УДК 631.312.34 DOI 10.22314/2073-7599-2018-12-6-15-19

Автоматизация управления работой садовой фрезы

Виктор Николаевич Зволинский,
старший научный сотрудник;

Максим Александрович Мосяков,
аспирант, младший научный сотрудник,
e-mail: Maks.Mosyakov@yandex.ru

Федеральный научный агроинженерный центр ВИМ, Москва, Российская Федерация

Реферат. Рассмотрели преимущества приводных почвообрабатывающих орудий перед машинами с пассивными рабочими органами, позволяющие оперативно изменять и контролировать качество крошения почвы, ориентируясь на состояние обрабатываемых участков и мощность двигателя используемого энергосредства. (*Цель исследования*) Разработать систему автоматического поддержания величины выбранного кинематического параметра во время работы почвообрабатывающей фрезы, оборудованной гидроприводом рабочих органов. (*Материалы и методы*) Провели исследования с привлечением запатентованных материалов по использованию автоматизированных систем управления технологическими процессами предпосевной обработки почвы орудиями с гидроприводом рабочих органов. (*Результаты и обсуждение*) Определили, что блоки сравнения частот могут содержать формирователи импульсов, которые преобразуются электронным блоком управления в сигнал, поступающий к низкооборотному высокомоментному регулируемому гидромотору типа Danfoss МГП-160. Разработали систему автоматического поддержания величины выбранного кинематического параметра почвообрабатывающей фрезы путем оборудования ее рабочих органов гидроприводом с двухступенчатым гидрораспределителем, управляемым электронным блоком, позволяющую производить автоматическую настройку необходимой частоты вращения ножей фрезбарабана, оптимальной для обрабатываемого агрофона. (*Выводы*) Выявили принципиальную схему автоматизированного гидравлического привода садового культиватора, способного отслеживать и корректировать частоту вращения фрез барабана.

Ключевые слова: садовая фреза, рабочие органы, автоматизация, эффективность, крошение почвенного пласта, кинематические параметры, гидропривод.

Для цитирования: Зволинский В.Н., Мосяков М.А. Автоматизация управления работой садовой фрезы // *Сельскохозяйственные машины и технологии.* 2018. Т. 12. N6. С. 15-19. DOI 10.22314/2073-7599-2018-12-6-15-19.

Automatic Operation of a Rotary Garden Cultivator

Viktor N. Zvolinsky,
senior research associate, engineer,
e-mail: vim@vim.ru;

Maksim A. Mosyakov,
postgraduate student, junior research associate

Federal Scientific Agroengineering Center VIM, Moscow, Russian Federation

Abstract. The paper discusses the advantages of power-driven tillage tools as compared with machines with passive working elements, which provide for quick changing and controlling of the quality of soil crumbling, guided by the condition of the treated areas and the engine power of the power source used. (*Research purpose*) To develop a system for automatically maintaining the magnitude of a selected kinematic parameter during the operation of a rotary cultivator equipped with a hydraulic drive of working elements. (*Materials and methods*) The authors have conducted research involving patented materials on the use of automated process control systems for pre-sowing soil cultivation with tools featuring hydraulic actuators of working elements. (*Results and discussion*) It has been determined that the frequency comparison blocks may contain pulse shapers that are converted by the electronic control unit into a signal sent to a low-speed, high-torque adjustable motor of a Danfoss MGP-160 type. A system has been developed to automatically maintain the value of a selected kinematic parameter of a rotary cultivator by equipping its working elements with a hydraulic actuator with a two-stage hydraulic distributor controlled by an electronic unit that allows automatic adjustment of the required speed of the rotary drum cutters, optimal for the treated soil background. (*Conclusions*) The authors have identified a schematic diagram of an automated hydraulic drive of a rotary garden cultivator capable of tracking and adjusting the rotary drum speed.

Keywords: rotary garden cultivator; working elements; automation; efficiency; crumbling of soil layer; kinematic parameters; hydraulic drive.

