

Justification of the construction automated device for hydraulic removal of weeds in horticultural

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Abstract. Currently, the search continues for efficient, low-energy, environmentally friendly technologies for the destruction of weeds. The practical application of an environmentally friendly method of removing weeds using high-pressure water jets is hampered by the lack of technical solutions to ensure compliance with the treatment regimes in field conditions. The article presents a device for the hydraulic removal of weeds for use in gardening. To comply with the treatment regimens when performing technological operations in the field, a system of adaptation of the spray head has been developed. The results of field studies of the developed device with the proposed automated adaptation system are given.

1 Introduction

Scientists around the world are conducting research on the development of new methods of weed control. The effectiveness of these methods depends on the designs, principles and modes of operation of specialized machines. Modern manufacturers of agricultural machinery and equipment pay great attention to the development of machines for weed control without the use of chemicals, with the aim of transition to environmentally friendly (organic) agriculture. The development of these principles results in trailed devices that use tractor energy, gas or hydraulic equipment to carry out tillage in rows of vineyards, berries and in areas near the trunk of fruit trees [1-3]. The practical application of an environmentally friendly method of removing weeds using high-pressure water jets is hampered by the lack of technical solutions to ensure compliance with the treatment regimes in field conditions [4-5]. The substantiation of the parameters of new environmentally friendly technologies and technical means to combat weed vegetation in the near-forest zone of garden plantations with an automated system of adaptation of the working body is an actual problem and has an important scientific and industrial importance.

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2 Materials and methods

According to the results of the analysis of existing technologies and technical means, the FSAC VIM developed a device for the hydraulic removal of weeds in the areas near the trunk of horticulture plantations without the use of herbicides. The device represents construction of the trailed type. The main components and assembly units are fixed on the frame by means of bolted and welded joints (Fig.1).

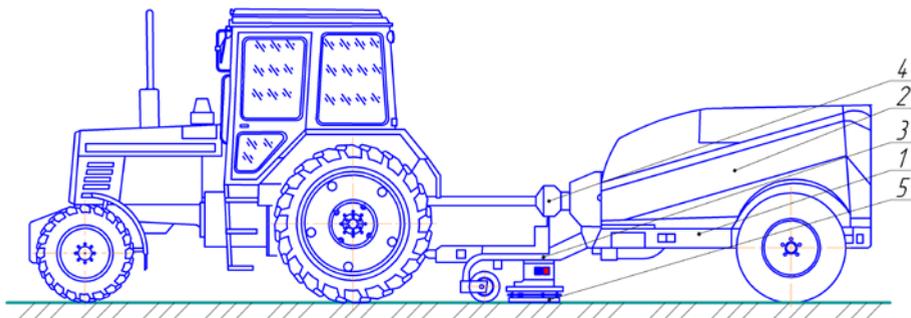


Fig. 1. Scheme of the unit for hydraulic removal of weeds vegetation: 1 – device frame, 2 – working fluid tank, 3 – remote section guide, 4 – power take-off drive (PTO), 5 – sprayer head

A device for the hydraulic removal of weeds includes a frame, a tank for the working fluid, a pump, a pressure regulator, a filter, a power take-off drive, nozzles, a deflected rod, a spray head with a protective cover. The device is equipped with a microcontroller, an ultrasonic sensor and technical vision for controlling weeds and soil lumpiness mounted on the spray head, and the deflecting rod is equipped with actuators. With the help of a spring fixed on the guide, the spraying of the spray head around the tree trunk and its reverse return to the working position after overcoming the obstacle is carried out. Adjustment of the vertical and horizontal position of the spray head is carried out with the help of double-acting actuators, mounted on the guide remote section of the working body (Fig. 2).

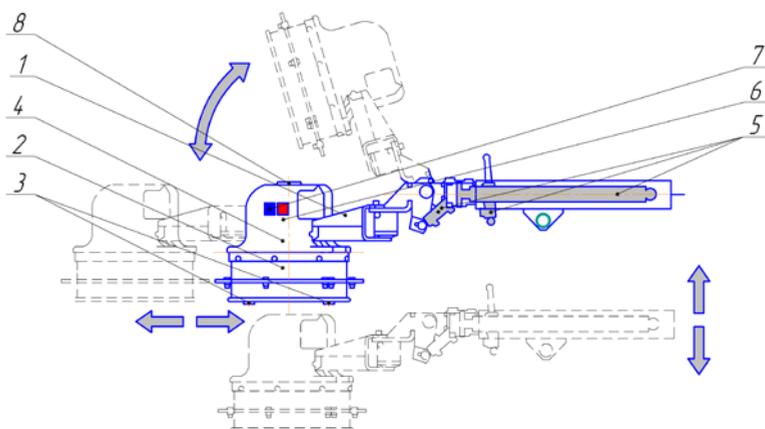


Fig. 2. The layout of the remote section of the spray head: 1 - remote section frame, 2 - spray head, 3 - nozzles, 4 - protective cover of the spray head, 5 - double-acting actuators, 6 - ultrasonic sensor, 7 - vision system, 8 - microcontroller.

