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ANALYSIS AND SELECTION OF METHODS AND SENSORS FOR CONTROLLING THE WIDTH OF THE WORKING SLOT OF THE HARVESTING DEVIC CP.

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Abstract: *A review and analysis of known works on the automation of control and regulation-monitoring of the width of the working slots of the harvesting apparatus (HA) of the cotton harvester, in particular, the automation of control and regulation of working units, which determines the indicators of the quality of the harvest and the productivity of the cotton harvester, is carried out. It has been substantiated that in order to increase the efficiency of the functioning of the cotton picker, automatic control and management systems are needed that perform the functions of information-measuring and control systems that perform horizontal and vertical adjustment of the position of the harvesting device and adjust the working gap according to the agricultural background, inform the driver about other important parameters of the cotton picker and cotton-growing machine-tractor units (CGMTU). It has been established that one of the most important parameters to be monitored and regulated by the cotton harvester is the width of its working slot (WWS), which determines the productivity and quality of the cotton harvester collection. It was revealed that despite some progress in this direction, there is still a lot of research work to be done on the development of intelligent converters, sensors, instrumentation and control devices. At the same time, one of the main element and node that determines the accuracy of control and regulation of the width of the working slot is sensors that control and convert the width of the working slot into a different type of signal proportional to them, convenient for further use, which is an urgent issue. In this regard, the work considered and carried out a critical analysis of the principles of construction and operation, methods and sensors for controlling the width of the working slots (WWS), for example: contact with mechanical switches, inductive and potentiometric sensors with outputs of the controlled parameters to various display elements: numbered color lamps, displays, etc. The main characteristics, advantages and disadvantages of the considered sensors are given, as a result of which it is concluded that it is necessary to continue research and development in this direction.*

Keywords: *cotton picker, harvesting machine, working slot, sensor, capacity, inductance, potentiometer, error, parameters, width, linear movement.*

INTRODUCTION. The automation of the cotton picker (CP), in particular, the automation of control and management of the technical adjustment of the harvesting machine (UA), which is the most sensitive to changes in the agricultural background of the field and determines the performance indicators of the machine, is one of the main ways to increase the automation of technological parameters and productivity of the cotton picker. To increase the efficiency of the functioning of the CP, automatic control and management systems (AC&MS) are needed, which perform the functions of information-measuring and recovery systems, which, at an appropriate speed, carried out horizontal and vertical adjustment of the position of the UA and adjustment of the working gap along the agrophone, informed the driver about other important parameters of the CP and cotton-growing machine-tractor units (CMTU) in general. [1,2,3]. The specified UA adjustment is directly interconnected with the parameters of the agricultural background (the profile of the bed surface, the deviation of the bushes from the axis of the garden, the density of standing and the parameters of the bushes, the yield, and the degree of opening of the bolls, etc.) [5].

One of the most important parameters subject to control and regulation of the CP is the width of its working slot, which determines the productivity and quality of the CP collection. On the control and regulation of the width of the working slot, the authors of the work carried out a lot of research and development. Certain successes have been achieved in this direction. For example, control and regulation systems have been developed [3,4]. However, due to some shortcomings associated with the accuracy of monitoring and converting the width of the working slit into parameters proportional to them, convenient for measurement, it becomes necessary to continue research in this direction, which is an urgent issue.

Statement of the research problem. The aim of the work is to analyze and select methods and sensors for monitoring the width of the working slot of the CP cleaning device that meets the stated requirements. Note that the quality of linear displacement sensors (LDS) is characterized by a set of technical indicators that can be divided into two groups: one of them determines the accuracy and measurement range, and the other is operational and production characteristics [7,8,9].

The initial data and requirements for the selection and development of a sensor for controlling the width of the working slot of the UA is the width of movement of the gap between the spindle of the harvesting device (from 20mm to 40mm). The general requirements for linear encoders include the following criteria:

The accuracy characteristics of the LDS and the possibilities of their application are determined by the following parameters.

Linearity of the LDS scale. The most common is to assess the nonlinearity of the scale by the reduced measurement error:

$$\gamma_{пр} = (\Delta a / a_{max})\ 100\% \qquad (1)$$

where Δa – maximum absolute measurement error with optimal construction of a straight line that approximates the characteristic of the LDS; a_{max} – maximum measured moving.

