APPLICATION OF ELECTRONIC SYSTEMS FOR CONTROL AND NAVIGATION IN AGRICULTURE

Assoc. Prof. Mihaylov M, PhD, Asst. Prof. Bratoev K.PhD, Assoc. Prof. Mitev G. DSc., Vezirska, G., PhD student, MSc
University of Ruse "Angel Kanchev", Bulgaria
mmihaylov@uni-rusw.bg, kbratoev@uni-ruse.bg, gmitev@uni-ruse.bg, gvezirska@uni-ruse.bg

Abstract: The agricultural machines become more and more complex and complicated systems aimed to produce cheaper and plenty of agricultural products. The modern farmers uses computer technology and equipment not only for monitoring and analysis of the financial results from his activity, but also for expert assessment of yields, state of soil, crops, animals, machinery, product parameters, climatic conditions. Being acquainted with the principles of operation, structure, parameters and modes of adjustment and work with such electronic systems is becoming an obligatory part of the training of agricultural production experts.
***KEYWORDS**: ELECTRONIC SYSTEMS, CONTROL, NAVIGATION, AGRICUTURAL MACHINES*

1. Introduction

Though slower at first, in the second half of the 20th century, electronics has been introduced at a growing pace to occupy a key position at every stage and level of agricultural production today. The modern farmer is using computer technology and equipment not only for monitoring and analysis of the financial results from his activity, but also for expert assessment of yields, state of soil, crops, animals, machinery, product parameters, climatic conditions. Every modern tractor and harvester is equipped with on-board computer, many computer modules and dozens of sensors, necessary for the precise and efficient work with these machines. Being acquainted with the principles of operation, structure, parameters and modes of adjustment and work with such electronic systems is becoming an obligatory part of the training of agricultural production experts.

2. Electronic systems for monitoring and control of precise and fused sowing

The most important technological parameters, which determine the quality and efficiency of sowing are: rate of sowing, depth of laying of seeds, pressure/vacuum of air flow (for pneumatic/vacuum seed drills), percentage of single, zero, double and triple sockets (for precise sowing). Measuring most of these parameters during work with electronic devices is done for the serial seed drills. The electronic systems in the seed drills can be classified in two groups (generations): first generation with basic functions and second generation – with extended capacities.

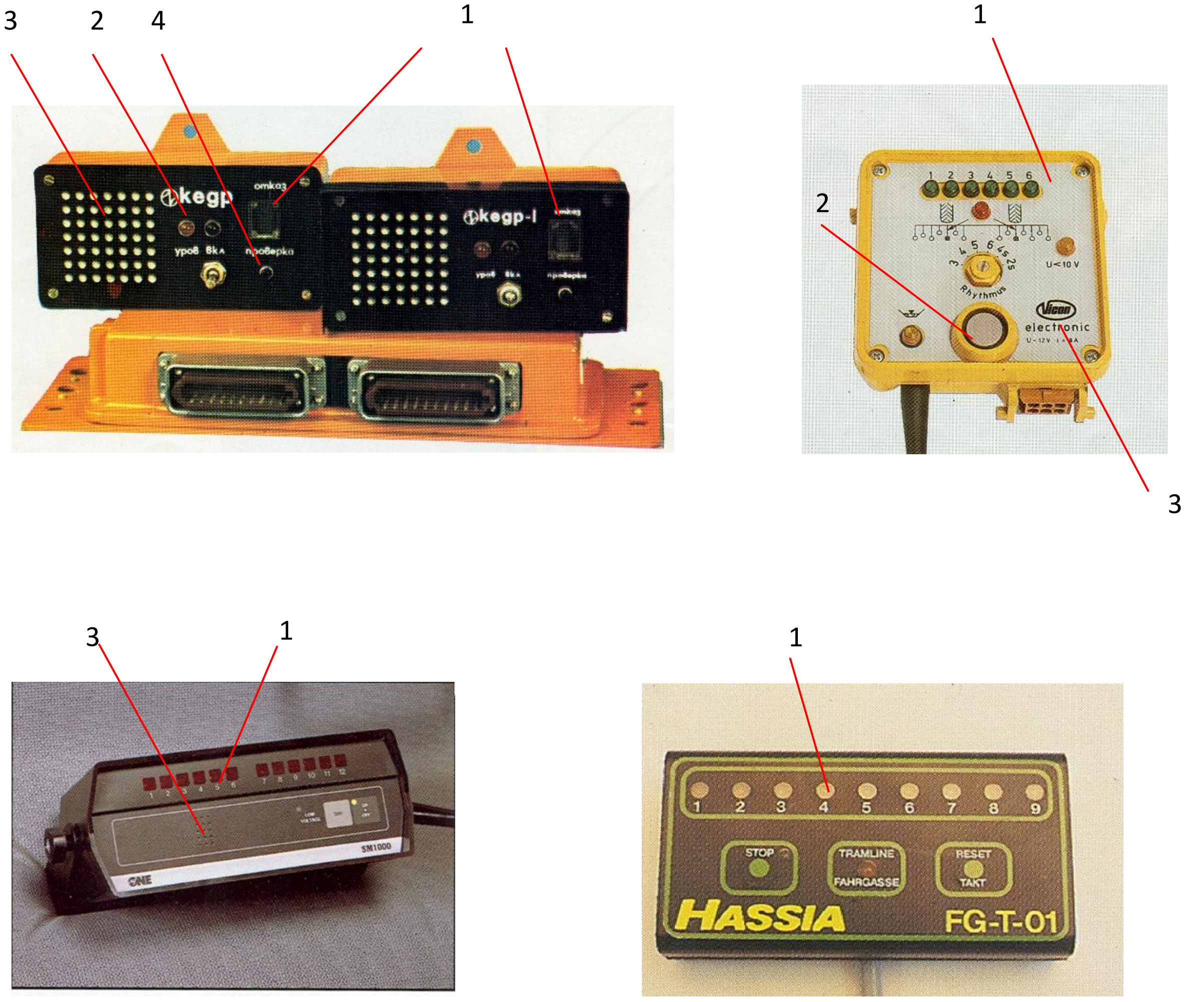


Fig. 1. Systems for control of first generation precise and fused sowing:
1 – light signal for non-sowing boot(s); 2 – light signal for minimum level in the seed box; 3 – sound signal for non-sowing boot(s); 4 – button for cable and sensor self-diagnostics

Controlling the flow of seeds through the boots is carried out by optical sensors. Infrared LEDs are used as light source while the receiver is a photodiode or phototransistor. The mounting location of the sensors is below the metering unit or in the boot (fig. 2).

Fig. 2. Mounting location of the seed sensor

Second generation electronic systems are microprocessor systems (controllers), which, besides fulfilling basic functions, can count the seeds planted by each boot, measure the area sown, calculate the instantaneous and average value of sowing rate, switch sections on and off (fig. 3).