For citation: Zvolinsky V.N., Mosyakov M.A. Avtomatizatsiya upravleniya rabotoy sadovoy frezy [Automatic operation of a rotary garden cultivator]. *Sel'skokhozyaystvennyye mashiny i tekhnologii*. 2018. Vol. 12. N6. 15-19. DOI 10.22314/2073-7599-2018-12-6-15-19 (In Russian).

Power-driven tillage tools leave behind machines with passive working elements due to their ability to quickly change the quality of soil crumbling, focusing on the condition of plots and the applied engine power [1, 2]. This is usually done in two ways – by selecting the required speed of the unit or adjusting the speed of the working elements through the use of multispeed drive mechanisms (stepped or stepless). The rotary cultivation intensity can be changed by selecting the required number of knives on the rotary cultivator drum, however, this is rather laborious and time-consuming and it leads to the increased complexity of the tool design [3].

To automatically maintain the constancy of the kinematic parameter λ, the most promising option is design improving of hydraulically driven rotary machines, that are often used in garden cultivators. To this end, the machine is equipped with units for comparing the speed of a rotary drum and devices indicat-ing the parameters of the forward movement of the implement (for example, sup-port wheels or compactors) [4]. In this case, the speed comparators may contain pulse formers that are sufficient to alert the tractor driver in case of the violation of a known kinematic parameter:

$$\lambda = \frac{V_О}{V_П}, \tag{1}$$

where $V_о$ is drum peripheral speed, m/s; $V_П$ is translational speed of the unit, m/s.

Calculation and installation of the value of the supported kinematic parameter is carried out immediately before the work, focusing on the type of soil treatment, the type of soil, its humidity, the depth of tillage, and the design of working elements, etc.

The research purpose is the development of an automatic support system for the magnitude of the selected kinematic parameter of the work of a soil-tilling rotary cultivator equipped with a hydraulic actuator of working elements.

Materials and methods. The studies were carried out with the use of patented materials on the use of automated process control systems for pre-sowing soil tillage with hydraulically actuated tools of working elements [5, 6].

Results and discussion. The kinematic parameter λ and the main characteristics of the rotary cultivator can be described with the following relationship (2):

$$\lambda = \frac{V_О}{V_П} = \frac{R}{\sqrt{2Rh_{гр} - h^2{}_{гр}}} \times \left[\frac{\pi(z+2)}{2z} - \arcsin\frac{R - h_{гр}}{R}\right], \tag{2}$$

where R is the radius of the knife drum, m; $h_{гр}$ is the permissible height of combs at the furrow bottom, cm; z is the number of one-sided knives on the blade disk, pcs.

Due to the absence of reference information on the direct dependence of the quality of soil crumbling on such parameters as the peripheral speed and the shape of knives, the tillage depth, the drum speed and the methods of locating the knives on the rotary cultivator drum and the soil conditions at the time of tillage, soil fractions of certain sizes specified in the initial requirements can be obtained in several ways. The easiest way is to perform the tillage basing on the tillage feed $S=2\pi R/\lambda z$ the thickness of the cut layers $\delta=S\cos\alpha$, the volume of the cut fraction $V=Shb$, the cross-sectional area of the cut layer $F_П$ in accordance with equation [3]:

$$F_П = Sb\delta_{max}. \tag{3}$$

Inserting the data from equation (2) into (3), we get:

$$\delta_{max} = \frac{2\pi V_П \sqrt{2R \cdot h_{гр} - h^2{}_{гр}}}{V_О z}, \tag{4}$$

where b is the knife width, h is the depth of tillage, α is the angle of the knife rotation.

The volume of the cut soil fraction is determined by the formula:

$$V = Shb.$$

The most accurate is the method of calculating the predicted quality of crumbling over the cross-sectional area, linking the greatest number of parameters of the instrument and experimental data obtained, for example, in soil channels [7].

When choosing a kinematic parameter of tillage, one should take into account a possibility of the formation of so-called combs at the furrow bottom, which arise when the translational speed increases. On the other hand, the desire to get a smooth bottom, increasing the rotation speed of the knives, leads to excessive dust formation, which is also regulated by the requirements [2, 8].

