TEKA. SEMI-ANNUAL JOURNAL OF AGRI-FOOD INDUSTRY

TEKA. Semi-Annual Journal of Agri-Food Industry, 2021, 21(1), 33–40
https://doi.org/10.12912/27197050/139346
ISSN 2657-9537, License CC-BY 4.0

Received: 2021.03.08
Accepted: 2021.05.28
Published: 2021.06.30

IMPROVING THE STABILITY OF MOVEMENT OF SECTION OF COMBINED MACHINE FOR SOIL PREPARATION AND SOWING

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Abstract

The subject of the study is the process of operation of a combined machine for soil preparation and sowing of sunflower and corn seeds. The technological process of the machine operation with passive rotating flat disks with flanges installed (which properly ensure the movement of soil along the share to the ripping and separating device), a sowing machine, a seed tube, a furrow former, a rotor, a separating grate, a parallelogram mechanism, a spring, a share is described. The dynamic prerequisites for increasing the uniformity of the depth of furrow formation and seed placement in depth in the soil are considered. The values of the length of the links of the parallelogram mechanism, the initial angle of their installation and the stiffness of the spring, the deviations of the section of the combined machine from the specified depth of the plowshare are determined. It is proved that with an increase in the length of the levers of the parallelogram mechanism, the maximum deviations of the section increase. An increase in the initial tilt angle of the levers of the parallelogram mechanism causes an increase in the maximum deviations. As the spring stiffness increases, the maximum deflections decrease. The relevance of the study lies in ensuring the stability of copying the soil surface by the working bodies of the combined machine with the depth of seed placement unchanged along the entire length of the movement, which will make it possible to increase the speed of movement and the width of the unit. The target group of consumers of information in the article are designers, specialists involved in the development of tillage machines.

Key words:
combined machine, soil redistribution, rotor, furrow former, frame, support and press wheel, sowing, separating grid, ploughshare, seed placement.

Introduction

The development of sowing equipment has long been aimed primarily at increasing productivity, that is, at increasing working speeds, working widths, and tractor power, and in this regard, significant progress has been made.

Formulation of problem

The technology based on the use of combined machines has a positive effect on reducing energy costs by reducing the number and depth of processing, combining mechanical operations in one unit – processing, sowing (Rahmati *et. al* 2020; Great Plains / Product catalog. 1994; López *et. al 2019*).

Therefore, such combined machines, which in one pass provide the preparation of the seed bed and sowing, are usually called direct sowing seeders (Syromyatnikov 2021; Pisarev O. *et al.* 2019).

There are three types of direct drills:

- strip loosening of the soil with a wavy disk;
- undercutting type with seed distribution under the lancet share;
- combined, combining working bodies of the undercutting type and coulter systems.

The evaluation criterion in this case is the indicator of uniform distribution of seeds in depth (Nanka et al. 2019; Gao et al. 2020).

They are used for sowing grain crops on cultivated and uncultivated soils with preserved stubble.

Direct sowing seeders with undercutting paws, or seeders with paw coulters are used for sowing seeds of grain crops on stubble or on insufficiently cultivated soil (Syromyatnikov et al. 2021; Rogovskii et al. 2021). Such a coulter performs several operations simultaneously - loosening the soil, removing weeds, sowing seeds.

The advantages of direct sowing drills are that they loosen the soil only in the seed placement zone and create the necessary seed-to-soil contact. Direct sowing seeders in Western Europe, which has light soils, provide soil preparation according to "zero" technology. In the conditions of the USA, Canada and the Forest-Steppe of Ukraine on soils of medium and heavy mechanical composition, as practice has shown, the "zero" technology does not provide the necessary contact between seeds and the solid phase of the soil (Or D. *et. al* 2021; Bartley 2019; Feurdean *et. al* 2021). Therefore, in our conditions, direct sowing seeders, which provide tillage in the seed bed, have a perspective.

Direct sowing seeders with flat-cutting shares provide the most promising way of sowing - broadcast. At the same time, weeds are removed across the entire width of the seeder, and the presence of seed bins in them helps to increase their productivity (Bogus *et. al* 2019; Jiang *et. al* 2021).

The disadvantages of such machines include the fact that they can provide the required agricultural technology for the cultivation of grain crops and the uniformity of seed placement in depth only on leveled fields, where plowing is not used in the main sowing treatment system. In addition, they cannot work in the presence of a large amount of crop residues and weeds (Pastukhov *et. al* 2020; Radnaev *et. al* 2022).

