be cultivated
2	Technological abilities	T	Opportunity to develop promising technology to reduce the number of soil treatments
3	Influence on the already applied (up to now) technological processes.	B	Ability to raise a higher level of technical and technological opportunities for soil cultivation, sowing and water use for plant needs.
4	Management and technological prerequisites for improvement of the technological processes.	O	Opportunities for proper organization in the implementation of optimized technological processes. Engagement and commitment of all participants according to the final results obtained.
5	Possibilities for universal use of the machines	M_y	Are used machines included in other TCM during the examination period of vegetation
6	Possibilities for technical and technological success	Y_T	Likelihood of achieving the technical and technological indicators of the machines according to the specified agrotechnical requirements
7	Probabilities for manufacturing or delivery of the tested machines for optimization of the terchnological processes.	П	Ability to reorganize and / or use already used units and aggregates for new construction machines

8	Икономическа ефективност от усъвършенстване на технологичните процеси	И3	Has the number of passes on the soil surface been reduced? Is the volume of soil that is used by the root system of plants optimized? Is it possible more effectively to use water from natural rainfall?
9	Икономическа перспектива	И п	Possibility to further significantly increase the interest in the improvement of the technological processes.
10	Вероятност за икономически успех	УИ	Competitiveness on exit to the external market and risk factors
11	Кадрова обезпеченост	К	The availability of qualified specialists to show ways to improve technological processes

Practically, a mixed type scale is used to evaluate the criteria in Table 2. It is a continuous scale divided into several areas. For each of these areas the characteristics of the assessed criterion are formulated [1, 3, 4, 8, 17,].

Table 2. Continuous (1.00-6.00) Scoring Criteria (Sixth scale)

Evaluation	Qualitative characteristic
1	Totally inappropriate
2	Inappropriate level. It may be an obstacle to optimizing technological processes and introducing new technology
3	Critical area. Part of the technological, technical and economic criteria do not meet the set agrotechnical requirements.
4	Insufficient good but still acceptable level, in accordance with technological, technical and economic criteria.
5	Good and completely satisfactory level
6	Very good level of the optimized technological process criterion considerably exceeding the level of the relevant criterion in the classical performance

The expert group includes the most competent specialists. Of these, the most reliable estimates are to be expected. The procedure for formation of the expert group is as follows:
Drawing up a list of questions and criteria on which expert advice should be obtained.
Drawing up a list of possible experts.
Send the list to each of the experts, asking them to comment on which questions they can answer competently.
The expert group shall be composed in such a way that each question can be evaluated by at least one expert. According to the literature, the number of experts is at least 15, [4, 8,15,16,17].

After obtaining and ranking the proposed technological solutions for optimization of the technological processes in the conditions of drought and changing climate, the results are presented in an expert ranking table.
Based on the assumption that some of the contributing experts are unable to evaluate the proposed technological and technical solutions from the aggregate examined, the resulting primary preference matrix will be incomplete. Summing on the basis of the sum of the ranks gives unreal results. To overcome the difficulties resulting from incomplete ranging, the method of Gordon and Hayward was used [8,16,17].
The following symbolic symbols have been entered for this purpose:

x_{ij} the rank that the expert has attributed to this jth technological solution;

n - the number of technological solutions evaluated;

m- the total number of experts involved;

m_j M_j - the total number of experts who evaluated the j[th] technological solution.

Determine the average rank of each of the technological solutions, $R_{\text{ср}.j}$

$$R_{\text{ср}.j} = \frac{\sum_{i=1}^{n} \sum x_{ij}}{\sum m_j} \tag{1}$$

Determination the arithmetic mean $S_{\text{ср.д}}$ of all rankings

$$S_{\text{ср.д}}^2 = \frac{\sum \quad \sum x_{ij}^2 - R_{\text{ср}} \sum \quad \sum x_{ij}}{\sum m_j - n} \tag{2}$$

Determination of dispersion $S_{\text{ср.д}}^2$ of average ranks for all technological solutions

$$S_{\text{ср.р.}}^2 = \frac{\sum_{j=1}^{n} [R_{\text{ср}.j} \sum x_{ij}] - R_{\text{ср.}} \sum \quad \sum x_{ij}}{n-1} \tag{3}$$