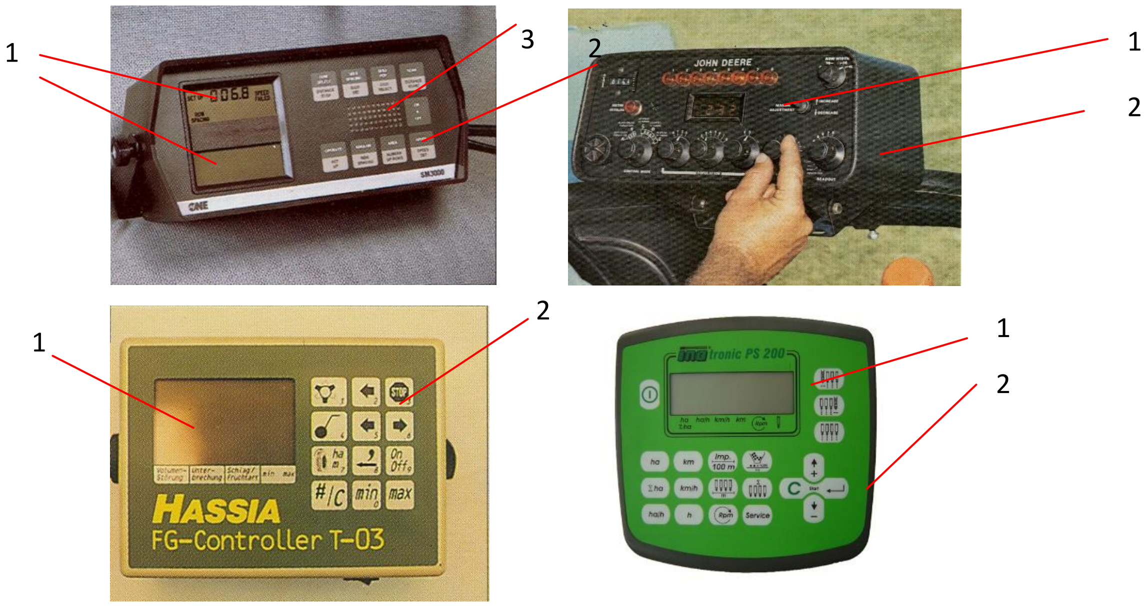


Fig. 3. Second generation controllers:
1 – display; 2 - keypad, regulators; 3 – sound signalling device

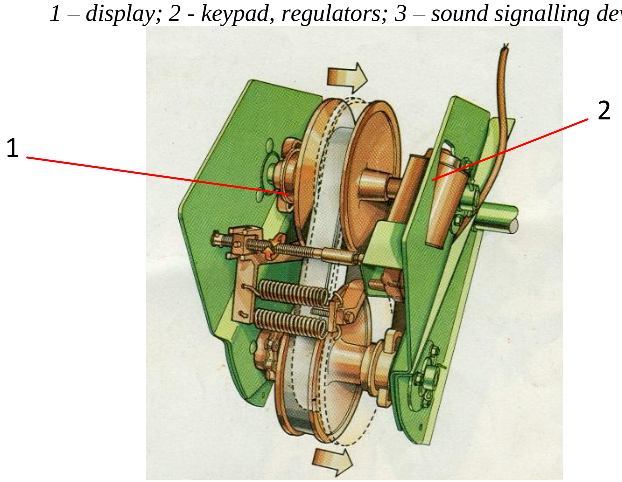


Fig. 4. Mechanism for regulating the distance between seeds (rate):
1- variator 2 – electric motor

3. *Calibration of the sensor for the distance covered by the seed drill and adjustment of seed sensors.*

One of the signals, sent to the seed drill controller by the sensor, is for distance covered. The sensor is normally mounted on one of the seed drill's wheels. Most often inductive type of sensors are used (fig. 5). Using it, the computer can calculate the distance covered L, m and the area sown S, m^2:

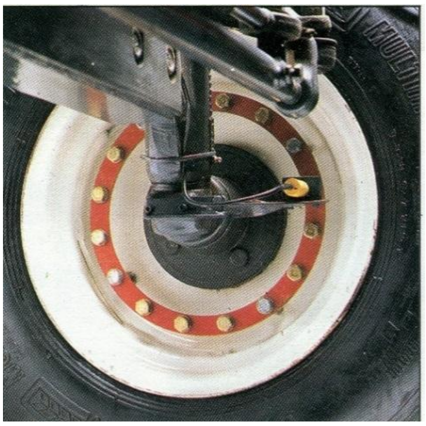


Fig. 5. Mounting location of the distance sensor

Sensitivity S of the optical sensor for seed flow has to correspond to the type of crop. For normal work of the sensors with specific size of seeds, it is necessary to adjust the value of the coefficient for amplifying their signal. The producers enclose in the Manual a table with calculated values S for each type of seeds sown and the operator should only enter the specific value in the system's memory. For example, for the electronic system MC 800G (fig. 6) of Gaspardo seed drills, the Table looks like it is shown on fig. 7.

Fig. 6. Control system MS 800G

Corn, sunflower	Beet	Soy beans	Small seeds
S=4-6	S=6-9	S=7-12	S=12-19

Fig. 7. Table for sensitivity S of the seed sensors

4. *Technological requirements and main parameters of the processes and machines for spraying and fertilising.*

The technologies and machines for spraying and fertilising used are different, depending on: the type and stage of development of the crop or plants; the production technologies to be used; the degree of infection, weed growth and the biological requirements of crops/plants, etc.

The most important technological parameters, defining the quality and efficiency of spraying and fertilising, are: rate (l/dka, кg/dka); uniformity of spraying/fertilising by working width and by area; mean diameter of drops; degree and uniformity of spraying the foliage.

5. *Electronic systems for monitoring and control of machines for spraying and fertilising.*

The electronic systems that control or manage the processes of spraying and fertilising are a standard part of equipment for the machines used for these processes in the developed countries. The reasons for this are: the high price of sprays and fertilisers, the environmental standards for the content of harmful substances introduced and strictly observed for agricultural products, the possibility of slowing growth or damaging crops with elevated rates of spraying and fertilising.

The most important technological parameters, determining the quality and efficiency of spraying and fertilising are: rate (l/dka, кg/dka), uniformity of spraying/fertilising by working width and by area, mean diameter of drops, degree and uniformity of spraying the foliage, liquid/air flow. Most of these parameters are measured at work by electronic devices for the serially produced machines for spraying and fertilising.

The electronic systems in the machines for spraying and fertilising can be classified in two groups (generations): first generation with basic functions and second generation – with extended capacities.

The representatives of the first group have unsophisticated construction and can be executed without the use of microprocessors.