With the increase in the level of intensification of production and the development of a biotechnological approach to the cultivation of grain crops, the issues of technical support for high-quality sowing came to the fore in sowing technology: optimal placement of seeds in area and depth, creation of a dense seed bed. To achieve such conditions for sowing, and most importantly, to create favorable conditions for the growth and further development of plants is possible only with high-quality pre-sowing tillage and sowing with combined aggregates.

Known developed by V. F. Pashchenko combined machine for soil preparation and sowing of sunflower and corn seeds.

The general view of the combined machine for pre-sowing soil preparation and sowing by fractional redistribution of soil over the seeds previously laid in the furrow is shown in Fig. 1.

The machine consists of a frame, six working sections, an ejector device, support wheels and markers. The working section includes a frame, a parallelogram mechanism, a plowshare with a furrow former, guide discs, a separating grid, a rotor, a sowing unit of the SUPN-8 seeder, a box for seeds and a seed duct.

The working process of the machine proceeds as follows (Pashchenko *et. al* 2017; Pashchenko *et. al* 2019). The soil, trimmed with a plowshare, is fed to the ripping and separating device with the help of guide discs. At the same time, the seeds from the sowing unit are fed through the seed pipeline into the wedge-shaped soil furrow formed by the furrower. The rotor pinches soil clods between the knives and the separating grate, crushes and transports them (Pashchenko *et. al* 2018; Pashchenko *et. al* 2019).

Figure 1. Combined seedbed and seedbed machine.

Small soil particles pass through the gaps of the separating grid and cover the seeds laid in the furrow. When tedding the soil along the separating grid, large particles are pushed to the surface, while small ones fall down (Pashchenko *et. al* 2019).

An important factor providing an increase in the yield of agricultural crops is the uniform distribution of seeds over the depth in the soil (Kalabushev *et. al* 2019; Nielsen *et. al* 2018).

Therefore, along with other technical and technological requirements for tillage and sowing machines, the requirement regarding the uniformity of the depth of tillage and seed placement is important.

In this case, such requirements relate to the depth of the formation of the groove in which the seeds of the plants must be placed.

Modern science increasingly recommends the use of a soil-protective tillage system for production by reducing the depth of cultivation, the number of mechanical treatments, or by combining a number of technological operations. This technology achieves the preservation of the soil structure, eliminates excessive soil compaction, and increases its resistance to erosion processes.

There are many scientific justifications about the possibility of completely abandoning a large number of mechanical tillage.

The ideas of reducing the number of operations performed in agriculture have long been put forward by scientists. More D.I. Mendeleev wrote that "... regarding the quality of plowing, many are mistaken, thinking that the more times to plow, the better."

The priority direction is increasingly gaining the use of combined tillage machines and aggregates (Syromyatnikov 2021). The latter have high productivity, are cheap to use, do not violate agri-technical requirements and help to reduce the time of technological operations.

The use of these machines in production makes it possible to combine from two to six operations and reduce fuel consumption for seedbed preparation by 20–40% (Syromyatnikov *et. al* 2021).

Aggregates based on a combination of single-operation tools, although they have some advantages, do not justify themselves because of their bulkiness, instability of movement in a straight direction and inconsistency in their working width. Sowing combines, with the working bodies of the seeder and tillage implements installed on the same frame, made in the form of paws or discs, are less bulky.

Reducing the metal and energy consumption of combined machines with active working bodies can be obtained by strip tillage. Such machines are created on the basis of row cutters and seeders.

Less energy-intensive and more reliable in operation are combined tillage machines with active-passive working bodies. These include the Dokuchaev PRSM-5 soil-cultivating ripping-separating machine (stratifier) (Syromyatnikov *et. al* 2022).

Production tests of the proposed types of combined machines show that the best performance in work is given by the type of combined machines equipped with special working bodies and a coulter system for consistent implementation of the technological process of soil preparation and sowing (Syromyatnikov *et. al* 2021).

It was found that the uniformity of the coulter stroke is determined by their ability to copy the soil relief (Syromyatnikov *et. al* 2021; Matin *et. al* 2021). This is the main agri-technical requirement for a sowing machine - ensuring the stability of copying the soil surface with a constant seeding depth along the entire length of the movement (Starovoytov *et. al* 201; Parkhomenko *et. al* 2021).

Purpose of research

The purpose of the study is to increasing the uniformity of the depth of groove formation and seed placement by the working bodies of the combined machine.

Research results and discussion

To solve this problem, it is necessary to have the equations of motion of the combined machine as a whole. Since it is almost impossible to compose such equations taking into account the exact dimensions of structural elements and their location, it is advisable to confine ourselves to considering the equations of motion of its equivalent circuit (Fig. 2), i.e. build a calculation model of the functioning of the considered machine.

