DEVELOPMENT OF MECHATRONIC MODULE FOR THE SEEDING CONTROL SYSTEM

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РОЗРОБКА МЕХАТРОННОГО МОДУЛЯ ДЛЯ СИСТЕМИ УПРАВЛІННЯ ВИСІВОМ

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ABSTRACT

Existing control systems of sowing machines are intricate and not reliable enough. In these systems, devices are connected by a variety of signal and power wires. This leads to a "problem of interfaces" and a decrease in the efficiency of the control process. The solution to this problem is based on the mechatronic approach or combining elements and control units into mechatronic modules. They are characterized by reliability, compact design and lower cost. The improvement of functional and structural integration of the control system components by their integration into the mechatronic module is considered. The module of regulation of seeding rate on the basis of software and hardware platform Arduino is developed. The work of the proposed control system when changing the seeding rate in the seeding system is studied.

АНОТАЦІЯ

Існуючі системи управління роботою посівних машин складні і недостатньо надійні. В цих системах пристрої з'єднуються безліччю сигнальних і силових проводів. Це призводить до «проблеми інтерфейсів» і зниження ефективності процесу управління. Рішення даної проблеми засноване на мехатронному підході, або на об'єднанні елементів і блоків системи управління в мехатронні модулі. Вони характеризуються надійністю, компактністю, меншою вартістю. Розглянуто поліпшення функціонально-структурної інтеграції компонентів системи управління їх об'єднанням в мехатронний модуль. Розроблено модуль регулювання норми висіву на основі програмно-апаратної платформи Arduino. Досліджено роботу запропонованої системи управління при зміні норми висіву у висівній системі.

INTRODUCTION

The structural complexity of the system is determined by the number of elements and the intensity of the links between them. Analysis of existing automation and control systems (*Boyko A. I., Sviren M. O., 2006; Parkhomenko Yu.M. et. al., 2014; Sivak I. M., 2012; Aniskevich L. V., Popovich A. N., 2014*) establish that numerous interfaces connect devices of different physical nature (mechanical, electronic and informational). This determines the design and hardware-software complexity of the systems. In the traditional design of control systems for communication devices there is the need to connect dozens of signal and power wires. Experience of such systems' operation shows that up to 70% of the problems in their work are associated with unreliable connections. This is a wire break and poor contact in the connections, which causes failures and false positives (*Poduraev Yu.V., 2006*). An example of a traditional system is a block diagram of seeding control (Fig. 1) (*Boyko A. I., Sviren M. O., 2006*). It is implemented on traditional electric and hydraulic actuators with program control and includes the following elements:

– coordinate sensor with global positioning system (GPS) antenna to obtain information about the location of the machine in the field;

– on-Board computer to regulate the seeding rate based on the information about the place of the machine and the given seeding rate;

– matching device - information-electrical Converter that implements the transmission of the control signal from the computer to the power actuator;

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–force actuator (electric motor driven), which performs electromechanical conversion, to control the operation of the seeding system;

– a device that implements a given control movement or working body that interacts with external objects — seeding system of seeder;

