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DEVELOPMENT OF A SYSTEM FOR POSITIONING THE WORK OF GATHERING CRANES ON CONTAINER SPACES OF FREIGHT STATIONS

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ABSTRACT

The paper presents a system developed by the authors for positioning the work of gantry cranes on container sites of freight stations. The preliminary design of the device for reading information about the coordinates of the crane was developed on the basis of the copyright certificate (No. 1796681 "Device for reading information about the coordinates of the crane" dated 02.23.1993. Lee S.V. et al. Bull. No. 7). The design of the reader is an integral part of the control equipment of the crane positioning system. This project is part of an automated container cargo management system. The article substantiates the choice of the type of sensors and the principle of reading the coordinates of the gantry crane. The proposed crane positioning system consists of addressable elements and a system of reading elements. It implements the code principle for reading container positions. Address elements are delta planks. In accordance with the position code, metal screens are fixed on them, the size of which is determined by the type of sensors selected and their characteristics. The reading element system is a series of proximity sensors. The sensors are mounted on a special pinch device, which provides the necessary clearance between the sensors and code plates. The signal reception and processing unit remembers the code of the positions coming from the sensors and stores information until the next signal arrives. The position code is displayed on the on-board computer screen of the crane operator. The developed crane positioning system improves the accuracy of determining the position of the crane and simplifies information processing equipment. The positioning system of the crane can significantly increase the efficiency of cranes in handling containers and other cargo. In addition, the fatigue of the crane driver is reduced and his labor productivity is increased. Using the crane positioning system developed by the authors will undoubtedly give a great economic effect. The efficiency of cranes for reloading containers is provided by accelerating the search for containers loaded directly into the car, improving the quality of accounting. All this ultimately provides the ability to transport additional goods with an existing fleet of containers. In conclusion, the paper gives an analysis of the selected design of a crane positioning system.

Keywords: *Gantry Crane, Container, Positioning System, Overload Efficiency, Performance, Address Elements, Proximity Sensor, Pinch Device.*

1. INTRODUCTION

One of the most important directions of increasing labor productivity and efficiency of mechanization of loading and unloading operations in transport is the further development of container cargo transportation based on the use of new types of universal containers and appropriate technical means for their transshipment and transportation [1].

Increasing the level of container transport is a major challenge, providing a significant reduction in the cost of manual labor during loading and unloading operations. At the same time, the equipment that provides work with containers is not always fully used, so improving the means of mechanization of loading and unloading operations and reducing the cost of operations on this basis is of great importance.

Currently, automated lifting cranes are increasingly being introduced in the CIS and abroad [1-3]. The main objects of automation in the first place are cranes involved in the transport and transshipment process of technological systems with a sufficiently organized working environment and certain routes of cargo flows. Among them include systems for the transshipment of containers.

2. LITERATURE REVIEW

The introduction of intensive technologies based on advanced technology, robots, advanced technological processes and flexible technologies for the production of installation works allows you to create fundamentally new resource-saving, waste-free, low-operational effective technologies.

The relevance of the issues under consideration is emphasized by the presence of serious shortcomings in the construction of buildings from modules, related to the incomplete development of industrial methods and methods of module installation, the lack of promising means of mechanization and automation of module installation on construction sites [4-10].

The most time-consuming stage in the process of installation of building structures is the process of pre-installation and reconciliation of building structures. Neither the level of technological equipment nor the methods of controlling the position of the structure in space meet the increasing requirements of production. The solution of the emerging problems is possible only with the complex automation and robotization of the installation process of modular structures.

In general, an automated process control system (APCS) provides automated collection and processing of information necessary to optimize the control of the object in accordance with the accepted criterion, and the implementation of control actions on the technological process. The control object is a set of technological equipment and implemented on its basis according to the appropriate algorithms and regulations of the technological process of installation of bulk modules [11].