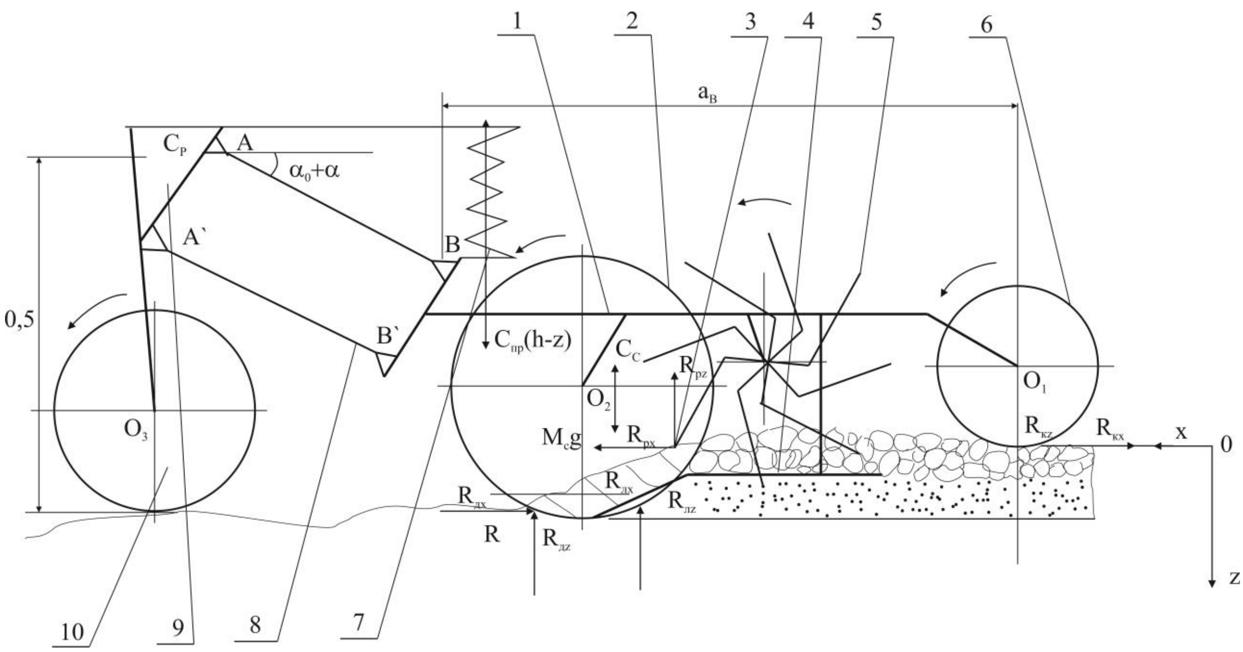

Figure 2. The scheme of sections of the combined machine is equivalent to the constructive.

The section of the combined machine can be considered as a system consisting of the following links:

a) section frame 1, on which guide disks 2, a plowshare 3, a separating grid 4, a rotor 5 and a support-press wheel 6 are installed.

b) spring 7, which ensures the mobility of the section frame with the working bodies attached to it, allows the support-packing wheel to copy the field relief and contributes to the stable movement of the working bodies in the soil at a given depth;

c) a four-link parallelogram mechanism 8 provides plane-parallel movement of the section frame with working bodies;

d) machine frame 9 with gauge wheels 10, the axles of the wheels are rigidly connected to the frame.

Such a structural combination of working bodies with frames of the section and the machine was carried out in order to ensure both the fractional separation of the soil and the uniform distribution of seeds in depth. In this case, the task becomes to ensure the minimum possible deviation of the position of the seeds relative to the track of the support-packing wheel.

The solution of the problem is carried out by selecting the stiffness of the spring 7, the dimensions of the links of the parallelogram mechanism 8 and the initial angle of their inclination to the horizontal plane φ_0.

We refer the system under consideration to the fixed Cartesian coordinates x and z. The direction of rotation of the links of the parallelogram mechanism clockwise is assumed to be positive.

To solve the problem in the first approximation, it can be assumed that with the floating position of the spool of the distributor of the tractor hydraulic system in the steady-state operation mode ($V_M = const$), the frame of the combined machine, copying the sinusoidal surface of the field, moves according to the law

$$x_P = V_M t\,,$$

$$z_P = \mu \cdot \sin\lambda \cdot x_P - a_5\,, \qquad (1)$$

where x_P, z_P are the coordinates of the center of mass of the machine frame and its supporting wheels, m; t – time, s; μ, λ are constant coefficients depending on the field topography; a_5 – distance from the axle x to the center of mass of the machine frame and its support wheels, m.