–feedback device. It is a seeding control sensor that gives information about the intensity of the seed flow;
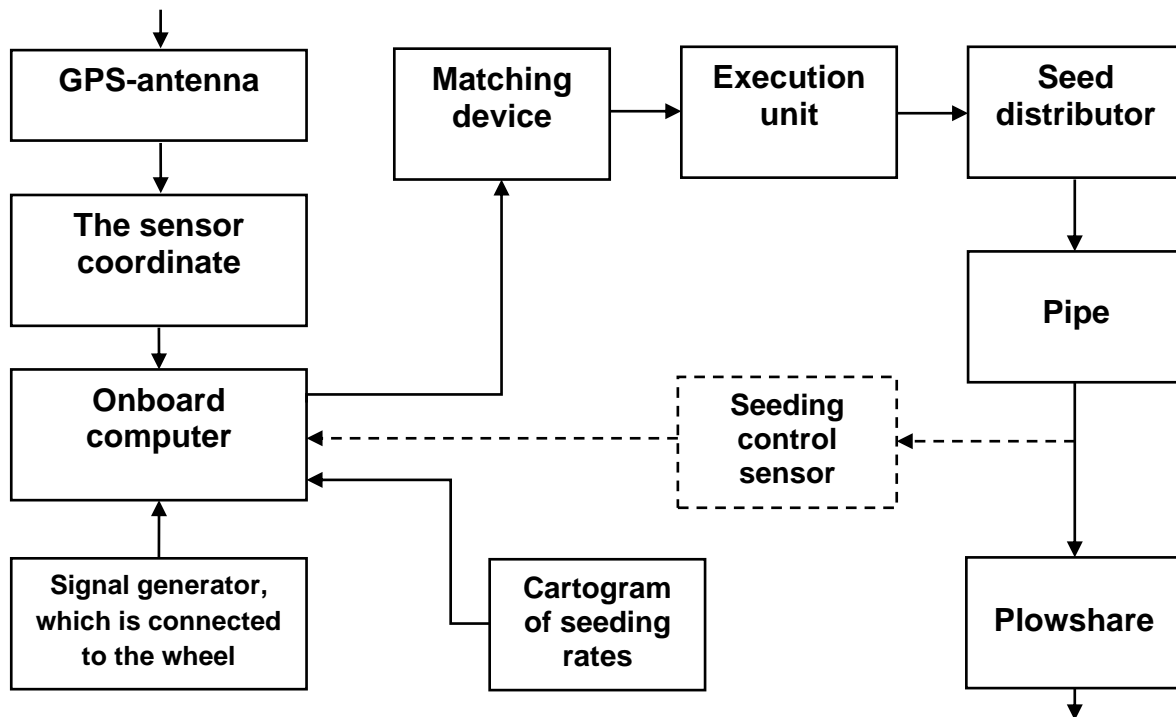
–interface devices, indicated in Fig. 1 by the arrows.

Fig. 1 – Structural model of the traditional system of sowing control

In the process of analyzing the model in Fig.1 by Poduraev's method *(Poduraev Yu. V., 2006)* it is established that there are six functional transformations in it: informational, mechanical, information-electrical, electromechanical, as well as electro-informational and mechanical-informational in feedback circuits (*Aulin V. V. et. al., 2017*). This complicates the seeding control system and reduces the reliability of its operation.

Currently, there is a trend of development of controls based on a new, mechatronic approach (*Teryaev E. D. et. al. In 2009; Antoshenkov R. V., Kovalev R. Yu., 2011*). Its essence is to combine elements and components into integrated modules, which solves the "problem of interfaces". The structural complexity of the control systems is reduced and their efficiency is increased.

The advantage of mechatronic modules (MM) consists in reliability, accuracy of movements, compactness of structures and ease of programming. Such solutions are cost-effective, as the service of the machine is simplified and its suitability for repair is improved (*Poduraev Yu.V., 2006; Aulin V., Hrinkiv A. et. al., 2018*). In (*Kosik P. O., 2009; Pastukhov V. I. et. al., 2015; Antoshenkov R. V., Kovalev R. Yu., 2011*) shows the advantages of mechatronic approach due to the durability, speed and almost trouble-free operation of mechatronic modules.

A feature of the modern stage of mechatronics development is the creation of a new generation of mechatronic modules - intelligent mechatronic modules (IMM). In comparison with the existing mechatronic modules, computer devices and power electronic converters are additionally integrated into the design of the IMM. This allows the IMM to perform manipulations on its own, without having to access the upper level of control.

The implementation of the hardware and software part of the IMM should be based on structural solutions that are open to development and have a hierarchical structure (*Poduraev Yu.V., 2006; Aulin V., Arifa W. et. al., 2016; Aulin V., Lyashuk O. et. al., 2018*). Arduino is a tool for developing devices that interact with the physical environment.

It is an open hardware and software platform for working with physical objects. Arduino is a Board with microcontroller and development environment to create software. The platform has built-in elements for programming and integration with other devices and circuits.

Therefore, the Arduino platform is the basis for research in the field of mechatronics (Omelchenko *E. Ya. et. al., 2013*). Arduino simplifies the work with microcontrollers and provides the following advantages: low cost, cross-platform, the use of additional modules for automation, control and control of various physical processes and functions.