In a controlled technological process, information flows are distinguished, characterized by the following groups of parameters:

1. Measured parameters X=(X1, X2 ... Xn), which include measurable but unmanageable parameters that depend on external factors; output parameters that directly or indirectly determine the efficiency of the production process or restrictions imposed on the conditions of its flow [12].
2. Controlled parameters Y=(Y1, Y2 ... Yn), which can be changed by the action of the actuators, etc.
3. Unmeasurable and unmanageable parameters P=(P1, P2 ... Pn), time-varying characteristics of process equipment, characteristics of raw materials, etc. When installing prefabricated building structures, the mounting crane is used in the operations of transporting the structure to the installation site, pre-installation and alignment of the structure. During installation, prefabricated structures moved by load-lifting mechanisms are not always located in adjacent vertical and horizontal planes, since the length of the slings is not the same, and the structures have technological manufacturing errors. This makes it difficult to install the structure in the design position [13].

Operations related to pre-installation, alignment of elements and installation of the assembled structure are carried out manually by a link of installers. This is due to the fact that the designs of cranes intended for mass production are intended only for carrying out lifting and transport operations. None of them is suitable for performing operations related to the alignment and installation of structures in the design position [14].

The crane provides automated flow element for the place of installation, and acceptance of the item and restoring the system to the installation site and installation in the mounting platform [15].

Modern technical means do not allow automated slinging and rasstropovku, orientation in space, damping the amplitude of the swing of the load, straightening and temporary fastening, alignment and control of its position, self-fixing, the device of the mortar bed, sealing horizontal and filling vertical seams, etc. As a result, manual labor costs significantly exceeded mechanized ones. For almost every machine-shift of the crane operation, manual labor is spent 4...5 times more than mechanized labor [16].

Given that a residential and industrial building is most often a rectangular parallelepiped, the structural elements of which are located in a Cartesian coordinate system, their position should be controlled by all six spatial coordinates (three linear and three angular), and the mounting tool should contain mechanisms that provide linear movements along the X, Y, Z axes and rotational movements relative to these axes. At the same time, for all manipulating operations, it is necessary that the manipulator crane has a fundamentally new technical solution that performs the so-called hard grip of the mounted structure, accelerated delivery to the installation site and accurate landing in the design position at reduced speeds [17].

To do this, the executive device of the manipulator crane, in contrast to modern construction cranes, must be built according to the so-called rigid or close to it kinematic scheme with working bodies that provide a rigid grip of the element [18].

To achieve the required high positioning accuracy when servicing a large working area, it is possible to implement two-stage positioning of elements. For this purpose, it is necessary to introduce a transport device with general and local degrees of mobility into the kinematic scheme of the manipulator crane, which moves the element into the installation area at high speeds with an accuracy equal to tenths of a meter, and an orienting device with local degrees of mobility. The latter should perform orientation and positioning of the element at lower speeds within the installation area with the required high accuracy, as well as the subsequent smooth landing of the element on the mortar bed [19].

Due to the fact that in the process of work, four main functions are performed — logistics, executive, registration (control) and regulation-further development and design of new technical means for the construction of buildings should be carried out in groups, with the assignment of each of them from one to four functions performed independently or jointly with the service personnel [20].

To ensure the required high accuracy of positioning and maintenance of a large target area, it is proposed to implement a two-stage positioning of the elements. In the first stage, the construction element must move from the capture zone to the installation horizon using crane mechanisms with high speed and accuracy equal to tenths of a meter. In the second stage, the construction element, using the mechanisms of a new orienting device that provides six degrees of mobility at lower speeds, must be installed in the design position with an accuracy equal to hundredths of a meter. Positioning accuracy cranes must meet regulated by SNiP tolerances on the accuracy of the installation of structures at the design position, for example ±5 mm offset horizontal axes of the mounting structure (wall panel) in the lower section relative to the installation of the axes and ±10 mm for the deviation of the planes of the structure from the vertical cross section in the upper floor [21].

Overhead cranes are used for maintenance of open and closed warehouses, loading platforms, installation of prefabricated construction structures and equipment, industrial enterprises, maintenance of hydraulic structures, transshipment of large-capacity containers and long-length cargo. Currently, the operation of such a crane is very expensive, since the equipment installed on it is imported. Gearboxes and engines, taking into account the current exchange rate, are becoming very expensive. Replacing these units with domestic analogues will reduce the cost of the design, with the same characteristics as before [22-25].