The soil will be considered as an elastic medium, and the rim of the support-packing wheel 6 will be considered non-deformable.

We will also assume that the forces applied to the disks, the plowshare and the rotor are reduced to some resultant forces that have a constant value, as for the reactions applied to the support-press wheel 6, then, based on the available data, we can take:

$$R_{KX} = f \cdot C_\Pi \cdot \Delta_\Pi\,,$$

$$R_{KZ} = C_\Pi \cdot \Delta_\Pi\,,$$

where R_{KX}, R_{KZ} are the vertical and horizontal components of the forces applied to the wheel, N; C_Π – soil stiffness, N/m; f – rolling coefficient; Δ_Π – magnitude of soil deformation, m.

Let us determine the magnitude of soil deformation through the angle of rotation of the links of the parallelogram mechanism. Then we get

$$\Delta_\Pi + z_C - z_P = l\left[\sin(\varphi_0 + \varphi) - \sin\varphi_0\right] + a_5\,, \qquad (2)$$

where z_C is the coordinate of the center of mass of the section, m; l - the length of the lever AB, m.

$$z_C = \mu \cdot \sin\lambda\left(V_M t - V_M t_1\right),$$

$$t_1 = \frac{l\cos(\varphi_0 + \varphi) + a_6}{V_M}\,,$$

where a_6 is the distance from the O axis of the wheel 6 to the hinge B of the link of the parallelogram mechanism in the horizontal plane, m.

Then

$$z_C = \mu \cdot \sin\lambda\left(V_M t - l\cos(\varphi_0 + \varphi) - a_6\right).$$

After substituting the values z_C and z_P into equation (2), we obtain:

$$\Delta_\Pi = l\left[\sin(\varphi_0 + \varphi) - \sin\varphi_0\right] + \mu \cdot \sin\lambda \cdot V_M \cdot t - \mu \cdot \sin\lambda\left(V_M t - l\cos(\varphi_0 + \varphi) - a_6\right). \qquad (3)$$

Considering that soil deformation occurs only when the section is displaced in the positive z direction, we obtain:

$$\Delta_\Pi = \frac{l\left[\sin(\varphi_0 + \varphi) - \sin\varphi_0\right] + \mu \cdot \sin\lambda \cdot V_M \cdot t - \mu \cdot \sin\lambda\left(V_M t - l\cos(\varphi_0 + \varphi) - a_6\right)}{2} + \left|\frac{l\left[\sin(\varphi_0 + \varphi) - \sin\varphi_0\right] + \mu \cdot \sin\lambda \cdot V_M \cdot t - \mu \cdot \sin\lambda\left(V_M t - l\cos(\varphi_0 + \varphi) - a_6\right)}{2}\right|.$$

Then

$$R_{KX} = f \cdot C_\Pi \left\{ \begin{aligned} &\frac{l\left[\sin(\varphi_0 + \varphi) - \sin\varphi_0\right] + \mu \cdot \sin\lambda \cdot V_M \cdot t - \mu \cdot \sin\lambda\left(V_M t - l\cos(\varphi_0 + \varphi) - a_6\right)}{2} + \\ &+ \left|\frac{l\left[\sin(\varphi_0 + \varphi) - \sin\varphi_0\right] + \mu \cdot \sin\lambda \cdot V_M \cdot t - \mu \cdot \sin\lambda\left(V_M t - l\cos(\varphi_0 + \varphi) - a_6\right)}{2}\right| \end{aligned} \right\} \qquad (4)$$

$$R_{KZ} = C_\Pi \left\{ \begin{aligned} &\frac{l\left[\sin(\varphi_0 + \varphi) - \sin\varphi_0\right] + \mu \cdot \sin\lambda \cdot V_M \cdot t - \mu \cdot \sin\lambda\left(V_M t - l\cos(\varphi_0 + \varphi) - a_6\right)}{2} + \\ &+ \left|\frac{l\left[\sin(\varphi_0 + \varphi) - \sin\varphi_0\right] + \mu \cdot \sin\lambda \cdot V_M \cdot t - \mu \cdot \sin\lambda\left(V_M t - l\cos(\varphi_0 + \varphi) - a_6\right)}{2}\right| \end{aligned} \right\}. \qquad (5)$$

As an independent (generalized) coordinate of the system under consideration, it is convenient to take the angle of rotation of the link of the four-link parallelogram mechanism AB relative to the hinge A. Then the differential equation of motion of the section will be written as

$$\frac{d\partial T}{dt\partial\varphi}-\frac{\partial T}{\partial\varphi}=Q_{\varphi}, \qquad (6)$$

where T is the kinetic energy of the system, Nm; Q_{φ} – generalized force, Nm.