The second generation electronic systems are of the microprocessor type (controllers), and besides the basic functions they can also perform:

- measuring of the spraying/fertilising rate
- regulating the rate from the cabin
- automatically maintaining the rate set and its uniformity

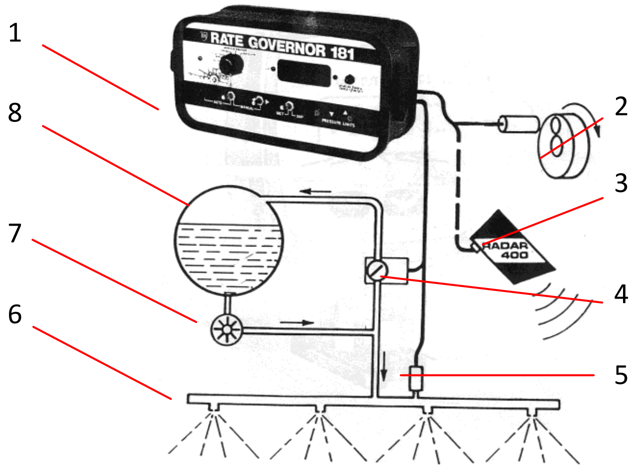


Fig. 8. Diagram of automatic sprinkler control system:
1 –electronic block; 2 – inductive speed (distance) sensor; 3 –optional radar speed (distance) sensor ; 4 – electronically controlled valve; 5 – pressure sensor; 6 – sprinkler bar; 7 - pump; 8 – working liquid container.

By continuous measuring of machine's speed and work pressure the electronic block determines whether the rate set by the operator is ensured. If necessary, a control signal is sent to the controllable valve for the respective pressure change. In this way, the system guarantees observing the rate and uniformity of spraying the work liquid with fluctuating speed of the machine, caused by the terrain or the state of the soil.

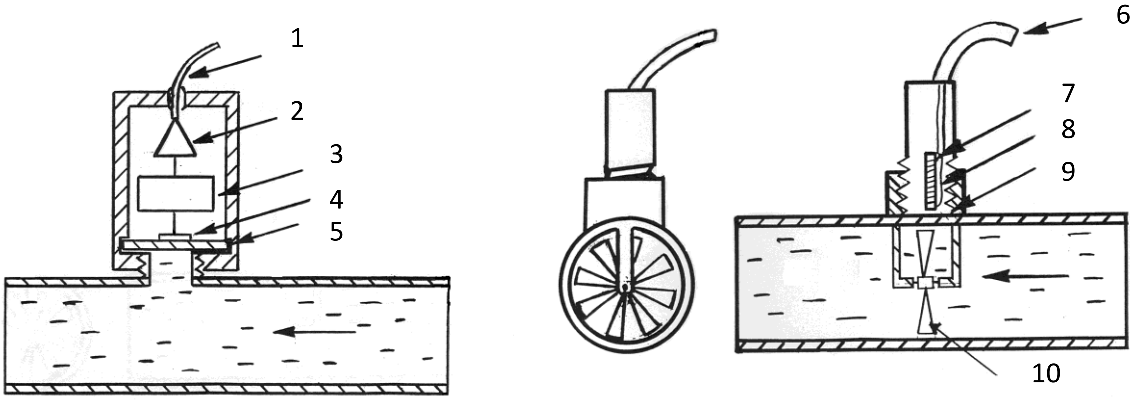


Fig. 9. Pressure and flow sensors:
1,6 – output cable, 2 – amplifier, 3 – temperature compensation, 4 – tensoresisto r, 5 – membrane, 7 – coil, 8 – magnet, 9 – clearance, 10 - fin

Machines with operational width of over 10 m are equipped with electronic systems for maintaining the height of the wings (fig. 10). The operator should set the desired working height to the soil surface or the crop from the control panel. This automatic control allows to maintain a constant height of spraying along uneven terrain, thus helping to achieve high quality results from the operation. Using such an electronic system allows machine spraying up to 40 m work width and up to 30 km/h working forward speed.

a) b) c)

Fig. 10. Elements of a system for maintaining the height of the wings:
a) – controller in the cabin; b) – ultrasound emitter and receiver of the wing; c) – proportional electro-hydraulic distributor

Contemporary models of electronic control systems for spraying and fertilising machines (fig. 11) have touch screen displays, including coloured ones, with a number of additional functions: switching on/off nozzles by sections, alerting for large deviations from the rate, recording the parameters at the time of spraying/fertilising on the SD card, possibility for connection to a GPS system and working on a variable rate card.

Fig. 11. New generation electronic systems for spraying and fertilising

The service staff should make some one-time adjustments to provide the correct operation of the system. For example, real data for the work width of the machine, type of nozzles, sensor parameters for pressure/ flow, rotational frequency of the pump, amount of work liquid in the tank and speed of movement should be entered into the controller's memory. These settings are only updated if other nozzles are mounted or a faulty sensor is replaced.

For some machines the type of nozzle is selected by a computer. Prior to starting work, the operator enters the desired value of the rate and the mean value of the machine's forward speed, using the keypad. By starting a nozzle selection menu, from the list on the display the appropriate type of nozzle can be selected, which would provide optimal operation at the desired rate and speed. The nozzles standardised under ISO have lettering and the respective colouring: A – orange, B – green, C – yellow, D – blue, E – red, F – brown, G – grey and H – white. For each nozzle, its work pressure is displayed. The nozzle which falls within the interval, calculated by the controller is selected (fig. 12). For the specific example from the figure, this is nozzle type E with work pressure 2.6 bar, which falls within the interval calculated from 1.2 to 4.7 bar.

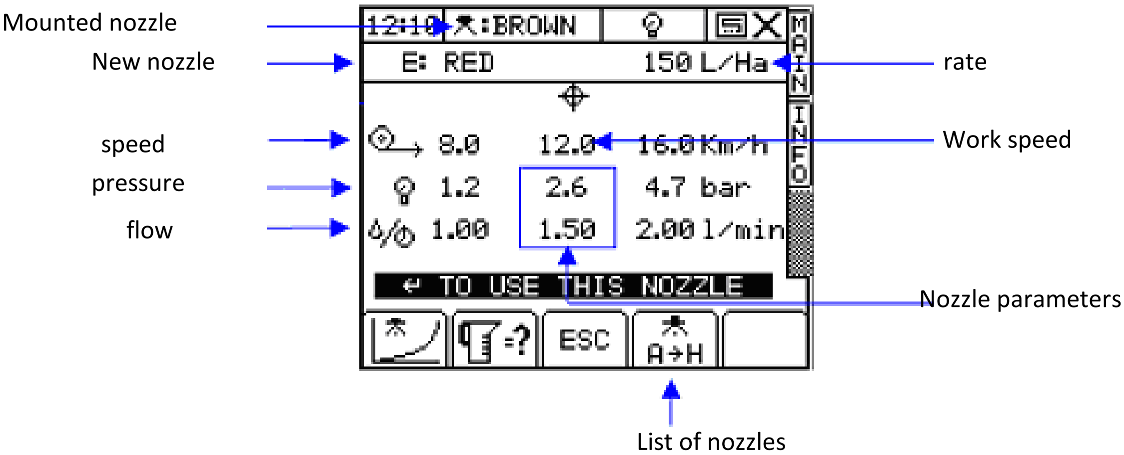


Fig. 12. Dialogue screen for nozzle selection

Another important setting to be performed by the operator is entering a real value of the solution's density. Through this value, the controller calculates the pressure, flow, controlling impacts and other parameters of the machine at work.

Due to wear of the nozzles, at the beginning of each working season for the machine, the flow sensor is calibrated. Electronic systems for precise rate control are fitted as a standard feature in the machines with a direct injection system for spraying (fig. 13 and 14) and ensure dynamic control over the solution parameters. Manual control is not applicable at all for such machines.