The aim of the research is to develop and test a seeding control system with a minimum number of structural elements combined in the mechatronic module.

Research problem:

– to analyse functional and structural schemes of seeding control systems;

– on the basis of mechatronic approach, combining structural blocks and reducing the number of interfaces to develop a new seed control system;

– to select the hardware and software platform for the new seeding control system;

– to test the developed control system of seeding.

MATERIALS AND METHODS

Study of control system with mechatronic module for the sowing system with fluidics elements, proposed by *Pankov A. A. et. al. (Pankov A.A. et. al., 2016)* and *Aulin V.V. et. al., (Aulin V.V. et. al., 2017)* was carried out at the stand, which includes the devices and equipment presented in Fig. 2.
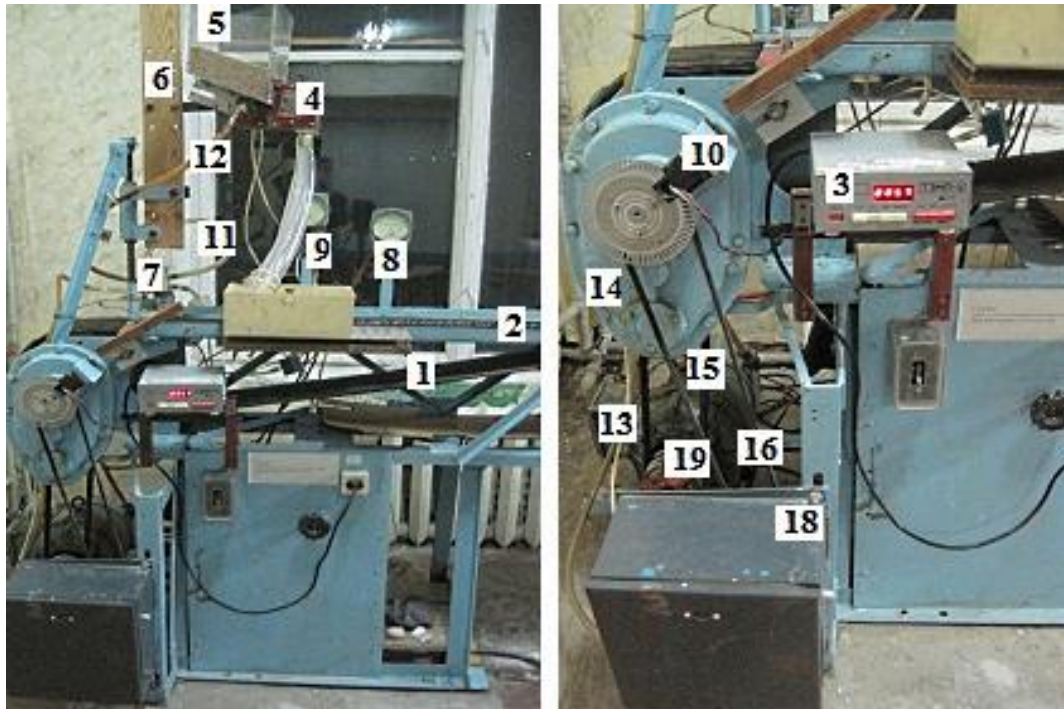

Fig. 2 – General view of the test bench:
1 – conveyor with a length of 6.5 m and a width of 0.2 m; 2 – dimensional grid; 3 – pulse recorder TEMP-4 (measurement error ± 1,0%);
4 – sowing system; 5 – hopper; 6 – tripod; 7 – switch; 8, 9 – pressure measuring devices; 10 – photo sensor; 11, 12 – air ducts;
13 – signal tube; 14 – gearbox; 15, 16 – belt drive; 17 – valve; 18 – control unit with developed mechatronic module;
19 – DC motor P-21, power 1.5 kW.

Seeding rate depends on the number of pneumatic pulses supplied to the seeding machine. The number of pulses is set by the computing device of the mechatronic module in the control unit *18*. The control unit *18* is connected to the shaft of the reducer *14* by a belt drive *16*. The control unit *18* includes: perforated disc, speed sensor, jet elements, pneumatic pulse delay line (*Pankov A. A. et. al., 2016; Aulin V. V. et. al., 2016*). When the conveyor belt moves *1* rotation is transmitted to the perforated disk in the control unit. The perforated disc speed sensor generates pneumatic pulses. Then the pneumatic pulses through the signal tube *13* through the switch *7* enter the sowing system *4*. The air pressure in the pneumatic sowing system 4 is measured by devices *8* and *9*.