Before writing the expression for the kinetic energy of the system, we note that in the problem being solved, if the rotation of disks 2, rotor 5, wheel 6 is assumed to be uniform and the forces of resistance to their rotational motion are constant, then there is no need to formulate the equations of motion of the latter.

With this in mind, the expression for the kinetic energy of the system can be written as

$$T=\frac{1}{2}M_C\left(\dot{x}_C^2+\dot{z}_C^2\right), \qquad (7)$$

where M_C is the mass of the section, kg; , x_C , z_C are the coordinates of the center of mass of the section, m.

Expressing x_C and z_C from the geometric conditions in terms of the values x_P and z_P, differentiating them with respect to time and substituting into equation (7), we obtain:

$$T=\frac{1}{2}M_C\begin{bmatrix}V_M^2+2V_Ml\dot{\varphi}\sin\left(\varphi_0+\varphi\right)+l^2\dot{\varphi}^2\sin^2\left(\varphi_0+\varphi\right)+\\+\mu^2\lambda^2V_M^2\cos^2\lambda V_Mt+2\mu\lambda V_M\cos\lambda V_Ml\dot{\varphi}\cos\left(\varphi_0+\varphi\right)+\\+l^2\dot{\varphi}^2\cos^2\left(\varphi_0+\varphi\right)\end{bmatrix}. \qquad (8)$$

Because

$$\frac{\partial T}{\partial\dot{\varphi}}=M_Cl\left[V_M\sin\left(\varphi_0+\varphi\right)+l\dot{\varphi}+\mu\lambda V_M\cos\lambda V_Mt\cos\left(\varphi_0+\varphi\right)\right],$$

$$\frac{d\partial T}{dT\partial\dot{\varphi}}=M_Cl\left[V_M\dot{\varphi}\cos\left(\varphi_0+\varphi\right)+l\ddot{\varphi}-\mu\lambda^2V_M^2\sin\lambda V_Mt\cos\left(\varphi_0+\varphi\right)-\mu\lambda V_M\dot{\varphi}\cos\lambda V_Mt\sin\left(\varphi_0+\varphi\right)\right]$$

$$\frac{\partial T}{\partial\varphi}=M_Cl\left[V_M\dot{\varphi}\cos\left(\varphi_0+\varphi\right)-\mu\lambda V_M\dot{\varphi}\cos\lambda V_Mt\sin\left(\varphi_0+\varphi\right)\right],$$

we get

$$\frac{d\partial T}{dT\partial\ddot{\varphi}}-\frac{\partial T}{\partial\varphi}=M_Cl\left[l\ddot{\varphi}-\mu\lambda^2V_M^2\sin\lambda V_Mt\cos\left(\varphi_0+\varphi\right)\right]. \qquad (9)$$

To determine the generalized forces, we use the principle of possible displacements.

Then, if we bring all the reactive forces to the hinge B of the link of the parallelogram mechanism 8, using the theorem on the parallel transfer of forces, we obtain

$$\partial A_{\varphi}=\begin{bmatrix}R_Xl\sin\left(\varphi_0+\varphi\right)+R_Zl\cos\left(\varphi_0+\varphi\right)+C_{\textit{ПР}}\left(h-z_C\right)l\cos\left(\varphi_0+\varphi\right)-\\-R_{KX}l\sin\left(\varphi_0+\varphi\right)-R_{KZ}l\cos\left(\varphi_0+\varphi\right)\end{bmatrix}d\varphi,$$

where R_X , R_Z are the horizontal and vertical components of the resultant forces applied to the disks, the rotor, the plowshare, the separating grate and the weight of the section, N; $C_{\textit{ПР}}$ – spring stiffness, N/m; h – spring pretension, m;

$$R_X=R_{PX}-R_{DX}-R_{LX}-R_{FX},$$

$$R_Z=M_{CG}-R_{LZ}-R_{DZ}-R_{PZ},$$

where R_{LX} , R_{DX} , R_{PX} , R_{LZ} , R_{DZ} , R_{PZ} are the horizontal and vertical components of the resultant reactive forces applied to the share, disks and rotor; R_{FX} is the force of resistance to friction of the soil against the separating grid, N.