6. *Electronic systems for control of machines with direct injection.*

Modern technologies for precise and environmentally-friendly agriculture require the use of a new generation of spraying machines, in which the spraying solution is dosed through an injection pump and the concentration needed is obtained during operation.

Electronic systems have been designed for such machines (fig. 5.13), in which water flow is adjusted at the start of the operation by regulating the pressure valve.

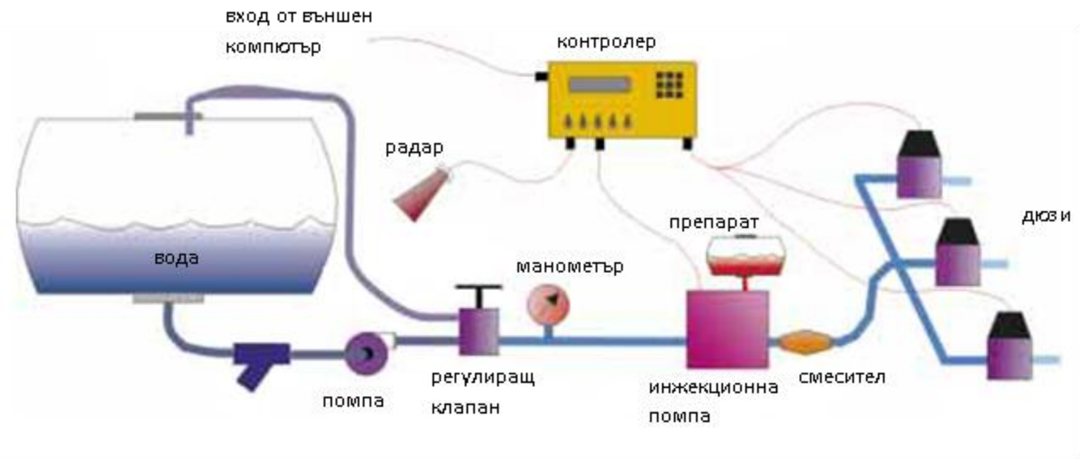
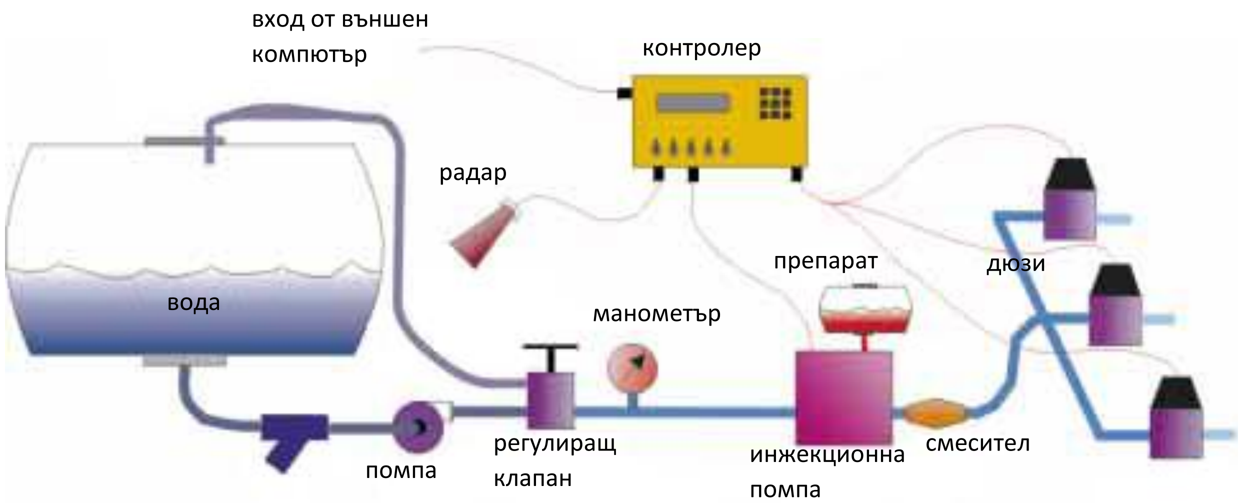


Fig.13. Control system for machines with direct injection of spray and constant water pressure

Introducing a second adjustable parameter (fig. 14), namely, the water flow, shortens the time to achieve the desired concentration of the solution and the norm for its application, which is a considerable advantage during treatments with variable rate. This increases the precision of machine operation when using an external computer.



Using machines with direct injection of spray and embedded electronic systems provides a number of technological, ecological and economic advantages. Highly accurate dosing at minimum costs is achieved through computer control of spray injection. The process is automatically controlled and the operator does not have a direct contact with the spray dosing organs, so for him the health risk is minimal. At the end of the work, the operator and the environment are less exposed to the risk of contact and contamination with toxic substances, because the tank contains pure water. The remaining substance for spraying remains undissolved and is often in its original container, which can be put aside and stored safely for further use.

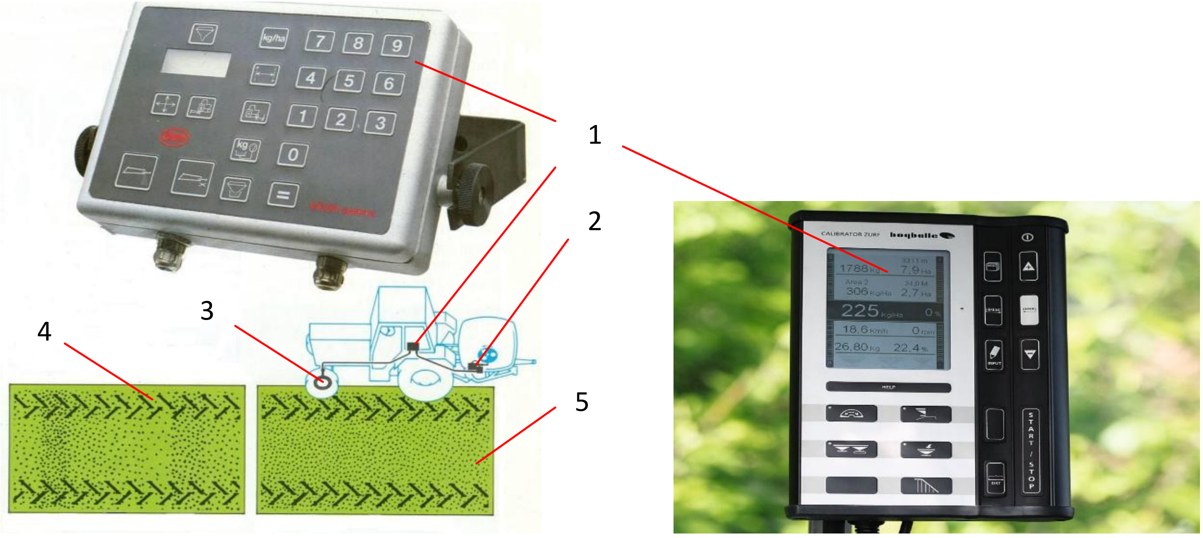


Fig. 15. Electronic control of machine for granulated fertilisation:
1 – controller, 2 – electrically controlled dispenser, 3 – speed sensor, 4 – system turned off, 5 – system turned on

Electronic systems of the type shown on fig. 15 are used in the machines for granulated fertilisation. The controller 1 sends a signal to the dispenser 2, to regulate the feeding of granules to the dispenser, depending on the changes in its forward speed, measured by the sensor 3. This guarantees an even distribution of the granules over the treated area, in compliance with the prescribed fertilisation rate.