The installation of backup disc brakes on the lifting drums will increase safety during the installation and maintenance of cargo. Disc brakes are increasingly used in the production of cranes, they are easy to operate, create a braking torque greater than pad brakes with the same dimensions, they have a shorter response time, the replacement of components does not require a long time. This task is relevant in the production of cranes, so it is taken for development in this diploma project [26].

Overhead cranes are the main lifting equipment of production workshops, closed and open warehouses, loading areas, are used for the installation of prefabricated construction structures, maintenance of hydraulic structures. As a lifting body of cranes are: hooks, grabs, electromagnets, grippers and other special devices.The circular electric overhead crane with a lifting capacity of 360 (205)-32t and a span of 41.5 m is installed in the building of the reactor department of the Leningrad NPP (LNPP-2) and is designed for:

during the construction of nuclear power plants-to perform lifting and transport operations for the transportation and installation of equipment (reactor, steam generators, etc.) [27];

during NPP operation, during PM and reconstruction for transport and technological operations with the fresh and spent fuel, radioactive waste, the elements of the reactor plant, etc. [28];

in the derivation of the nuclear power plant crane will perform lifting and transport operations to dismantle equipment sealed areas of the reactor building [29-30].

3. MATERIALS AND METHODS

In the course of the work on the development of a block diagram for controlling the positioning and selection of gantry crane position sensors, the data obtained as a result of patent studies of a number of companies in Japan, Germany and other countries that have experience in creating automatic control systems for sea port cranes and stacker cranes were analyzed. The development trends and the level of automation of control systems were analyzed. It also takes into account the work carried out in the CIS on the partial automation of the positioning control of gantry cranes, taking into account the design features of gantry container cranes currently serving container platforms of cargo stations [31-35].

The existing control systems of marine terminals are highly automated, i.e. all operations, except for the capture of the container by the spreader, are performed automatically and contain, as a rule, two types of sensors:

- the relative displacement is determined by the incremental sensors;
- the absolute position of the cargo spaces is determined using position sensors.

Sensor systems compensate for the disadvantages inherent in each of them. Incremental sensors allow for coordinate feedback, as they provide information about the current coordinates at any given time. Positional sensors compensate for the accumulated error of incremental ones.

The principle of operation of stacker cranes in automatic mode, as a rule, differs from the control of cranes at sea terminals. They do not contain incremental sensors, there is no coordinate feedback. The stacker cranes are operated in an open loop. When moving to a given position at some point X/, the nominal speed of movement is switched to the finishing Vg, and then braking occurs at point Xc. Braking distance Δ is the component of the positioning error (Figure 1). Since the nature of the speed change in certain sections of the crane movement in our case does not matter in principle, the trajectory is conditionally assumed to be straight.

Working according to this scheme allows stacker cranes to achieve positioning accuracy of 5-10 mm. However, the operating conditions and technical parameters (weight, dimensions, etc.) of stacker cranes differ significantly from the operation of gantry container cranes at open cargo stations.

The proposed positioning control scheme provides only for the use of positional sensors. The use of incremental sensors (distance sensors) at the first level of automation is not advisable, because possible accumulation of sensor errors require periodic correction devices (i.e. additional sensors), which complicates the system and significantly increases the cost of its production. The use of two systems of sensors (position, incremental) for a given level of automation, as is done in systems motion control of marine terminals, are also not advisable, because in the manual mode of the pickup to the position of crane operator selects the mode of inhibition and it needs to know the beginning of the transition to finishing speed and time of exact stop. Incremental sensors are typically used in closed-loop automatic braking control systems.