Depending on the class of tasks solved using LDS, high-precision displacement sensors are characterized by the following values:

$$0{,}01 < \gamma_{пр} < 0{,}1\ \% \qquad (2)$$

2. Stability of the scale factor. The scale factor is determined during calibration in such a way that the reduced (or relative) error in the estimated measurement range is minimal. The stability of the scale coefficient of the LDS is estimated at a value of about 0.01 %.

3. Zero offset errors. The zero offsets of the LDS are characterized by the average value of the output signal when there is no signal at the input. In practice, zero offset compensation is usually used, and if it does not completely select zero offsets, "zero offset errors" occur.

4. Sensitivity threshold. When measuring linear movements at the output of the LDS, in fact, not one specific value of the input action corresponds, but a certain band of values formed due to mechanical and electrical dead zones. The width of this band determines the sensitivity threshold of the LDS Δa_o, i.e., it determines the change in the actual value at which changes in the output signal will necessarily be observed. The sensitivity threshold is estimated by the value Δa_o,

5. Dynamic measurement range. It is defined by the relationship

$$D = a_{max} / \Delta a_o \qquad (3)$$

and varies within $10^4 \ldots 10^6$.

6. Limits of measurement of movements. Typical for LDS are the following movements measurement limits: 0 ... 5mm; 0...10mm; 0...20mm; 0 ≥ 40mm. (The range of variation of the working slot width is in the range from 20mm to 40mm).

Preferred designs are LDS, allowing a fairly simple adjustment of the measurement ranges.

7. Non-uniformity of the frequency response, which should not exceed 1% for high-precision LDSs.

At the same time, the following requirements are set for the methods and sensors designed to convert the width of the working slot ACP:

- you need to choose a conversion method that creates the following: ease (convenience) of converting the width of the working slot to another type of parameter;
- the ability to pass the converted parameter for further processing;
- the simplicity of the technology of developing and manufacturing the sensor-converter according to the chosen method, etc.

The method of solving the problem is to analyze the known methods and sensors for monitoring and converting the width of the working slot of the harvesting machine and select the method and sensor that meet the specified requirement.

As a result of the analysis of research works related to the control, transformation, and regulation of the working slot of the CP brand HVS 1.8. The main reasons affecting the accuracy of the conversion of the width of the working slot are identified, these include non-linearity and error of sensors; large vibration of the CP harvesting machine, the influence of changes in environmental parameters. In this regard, the paper analyzes the known methods and sensors for monitoring and converting the width of the working slot of the harvesting machine and selects the method and sensor that meet the specified requirement. Below we present an analysis of the methods and sensors that have the closest possible application for monitoring changes in the width of the working slot of the UA CP.

Potentiometric sensors (PS). Potentiometric sensors are designed to convert mechanical movement into an electrical signal [8,9,10]. The main part of the sensor is a rheostat, the resistance of which changes when the motor moves, sliding along the wire (the circuit of the potentiometric sensor is shown in Fig. 1.) The supply voltage is applied to the entire winding of the rheostat through the fixed terminals of this winding. The output voltage proportional to the movement of the motor is removed from one of the fixed terminals and from the movable motor.