Many years of experience in the use of rotary cultivators has shown that most often in the pre-sowing soil preparation, rotary cultivation in the range of 5-15 cm is used for soil tillage for grain crops and in gardens, 5-10 cm for row-crop cultivators, and 15-25 cm for rotary plows [9]. The cutting speed varies from 2.35 to 11 m/s, the translational speed varies from 1.1 to 2 m/s, and the cultivation feed varies from 2.5 to 18.6 cm.

To achieve the proper quality of the cutter operation under the selected modes, it is necessary to maintain the constancy of these parameters during operation. Changing the preliminary settings of the drive of the machine can occur due in areas with high humidity or soil hardness, working on fields with a slope of more than 3°, re-deepening or sticking of working bodies and for a number of other reasons. In these cases, a tractor operator stops the unit using the mechanical transmission and switches the rotational speed of the working parts on the central gearbox or reduces the working speed [10, 11]. These actions typically result in the loss of time and reduced shift performance of the unit. In addition, it is not always possible to trace the cases of stopping the machine operation when the friction clutch is actuated, as the tractor operator has his back to the machine and, due to engine noise, cannot tell by ear whether the machine is working or not. The rotary cultivator deepens and rolls on the non-working knife drum, while the tractive force of the inoperative rotary cultivator differs little from the tractive resistance of the operating machine [3, 12].

As an example, let us consider the design of a rotary cultivator used for tillage in gardens with working elements driven from a low-speed high-torque adjustable hydraulic motor of type 2 – Danfoss MGP-160 (*Fig. 1*).

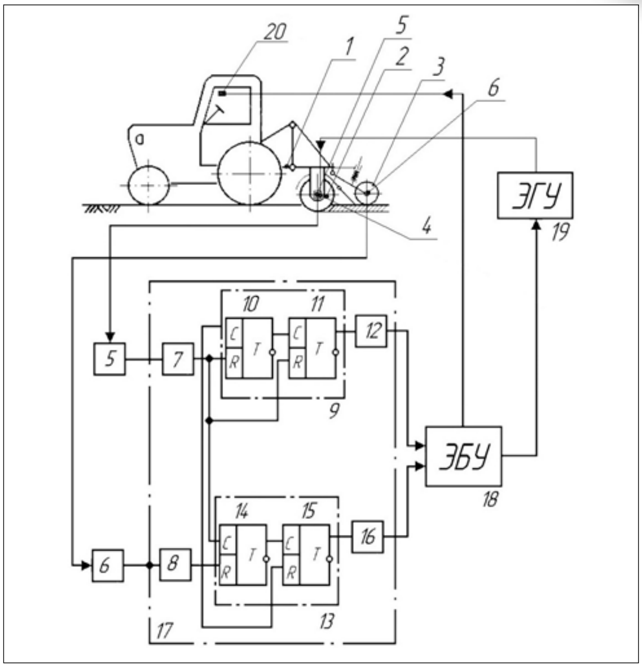

Fig. 1. Schematic diagram of an automated rotary cultivator with a hydraulic actuator of the working elements: 1 – frame; 2 – rotary drum; 3 – roller; 4 – hydraulic motor; 5 – rotary drum speed sensor; 6 – roller drum speed sensor; 7 – pulse shaper of rotary drum rotation; 8 – pulse shaper of roller rotation; 9 – output of a two-digit counter; 10, 11, 14, 15 – trigger; 12, 16 – start-stop multivibrator; 13 – two-digit counter; 17 – frequency comparator; 18 – electronic control unit; 19 – electro-hydraulic amplifier; 20 – tachometer; ЭБУ – electronic control unit, ЭГУ – electronic hydraulic amplifier

The cultivator contains rotary drum *2* driven by hydraulic motor *4* with rotational speed sensor *5*, supporting element *3* (for example, a compacting roller) rotating from soil reaction and equipped with rotational speed sensor *6*; comparator *17* analyzing the indicated frequencies normalized in amplitude and duration by means of pulse formers *7* and *8*; two two-digit counters *9* and *13*, containing four triggers *10*, *11*, *14*, *15*, and two single vibrators *12* and *16*.