Determination of average B for technological solutions

$$\text{B} = \frac{\left(\sum m_j\right)^2 - \sum m_j^2}{(n-1) \sum m_j} \tag{4}$$

Determination of average reliability y in single ranging

$$y = \frac{S_{\text{ср.д.}}^2 - S_{\text{ср.р.}}^2}{S_{\text{ср.р.}}^2 + (\text{B}-1) S_{\text{ср.д.}}^2} \tag{5}$$

Determining the reliability estimate y_i of each technological solution

$$y_i = \frac{m_j y}{1 + (m_{j-1}) y} \tag{6}$$

Determine the actual rank rating a_j of any technological solution

$$a_j = R_{\text{ср.}} (1 - y_i) + y_i R_{\text{ср}.j} \tag{7}$$

In the case of unrelated ranks, the coincidence coefficient W is determined by the formula.

$$W = \frac{12 L^2}{m^2 (m^2 - n) - m \sum_{j=1}^{n} T_j} \tag{8}$$

Where n is the number of technological solutions evaluated;
m - the total number of experts involved;
L - the consistency of the opinion of the experts;

With the full consistency of expert opinion, the sum of L^2 has the maximum.

$$L^2 = \frac{1}{12 m^2 (n^3 - n)} \tag{9}$$

$$T_j = \sum_{j=1}^{n} \left(t_{ij}^3 - t_{ij}\right) \tag{10}$$

where t_{ij} is the number of iterations of each i-th rank in the j-rank. The coincidence factor takes values in the range $0 < W < 1$. With W=0 there is a complete inconsistency in the expert opinion, and with W=1 - there is a full agreement of their opinions. The significance of the coincidence factor is checked by χ^2, as the number of factors e $n > 7$. $(n = 11)$

$$\chi^2 = m(n-1)W$$

With a true zero hypothesis H_o: W=0 and the magnitude of λ^2, we have a λ^2distribution with degrees of freedom $k = n - 1$. In the case of $\chi^2 > \chi_{\alpha,\text{к}}^2$,, the hypothesis H_o is rejected and the coincidence coefficient is significant.

The main treatment of the soil as a technological process can be done in several ways, Table 3.

In the conducted experiments a comparison of the eight ways of cultivation of the soil is made. Take the deep plow for control. The reason to assume control is the massive and annual application. For ease of processing the results, the comparing technologies are presented in Table 3.

The experiments are carried out on areas of the same size, similar relief and uniform soils. The type of soils belongs to the group of carbonate chernozems, which are characteristic of the region of Northeastern Bulgaria. The size of the parcels surveyed is determined by the accuracy with which the parameters of the experiment have to be read.

According to the accepted dimensions of the investigated sections, the working machines with the appropriate working width and the wheeled power machines with the necessary weight class are selected.

Table 3. Coding of comparing methods for soil treatment

No:	Type of the soil tillage	Code	Period of conducting	Statement
1	2	3	4	5
1	Дълбока оран с лемежен плуг	A	Annually	Control plot
2	Дълбоко разрохкване по цялата повърхост почвата чрез разрушаване почвения слой на големите почвени агрегати	B	Annually	Comparison
3	дълбока оран + продълбочаване	C	Annually	Comparison
4	продълбочаване + дълбока оран	D	Annually	Comparison
5	продълбочаване с внасяне на водоакумулиращи материали (ВАМ) + подравняване + дълбока оран	E	In every 5 years	Comparison
6	обработване на почвата в ивици без внасяне на минерални торове	F	Annually, (included into the crop rotation)	Comparison
7	обработване на почвата в ивици с внасяне на минерални и/или органични торове	G	Annually, (included into the crop rotation)	Comparison
8	Дисковане	H	Annually	Comparison
9	Нулево обработване на почвата	I	(included into the crop rotation)	Comparison

The duration of the study was 5 consecutive years during which the results of the experiment were observed. With regard to one of these the yields, the research by a number of authors suggests that such a length is statistically sufficient to track a trend.