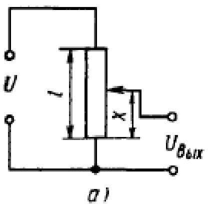


Fig. 1. Switching circuit of the potentiometric sensor

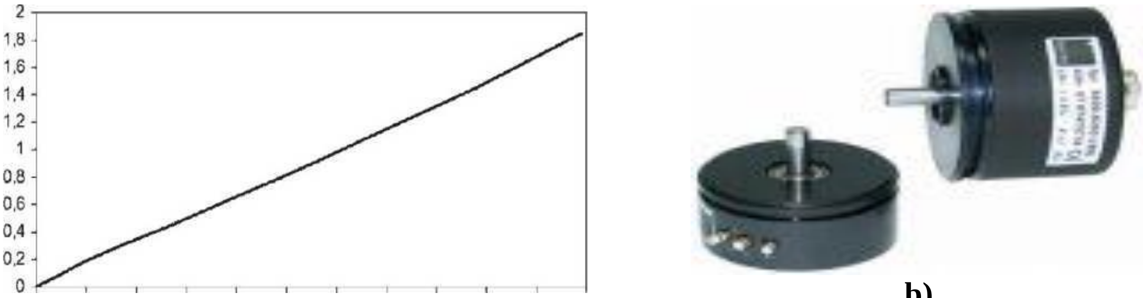
If the resistance of the entire sensor winding is denoted by R, and the resistance of the part of this winding, from which the output voltage is removed, through R_{exit}, then the potentiometric circuit of switching on the sensor can be represented as a series connection of resistors with a resistance R_{exit} и $(R-R_{exit})$ (fig. 1, b). Current through the sensor winding I = U/R, and the applied voltage is distributed between the series-connected resistors: $U= IR_{exit} + I(R-R_{exit})$. If the resistance of the winding is evenly distributed along the length I, and the movement of the motor is denoted by x, then the output voltage of the sensor

$$U_{exit} = IR_{exit} = Ux/l. \quad (4)$$

If the resistance of the winding is evenly distributed along the length l, and the movement of the motor is denoted by x, then the output voltage of the sensor, so the output signal of the sensor will be proportional to the movement of the motor.

By means of potentiometric sensors, it is possible to build sensors for measuring the width of large (from 30 mm and more) gaps. Currently, potentiometric sensors have been released to measure the linear movement of objects over 1000 mm. With a measurement error of 1-2mm. The general view of the commercially available HEM12 series LP sensor is shown in Fig. 2.

Fig. 2. Linear displacement potentiometric sensor-HEM12 series



a) **b)**

Fig. 3. a) Static characteristic of the linear displacement potentiometric sensor b) and general view potentiometric rotation angle sensors Model 8820.

The advantage of PSLD is the ability to measure linear displacement in large areas with sufficient measurement accuracy. The disadvantage is the presence of a mechanical part (the contact between the moving part of the plate and the resistance of the winding-a resistor), which can lead to a decrease in the service life and deterioration of the measurement accuracy, another disadvantage is the large dimension, i.e. for measuring a large distance (length), a PSLD greater than this length is required.

As a LDS, you can use potentiometric rotation angle sensors, the general types of which are shown in Figure 5. The disadvantage of such a sensor is the complexity of the design, i.e. for use as an LP sensor, it is necessary to develop a special design for installing the sensor between the working slot of the CP harvester.

Capacitive method (sensor) [8,9,10].

Capacitive converters use the method of changing the capacitance of the capacitor when changing the distance between the plates. A capacitive sensor is a parametric type converter in which a change in the measured value is converted into a change in the capacitive resistance.

The principle of operation of capacitive sensors is based on the dependence of the capacitance of the capacitor on the size of the plates, the distance between them, and the dielectric constant of the medium between the plates.

The capacitance of a capacitor having two flat plates is calculated by the well-known formula:

$$C = \varepsilon\varepsilon_0 s/d, \quad (5)$$

where ε is the relative permittivity of the medium between the plates; ε_0 - is the dielectric constant (ε_0= 8,85•10^{-12} F/m); s - is the area of the plates; d - is the distance between the plates.

It follows from (1) that the change in the capacitance of the capacitor can occur due to a change in any of the three values: d, s, ε. The most common are capacitive sensors that measure linear displacements. In Fig. 7a, b shows the circuit of the linear displacement capacitive sensor and the dependence of the sensor capacitance on the input signal-displacement x.

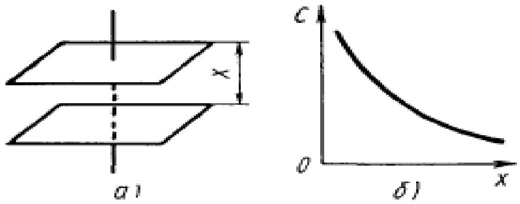


Fig. 4. Capacitive linear motion sensor

Capacitive sensors can also be used in AC circuits. In this case, the capacitance is inversely proportional to the supply frequency:

$$X_c = 1/(\omega c) = 1/(2\pi f c), \quad (6)$$

where ω=2nf is the angular frequency; f - is the frequency of the network or generator, Hz.