In some models, sensors for the weight of fertiliser in the hopper are incorporated, which allows the system to calculate the rate of fertilisation at any moment and to maintain it precisely at the value set by the operator. For a construction with two disc dispensers, switching the rotation direction is introduced, as well as their individual start and stop. When such a system is equipped with a GPS navigation module, the framing of the field is carried out automatically, in compliance with the rate and its uniformity along the whole fertilised area.

7. Electronic systems in the tractors.

Using the achievements of microelectronics, all world producers are developing electronic systems, consisting of main (on-board) computer and subordinate computer modules for control of individual tractor units and the aggregate working machine.

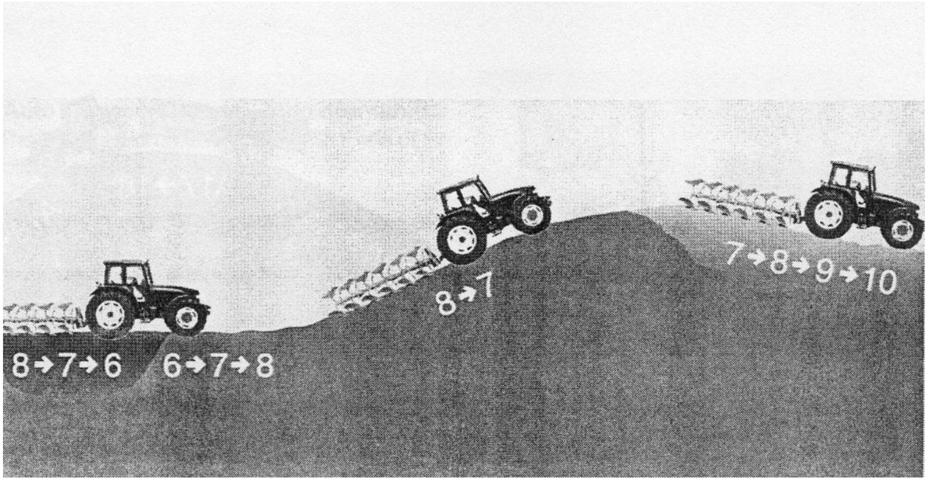
With the improvement of the element basis of electronics in the on-board computers in tractors, new features and functions are introduced – the displays are coloured, a slot for SD memory card is added. Features for automatic control of working machines, for recording the parameters and reporting in electronic form, for manual and automatic programming of the turns at the end of the field have been embedded and opportunities for connecting a GPS receiver and creating a map of the work done, etc.

The further development of on-board computers is related to gradual introduction of standards, e.g. ISOBUS, enabling the interconnections of electronic control modules for inventory of various manufacturers, building-in touch control displays, strong development of self-diagnostic system, adding modules for automatic driving and Internet connection.

The computer systems in tractors today are assigned many functions that can be classified in the following groups:

- related to control of the engine, transmission, towing system, chassis (maintaining constant speed and frequency of the engine), power take-off shaft;
- for an interactive information connection to the tractor driver – regulations, calibrations, monitoring of current values, signalling;
- for tractor driver counselling in terms of optimal and safe operation, technical service, etc.;
- for avoiding tractor accidents;
- providing reporting of results and costs;
- providing comfort to the tractor driver;
- for self-diagnostics of all controllers, executive devices, sensors and their cable connections;
- for determining the exact tractor and machine location;
- for automatic driving during field work and when turning at the edges of the field.

The systems for control of the engine operation automatically control the automatic fuel injection, thus helping to achieve fuel consumption reduction, as well as limiting harmful emissions into the atmosphere. In tractor series T6, T7 and T8 of New Holland, the system supports ECOBlue™ SCR (selective catalytic reaction) technology, where the control system injects a catalyst (aqueous urea solution) from a special tank into the exhaust gases to decompose the harmful nitrogen compounds. Thus a compliance with Tier 4A standard for environmental compatibility is achieved while eliminating exhaust gases recirculation leads to an increase of power and decrease of fuel consumption over 10 % from the Tier 3 standard. Producers also determine longer intervals for technical servicing of tractors, which are equipped with such electronic systems.



compacted zone ascent descent and soft soil

Fig. 16. Adaptive automatic gear switching

One of the controllers of the modern tractors is designed for precise control of the rear and front (if mounted) hinged systems (fig. 17). Through its console (fig. 18) the hinged system functions are set.

When performing operations, related to soil treatment, the mode of maintaining a constant load of the tractor leads to economic fuel consumption. The impact load and the wear on the machine's operating parts, the units of the hinged system, the transmission and the engine are reduced. The even load on the tractor reduces the vibrations in the cabin and the driver's fatigue.

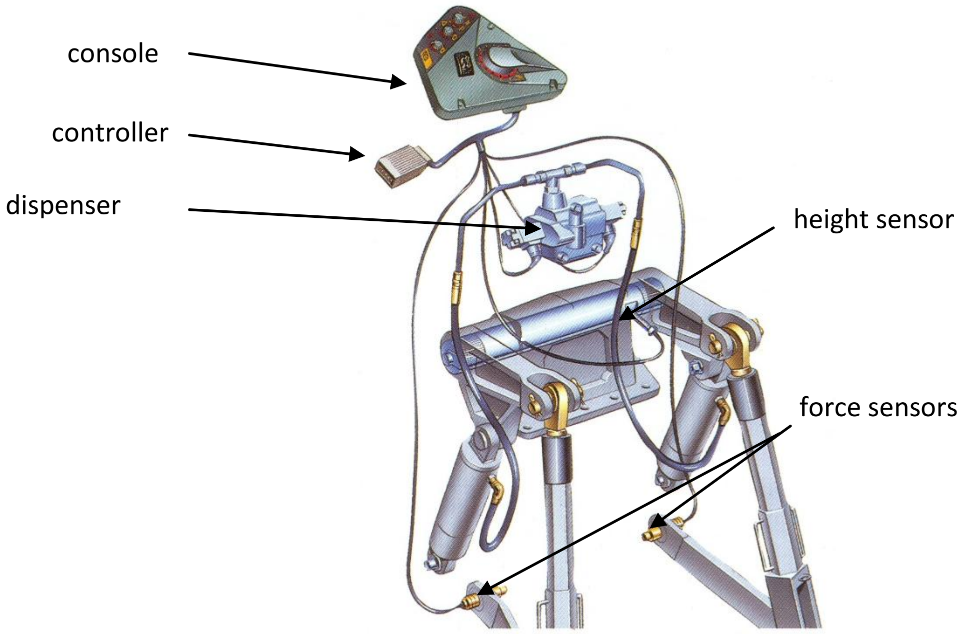


Fig. 17. Hinged electronically controlled system

Locking of the hinged system by the descent speed regulator has one more crucial role. In that position, the controller tracks the speed and if it exceeds a specific value (in most cases 8-10 km/h), it starts tracking the oscillations of the hinged system, caused by the machine. Through the regulator 3 (fig. 18) the tractor driver sets the maximum lifting height of the hinged system. This is necessary when working with mills, mowers, pneumatic seeders, and other machines driven by the power take-off shaft of the tractor through a transmission shaft, due to the limits to the rotation transmission angle. There should be height limitation when operating machines that don't have such drive, but would affect the cabin and other parts of the tractor if unrestrictedly lifted. When working with hinged ploughs, the lifting height should be the maximum possible and the regulator should be at extreme right position.