The inputs of the pulse shapers are connected to the outputs of the rotational speed sensor of the rotary cultivator and the support element, as well as with electronic control unit 18 and electronic hydraulic amplifier *19*.

The rotary cultivator works as follows. Before starting the operation, one should determine the required speed of the rotary drum knives and the required value of the translational speed of the unit, for which an appropriate gear is selected.

When the unit operates with a nominal ratio of the rotational speeds of the support element and the rotary drum, the pulse frequencies at the outputs of sensors *5* and 6 are equal to each other. The outputs of the pulse shapers *7* and *8* record pulses, normalized in amplitude and duration. In case of equal periods of pulse repetition, the level of logic zero is preserved, and the electronic control unit operates in the mode established before the operation. There is no voltage at the input of the electronic control unit. If the established relationship between the pulse frequencies on the rotary drum and the supporting element is violated, the voltage is applied to the ECU, it amplifies it and transmits to the EGU (*Fig. 2*), which through the choke begins to affect the change in fluid flow in the motor hydraulic circuit, by increasing or decreasing the rotational speed of the output shaft.

As an example, let us consider the operation of a two-stage hydroelectric distributor EGU incorporating an electromechanical converter, where the electrical signal is converted into mechanical energy (shaft rotation, magnet pusher moving) using a hydraulic power amplifier [12-14].

The EGU consists of two slide-type hydraulic distributors, slide valves, two pairs of centering springs 3 and 6 (controlled from electromagnets EM-1 and EM-2) with hydraulic control. The first stage serves to

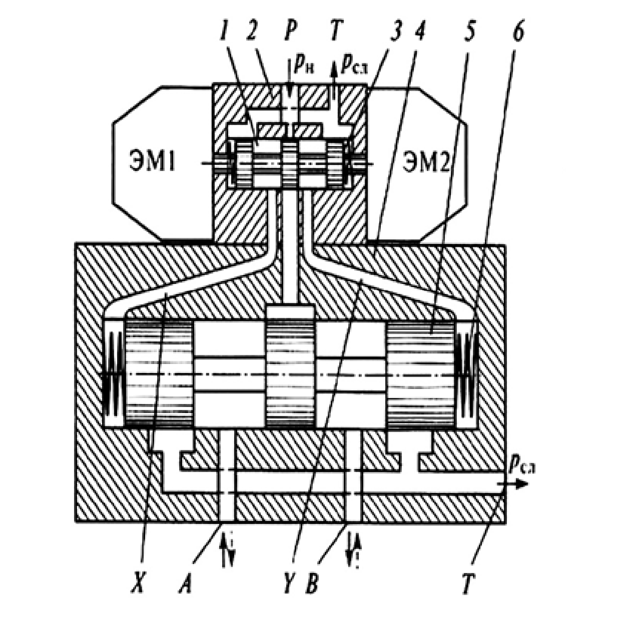

Fig. 2. Two-stage hydraulic valve with electrohydraulic control: 1, 5 – slide valves; 2 – the casing of the first-stage distributor; 3,6 – centering springs; 4 – distributor case of the second stage; R, T, A, B – connecting holes; X, Y – outlet openings of the first-stage distributor; EM-1, EM-2 – electromagnets

pre-amplify the power of the input control signal. In this device, an electrical signal is fed to the input, and the output presents the working fluid changed in pressure or flow rate. The magnitude of these changes is proportional to the input power. The end cavities of the second-stage distributor are connected with channels *X* and *Y* to the outlet openings of the first-stage distributor.

In the absence of an electrical control signal, the slides of both valves under the action of end springs are in the middle (neutral) positions. At the same time, slide valve 1 connects the end faces of the second-stage distributor with the discharge unit, and slide valve 5 overlaps all flow sections.

When a signal arrives, for example, on the electromagnet EM-1, slide valve *1* is shifted all the way to the right, so that the first-stage distributor switches in such a way that the fluid flow under pressure enters the left end valve of the second-stage hydraulic distributor through the channel *X*, and the right end cavity is connected to the discharge unit through the channel *Y*. A pressure differential is observed at the ends of slide valve *5*, under the action of which it is displaced to the right and pushes the main hydraulic valve. This connects the hydraulic lines *P* with *A*, and *B* with *T*.