Capacitive sensors have a number of advantages over other types of sensors. Their advantages include:

■ easy to manufacture, using low-cost materials for production;
■ small size and weight;
■ Low power consumption;
■ High sensitivity;
■ no contacts (in some cases, a single current connector);
■ long service life;
■ the need for extremely small forces to move the moving part capacitive sensor;
■ easy to adapt the sensor shape to different tasks and structures.

The disadvantages of capacitive sensors include:

■ relatively small transmission (conversion) ratio);
■ high requirements for shielding parts;
■ the need to operate at a higher frequency (compared to 50 Hz).
- the need to use an additional converter (frequency generator).

Photoelectric sensors. [8,9,10]. According to the physical principle of operation, this converter belongs to the class of photovoltaic sensors.

Photovoltaic sensors respond to changes in light conditions. The photoelectric sensor consists of a source and a receiver of the light flux. The light source can be the measurement object itself or a special illuminator (for example, in the form of a conventional LED, Fig. 5**.**

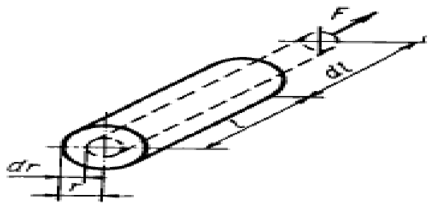


Fig. 5. Conventional LED

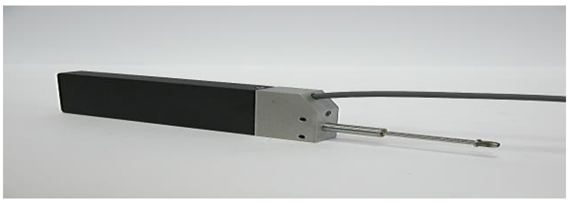


Fig. 6. General view of a linear motion photoelectric sensor with a rod.

According to the possible variations in the luminous flux, the movement can be measured using photovoltaic sensors.

One of the variants of a linear motion photoelectric sensor with a rod is shown in Fig.6. The principle of operation is photoelectric. Rod stroke (L dimension) - 40 mm Discreteness - from 0.1 to 10 microns Accuracy class-3. It is used for the contact measurement method.

The design and basic overall dimensions of the displacement converter are shown in Fig.7. A

Photoelectric displacement converter with a rod is distinguished by the following values: measuring range; Supply voltage, output signal type, signal period, microns, discreteness, microns, accuracy class, etc.