To ensure high-quality technological operation of hydraulic removal of weed vegetation using the developed device, it is necessary that when the unit moves at a set speed from 1.5 to 3 km / h, the required distance between the working member and weed vegetation from

0.1 to 0.2 m is maintained. and the supply pressure of the working fluid from 600 to 1000 bar. In the process of moving the tractor with a trailer device, the running systems replicate surface irregularities, thereby displacing the spray head, which leads to a change in the position of the treatment zone and significantly affects the quality of the technological operation.

To comply with the established modes, an automated system has been developed for adapting the working part of the device for hydraulic removal of weeds. The soil relief is copied automatically by horizontal and vertical deflection of the rod with the spray head with the help of actuators on the signal from the ultrasonic sensor and the microcontroller attached to the cover of the spray head [6]. The required supply pressure of the working fluid nozzles is set automatically by signals from the microcontroller to the pump, the indications of the vision system and depending on the clodiness and the degree of soil contamination by weeds. If there is no weed vegetation in the row, the water supply is automatically stopped and resumed in places where there is weed vegetation. The microcontroller with sensors is powered from the on-board network of the tractor.

The program code is written in the C++ programming language, the modules are included that provide control of the position of the device working body both in automatic mode and remotely, using the control panel.

3 Results and discussions

As a result of the research, an automatic system for adapting the working parts of the device for hydraulic removal of weed vegetation (Fig. 3) and an algorithm for controlling electric drives and pressure for supplying the working fluid by nozzles have been developed.

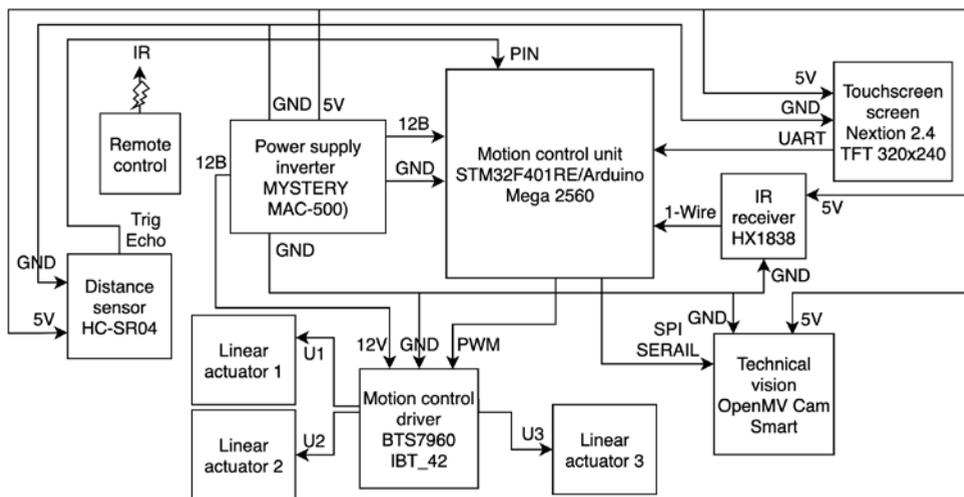


Fig. 3. Block diagram of the automatic system of adaptation of the working body and control of the working fluid supply of the device for hydraulic removal of weed vegetation

The main component of the adaptation system of the operating elements of the device for hydraulic removal of weeds is the STM32F401RE microcontroller. Elements of the sensor system are connected to the module via pin connectors according to standard schemes: ultrasonic distance sensor via one of the GPIO lines of the microcontroller, infrared remote control sensor to the GPIO line using one wiring protocol, current sensor into the output gap of the bridge amplifier. The developed system monitors the state of linear drives and implements the software-defined laws for moving the working point. The amplifier functions

as an H-bridge on a BTS7960 microcircuit connected to the GPIO ports of the microcontroller with PWM modulation capability (PWM). The maximum allowable current 43A. The reverse movement of the engine (the direction of movement of the rod) is set by the control signals on the digital outputs of the GPIO controller. The signals from the ultrasonic sensor HC-SR04 contain the information needed to estimate the torque on the motor shaft and determine the position of the actuator stem. To display graphic information and interact with it, select the operating mode, the Nextion 2.4 screen is used. It is also possible to remotely control the position of the working bodies using the control panel (module HX1838).

The device works as follows: a tractor in an aggregate with an automated device for removing weeds using high pressure water jets drives into rows of garden plantations and treats the near-stem zones of plants. The soil relief is copied automatically using double-acting actuators by changing the horizontal and vertical angle of inclination of the spray head according to the signal from the ultrasonic sensor and microcontroller mounted on the cover of the spray head. The microcontroller, after processing information from the OpenCV vision module, sends a control signal to the pump to set the required water supply pressure depending on the clodiness and the degree of soil contamination by weeds. The microcontroller with sensors is powered from the tractor's on-board network. As a result of field studies (Fig. 4) of the developed adaptation system, it was found that the range of variation of the numerical values of the distance to the processing object decreased to 5.1 times as compared with the disabled system.