Because

$$z_C=l\left[\sin\left(\varphi_0+\varphi\right)-\sin\varphi_0\right]$$

then, taking into account equations (4), (5) and (9), we obtain

$$Q_\varphi = R_X l\sin(\varphi_0+\varphi)+R_Z l\cos(\varphi_0+\varphi)+C_{ПР} l\cos(\varphi_0+\varphi)\times$$
$$\times\left\{h-l\left[\sin(\varphi_0+\varphi)-\sin\varphi_0\right]\right\}-C_П l\left[\cos(\varphi_0+\varphi)+f\sin(\varphi_0+\varphi)\right]\times \quad (10)$$
$$\times\left\{\begin{array}{l}\dfrac{l\left[\sin(\varphi_0+\varphi)-\sin\varphi_0\right]+\mu\cdot\sin\lambda\cdot V_M\cdot t-\mu\cdot\sin\lambda\left(V_M t-l\cos(\varphi_0+\varphi)-a_6\right)}{2}+\\ \left|\dfrac{l\left[\sin(\varphi_0+\varphi)-\sin\varphi_0\right]+\mu\cdot\sin\lambda\cdot V_M\cdot t-\mu\cdot\sin\lambda\left(V_M t-l\cos(\varphi_0+\varphi)-a_6\right)}{2}\right|\end{array}\right\}$$

Substituting expressions (8) and (10) into equation (6), we obtain a calculation model for the functioning of the section of the combined machine for planting seeds and the fractional distribution of soil over the depth of the sowing layer

$$\ddot{\varphi}=M_C l\left[R_X l\sin(\varphi_0+\varphi)+R_Z\cos(\varphi_0+\varphi)\right]+\frac{C_{ПР}\cos(\varphi_0+\varphi)}{M_C l}\times$$
$$\times\left\{h-l\left[\sin(\varphi_0+\varphi)-\sin\varphi_0\right]\right\}-\frac{C_П\left[f\sin(\varphi_0+\varphi)+\cos(\varphi_0+\varphi)\right]}{M_C l}\times$$
$$\times\left\{\begin{array}{l}\dfrac{l\left[\sin(\varphi_0+\varphi)-\sin\varphi_0\right]+\mu\cdot\sin\lambda\cdot V_M\cdot t-\mu\cdot\sin\lambda\left(V_M t-l\cos(\varphi_0+\varphi)-a_6\right)}{2}+\\ +\left|\dfrac{l\left[\sin(\varphi_0+\varphi)-\sin\varphi_0\right]+\mu\cdot\sin\lambda\cdot V_M\cdot t-\mu\cdot\sin\lambda\left(V_M t-l\cos(\varphi_0+\varphi)-a_6\right)}{2}\right|\end{array}\right\}+ \quad (11)$$
$$+\frac{\mu\lambda^2 V_M^2\sin\lambda V_M t\cos(\varphi_0+\varphi)}{l}$$

The differential equation is solved by Runge-Kutt method. Then the obtained value of the angle was substituted into equation (3) and the values of the deviation of the combined machine section from the specified depth of tillage and seeding were found.

For calculation it was accepted: $R_X=-700$ N, $R_Z=-40$ N, $h=0,08$ m, $M_C=88$ kg, $C_П=80000$ N/m, $f=0,02$, $\mu=0,04$, $\lambda=0,5$, $V_M=2,2$ m/s.

The values of the length of the links of the parallelogram mechanism, the initial angle φ_0 of their installation and the stiffness of the spring $C_{ПР}$ were changed and various deviations of the combined machine section from the given depth of the plowshare were determined. The character of section vibrations is shown in Fig. 3. The dependences of the numerical values of the maximum deviations of the combined machine section are shown in Fig. 4.

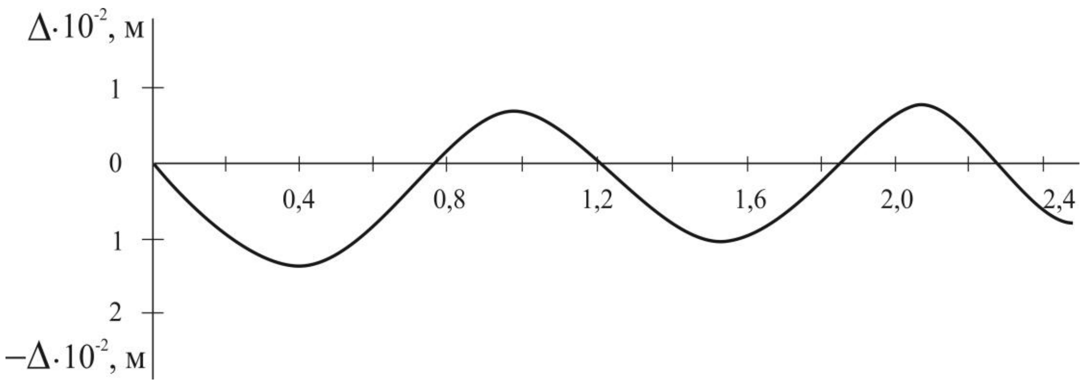

Figure 3. The nature of the deviation of the combined machine section from the specified depth of tillage.