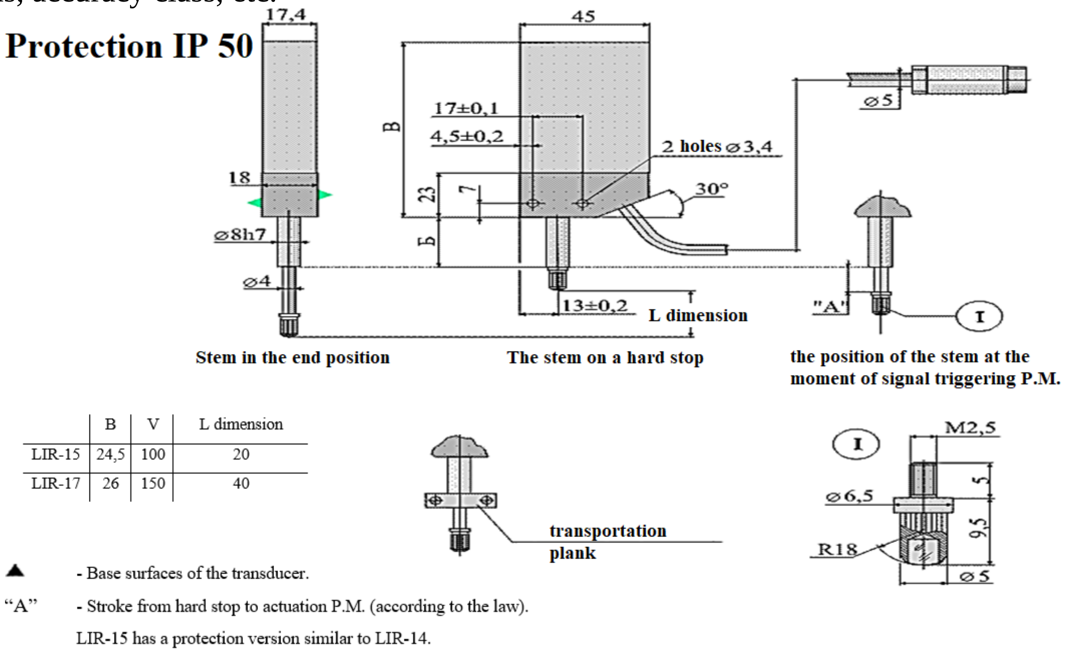


Fig. 7. Design and main overall dimensions of the photovoltaic displacement converter with a rod.

Optical linear movements sensor developed at Tashkent State Technical University (4).

The design of the optical linear motion sensor is designed according to the technical specification, depending on the location of its placement. Fig.8 shows a general view of the optical sensor for monitoring linear motion, developed by the authors of the work. Fig.8 shows its construction.

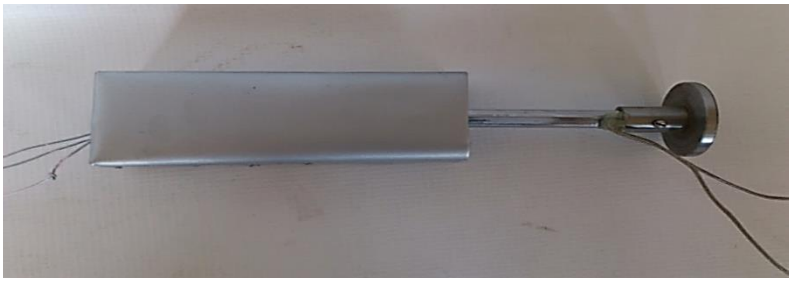


Fig. 8. General view of the optical linear motion sensor based on a metal tube (front view).

The main technical data of the optical linear motion sensor meets the above requirements.

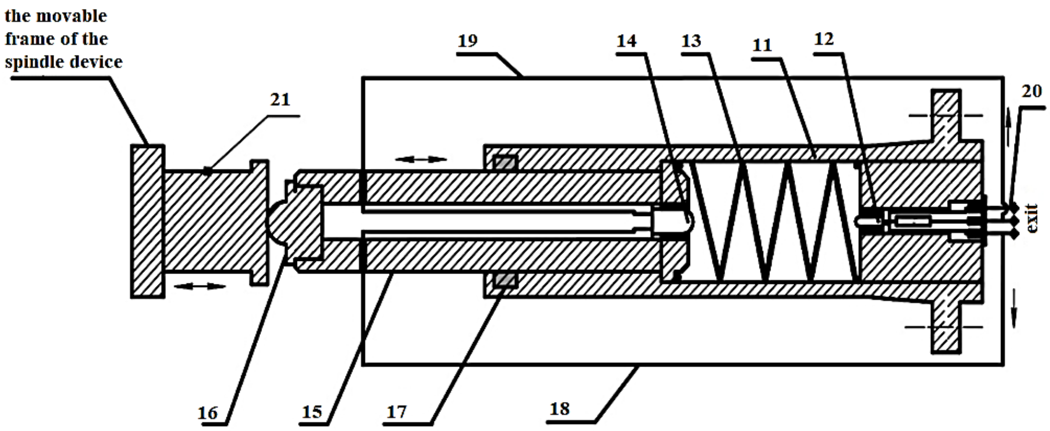


Fig. 9. Construction of the optical sensor for monitoring changes in the working slit.