Fig. 4. Field studies of the developed system of adaptation of the device for hydraulic removal of weeds.

The coefficient of variation when using the system of adaptation of the working bodies was 2%, with the system turned off 13%, which positively affects the quality of the technological operation of hydraulic removal of weeds (Table 1).

Table 1. The results of the analysis of the data obtained field experiment.

Variation index	Using an automatic adaptation system	Without using an adaptation system
The range of variation, m	0,11	0,56
Mean linear deviation, m	0,0025	0,017
Dispersion in the general population, m ²	0,0008	0,037
Dispersion by sample, m ²	0,0009	0,039
General standard deviation, m	0,0029	0,0192
General standard deviation by sample, m	0,003	0,0198
Coefficient of variation, %	2	13
Coefficient of oscillation	0,07	0,37

The graph of deviation of the spraying head distances from those required with and without using an automatic adaptation system is presented in Figure 5.

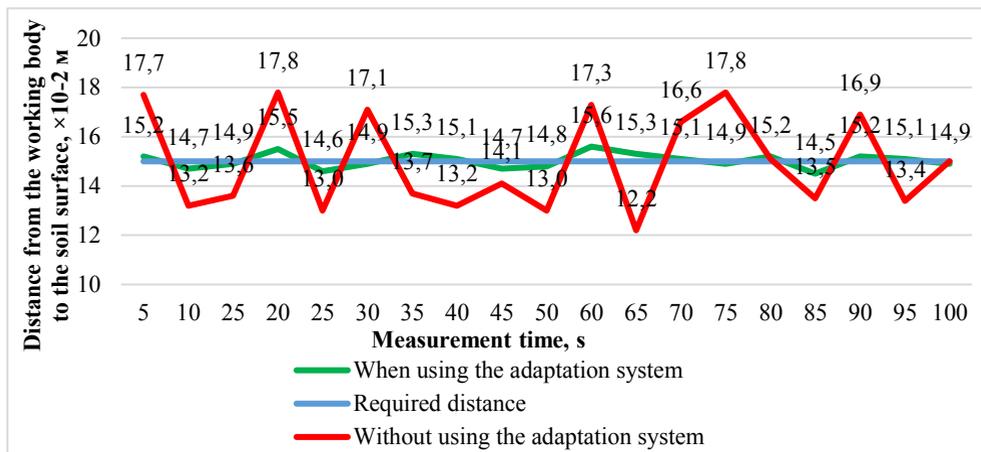


Fig. 5. Schedule of deviation of the spray head from the required distance when performing the technological operation of hydraulic removal of weed vegetation.

As a result of the conducted research, it was revealed that high-quality loosening of the soil to a depth of 0,05 m is ensured at an aggregate speed of 2,5 km / h (Table 2).

Table 2. Agrotechnical indicators of field research devices for hydraulic removal of weeds.

Name of indicators	The value of the indicators before the technological operation of weed vegetation removal	The value of the indicators after the technological operation of the removal of weeds
Soil moisture in layers, %		
- 0 to 0,05 m:	8,1	37,5
- over 0,05 to 0,1 m:	13,4	28,4
- from 0,1 to 0,2 m:	16,2	21,3
Soil hardness, MPa, in layers		
- from 0 to 0,05 m:	0,7	0,2
- over 0,05 to 0,1 m:	1,5	0,6
- from 0,1 to 0,2 m:	2,2	1,2
The crumbling of the soil fractions, %		
- more than 0.0005 m:	41,2	16,4
- 0,025-0,030 m:	18,9	21,2
- 0,010-0,025 m:	13,6	20,9
- 0,004-0,011 m:	11,5	17,3
- 0,0015-0,004 m:	7,7	16,6
Content erosion dangerous particles, %:	7,1	7,6
Removal of weeds in the tree trunks, %:	-	87,9

As a result of double execution of the technological operation of hydraulic removal of weeds in the forest zone when using the adaptation system, the percentage of weeds does not

exceed 87,9%. After the passage of the unit with the initial surface coverage with weeds of 92%, only 16% of the green mass remains. With a double passage of the unit, the intact root system of weeds remained on the area of 8%.

4 Conclusions

Evaluation of hardness, moisture and soil crumbling in the stalk zone before and after the technological operation showed that the device meets the requirements of the technological operation of removing weeds in the areas near the trunk fruit trees without using any herbicides and has high technological indices. The developed algorithm and the control program of the working bodies ensure the automatic adaptation of the spray head to the agrotechnological parameters of plants and the adjustment of the operating modes of the device.

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