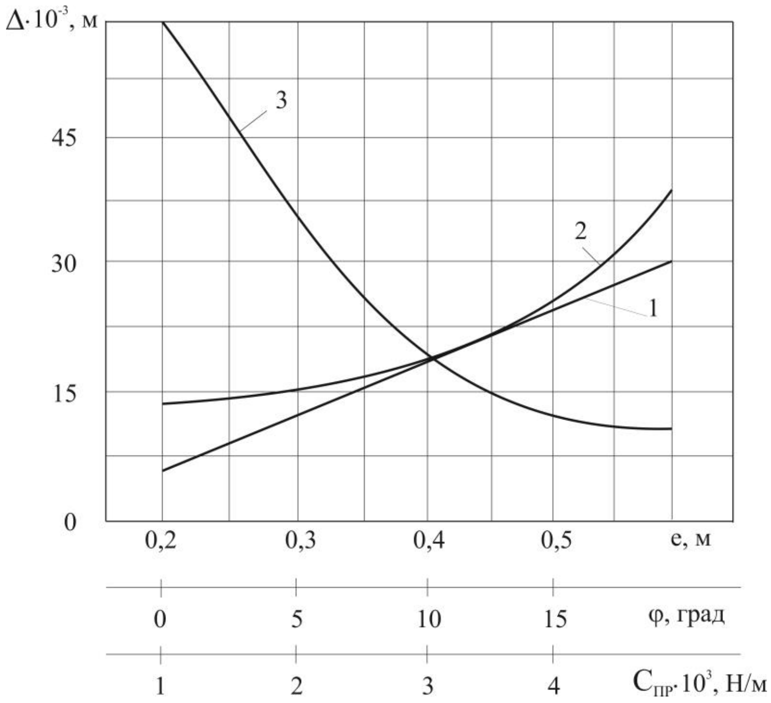

Figure 4. Dependence of the maximum deviation of the combined machine section relative to the specified processing depth.

The data of the graph (Fig. 4) indicate that with an increase in the length of the levers of the parallelogram mechanism from 0.2 to 0.4 m, the maximum deviations of the section increase by 3 times; with an increase in length from 0.2 to 0.6 m – five times. An increase in the initial tilt angle of the levers of the parallelogram mechanism from 0 to 100 causes an increase in maximum deviations by 28.5%, and from 0 to 200 - by 185%. By increasing the spring rate from 1000 to 3000 N/m, the maximum deflections are reduced by 50%, and from 1000 to 8000 N/m by 100%.

Conclusions

To increase the stability of the movement of the combined machine section, the length of the links of the parallelogram mechanism and the angle of their inclination to the horizontal plane must be chosen as small as possible, and the spring stiffness should be close to 8000 N/m.

References

Rahmati M. et al. 2020. Changes in soil organic carbon fractions and residence time five years after implementing conventional and conservation tillage practices. *Soil and Tillage Research*, T. 200, P. 104632.

Great Plains / Product catalog. 1994. Great Plains Manufacturing, Inc: Printed U.S.A., BAC 13599/10/94. 68 p.

López F. J., Pastrana P., Casquero P. A. 2019. Soil physical properties and crop response in direct seeding of spring barley as affected by wheat straw level. *Journal of Soil and Water Conservation*, T. 74, №. 1, P. 51–58.

Syromyatnikov Yu. N. 2021. Influence of direct sowing methods on the growth, development and productivity of spring barley grown under the conditions of the north-eastern part of Ukraine. *Scientific journal "Izvestiya of Timiryazev Agricultural Academy"*, №. 3, P. 27–39. https://doi.org/10.26897/0021-342X-2021-3-27-39.

Pisarev O. et al. 2019. Experimental studies of combined coulter for direct strip sowing of seeds. *MATEC Web of Conferences*. – EDP Sciences, T. 298, P. 00140.

Nanka A. et al. 2019. Improving the efficiency of a sowing technology based on the improved structural parameters for colters. *Eastern-European journal of enterprise technologies*, №. 4 (1), P. 33–45.

Gao X. et al. 2020. Numerical simulation of particle motion characteristics in quantitative seed feeding system. *Powder Technology*, T. 367, P. 643–658.

Syromyatnikov Y. N. et al. 2021. Improving stability of movement of machine section for soil preparation and seeding. *Journal of Physics: Conference Series. IOP Publishing*, T. 2094, №. 4, P. 042027.