Bench tests of the developed control system with mechatronic module are to determine the seeding rate when the servo motor is rotated by an angle corresponding to the location of the pneumatic switch nozzles (Fig. 5). From the vertical (neutral) position, the servo motor rotates at fixed angles (30, 90, 150, 210, 2800). This changes the number of supplied pneumatic pulses and seeding rate in the seeding system.

The experiment begins with the installation of the required seeding rate. Conveyor drive is switched on; its belt begins to move. The seeding system starts and seeding is performed on the moving belt. After sowing the seeds on the tape length section, the seed supply stops.

To determine the number of pneumatic pulses, pulse recorder *3* is used. To find the mass of seeds sown per meter of movement (seeding rate), the sown seeds were collected from the conveyor *1* and weighed. According to the results of measurements, graphical dependences were built.

RESULTS AND DISCUSSION

The purpose of the control system integration elements is the exclusion of intermediate interfaces. In the original model (Fig. 1) structural blocks are combined and interfaces are excluded. This preserves the functional transformation performed by the resulting mechatronic module.

Therefore, the traditional structural model (Fig. 1) it is proposed to replace the improved structural model of seeding control with a mechatronic module (Fig. 3). The developed mechatronic module is more compact and assembled from common elements and assemblies, which reduces its cost.
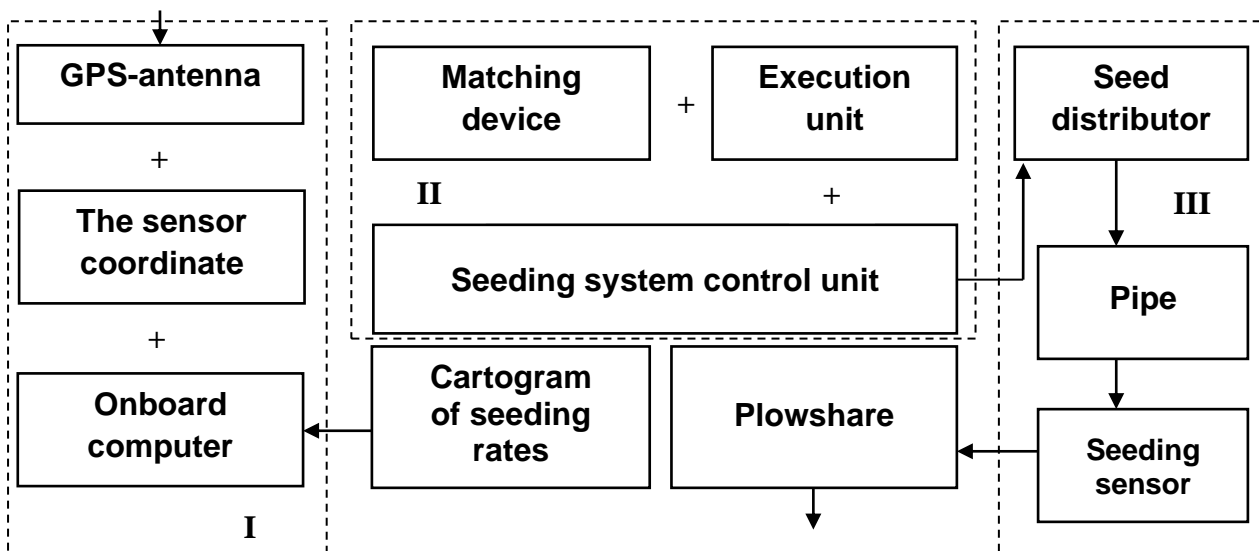

**Fig. 3 – The structural model with the mechatronic control module sowing
for seeding apparatus and devices with fluidic elements:**
I – calculator; II – mechatronic module; III – sowing system

In the structural model with mechatronic module, the coordinate sensor with the GPS antenna and the on-Board computer are combined in one module – a smartphone or a tablet. The matching device and the executive device when combined form a mechatronic module. It is located in the control unit 18 of the seeding system (Fig. 2). The sensor of the seeding control is the wired interface which transmits the data via wireless communication. The total number of interfaces is reduced.