Measurements shall be made for each of the surveyed agricultural areas for each of the years mentioned.

From the preliminary tests with a soil penetrometer, it was found that in a five-fold repetition of the measurements at one point, the average relative error was less than 5%. This is a reason to assume sufficient five times repeatability at each of the nine measuring points from the "intensive grid" of the surveyed agricultural area, fig. 1, [6, 14].

.

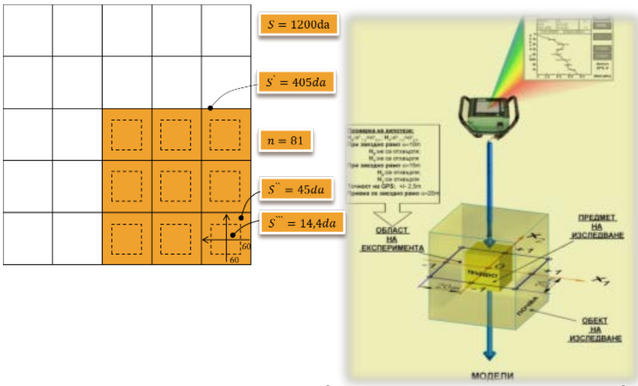


Fig. 1. Intensive grid for making measurements in field conditions

In the conducted study we study separately the influence of the different ways of soil treatment on the content of organic matter and the yield of plant production. The processing of the experimental results is carried out according to the methodology for carrying out one-factor dispersion analysis. The analysis is performed separately for each of the parameters - organic matter and yield. The studies for each of the parameters were conducted with 5 (five) parallel (repeat) experiments - one per marketing year. The results of the experiment are presented in tabular form, with an individual table being formed for each individual parameter of the study. The data are processed by the dispersion analysis methodology

If the influence of the factor on the research parameter is proven, an optimization task should be solved. The aim is to establish in which of the studied soil cultivation technologies the maximum values of the organic matter in the soil and the yield from plant production are observed with minimum values of the erosion index. To solve this task, the methodology is used to form a general optimization criterion through a desirability function. Each of the criteria (the parameters studied in the dispersion analysis) is involved in the acquisition of private desires of function, which then determine the generalized function of desirability. The desirability scale ranges from 0 to 1, with the value 1 (unit) of the generic desirability function corresponding to the best possible value of the parameters.

Exposition

The applied method of expert assessments is intended To verify the ranking of the eleven criteria relating to the three alternative soil cultivation technologies presented. The method makes it possible to identify the most important criteria according to the experts for each of the technologies to be observed in their application.

The results of the fourteen expert surveys are presented in Tables 4, 5 and 6.

The sum of the rankings of the individual criteria is indicated in the last column of each of the three rank matrices. By incorporating this amount into a dedicated methodology, two main elements of this assessment are identified. This is the consistency of the experts' opinions on the given criteria and the ranking of these criteria of significance.

Table 4. Ranking matrix for alternative 1

Expert / Criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	$\sum_{j=1}^{n} X_i$
X1	9,5	9	6	10,5	10,5	9	6,5	3,5	8	10,5	8,5	7,5	9,5	10	118,5
X2	5,5	9	6	10,5	4	9	9,5	8	8	8	5	7,5	9,5	10	109,5

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	$\sum_{j=1}^{n} X_i$
X3	5,5	9	2	5	7	2	3	3,5	6	8	8,5	3	4,5	4,5	71,5
X4	9,5	4	4	5	5	4,5	6,5	8	3	4	5	7,5	4,5	7,5	78
X5	4	9	6	8	1	9	3	8	6	4	2,5	3	4,5	1,5	69,5
X6	5,5	4	9,5	5	7	3	6,5	3,5	6	4	5	7,5	4	4,5	75
X7	5,5	9	2	2,5	2	4,5	6,5	3,5	2,5	4	5	7,5	4,5	4,5	63,5
X8	1,5	4	2	1	10,5	2	1	1,5	1	2	1	1	1	1,5	31
X9	5,5	1	6	8	4	9	5	10,5	8	10,5	8,5	4	9,5	7,5	97
X10	5,5	4	9,5	2,5	4	2	3	1,5	2,5	1	2,5	3	2	4,5	47,5
X11	1,5	4	6	8	7	9	9,5	10,5	6	8	8,5	7,5	9,5	10	105
														$\sum$	866