The use of a non-contact photoelectric sensor for monitoring the working gap is justified by its linear characteristic, high reliability, the possibility of continuous and accurate monitoring of changes in the working gap, and the expansion of the measurement range (control). The photoelectric sensor is built on the basis of a photoelectric converter, made in the form of a pair of spring-loaded sliding tubular housings. The radiation source is located on the mobile part of the tube, and the radiation receiver is located on its stationary part. The movable part of the tube is loaded and installed inside the tubular body with the possibility of light exposure to the photodetector located inside the fixed part of the tube, and the tubular bodies of the movable and fixed parts (the working slot width sensor) are installed on the fixed frame of the cotton harvesting machine.

The above devices with a photovoltaic converter of linear movement into an electrical signal are:

- complexity of the design of photovoltaic sensors;
- large dimensions;
- the dependence of the measurement accuracy on the change in the supply voltage.

Inductive sensors [5,6]. The principle of construction and operation of an inductive sensor is based on the change in the inductive resistance of the winding (inductor) from the change in the position (movement) of its core relative to the initial state. Various variants of inductive LP sensors are known, designed to control the movements of various objects.

LDS-AS/BS Series Inductive Linear Movement Sensors

The LDS-AS / BS series displacement sensors use the principle of a linear variable differential transformer (LVDT), which converts the mechanical movement of the rod into an electrical signal. These sensors require power at a carrier frequency of 5 kHz and can work with DPM KYOWA series amplifiers

There are the following models of inductive sensors, which differ in frequency range, dimensions, etc. Indicators: LDS-5AS/BS, LDS-10AS/BS, LDS-20AS/BS, LDS-30AS/BS, LDS-50AS/BS, LDS-200AS/BS, LDS-500AS/BS

The design of the linear movement sensor developed by the authors of this work is shown in Fig. 10. The principle of operation of which is based on the change in the inductive resistance from the change in the movement of the magnetic core associated with the moving object. A schematic diagram of a frequency converter based on an inductive linear displacement sensor is shown in Fig. 10, and its wiring diagram is shown in Fig.11. The circuit diagram is made on the basis of an operational amplifier and operates from a supply voltage of +12V. The wiring diagram is made on the basis of one-sided foiled textolite.

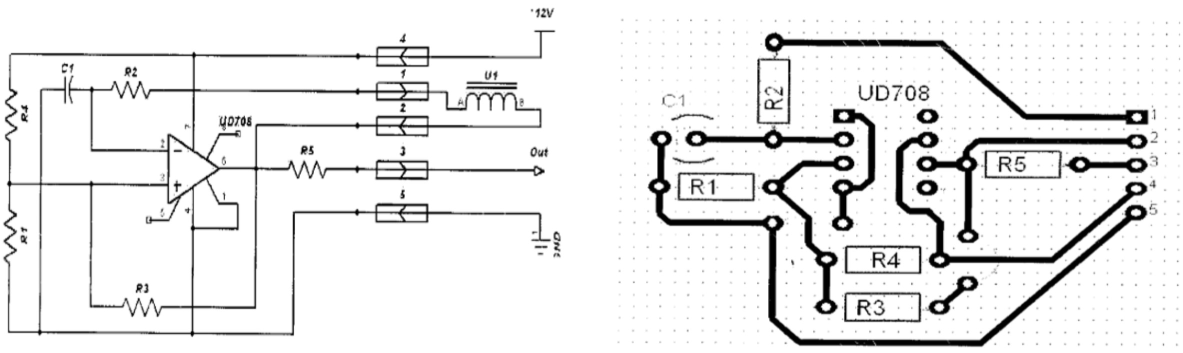


Fig. 11. Schematic and wiring diagrams of a linear movement to frequency converter based on an inductive sensor.

The disadvantages of linear movement sensors based on inductive converters into an electrical signal are:
- complexity of the design; - large dimensions; - dependence of the measurement accuracy on changes in the supply voltage; - dependence of the output signal on vibration and external magnetic field and ambient humidity.

Conclusion. Analysis of the principles of construction and operation of methods and sensors showed that to control the width of the working slot of the harvesting machine in the range from 20mm to 40mm, sensors built on the basis of potentiometric, photoelectric, and capacitive sensors of various designs can be used. For the use of these sensors, it is necessary to develop special mechanical structures that ensure the smooth movement of the moving parts of the selected sensors.

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