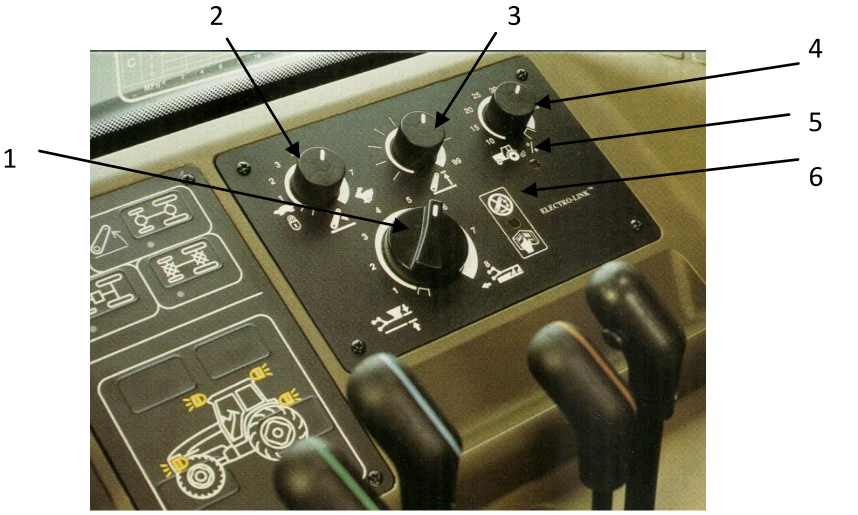


Fig. 18. Console for hinged system settings

In the tractors, equipped with a radar sensor for speed, the controller of the hinged system maintains also a function for automatic limitation of logging in tillage operations.

The main parameters of the tractor, observed on the driver's panel are:

- crankshaft rotation frequency; forward speed; power take-off shaft rotation frequency; distance, cultivated area, productivity; temperature of the engine and of the transmission oil; oil pressure in the engine and in the transmission;
- fuel consumption; engine hours; remaining time to maintenance.

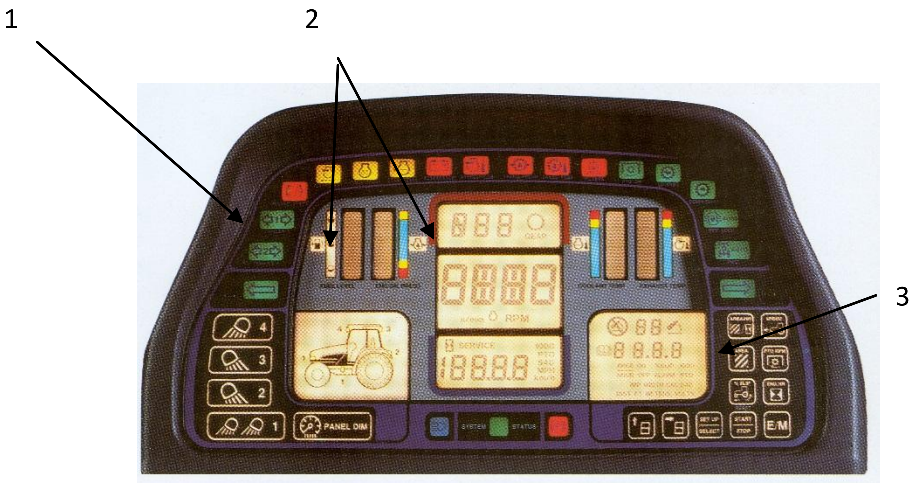


Fig. 19. Electronic instrument panel seen by the tractor driver

The layout of signal lamps 1, instrumentse 2 and keypad 3 (fig. 19) is in line with the ergonomic rules. The red light for pressure or oil temperature in the engine or in the transmission is always combined with the respective sound signal. This is a sign of a major accident and the tractor driver should immediately stop the tractor and turn off the engine. If this is not dine within a few dozens of seconds, the on-board computer turns off the engine by stopping the fuel flow. The manufacturers provide for the possibility for starting the engine after such a situation, but only to move the tractor a few metres with the purpose of taking it off the road and putting it on a platform.

Before the start of work the tractor driver needs to enter the values of inventory working width and the radius of the tractor rear wheel into the memory of the computer. These data are necessary for calculating and reporting the distance covered, logging, cultivated area, productivity, etc.

8. Computer diagnostics of failures.

In addition to driving the tractor and performing a number of manual or automatic adjustments, the on-board computer system performs internal self-control of dozens of parameters, related to its operational processes. Each current value obtained is compared to the nominal one and if there is a deviation from the allowed values, the self-diagnostic system shows on the electronic instrument panel display a failure code of the type Fxxx, where xxx is the number, identifying the specific failure.

Simultaneously, the system records the code in the failure memory log, together with the time and date of its appearance. A sound signal is also heard in the cabin. All failure codes are usually classified into three groups, depending on the severity of the failure. On the same sign a sound signal is emitted with a different rate of recurrence.

9. Calibration of electrical and hydraulic transmissions.

Another important task assigned to the on-board computer in the tractor is calibration of clutches in the electrical and hydraulic transmissions. This can be carried out in a semi-automatic or fully automatic mode. The requirements for performing the calibration are: the tractor should be stopped on an even terrain, the hand brake should be on, the engine should be working at the revolutions given in the instruction, all electric consumers and hydraulic devices should be switched off, the temperature of the transmission oil should be within the limits pointed in the instruction for calibration.

10. Electronic systems in harvesters.

Today grain harvesters are the most electronically mobile machines in agriculture. Several computer modules are integrated in them, as well as dozens of sensors and adjusting executive devices.

The driver of the harvester is not engaged and his tasks are to monitor the accurate work and to react in situations when the automation fails to work adequately or its automatic intervention is not foreseen.

The computer systems in grain harvesters are assigned numerous functions, which can be classified in the following groups:

- related to control of engine, headers, threshing and scrubbing systems, transmission and double transmission;
- for interactive information link with the driver – regulations, calibrations, monitoring of current values, signalling;
- tips to the driver in terms of optimal safety, maintenance, etc.;
- ensuring the harvester against accidents;
- ensuring reporting of operation and costs;
- providing comfort to the driver;
- for self-diagnostics of all controllers, executive devices, sensors and their cable connections;
- for measuring yield and grain loss;
- for automatic horizontal alignment of the harvester;
- for automatic load maintenance;
- for determining the exact location of the harvester and creating a map of yields;
- for automatic driving during operation on the field and turning at the edges.