Table 5. Ranking matrix for alternative 2

Експерт / Критерий	1	2	3	4	5	6	7	8	9	10	11	12	13	14	$\sum_{j=1}^{n} X_i$
X1	9	9,5	4	4	8	3	4	10,5	8,5	10	10	8	7,5	6,5	102,5
X2	4	9,5	9	8,5	8	4	8	7	8,5	10	3	8	4	10,5	102
X3	4	1,5	4,5	4,5	2,5	2	3,5	3	3,5	4	3	8	3	6,5	53,5
X4	9	5	9	4,5	4,5	6,5	3,5	3	3,5	4	6,5	3	7,5	3	72,5
X5	9	5	4,5	8,5	1	6,5	8	3	3,5	1,5	6,5	2,5	7,5	2	69
X6	4	5	1	4,5	8	6,5	3,5	7	8,5	4	6,5	2,5	3	6,5	70,5
X7	1	1,5	4,5	1,5	2,5	2	1	1	1	1,5	1	1	1	1	21,5
X8	4	5	4,5	4,5	8	6,5	8	7	3,5	10	10	8	7,5	6,5	93
X9	9	5	4,5	1,5	4,5	2	3,5	10,5	8,5	7	3	8	7,5	10,5	85
X10	4	9,5	4,5	8,5	8	6,5	8	7	8,5	7	10	8	3	6,5	99
X11	9	9,5	9	8,5	5	6,5	8	7	8,5	7	6,5	8	7,5	6,5	106,5
														$\sum$	875

Table 6. Ranking matrix for alternative 3

Експерт / Критерий	1	2	3	4	5	6	7	8	9	10	11	12	13	14	$\sum_{j=1}^{n} X_i$
X1	6	6	9,5	6	5,5	6	9	9,5	9	10,5	9	5,5	9,5	5	106
X2	6	6	9,5	6	5,5	10	9	5,5	5,5	8	9	5,5	9,5	5,5	100,5
X3	6	6	2,5	6	3,5	1,5	5	5,5	3	5	3,5	4	5,5	5,5	62,5
X4	2	2,5	6	6	1,5	6	2,5	2,5	3	2,5	3,5	4	3	2,5	47,5
X5	2	2,5	2,5	6	1,5	6	5	2,5	3	5	3,5	1,5	1,5	2,5	45
X6	6	6	2,5	6	9,5	6	2,5	5,5	5,5	2,5	3,5	4	1,5	5,5	66,5
X7	2	1	2,5	1,5	3,5	1,5	1	1	1	1	1	1,5	2	1	21,5
X8	10	6	9,5	6	9,5	6	9	9,5	9	10,5	9	9,5	9,5	9	122
X9	10	10	6	1,5	9,5	2	5	9,5	9	5	9	9,5	9,5	9	104,5
X10	6	10	6	3	9,5	10	9	9,5	9	8	9	9,5	5	9	112,5
X11	10	10	9,5	4	9,5	10	9	5,5	9	8	3	9,5	5,5	5,5	108
														$\sum$	896,5

Typical of the three tables is the association of ranks in them. This shows that experts can not confidently differentiate the significance criteria. From the values obtained for the co-ordinating factor, dependence (11) that are remote from a unit, it becomes clear that there is little consistency in their views. A little better consistency between expert opinions is observed with respect to alternative 3, where the ratio is the highest.

$$\begin{cases} W_1 = 0{,}361 \\ W_2 = 0{,}348 \\ W_3 = 0{,}582 \end{cases} \qquad (11)$$

However, this incomplete agreement between experts is considered to be significant because in all three cases Pirson's calculated criterion (12) is greater than its table value:

$$\begin{cases} \chi_1^2 = 139{,}63 > \chi_{0,05;10}^2 = 18{,}3 \\ \chi_2^2 = 139{,}65 > \chi_{0,05;10}^2 = 18{,}3 \\ \chi_3^2 = 139{,}42 > \chi_{0,05;10}^2 = 18{,}3 \end{cases} \qquad (12)$$

From the chart diagrams presented (Figures 2.a, 2b and 2.c) one can see what the influence of the criteria in each of the technologies is, according to expert assessments.