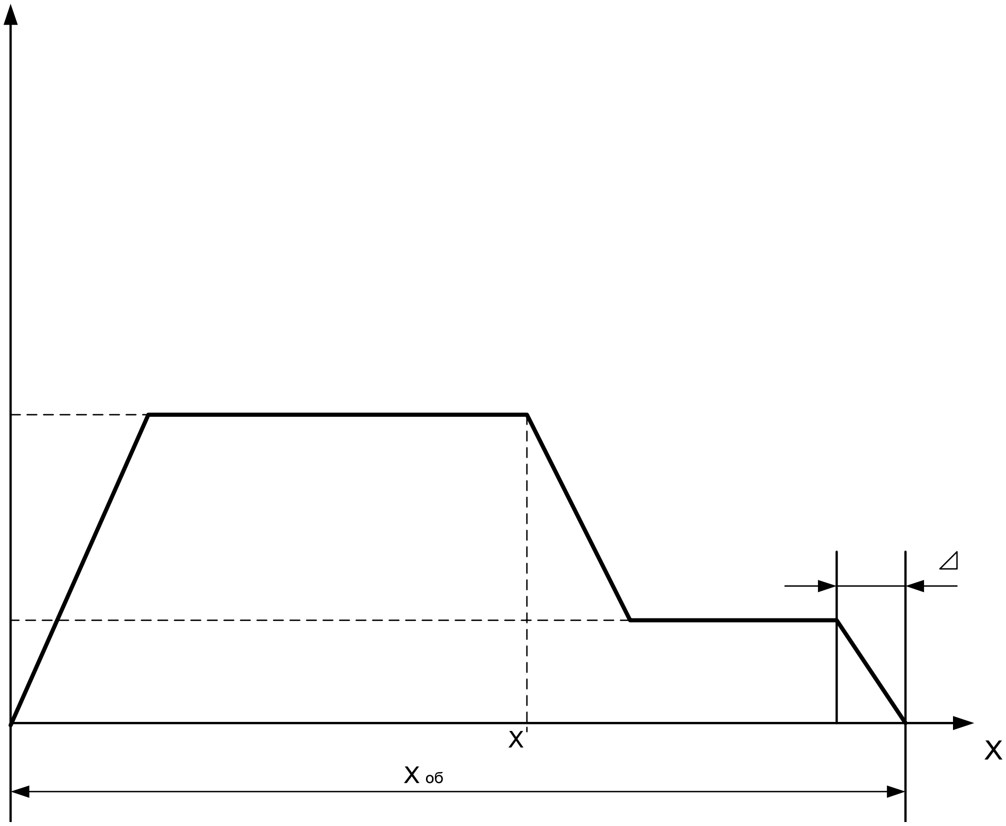

Figure 1 – Dependence Of The Crane Movement Speed On The Coordinate

The positional scheme can be implemented on the basis of contactless sensors that are mass-produced for various automation devices.

We have selected the DP-2 contactless motion sensor.

This sensor has a small size of 50x60 mm, a small weight of 150 g. and a relatively high sensitivity.

The optimal dimensions of the code screens for the stable operation of the sensors are taken from the experimental data of VNIIZHTA [31].

1. Code screen size 50x60x3, material steel 3;

2. The distance between the sensor axes is 90 mm.

4. OUR APPROACH

The main part. The choice of the coordinate reading principle is based on the domestic and foreign experience in creating automated control systems for positioning container cranes [34].

Currently, there are known systems for reading the coordinates of gantry cranes operating on the principle of sequential counting of passed positions and on the code principle. The principle of progressive bills passed position requires a smaller number of address elements. Technically, this principle is easier to implement. So, for example, for a container platform with 64 positions on the X-axis and 10 positions on the Y-axis, 64+10=74 address elements are required (64 address elements are located along the crane travel path and 10 on the crane bridge) and two reading elements. To implement the code principle, you need 6 address elements to encode one position on the X-axis and 4 to encode one position on the Y-axis. Total (6 • 64)+(4 • 10)=244 address elements (address carrier) and 6+4=10 reading elements (address receivers) located on the tap.

We will evaluate the reliability of these reading systems based on the logical-probabilistic method, assuming that they are implemented on the basis of the same reading elements [36-42].

Probability of safe operation of systems

$$P_c = P\{Y_1(X_1 ... X_n) = 1\}.$$

Probability of system failure

$$q_c = P\{Y_2(X_1 ... X_n) = 0\},$$

where $Y_1(X_1 .. X_n)$ - health function;

$Y_2(X_1 .. X_n)$ - inoperable function;

$P_1\{X_i = 1\}$ - probability of safe operation of the i-th reading element; $q = P\{X_i = 0\}$ - the probability of failure of the i-th reading element.