Compare the model with the mechatronic module (Fig. 3) and the traditional model (Fig. 1). It can be concluded that the number of blocks and interfaces in the traditional model is greater than in the developed model. Therefore, there is a structural redundancy of the system in Fig. 1.

Proposed in Fig. 3, the model with mechatronic module contains two information inputs (program of work and information feedback) and one output - impact on the sowing system. Therefore, the structural model with mechatronic module (Fig. 3) can be built as an information-pneumatic-mechanical Converter or intelligent mechatronic module. In it, functional transformations are concentrated in a single structural element (Fig. 4).
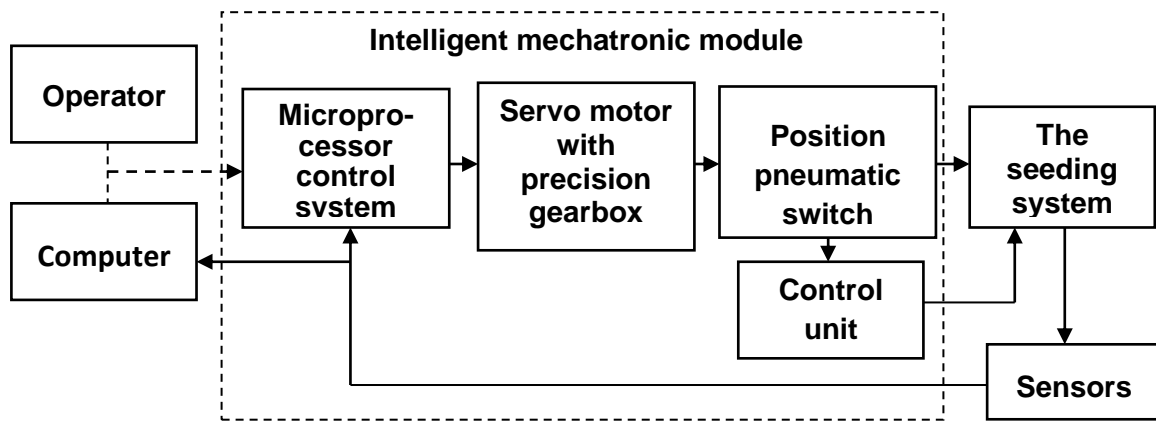
Fig. 4 - Block diagram of intelligent mechatronic module

Based on the diagram (Fig. 4), obtained as a result of functional and structural analysis and application of the hardware platform Arduino, a schematic diagram of the hardware-software complex regulation of the seeding rate (HSC RSR) with mechatronic module (Fig. 5) was developed.
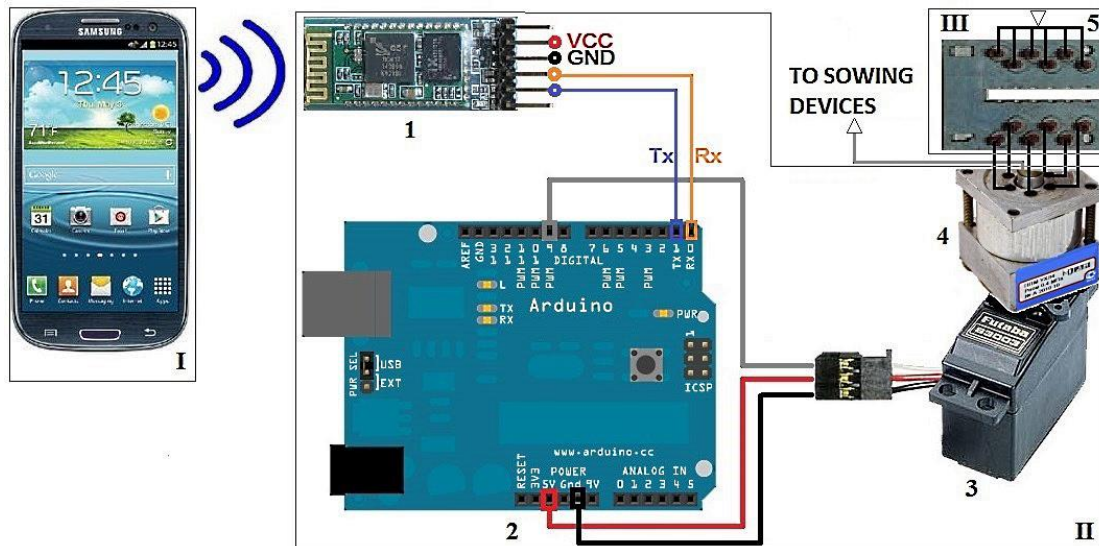

