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ABOUT A TEST BENCH FOR SIMULATING THE ROAD CONDITIONS OF A WHEELED AGRICULTURAL ROBOT[17]

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Abstract: *As the agricultural robot moves, it encounters various obstacles, accelerates and slows down its move. All the while, he carries on his structure a variety of equipment with which he works in the field. In the operation of the wheeled robot itself with the equipment or in the operation of this equipment, as well as during its movement to the working field, it is subjected to significant dynamic forces. The construction of the wheeled agricultural robot must be able to withstand high amplitude stochastic loads.*

This article aims to show the main moments in a test bench for the stability of the agricultural robot in laboratory conditions. With the help of specialized equipment, it will be possible to simulate the overcoming of various road obstacles related to the inclination of the robot. A road map has been created, simulating the movement of the robot and overcoming various obstacles and stopping the machine. In the bench there is a possibility to change the road surface and hence to change the coefficient of friction of the tires with the road.

Keywords: *stand; simulations; agricultural robot; road conditions; coefficient of friction.*

INTRODUCTION

Agricultural robots are autonomous machines that aim to operate in unattractive conditions (Hu, K., 2021; Kounalakis, T., 2016; Rusev, R., 2016; Chung, W., 2016; Ivanov, R., 2010). No matter what operations it performs, it carries a variety of equipment, often costly (Kounalakis, T., 2016; Rusev, R., 2016).

Agricultural robots are designed to work on a surface without a road surface, often with a different coefficient of adhesion. In this movement, it is possible that forces will appear to try to tilt it and there may be poor safety for the expensive equipment and for it (Ivanov, R., 2010). Apart from this, vibrations may occur that are particularly harmful to the machine and can lead to the destruction of structural elements (Reddy, N., 2016).

In a number of cases, the stability of the machine is affected by road conditions and suspension system (Jin, Y., 2021; Qu, Z., 2023; Reddy, N., 2016; Vasconcelos, G., 2023). Unlike cars and tractors, the suspension of agricultural robots is quite different. This difference originates from the way of aggregation with the working machine and the possibility of simplifying the

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construction (Reddy, N., 2016). Modern equipment for agricultural robots differs significantly from standard agricultural machines (Li, S., 2020).

In modern industry producing self-propelled machines, the force applied to much of the work piece is usually not in the same direction or angle. Specifically, some parts usually have to withstand large and complex stress conditions. However, there are also very complex movements of rotation and even rocking and linear movement. On the other hand, the absolute value of this load is not large (Gao, Z., 2021).

Prevention is the creation of specialized systems in which it is possible to continuously test these agricultural robots in the laboratory and only after tests to be put into operation (Andrzej, G., 2016; Gao, Z., 2021).

EXPOSITION

This paper aims to present constructively the technological features of a rig for simulation of road conditions in the movement of designed agricultural robots. Design performed with the CATIA V5 development environment. The fabrication and installation were carried out under the conditions of the Agricultural University – Plovdiv. The software provisioning of the program was done with the Scilab product.

On the bench, it is possible to test various robots used in agriculture with a wheel formula 4k2, 4k4 or tracked chassis.

The paper presents the main points and requirements in the design of the rig for simulating road conditions. The design stage begins with the idea of the rig namely laboratory testing of the resistance of agricultural robots. The next stage is the creation of the kinematic scheme and design documentation of the fabrication. The installation and features of the structural elements, the development of a block diagram of the control algorithm and the creation of a control program follows this.

The kinematic scheme of the developed stand is shown in Fig. 1.

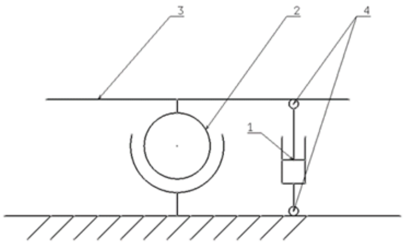

Fig. 1. Kinematic scheme of the road conditions simulation bench
1-executive unit; 2,4-hinged connections; 3-desktop.

The worktop is connected to the pivot connection 2, giving support with the foundation. To simulate road conditions – rough terrain, slopes, etc. The actuator 1 is connected to the system. Changing the position of this actuator by changing the angle and setting the inclination of the system is compensated in its hinged attachment to the countertop and to the foundation.

The general appearance of the stand (Fig. 2) for simulating the road conditions of agricultural robots was realized at the Department of Mechanization of Agriculture at the Agricultural University – Plovdiv, Bulgaria.

Fig. 2. General appearance of a stand for simulating the road conditions of an agricultural robot

By means of the bench, different road conditions of movement of the machine can be simulated. The machine under test is placed on top of the bench by means of a lifting device. The static longitudinal and transverse resistance of the machine, the maximum sliding angles of the machine on different road surfaces can be tested on the bench. Changing the road surfaces is possible by placing it on the desktop. Individual elements of the robot's suspension can still be tested with the bench through a pre-designed training program. With the help of the bench, the running qualities of the designed agricultural robots can be tested in the laboratory. To report the results, it is necessary to use separate equipment.