The principle of sequential counting corresponds to a sequential logical connection (i.e., if one of the reading elements fails, the counting error is transferred to the information accounts of all subsequent elements and the system fails).

For a sequentially logical connection, the probability of safe operation is

$$P_c = \prod_{i=1}^{n} P_i$$

Path the probability of failure-free operation of the read elements over time T=(P_i=0,99) when P=$_1$= P_2 =…= P_n =0,99

$$P_c = P_i^n = 0{,}99^n$$

when n=64

$$P_c = P_i^n = 0{,}99^{64} = 0{,}52559 \approx 0{,}525$$

With a code reading system, the probability of safe operation, i.e. the probability that the position code will be read correctly at Pi=0.99 n=6

$$P_k = 0.99^6 = 0.941$$

For the code page

$$q_k = 1 - 0.941 = 5.9 \cdot 10^{-2}$$

For a sequential counting system, the probability of failure is:

$$q_c = 1 - 0.525 = 4{,}75 \cdot 10^{-1}$$

Thus, the probability of failures of the code system (and hence the reliability) of reading the coordinates of the gantry crane is an order of magnitude less than that of a reading system with a sequential count of positions.

To increase the reliability of the series system account using the notch located in 5 rows of 10, i.e. introduce an additional comparison and correction, which complicates an electronic circuit leads to its appreciation and benefits system consistent account (simple and low cost) they are lost. And, as a rule, most of the systems created recently work according to the code principle.

The proposed coordinate reading system implements the code principle of reading the position of containers by inductive sensors located on the crane, and metal screens are supposed to be used as address carriers.

The developed positioning system of the crane operation consists of address elements located along the trajectory of the crane's executive bodies, a system of reading elements(sensors), a signal reception and processing unit, a communication line, a device for interfacing with an indication unit and a receiving and transmitting device; a mechanical device that provides the necessary mutual orientation of the address carriers and reading elements, bearing structural elements.

Device for controlling the position of the faucet contains position sensors crane installed on the faucet, and the screens mounted on the stationary guide elements, fixed guide elements made of two wires, suspended on poles and screens installed on the straps fixed on Provo-Dah, with the position sensors mounted on the crane attached to the faucet under the wires and spring-loaded relative to the platform with the guide rollers interacting with the wires.

Figure 2 shows a device for monitoring the position of the crane, and Figure 3 shows a platform with sensors.

A device for controlling the position of valve 1 comprises a passive 2 code elements made in the form of screens mounted on the stationary guide elements 3, made of two wires, suspended on supports 4. Code element 2 mounted on rails 5, rigidly fixed to the wires 3 and perpendicular to them, and the position sensor 6 is mounted on the platform 7, including guide rollers 8, moving through the wires 3 and is made with possibility of rotation around the horizontal axis 9 and spring-loaded relative to the metal faucet 1 10 springs 11 and 12. The wires 3 with the bars 5 are located on the supports 4 below the power supply line 13 of the crane 1.