When a control signal arrives at the input of the EM-2 electromagnet, slide valves *7* and *5* move to the left, so that the control valve switches to position *II*. At the same time, the hydraulic line *P* is connected with *B*, and *A* with *T*.

Conclusions. As a result of the research, a schematic diagram of an automated hydraulic drive for a rotary garden cultivator has been developed. The cultivator is capable of tracking and, if necessary, adjusting the rotary drum speed.

БИБЛИОГРАФИЧЕСКИЙ СПИСОК

1. Зволинский В.Н. Результаты и основные направления работ по фрезерным почвообрабатывающим машинам // *Тракторы и сельхозмашины*. 1978. N11. С. 10-11.
2. Елизаров В.П., Артюшин А.А., Ценч Ю.С. Перспективные направления развития отечественной сельскохозяйственной техники // *Вестник ВИЭСХ*. 2018. N2 (31). С. 12-18.
3. Зволинский В.Н., Инаекян С.А. Пути совершенствования конструкций ротационных почвообрабатывающих машин // Обзорная информация. М. ЦНИИТЭИ Тракторосельхозмаш. 1984. Вып. 10. С. 161.
4. Измайлов А.Ю., Хорошенков В.К., Колесникова В.А., Алексеев И.С., Лонин С.Э., Гончаров Н.Т. Средства автоматизации для управления сельско-хозяйственной техникой // *Сельскохозяйственные машины и технологии*. 2017. Т. 11. N3. С. 3-8.
5. Лобачевский Я.П. Современные почвообрабатывающие технологии. М.: МГАУ им. В.П. Горячкина. 1999. 39 с.
6. Измайлов А.Ю., Хорошенков В.К. Автоматизированные информационные технологии в производственных процессах растениеводства // *Сельскохозяйственные машины и технологии*. 2010. Т. 4. N4. С. 3-9.
7. Зволинский В.Н., Мосяков М.А., Николаенко Н.Ю. Роль почвенного канала при изучении процессов в системе «рабочий орган – почва» // *Тракторы и сельхозмашины*. 2016. N1. С. 36-40.
8. Измайлов А.Ю., Лобачевский Я.П., Смирнов И.Г., Хорт Д.О. Актуальные проблемы создания новых машин для промышленного садоводства // *Сельскохозяйственные машины и технологии* 2013. N3. С. 20-23.
9. Измайлов А.Ю., Сидоров С.А., Лобачевский Я.П., Хорошенков В.К., Кудря А.В. Повышение технических характеристик рабочих органов сельскохозяйственных машин // *Вестник российской сельскохозяйственной науки*. 2016. N4. С. 58-60.
10. Лобачевский Я.П., Смирнов И.Г., Юрин А.Н., Хорт Д.О., Филиппов Р.А., Романюк Н.Н. Приоритетные технические средства для закладки и возделывания многолетних насаждений в садоводстве и потомниководстве России и Беларуси // *Техника и оборудование для села*. 2016. N10. С. 16-20.
11. Sidorov S.A.,Lobachevskii Y.P., Khoroshenkov V.K., Akhmedova T.S., Vorob'ev D.A. Ear and breakage resistance of hard alloy coatings strengthened with Tungsten carbide // Metallurgist. 2018. T. 61. N11-12. С. 1023-1028.

12. Демидов В.Г., Зволинский В.Н. Пути повышения надежности работы привода почвообрабатывающей фрезы // Повышение агротехнических показателей, технического уровня и качества сельскохозяйственных машин для зоны орошаемого земледелия. Ташкент. 1984. С. 42-47.

13. Гамынин Н.С. Основы следящего гидравлического привода. М.: Оборонгиз. 1962. 293 с.

14. Завражнов А.А., Завражнов А.И., Лобачевский Я.П. Реинжиниринг в производстве техники для садоводства // *Тракторы и сельхозмашины*. 2011. N9. С. 5-10.

REFERENCES

1. Zvolinsky V.N. Results and main directions of work on milling tillage machines. *Traktory i sel'khozmashiny*. 1978. N11. 10-11 (In Russian).