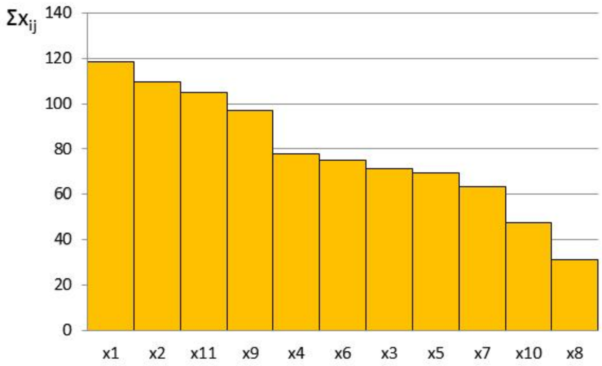


Fig. 2a. Rank diagram of alternative 1 (Maintain application of the main technological processes soil cultivation, sowing and use of water for the needs of plants at the level of their classical performance)

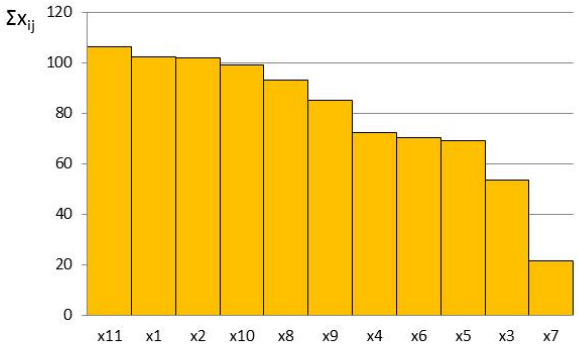


Fig. 2b. Alternative Ranking Chart 2. (Partial replacement of machines in existing Complex Technology Lines (KTL) for soil treatment, sowing and use of water for plant use)

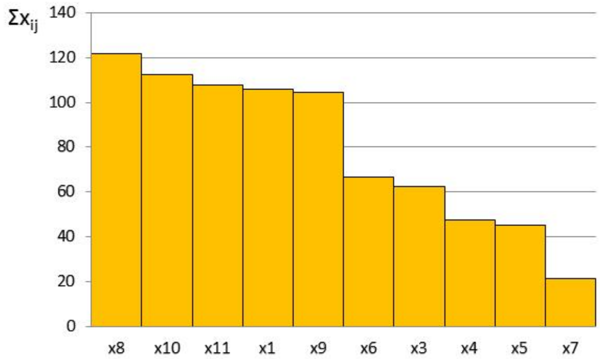


Fig. 2c. Ranking charts: c) - Alternative 3 (Complete renovation of the KTL for the above-mentioned technological processes meeting the requirements for protection of soil and water resources, preservation of soil fertility and increase in yields).

When assessing alternative 1, the experts rank first the criterion x_8 (denoted as Iz in Table 1) decrease in the number of passes on the soil surface, competition on exit to the external market, x_{10} (W1 of Table 1) The possibility of processing large areas, secondly - the possibility of raising a higher level of technical and technological possibilities for soil cultivation, sowing and use of water for the needs of plants.

The chart of alternatives 1 (Figure 2, a) has a linear character, which justifies each of the criteria being considered significant, but the criteria x_8, ($И_3$);〗 _3) can be given preference; x_{10} ($У_и$) and x_7(П _10 because they have the smallest sums of ranks.

When assessing alternative 2, it is first necessary to have qualified specialists $x_7$to show how to improve the technological processes followed by the possibility of processing large areas x_3. The ability to raise a higher level of technical and technological opportunities for soil cultivation, sowing and water use for plant needs is among the top three priorities.

The possibility of reorganizing and / or using already used units and aggregates for new machine constructions x_{11} is not preferred.

First of all, it is possible to reduce the number of passages on the soil surface, optimize the volume of soil used by the root system of plants and the possibility of more efficient use of water by natural rainfall.