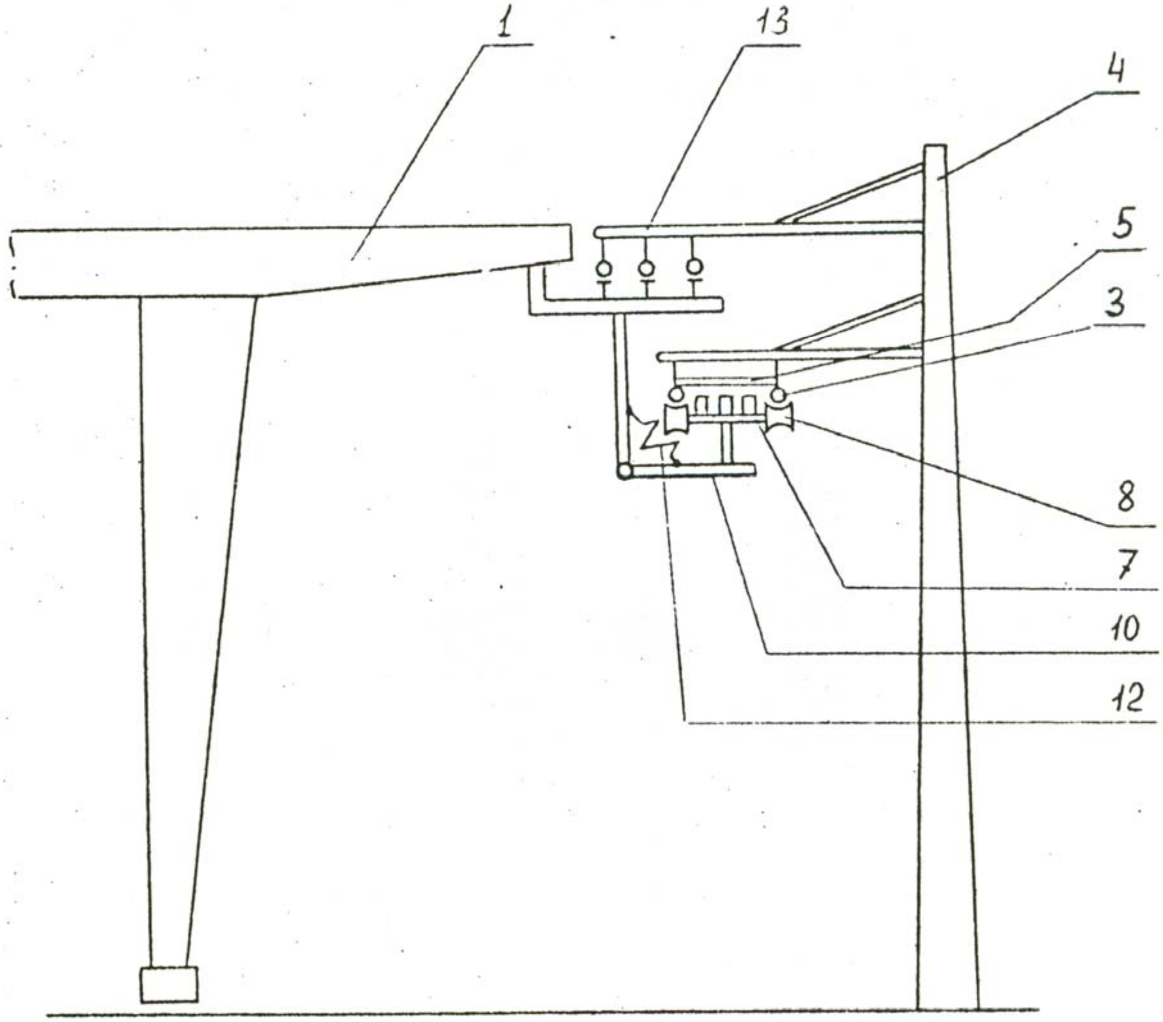

Figure 2 – Device for monitoring the position of the crane

The device for monitoring the position of the crane works as follows. When moving the crane 1 along the crane tracks, the rollers 8 will move along the wires 3. When passing the platform 7 under the slats 5, the sensors 6 will interact with the code elements 2. Information about the interaction of the sensors with the screens enters the control system (not shown).