Each of these functions or several of them are fulfilled by individual controllers, connected into a common CAN network, using unified standards for connection and communication. The engine control system controls the automatic fuel injection, thus reducing fuel consumption, as well as the harmful emissions into the atmosphere. One of the controllers in modern harvesters is designed for precise header control in operation and transportation. Automatic or manual correction signals are sent by this controller to the hydro cylinders, which move the header vertically or horizontally. The main problem while driving on the road is the oscillation of the header and that is why the header controller is assigned a function to suppress those oscillations actively (fig. 20). This mode enhances the stability of the machine, the comfort and safety of movement while allowing higher maximum speed.

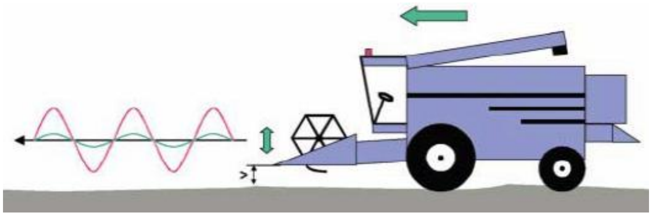
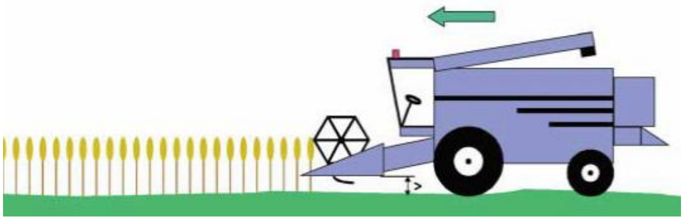


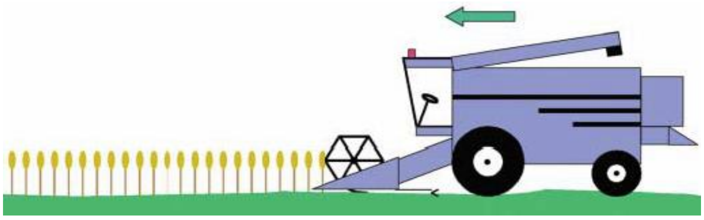
Fig. 20. Active suppression of header oscillations

The remaining automatic modes are used while the harvester is in operation and can be adjusted with precision by the driver, depending on harvest conditions. Most manufacturers offer three such modes:

✓ keeping the header in a selected position relative to the harvester frame;



✓ copying the terrain(maintaining the header at a height adjusted to the field surface);



✓ maintaining the set header pressure to the soil.

According to the current safety standards, the computer system controls the harvester in two modes: transport (moving on the road) and operational (harvesting). It is the driver's responsibility to switch to transport mode once the machine leaves the field and joins the road with other vehicles, as well as to switch it off when the machine is in the field.

When it is in transport mode, the machine blocks the following actions of the driver:

- lowering the header;
- turning on the drive of the header (cutting tool and winch);
- turning on the threshing device;
- rotating and turning on the unloading auger;
- turning on the double transmission (if there is any);
- turning on the lights;
- opening the hopper lids.

The main parameters of the harvester, observed on the front panel in transport mode are:

- the gear engaged;
- the speed;
- engine rotation frequency;
- fuel left;
- distance covered;
- hour of thresher;
- engine temperature;
- current date and time.

The main parameters of the harvester, observed on the front panel in operational mode are:

- the gear engaged;
- the speed;
- engine rotation frequency;
- rotation frequency of threshing drum;
- the counterdrum gap;
- fan rotation frequency;
- grain losses in straw and from the fan;
- level of grain returned for completion.

There is also a mode in which the harvesting parameters are visualised on the display.

An important function of on-board computers is the possibility to record the operations done in one shift, section, field, etc. In some models, this information is printed by a printer fitted in the cabin, in others, it is extracted electronically to the SD memory card. The output information includes data for: the area harvested in ha, productivity ha/h or t/h, fuel consumption, average yield t/ha, harvest and overlay time h etc. When the harvester is equipped with a mobile link to the Internet, this information can be obtained and analysed on a computer with an Internet connection at any time.

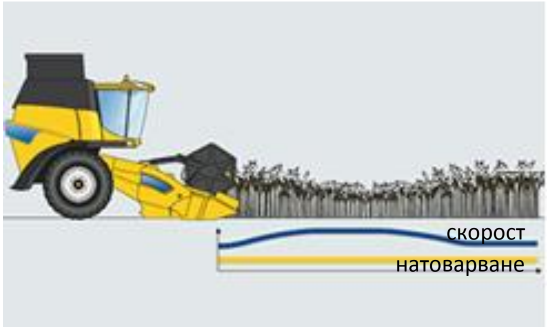


Fig. 21. Maintaining constant load

For automatic driving different principles are used, depending on the type of crops. For row crops there are systems for directing along the row trajectory (fig. 22).

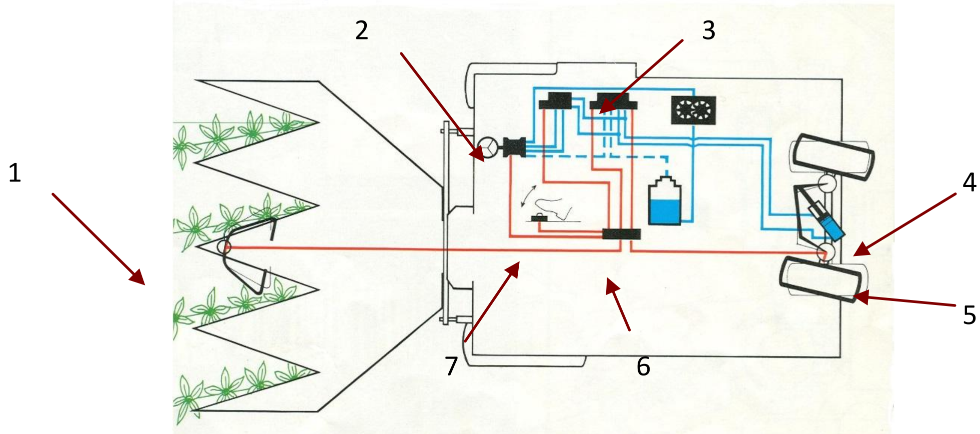


Fig. 22. Diagram for directing directing along the rows:
1 – direction sensor, 2 – steering wheel sensor , 3 – electric and hydraulic dispenser, 4 - steering wheel hydro cylinder, 5 – angle of wheels sensor, 6 – controller, 7 – key for manual/automatic mode

During harvesting of wheat, barley and other fused crops, the grain harvesters can be driven along the edge of the harvested or non-harvested area. Serial driving systems are implemented, which are equipped with a laser system for recognizing this track and automatically affect the steering system to guide the machine along it (fig. 23).