Rogovskii I. L. et al. 2021. Technological effectiveness of formation of planting furrow by working body of passive type of orchard planting machine. *IOP Conference Series: Earth and Environmental Science*. *IOP Publishing*, T. 839, №.5, P. 052055.

Or D., Keller T., Schlesinger W. H. 2021. Natural and managed soil structure: On the fragile scaffolding for soil functioning. *Soil and Tillage Research*, T. 208, P. 104912.

Bartley G. 2019. Wheat (Triticum aestivum) residue management before growing soybean (Glycine max) in Manitoba : diss.

Feurdean A. et al. 2021. The transformation of the forest steppe in the lower Danube Plain of southeastern Europe: 6000 years of vegetation and land use dynamics. *Biogeosciences*, T. 18. №. 3, P. 1081 – 1103.

Bogus A. E., Kuzmenko A. D. 2019. Substantiation of the technological scheme of pneumatic grain seeder of subsurface dense sowing. *E3S Web of Conferences. – EDP Sciences*, T. 126, P. 00040.

Jiang S. et al. 2021. Brief Review of Minimum or No-Till Seeders in China. *AgriEngineering*, T. 3. №. 3, P. 605 – 621.

Pastukhov V. et al. 2020. Study of seed agitation in the fluid of a hydropneumatic precision seeder. *Eastern-european journal of enterprise technologies*, T. 5. №. 1-107, P. 36 – 43.

Radnaev D. N. et al. 2022. The coulter effect on the spring wheat yield at different row spacing and seeding rate. *IOP Conference Series: Earth and Environmental Science*. – IOP Publishing, T. 949, №. 1, P. 012069.

Pashchenko V. F., et al. 2017. Substantiation of the parameters of a tillage machine for energy saving soil treatment technology. *Vestnik of the Sumy National Agrarian University Series: Mechanization and automation of virobnichikh processes*, №. 10, P. 36-40.

Pashchenko V. F. et al. 2019. Qualitative performance indicators of a ripping-and-separating machine for soil cultivation in the growth of sugar beet. *Vegetable and Melon Growing*, №. 65, P. 39–49.

Pashchenko V. F. et al. 2018. Soil-cultivating setting a flexible working organ to control of weeds growth. *Vegetable and Melon Growing*, T. 64, P. 33-43.

Pashchenko V. F. et al. 2019. The influence of local loosening of the soil on soybean productivity. *Tractors and Agricultural Machinery*, №. 5, P. 79 – 86.

Pashchenko V. F. et al. 2019. The transporting ability of the rotor of the soil-cultivating loosening and separating vehicle. *Tractors and Agricultural Machinery*, №. 2, P. 67 – 74.

Kalabushev A. N., Laryushin N. P., Shumaev V.V. 2019. Theoretical calculation of certain parameters of a combined coulter. *Volga Region Farmland*, №. 1, P. 94 – 97.

Nielsen S. K. et al. 2018. Seed drill depth control system for precision seeding. *Computers and electronics in Agriculture*, T. 144, P. 174 – 180.

Syromyatnikov Y. N. 2021. Justification of the parameters of the ripper of the tillage machine of the stratifier. *Engineering Technologies and Systems*, T. 31, №. 2, P. 257 – 273. https://doi.org/10.15507/2658-4123.031.202102.257-273.

Syromyatnikov Y. et al. 2021. Productivity of tillage loosening and separating machines in an aggregate with tractors of various capacities. *Journal of Terramechanics*, T. 98, P. 1-6.

Syromyatnikov Y. et al. 2022. Field tests of the experimental installation for soil processing. *Journal of Terramechanics*, T. 100, P. 81 – 86.

Syromyatnikov Y. N. et al. 2021. Cultivator points of the rotary tillage loosening and separating machine of the stratifier. *Journal of Physics: Conference Series. – IOP Publishing*, T. 2094. №. 4, P. 042024.

Matin M. A. et al. 2021. Optimal design and setting of rotary strip-tiller blades to intensify dry season cropping in Asian wet clay soil conditions. *Soil and Tillage Research*, T. 207, P. 104854.

Starovoytov S. I., Akhalaya B. KH., Mironova A. V. 2019. Konstruktivnyye osobennosti rabochikh organov dlya uplotneniya i vyravnivaniya poverkhnosti pochvy. *Elektrotekhnologii i elektrooborudovaniye v APK*, 2019. №. 4, P. 51 –56.

Parkhomenko G. G., Kambulov S. I., Pakhomov V. I. 2021. Agrotekhnicheskiye i energeticheskiye pokazateli pochvoobrabatyvayushchikh rabochikh organov. *Inzhenernyye tekhnologii i sistemy*, T. 31, №. 1.