2. Elizarov V.P., Artyushin A.A., Tsench Yu.S. Perspektivnye napravleniya razvitiya otechestvennoy sel'skohozyaystvennoy tekhniki [Perspective directions of development of domestic agricultural machinery]. *Vestnik VIESH*. 2018. N2(31). 12-18 (In Russian).

3. Zvolinsky V.N., Inaekyan S.A. Ways to improve the designs of rotary till-ers. Overview information. Moscow. TSNIIITEI Tractoroselhozmash. 1984. Iss. 10. 161 (In Russian).

4. Izmaylov A.Yu., Khoroshenkov V.K., Kolesnikova V.A., Alekseev I.S., Lonin S.E., Goncharov N.T. Automation tools for agricultural management technology. *Sel'skokhozyajstvennye mashiny i tekhnologii*. 2017. Vol. 11. N3. 3-8 (In Russian).

5. Lobachevsky Ya.P. Modern tillage technology. Moscow. MSAU them. V.P. Goryachkina. 1999. 39 (In Russian).

6. Izmaylov A.Yu., Horoshenkov V.K. Automated information technologies in crop production. *Sel'skohozyajstvennye mashiny i tekhnologii*. 2010. Vol. 4. N4. 3-9 (In Russian).

7. Zvolinsky V.N., Mosyakov M.A., Nikolayenko N.Yu. The role of the soil channel when studying the processes in the system "working organ – soil". *Tractory i selhozmashiny*. 2016. N1. 36-40 (In Russian).

8. Izmailov A.Yu., Lobachevsky Ya.P., Smirnov I.G., Hort D.O. Actual problems of creating new machines for industrial gardening. *Sel'skokhozyaystvennye mashiny i tekhnologii*. 2013. Vol. 7. N3. 20-23 (In Russian).

9. Izmailov A. Yu., Sidorov S.A., Lobachevsky Y.P., Khoroshenkov V.K., Kudrya A.V. Increasing the technical characteristics of the agricultural working military vehicles. *Vestnik rossijskoj sel'skohozyajstvennoj nauki*. 2016. N4. 58-60 (In Russian).

10.Lobachevskiy Ya.P., Smirnov I.G., Yurin A.N., Hort D.O., Filippov R.A., Romanyuk N.N. Prioritetnye tekhnicheskie sredstva dlya zakladki i vozdelyvaniya mnogoletnih nasazhdeniy v sadovodstve i potomnikovodstve Rossii i Belarusi [Priority technical means for laying and cultivation of perennial plantings in gardening and posterity of Russia and Belarus]. *Tekhnika i oborudovanie dlya sela*. 2016. N10. 16-20 (In Russian).

11. Sidorov S.A.,Lobachevskii Y.P., Khoroshenkov V.K., Akhmedova T.S., Vorob'ev D.A. Ear and breakage resistance of hard alloy coatings strengthened with Tungsten carbide. *Metallurgist*. 2018. Vol. 61. N11-12. 1023-1028.

12. Demidov V.G., Zvolinsky V.N. Ways to improve the reliability of the drive of the tiller. Increase of agrotechnical indicators, technical level and quality of agricultural machines for the zone of irrigated agriculture. Tashkent. 1984. 42-47 (In Uzbek).

13. Gamynin N.S. Basics of hydraulic servo drive. Moscow. Oborongiz. 1962. 293 (In Russian).

14. Zavrazhnov A.A., Zavrazhnov A.I., Lobachevskiy Ya.P. Reinzhiniring v proizvodstve tekhniki dlya sadovodstva [Reengineering in the production of gardening equipment]. *Traktory i sel'khozmashiny*. 2011. N9. 5-10 (In Russian).

Конфликт интересов. Авторы заявляют об отсутствии конфликта интересов.

Conflict of interest. The authors declare no conflict of interest.

Статья поступила в редакцию 09.10.2018
The paper was submitted to the Editorial Office on 09.10.2018

Статья принята к публикации 04.12.2018
The paper was accepted for publication on 04.12.2018