FIELD TESTS OF AN AUTONOMOUS FIELD ROBOT FOR WIDE-ROW CULTIVATION

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Abstract: *In Industrial Institute of Agriculture Engineering (Poznań, Poland), together with the Institute of Vehicle of Warsaw Technical University and firm Promar Poznań action have been taken to design autonomous field robot for sowing and cultivation of crops. Designed robot is to be autonomous device. It will automatically perform the sowing, weeding and selective spraying plant crops such as sugar beet or maize. The robot will work in various terrain and weather conditions. It will move on the dirt roads and on cultivated fields, and therefore it will have to overcome mud, sand, puddles and avoid obstacles such as ruts, bumps in the road and stones. The achievement of this objective required the development of a suitable chassis, system of autonomous control in terms of driving and realization of agronomic processes.*
KEYWORDS*: FIELD TESTS, AUTONOMOUS ROBOT*

1. Introduction

Care for the natural environment and health benefits of crops and the growing interest of consumers in tasty food encourage farmers to look for ecological agricultural production technologies. The threat to the environment and the quality of agricultural produce is primarily the excessive use of herbicides. The need to maintain high yields and low production costs requires alternative methods of plant protection against excessive weed infestation. A simple and effective method of destroying weeds is their mechanical removal. It should be remembered that weeds are competition for arable crops and the longer they occur in the plantation, the greater the losses they cause in the crop. Manual weeding e.g. on large plantations sugar beets, due to the high cost of labor and the problem of employing a sufficient number of employees to perform the work at the required time, effectively discourages growers from ecological farming.

For mechanical removal of weeds hoes with tools passive, active or a combination of them are used These machines are aggregated with an agricultural tractor and can be equipped with automatic guidance systems for working elements. Usually, they allow you to remove weeds only from inter-row surfaces. More advanced cultivars, called intelligent ones, locate desired plants using GPS signals (using knowledge of the position of sown seeds) or image processing systems. These are solutions in the testing phase, with limited use. Problems occur with obtaining the required accuracy of the location based on the GPS system, especially since the sowing and weeding operations are performed in separate operations often by various tool carriers. Location systems based on image analysis are unreliable with big weed infestation, which may occur, for example, at delayed emergence, as well as due to bad weather conditions that prevent entry of the tractor on the subsoil at the required time. The solution to these and similar problems can be find by application of a common tool carrier in the form of an autonomous field robot. Its construction (power demand, stability, maneuverability, way of hanging the tools) should be adapted to various field treatments. An important requirement is also that it is a light machine, with good traction properties, causing low soil degradation and capable of performing operations in difficult terrain conditions (Fig. 1).

The introduction to the widespread use in agriculture, horticulture and forest nurseries of autonomous field robots may be a breakthrough in the current approach to large-scale crops, where this type of production could not do without the use of herbicides. The possibility of using autonomous field robots will increase the availability of organic food products and should lower their prices.

2. The concept of the designed robot

At the Industrial Institute of Agricultural Engineering in Poznań, in cooperation with the Institute of Vehicles of the Faculty of Automobiles and Working Machines of the Warsaw University of Technology and with PROMAR Sp. z o.o. (*private limited companies*). An attempt was made to develop an autonomous field robot for sowing and cultivating plants.

Three types of systems implemented in this type of machines can be distinguished: driver assistants, automatic control and autonomous, unmanned machines. The last type assumes the possibility of working without an operator (possible supervision). A device with these features must meet a number of requirements and perform several basic work modes, such as: task initiation (mission), task calibration, path planning, track tracking, observing and waiting, avoiding obstacles, detecting mission errors / interrupting missions, ending missions. Some of these tasks are deterministic (e.g. planning and tracking the path), while the part is completely reactionary (avoiding obstacles). The essence of the implementation of individual modes is the appropriate algorithm, while the key information for him is the appropriate measurement.