The two diagrams (Figure 2b, Figure 2c) are distinguished by their parabolic character, which allows the criteria to be grouped into weak and strongly influential. In both alternatives, the group of highly influential ones consists of the same criteria - x_3, x_4, x_5, x_6 and x_7, arranged in a different sequence, without the last of them. It is evident from the sum of the ranks that the criterion x_7 has the greatest significance for both alternatives.

Because of their innovativeness, the technologies described as 4, 5, 6, 7 and 8 (Table 3) are still not applied in mass production. The interviewed experts determine first of all technologies 6 and 7, Table 3. Secondly, there are technologies for soil treatment in stripes and introduction of WAM. After further clarification of the advantages and disadvantages of each type of soil treatment, the experts rank the merged deep soil treatment at one of the last sites.

The survey also shows that it is imperative to supplement the TCMs with a new generation of machines that are consistent with the objectives of protecting soil and water resources while preserving and/or increasing soil fertility and yields.

Experts express two important agreed opinions on the importance of applying alternative technologies and the degree of risk that is real in drought and changing climates. They categorize risk conditions in five groups.

Group 1. Factors not influencing the risk category;
Group 2. Factors influencing poorly the risk category;
Group 3. Significant risk factors;
Group 4. Sufficiently important risk factors to be subjected to permanent control;
Group 5. Very important risk factors.

The analysis shows that 85% of all factors are classified as significant, sufficiently important and very important risk factors, fig. 3.

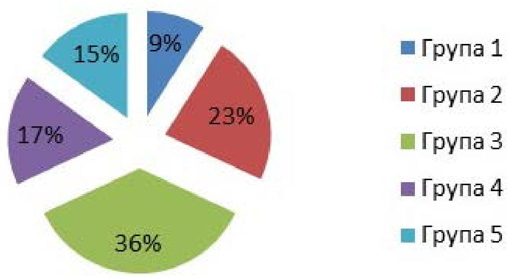


Fig. 3. Division of risk factors into groups of significance

An assessment of the activities to prevent or mitigate the effects of the negative effects of the listed factors is also presented, fig. 4 and Fig. 5.

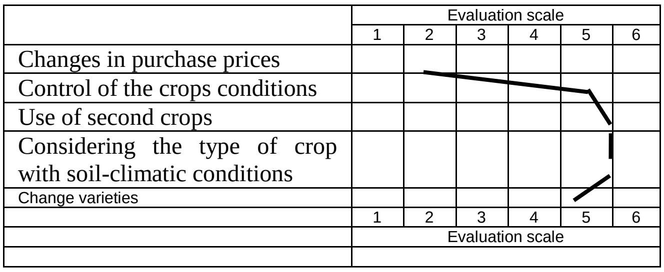


Fig. 4. Activities that offset the use of risky technologies

It is important for agricultural production that it is not immediately possible to set a sharp boundary between risk prevention activities and those that offset the use of conventional practices in technological processes, fig. 4