Fig. 5. – Schematic diagram of HSC RSR:
I – computer; II – mechatronic module; III – control unit of the sowing system; 1 – bluetooth module;
2 – Arduino platform; 3 – servo motor; 4 – pneumatic multi-position switch;
5 – speed sensor; VCC - plus power; GND - minus power; Tx, Rx – control signals

HSC RSR working. The seeding rate is set in the computing device *I*, transmitted to the bluetooth-module *1* and in the form of a control signal interacts with the program in the memory of Arduino *2*. From the Arduino *2*, the control action is transmitted to the servo motor *3*, which rotates the pneumatic switch *4* at a certain angle. Thus, the corresponding channels of the speed sensor *5* in the control unit III of the sowing system are connected. The number of seeds sown by the devices changes as the frequency of impulses changes. This is how the seeding rate is adjusted.

On the basis of structural and schematic diagrams (Fig. 4 and Fig. 5) the HSC RSR layout with the mechatronic module for the power control operation of the seeding system (Fig. 6), was designed.

The software of the mechatronic module consists of two parts. The first part is the Arduino *5* interaction program (Fig. 6) with actuator (servo 4) and computing device *1*. The second part is the seeding rate management application, which is designed for computing device *1*.

The Arduino interaction program with the servo drive and computing device is created in the Arduino IDE development environment. After debugging, the program is loaded into the Arduino memory to regulate the seeding rate in offline mode.
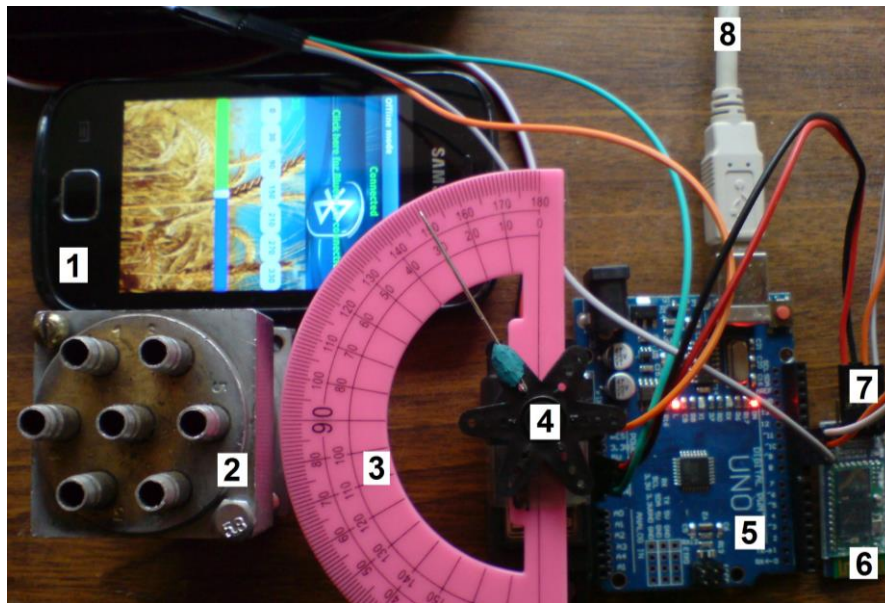
Fig. 6 - Mechatronic module HSC RSR:
1 – computing device (smartphone GT-S5660); 2 – multi-position pneumatic switch (it forms one node
with servo motor, but for clarity shown separately); 3 – protractor; 4 – servo motor Futaba S3003;
5 – Arduino UNO; 6 – bluetooth module HC-0,5; 7 – complete set of connecting cables; 8 – power supply Seekwood

Operator application in the computing device to control the seeding rate was created in the programming environment MIT_app. inventor. After debugging, the application is downloaded and installed on the mobile computing device.