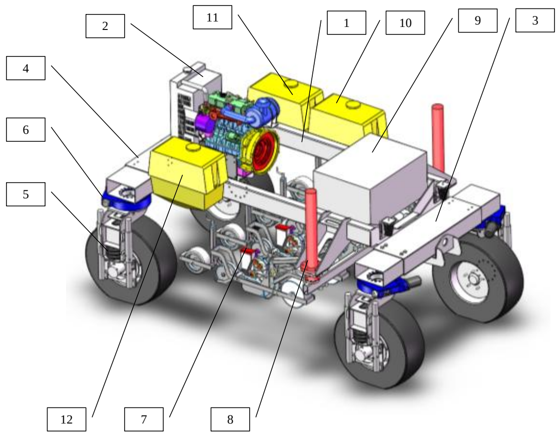

Fig.1. *Geometric structure of the initial robot model*
1 - supporting frame of the traveling platform; 2 - diesel engine; 3, 4 - suspension axle beams; 5 - running wheel assembly; 6 - turntable; 7 - tools (point seeder / active cultivator / sprayer); 8 - system of lifting the tools; 9 - oil tank; 10 - fuel tank, 11, 12 - sprayer tanks

The robot conception used in the project assumes building a device with the highest level of autonomy. The robot will automatically perform sowing, weeding and selective spraying of crop plants such as sugar beets or corn. The robot will operate in various field and weather conditions. It will move across field roads and arable fields, so it will have to overcome mud, sand, puddles and avoid obstacles such as ruts, road unevenness and stones. Achieving this assumption required the development of an appropriate chassis, control system and algorithms of autonomous control in the field of traction and execution of agro-technical processes.

It was assumed that the robot will have a modular construction [1]:

- carrier

The basic module is a stand-alone carrier cooperating with specialized modules. The carrier will be 4 wheeled vehicle, able to work remotely and autonomous. The drive wheels provide hydraulic motors and planetary gears. This way of transfer of power will get the high ground clearance of the machine (free space for tools) and independent suspension - important when working in difficult terrain. In addition, the speed differentiation of individual wheels and their appropriate setting will result in high maneuverability.

- sprayer

Sprayer will be able to realize during the sowing or weeding dosage of liquid fertilizer or other liquid preparations of plant protection. The application will be executed surfactants (for plants or soil), or to the soil (of the depth below the surface of soil) in a continuous or selective based on the optical identification and location of objects.

– seeder

For precision seeding seeder will be applied with the seed position recording system in the field.

- hoe

The main working unit will be active hoe robot for precise control of weeds in both the inter-rows and row crops.

Particularly noteworthy is a comprehensive approach to the mechanization of wide row crops, including the use of a common autonomous tool carrier for the execution of sowing procedures and the mechanical destruction of weeds, assisted if necessary by the selective use of liquid plant protection products and fertilizers.

Essential part of robot is its control system [2]. The main sensor system is based on a specialized GPS receiver that provides position information with an accuracy of less than 100 mm. This system is mainly used to guide the robot along a designated path, and also (in cooperation with the vision system) for precise sowing - accurate seed location information will be used to build seed maps that will be used as auxiliary information for precise weeding and spraying. The view from the front camera will be used to increase the accuracy of the robot positioning. This will allow you to improve the path accuracy of the robot relative to the rows of plants. The vision system will also be used to detect stationary objects (Fig. 2). At the same time, the second vision unit will also be used to acquire images from the camera directly in front of the active hoe and sprayer. Additional information from acceleration sensors and encoders embedded in the wheels will also be used for navigation purposes. To determine the angular acceleration, the IMU (Inerial Measurement Unit) will be required. This will enable:

- correction of the robot's trajectory,
- precise work of an active hoe,
- position adjustment and precise dosing of fertilizers or plant protection products by the sprayer.

The diagram of the robot drive control system is shown in Fig. 3.

3. Field research of the robot's test model

After the test model of the mechanical structure of the robot was built, tests of its motion properties were carried out. The robot was then equipped with executive elements, including tools for performing agrotechnical works [3], but algorithms of autonomous control were not yet launched. The robot was controlled manually using a special panel and manipulators (Fig. 4). Status of the robot was visible on a special interface (Fig. 5).