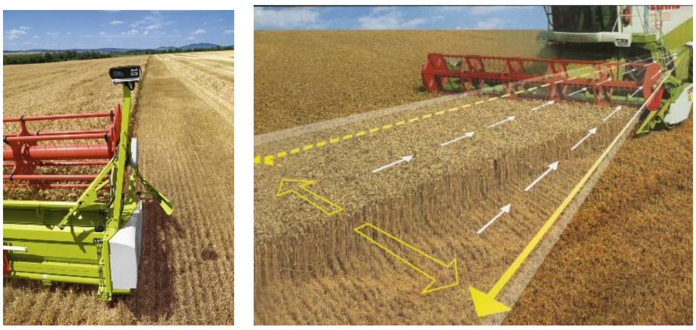


Fig. 23. Driving the harvester on the edge of the ravine

An important element of the modern harvester equipment is also the GPS navigation system. Identifying the coordinates of the machine at any moment with a precision of up to a few centimetres allows precise mapping of yields and automatic driving during operation.

The computer systems in the harvester have a special function for the so called calibrations. Through it, the driver enters numeric data for the working tools of the machine (width and type of header, type of counter drum, etc.), for precise calculation of operation parameters or adjustments. They are needed for the accurate operation of the automatic systems.

For example, the header calibration is carried out in several steps. The first one is calibrating of the header height sensor:

- the g-harvester stops at an even site;
- the engine runs at minimum speed;
- a manual mode for controlling the header is set;
- the header is placed in a horizontal position through the control buttons in transverse direction;
- the header is lowered until it touches the surface;
- a combination of buttons is pressed on the control joystick;
- the end of the relevant light or sound signal for successful calibration of the height sensor should be heard, which means that the controller has saved in its memory the signal for zero height.

At the second step, the oil pressure sensor for the oil in the hydraulic cylinders of the header is calibrated, following the respective procedure. At the third step the sensors for copying of the terrain, mounted at the two ends of the header are calibrated.

Calibration is obligatory in the following cases:

- when the type or size of header are changed, in order to maintain precisely its automatic modes and calculate correctly the harvested area;

- When the size of front wheels is changed, in order to accurately take into account the position of the header relative to the soil surface, to calculate the distance covered, the harvested area and the forward speed;

- when starting to harvest another crop, in order to determine correctly the humidity of the grain and the yield;

- when changing the counter drum and the sieves, in order to adjust them accurately;

- when there is a change of sensor, executive device (hydrocylinder, electric motor, electromagnetic valve) and controller, in order to enter the respective parameters in the computer memory. This is needed due to the presence of tolerable differences in the parameters of the new and the replaced components, or, if it is a controller – lack of specific data about the machine in its memory.

11. Controlled traffic of the aggregates in the field

Application environment. The increasing weight of agricultural aggregates is a factor, which should not be neglected, especially in the conditions of soil conservation agriculture. The pressure that such aggregates exert on the soil leads to unfavourable changes in the soil's properties. Thus, for example, clay soil loses half of its humidity when it is compacted to an extent when its bulk density increases from 1,4 g/cm^3 to 1,75 g/cm^3 [1]. Such negative consequences cannot be avoided in mechanized technologies, but they can be controlled and limited to a certain extent. One such possibility is provided by the system of controlled traffic of agricultural aggregates in the field.

Application and general provisions. The system of controlled traffic of agricultural aggregates separates the areas sown in the field from the tracks of the power machine, thus forming permanently separated zones there (fig. 24). Two main positions provide the opportunity to apply this system. The first one is related to the correct combination of the working widths with the transverse base (tracks of machines) of the machine and tractor attachments used in the production process. The second refers to the modes of driving, determining how to distinguish sections of the field.

Versions of the system for controlled traffic of the aggregates in the field. To identify the possible versions for controlled traffic in the field the diagram from fig. 24 is used. It comprises a sowing aggregate, a spraying machine and a harvester whose transversal bases (tracks) could be the same, but more often they are different.

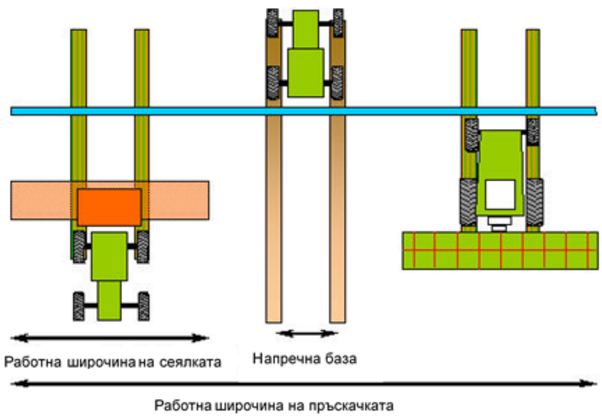


Fig. 24. Diagram for controlled traffic of the aggregates in the field

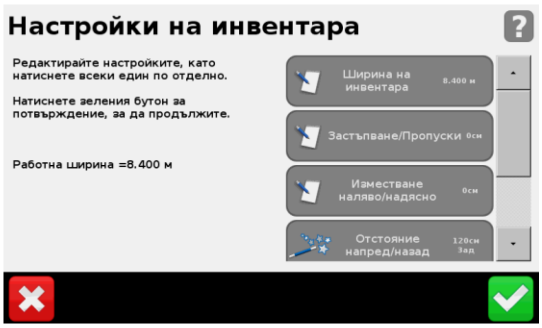
VERSION 1 – the power machines have the same tracks. To determine the traffic of the aggregates in the same tracks, it is important to set a certain proportion between their working widths. The width of the seed drill is the basic one and is assumed to be 6 m. If the widths of the other machines are the same or an integer multiples of this width, it means that they will move along the tracks, left by the two rows of seed drill wheels. In case their with is multiple of 1,5, 2,5 etc., they will alternate their traffic along the tracks left by the two rows of tires and the one left by the single row at adjacent passages.

VERSION 2 – the power machines have different tracks. Here too the seed drill's width is the determining factor. However, here this width is obtained by adding the transverse base of the tractor, to which the seed drill is attached and the transverse base of the harvester. Consequently, if the tractor's base is 1,5 m and the harvester's is 3,0 m, we obtain 4,5 m working width for the seed drill. In this case, the width of the header should be 4,5 m or 9 m, which ensures movement of the harvester along the tracks, left by one row of tractor wheels (fig. 25). Concerning the spraying machine, there are two options: it can move along the tracks left by the seed drill or those left by the harvester. In both cases the working width of the spraying machine should be an integer multiple of the seed drill's width.

Fig. 25. Diagram for controlled traffic with different tracks

Irrespective of the version, its precision depends on the type selected for driving the machines. The most precise way to do it is to use automatic drive and GPS control. It is necessary to determine a model of navigation for the different operations (fig. 26) and the working width of aggregates id set according to the version of controlled traffic (fig. 27).

Fig. 26. Menu for choice of navigation



The system for controlled traffic of agricultural aggregates in the field should be viewed as a possible option of enhancing the effect of implementing soil conserving agriculture.

12. References

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