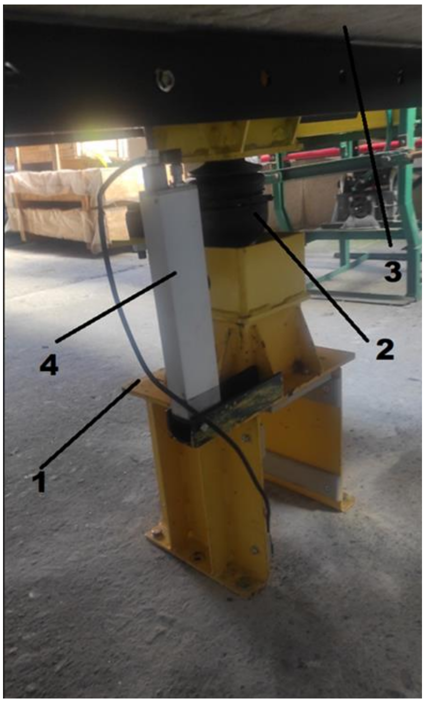

Fig. 3. Bottom view of a rig to simulate the road conditions of an agricultural robot
1-hull; 2-hinge; 3-desktop; 4-line motor

When working with the bench, a maximum angle of deviation of the worktop is generated in the transverse direction of 300, and in the longitudinal direction, this deviation is within 500 of the horizontal planes. The hinged joint is placed in the centre of the desktop and allows the deviation of the above angles.

The worktop gauge is 2000 x 1450 mm. At these dimensions, it is possible to test almost all autonomous working machines. The design of the rig is universal and allows testing both wheeled robots system 4x4 or 4x2 and crawler robots with certain limitations. There are limitations only in the mass of the machine, as they are introduced by the capabilities of the actuators. The dimensions of the desktop are tailored to the specifics of agricultural robots. Most of them work in beds with a width of 0.7-1.0 m. It is necessary that the robot's chassis is located in the inter rows so that the tines are on the bed.

In Fig. 3 the view from below of the rig is given. The rig itself consists of hull 1, which is mounted on a stable concrete site in an indoor hall. It consists of two parts and allows easy disassembly of the bench for prevention. On the upper detachable part of the housing is mounted the hinged connection 2.

The other end of the hinge is fastened to the worktop. The worktop is made of OSB board of appropriate thickness, mounted in a metal frame. The framework has two functions. One function is to create connections – hinge-top, countertop-linear motors. The other function is to create a frame in which different soil conditions can be simulated – soil, sand, wood and other cover with different coefficient of adhesion.

Apart from this, in the metal frame there are also special ears through which the robot is fixed when testing changing dynamic cycles and testing the resistance of the machine. The up-down movement, the change or deviation of the desktop from a horizontal plane is carried out by the linear motor 4. It is also the executive unit of the system. It is installed between the worktop and the housing by special profiles and hinged fastening at both ends. For the normal operation of the bench, two linear motors are needed.

The linear motors used have built-in sensors that detect the change of movement on the axis by changing the resistance in the measuring circuit. They must have the following characteristics:

Operating voltage 13,8 V;

Consumed current 2,5A;

Generated force 1000 N;

Potentiometer resistance variation 0.5-5.2 kΩ;

Signal variation 0.45-4.55 V;

The application of a linear motor instead of a hydraulic cylinder for an executive unit in the rig is because the output results faster and more precisely the desired value of the specified deviation of the particular executive unit. The lack of a hydraulic system, hoses and distributors greatly simplifies the system, but makes it dependent on the lifting force of the linear motors. The work cycle along which the change is made is quite simple and the commands are quickly transmitted to the executive element.

For communication between the linear motor and the control algorithm, a DAQ device of National Instruments USB 6001 was used. The general appearance of the controller used is given in Fig. 4.