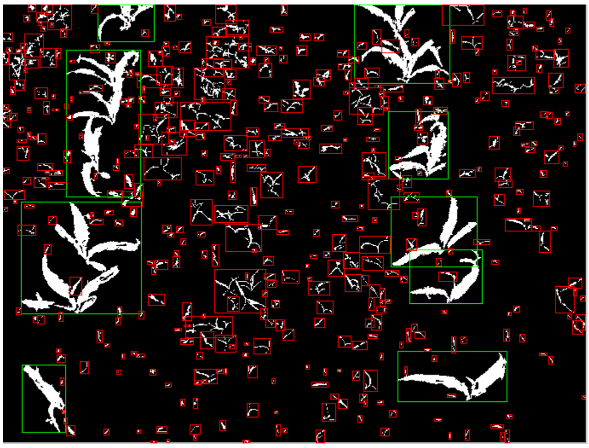

Fig. 2. Tests of the system distinguishing crop plants from weeds

In order to check the correctness of selected solutions and introduce any corrections:

A) Operating loads occurring under different operating conditions of the robot have been determined.

B) The hydraulic robot system has been tested. Pressure was measured in selected elements of the hydraulic system, including hydraulic motors driving individual wheels, during maneuvers in various operating conditions of the robot work.

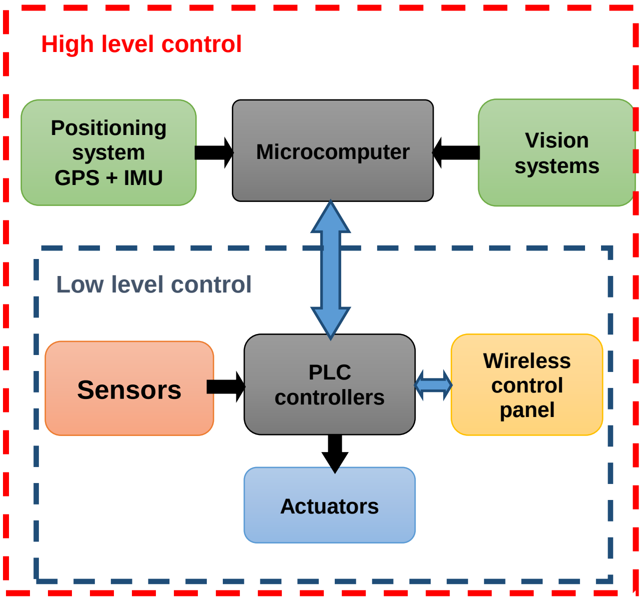

Fig. 3. Diagram of robot driving control system

Fig. 4. The panel used for manual robot control during field tests

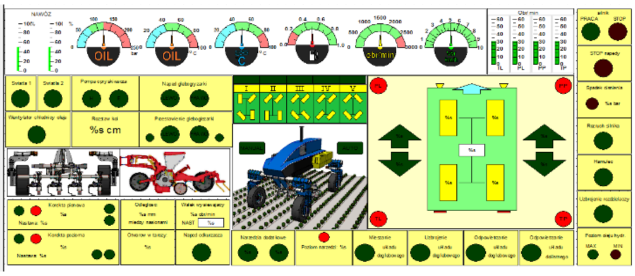

Fig. 5. *User interface used during robot tests*

C) Field tests of the robot's driving properties have been carried out (stability and drivability and the possibility of overcoming obstacles). The way of moving the vehicle with various configuration of driving wheels and for various configuration of the cornering method was checked.

D) Driveability of the field robot's work in terms of communication range, machine reaction and control quality has been checked. The correctness of the wheel control algorithms and the force with which the wheels of the field robot's platform interact on the ground have been checked.

E) Limit situations were determined for the robot's control system under various operating conditions (various types of ground and different speeds) in the range of obstacles, turns and turns (Fig. 6). During the tests on various types of ground (cultivated field and non-arable field), maneuvers of the running gear were tested for different speed settings. The possibility of moving during difficult conditions was also tested, where the robot's wheels went deep enough to prevent normal operation.

F) Introductory laboratory and field tests of the work of the tool modules were carried out. The sowing, weeding and spraying processes were tested.

4. Sample results and discussion

This section presents sample results obtained during robot field tests.

The figure 7 shows the behavior of the control system and the actuation system when robot is starting off. The characteristics show the start-up of the vehicle along with the gradual increase of the speed to the maximum and next rapid shutdown of the drives.