The developed mechatronic module is located in the control unit 18 (Fig. 2). The smartphone controls the position of the servomotor that move the pneumatic switch of the mechatronic module. For this purpose, a special program has been developed and installed on the smartphone. Then the number of pneumatic pulses per meter of the test bench conveyor movement was recorded. The results are presented in table. 1.

Table 1

The number of pneumatic pulses of the control unit of the meter movement

Position belt's on the pulleys drive's control unit *18* (Fig. 2)	Position of multi-position pneumatic switch of mechatronic module					
	1	2	3	4	5	6
1	0.51	1.00	2.05	4.03	5.55	6.08
2	0.61	1.21	2.46	4.82	6.84	7.28
3	0.74	1.46	2.97	5.83	8.03	8.80
4	0.88	1.76	3.56	7.00	9.84	10.56

Depending on the weight of the seeds sown in one pneumatic pulse, it is possible to determine the seeding rate per meter of movement of the machine. The resulting value of the seeding rate is equal to the mass of seeds sown per meter of conveyor length (Fig. 2). The graph of seeding rates for wheat seeds is shown in Fig. 7.
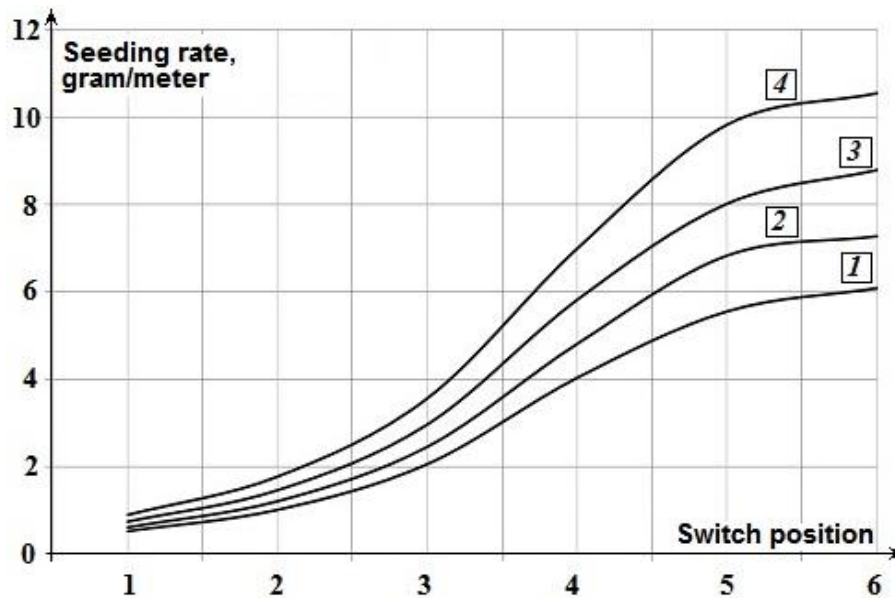
Fig. 7 – Change in wheat seeding rate:
1...4 – position of the timing belt on the pulleys of the drive control unit

According to Fig. 7 it is established that the regulation function of the seeding rate has the form of a cubic dependence. To regulate the seeding rate, it is rational to use a linear portion of the cubic dependence with increased frequencies of pneumatic pulses at the positions of the switch 3...5. This is necessary to improve the uniformity of the distribution of seeds in a row.

CONCLUSIONS

It is established that traditional automation and control systems have an excessive structure. The presence of redundant units and interfaces leads to a decrease in the reliability of control systems, the deterioration of their mass, size and cost indicators.

It is shown that the solution of the problem of interfaces is possible with the mechatronic approach in the development of automation and control systems of seeding. The essence of the mechatronic approach is to combine elements into integrated modules and eliminate unnecessary interfaces. Thus, the performance of control systems is improved.

It is proved that the development of software and hardware automation and control systems with mechatronic approach can be based on the Arduino platform.

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