Автоматизация управления работой садовой фрезы

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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 рабочими органами. (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 MGP-160. Разработали систему автоматического поддержания величины выбранного кинематического параметра почвообрабатывающей фрезы путем оборудования ее рабочих органов гидроприводом с двухступенчатыми гидрораспределителями, управляемым электронным блоком, позволяющим производить автоматическую настройку необходимой частоты вращения ножевой фрезебарабана, 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.


Automatic Operation of a Rotary Garden Cultivator

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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.


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 $\lambda$, 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 indicating 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:

$$\lambda = \frac{V_0}{V_\pi},$$

where $V_0$ is drum peripheral speed, m/s; $V_\pi$ 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 $\lambda$ and the main characteristics of the rotary cultivator can be described with the following relationship (2):

$$\lambda = \frac{V_0}{V_\pi} = \frac{R}{\sqrt{2Rh_{tp} - h_{tp}^2}} \times$$

$$\times \left[ \frac{\pi(z + 2)}{2z} \arcsin \frac{R - h_{tp}}{R} \right],$$

where $R$ is the radius of the knife drum, m; $h_{tp}$ 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 $S=2\pi R/\delta$ the thickness of the cut layers $\delta=Scosa$, the volume of the cut fraction $V=Shb$, the cross-sectional area of the cut layer $F_\pi$ in accordance with equation [3]:

$$F_\pi = Sb\delta_{\text{max}}.$$  

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

$$\delta_{\text{max}} = \frac{2\pi V_\pi \sqrt{2R \cdot h_{tp} - h_{tp}^2}}{V_0^2},$$

where $b$ is the knife width, $h$ is the depth of tillage, $\alpha$ 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 to 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 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.

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).

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; 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.

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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...
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.

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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

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