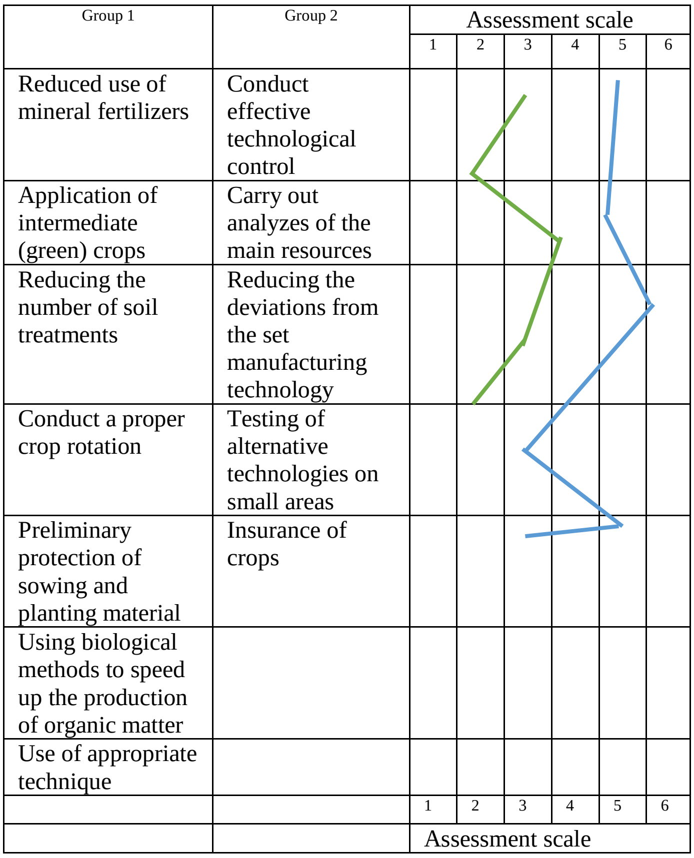


Fig. 5. Risk prevention activities group 1; group 2

Conclusion

Because of their innovativeness, the technologies described as 4, 5, 6, 7 and 8 (Table 3) are still not applied in mass production. The interviewed experts determine first of all technologies 6 and 7, Table 3. Secondly, there are technologies for soil treatment in stripes and introduction of WAM. After further clarification of the advantages and disadvantages of each type of soil treatment, the experts rank the merged deep soil treatment at one of the last sites. The survey also shows that it is imperative to supplement the TCMs with a new generation of machines that are consistent with the objectives of protecting soil and water resources while preserving and / or increasing soil fertility and yields.

It is important for agricultural production that it is not immediately possible to set a sharp boundary between risk prevention activities and those that offset the use of conventional practices in technological processes.

Literature

1. Agrostatistic Guide 2000-2014, Ministry of Agriculture and Food.
2. Angelov, D., M. Manolov, et al .; "Organization of the Agrarian Enterprise"; IM University of Economics - Varna; 2001;
3. Angelov, E., D. Ilkov, G. Dimitrov, I. Vatralov, K. Enikov, Soil Survey in Bulgaria, Kn. 2, Razgrad, Ruse and Silistra district, Sofia, 1975, Publishing House of the Bulgarian Academy of Sciences.
4. Банов, M. 2009. Program for the Priorities in the Development of Bulgarian Agriculture 2009 - 2013 Ministry of Agriculture and Food. 44 pp.
5. Beloev, Hr. Theoretical study on the influence of anti-erosion techniques and technologies on the quality of agricultural soils. Agricultural Machinery, No: 4, Sofia, 2008, pp. 28-35
6. Bratoev, Kr., 2015. Methodology for conducting studies with a hardometer, Mechanization in Agriculture, vol. 3, pp. 11-14.
7. Vasilev, K. At. Technology in Agriculture, Rousse, 2012
8. Венцель E.C. Theory probabilistic. Moscow, Fitmagis, 1962
9. Witliamov V. Automation and robotization of discreet production. PУ "A. Kanchev, 1998, ISBN: 954-712-019-0.
10. Georgiev I., St. Stanev. Harvesting machines. Zemzemat, 1989-1.
11. Dimitrov, P., A. Lazarov, D. Dimitrov, Hr. Beloev, P, Radulov, S. Valchinkov. Anti-erosion technology for grain maize production on inclined terrains. Agricultural Academy, Printing Center of Rousse University, 2008, p. 59.
12. Draper N., G. Smith. Приложей регресионный анализ, пер. With English, Moscow, Mir, 1981
13. Ilieva, V., Russeva, S., Kancheva, R., Vichev, H. 1991. Some physical characteristics of eroded soils: I. Chernozemes. Sat. Doc. IV National Symposium with International Participation "Physics - Agricultural Production", Sofia (11-14.XI.1991): 304-309.
14. Mitkov A. L., S. Kardashevski. Statistical methods in agricultural machinery. Sofia, Zemizdat, 1977
15. Mitkov A., D. Minkov. Statistical Methods for Exploration and Optimization of Agricultural Machinery - Part I. Zemizdat, Sofia, 1989
16. Mitkov, A.L., D.P.Minkov. Mathematical Methods of Engineering Studies. Ruse, 1993
17. Mitkov A. Experimental Theory. Danube Press, Rousse, 2011