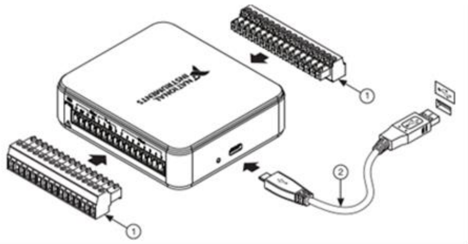

Fig. 4. General type of controller USB 6001
1-mounting adapters; 2-USB connection to computer

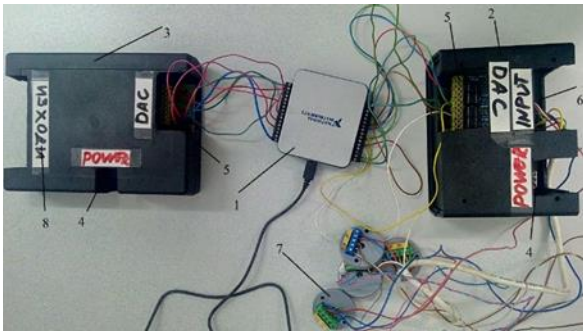

Fig. 5. General appearance of the power modules used
1-controller USB 6001; 2-input module; 3-output module; 4-power supply; 5-connections with the controller; 6-inputs from the position sensors on the axis of the linear motor; 7-transmitters; 8-outputs for connection to the linear motors

The controller used possesses eight analogue inputs, two analogue outputs and thirteen digital pins operating as inputs or outputs. The controller does not have a processor performing logical operations, so the use of a suitable computer is imperative. The computer must have appropriate software on which to set the logical elements and write the program on which the bench will work. Suitable software can be LabVIEW, Matlab or Scilab. In this paper, the XCon module of the Scilab product has been used.

The functions of the controller itself are limited and it does not have a power module to it, so the use of such is again mandatory. A wide range of such modules are available in the store network, but in this paper designed ones shown in Fig. 5. The application of such modules, in addition to protecting the controller from overloading the output, it also protects it from short circuit at the input. The modules used are two – one for input 2 and the other for output 3. An autonomous

220 V power supply is provided for the operation of the modules. The signal from the position sensors on the axis of the linear motor is fed to the transmitters 7. They serve to amplify the signal from the sensors. The other end of the transmitters is fed to the connector 6 of the input module. It is only control of analogue inputs. The connections between the USB 6001 controller and the modules were made by the connectors 5.

The control signals produced by the software are fed to the digital outputs 8. As mentioned above, the connection to the control computer is made via USB.

The block diagram of the logical work of the rig for simulating the road conditions in agricultural robot testing is given in Fig. 6. As mentioned, many times, the use of two linear motors is necessary for the operation of the stand. The control circuit detects signals from two sensors and generates control signals for two motors. Sensor signals are fed to the "Analog inputs" of the "USB 6001" controller. After the extraction of the pulse, it is necessary to transform it into a physical quantity, namely distance. This distance can be read with a direct axis length, with a deviation from the forward state or with a deviating corner of the desktop. The transformation of the change of the sensor resistance into dimensions is carried out by the element "Evaluating position. The already obtained linear value of parameter change is necessary to compare with the values preset for the given position. The comparison is done by the logical element "Check". The blocks are two, because the comparison is done for each motor separately. The logical element is given with two inputs to illustrate the dynamics of change of the values the boundary deviations. The limit values for comparison are supplied by the module "Line from program cycle", from where an exact deviation position is required. The module reads the current line for executing the preset program from the "Program cycle" block. There are stored different algorithms of different test cycles of the sustainability of the agricultural robot. The block is a kind of database for different training cycles.

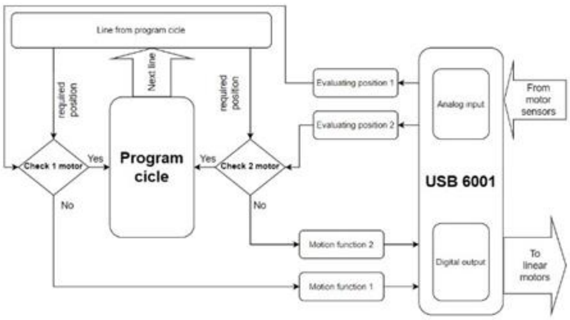

Fig. 6. Block diagram of the logical operation of the rig for simulating road conditions when testing agricultural robots

After performing the logical check of the correspondence of the set deviation of the linear motor with the measured and transformed value of its sensor, two outputs are possible. When the values from the two comparisons are matched, a signal is given to move to the next line of execution of the training cycle. In case of non-match of values, a signal is generated for another block that must decide how much to change the value of the control signal to the motors.

In case of non-compliance, one of the checks shall be re-examined through the whole procedure until two positive alerts are received from the checks.

The frequency of the checks performed, the speed of the deviation of the linear motors or the passage through the next line of the training cycle are individual and are related to the type of test itself, the creation of the program code of execution of the program and the way of reporting the results. It is also necessary to provide time for stabilization of movement with consideration of the frequency of oscillation of the mechanical system and the clearances in it.

That is why, taking into account all these variables, the code of the program is strictly individual.

CONCLUSION

A rig for simulating road conditions in agricultural robot testing has been designed and constructed. The stand is universal and takes into account the overall dimensions of various wheeled or crawler agricultural robots.

Different road conditions can be simulated with the constructed stand – soil, sand, etc. with a different coefficient of adhesion.

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