Fig.6. *Field tests of the robot in various operating conditions (various types of ground and different speeds)*

At start-up, you can see incorrect supply of current signal to feed pumps (A). This behavior was caused by deliberate tuning of the controllers in the controller for research purposes. The drive pump (hydraulic motors) on right side received working setting about 2 s faster. Due to the initiation of start only one of the parties, the pressure in the engines increased dramatically (B). After starting the second pump, the pressure dropped and began to stabilize at a set level. At increasing the speed to the maximum, pressure remained at a similar level. Interesting is the period when the vehicle moved at maximum speed and encountered harder working conditions, which caused rapid pressure jumps and speed reducing (11:03:40 - 11:03:45). The last fragment of the diagram shows the braking of the machine. After switching off the settings, the pressure on the pumps and motors increases temporarily due to the closing of the valves.

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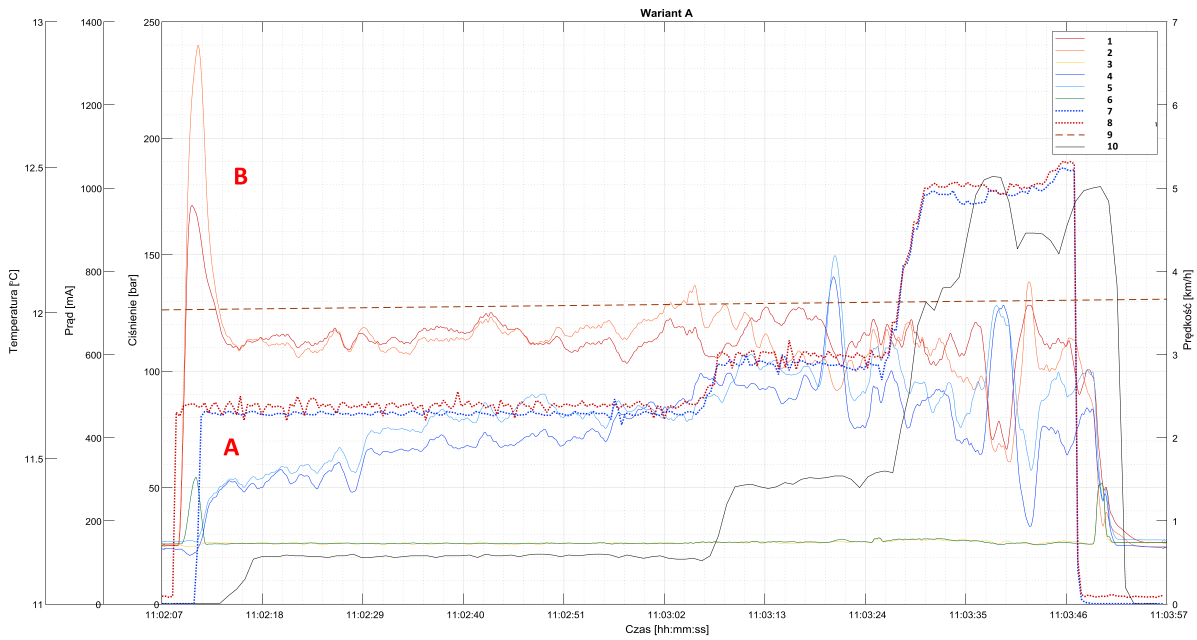

Fig. 7. *The working parameters of the robot during acceleration in a straight line*

1 - pressure in the right front wheel motor [bar]; 2 - pressure in the right rear wheel motor [bar]; 3 - pressure on the right side motor output; 4 - pressure in the left rear wheel motor [bar]; 5 - pressure in the left front wheel motor [bar]; 6 - pressure on the left side motor output [bar]; 7 - left wheels drive current [mA]; 8 - right wheels drive current [mA]; 9 – temperature [°C]; 10 – robot velocity km h^{-1}]

5. Conclusions

The carried out research allowed to remove defects occurring in the robot's structure, e.g. rebuilt the cover of the hoe working in inter-rows, in order to enable proper copying of the area. Also there was modified the hydraulic system, in which there was a harmful difference of pressure on both sides of the robot.

The general course of the tests, however, confirmed the correctness of the adopted structural solutions in the area covered by the tests.

Currently, the next cycle of research on robot work in the autonomous mode is being conducted. The subject of the research and tests are primarily robot control algorithms in the field of intelligent control of working tools and independent moving of the robot through the field.

6. References

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