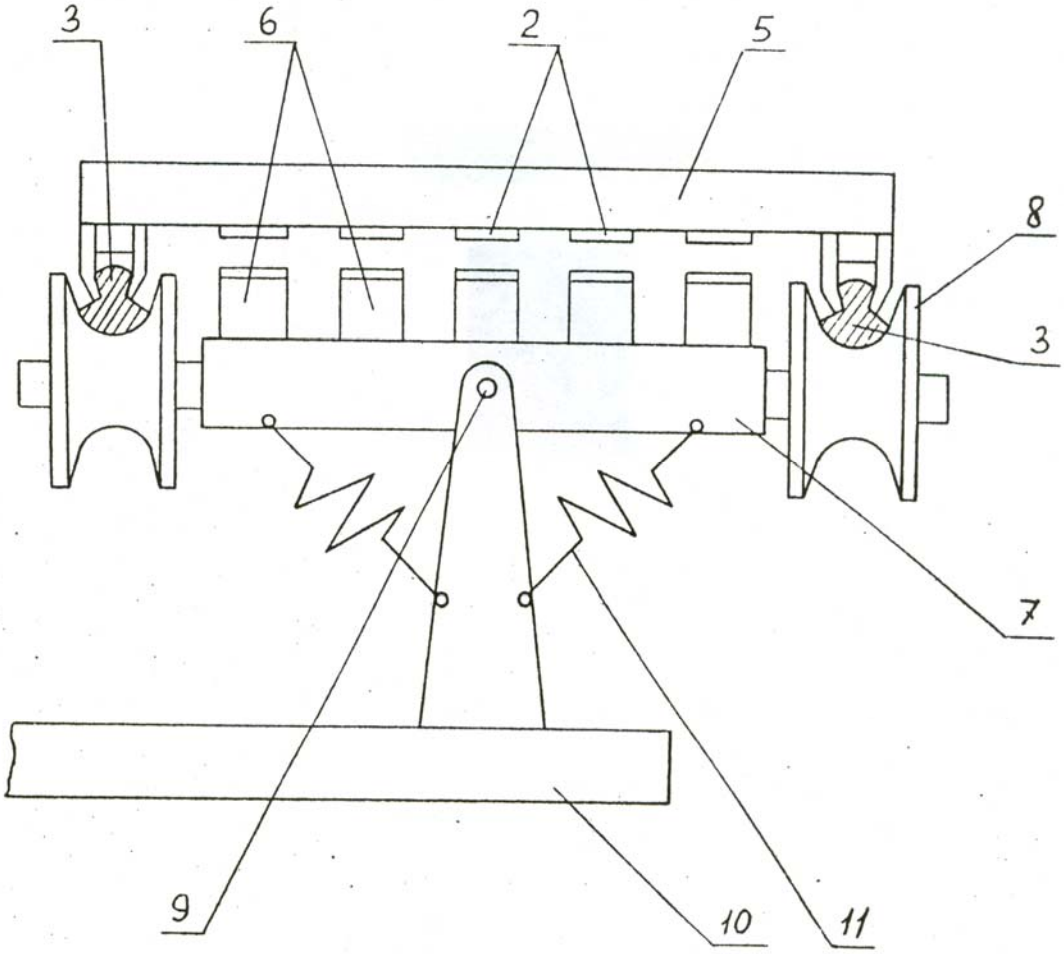

Figure 3 – Platform With Sensors

Stabilization of the distance between the code elements 2 and the sensor 6 is provided with flexible wires, rotation platform 7 about the axis 9, and the constancy of pressing rollers on wire springs 11 and 12.

The positioning system of the crane operation involves two variants of a mechanical device for preloading the reading elements to the address carriers. The first option provides for a telescopic preload of the reader to the code bar. In the second variant, the reader device is a cart on four wheels with BDP-2 sensors attached to it. Preloading to the trolleys, on which the code bars are located, is carried out by means of a four-link articulated joint connected to the crane by two rigid links and a spring (which gives the necessary force for preloading).

5. RESULTS

The first version of the preload device orienting the sensor system relative to the address plates is shown in Figure 4, the design of the preload device is shown in Figure 5. The sensor system 4 has the possibility of displacement in the YOZ plane. Thus, the possible error on the Y-axis is compensated (the non-parallelism of the axis of the code plates and the trajectory of the crane movement). With the help of telescopic preloads 1,2, the plate 3 with sensors 4 is preloaded to the trolls (not shown in the diagram). The trolleys act as guides along which the sensor system moves along the rollers. The disadvantage of the design is the low degree of rigidity of the structure, which has the bearings of telescopic preloads. With frequent alternating loads, it is possible to lose the parallelism of the telescopic preloads, which leads to an error when reading the position, i.e. the position code is not read completely due to the skew of the code bar relative to the reader. The extreme sensor is triggered, the sensor that is located on the other edge has not yet reached the code bar and the trigger does not occur.

In the second variant, the code bars are placed on two trolls suspended below the power supply trolls.

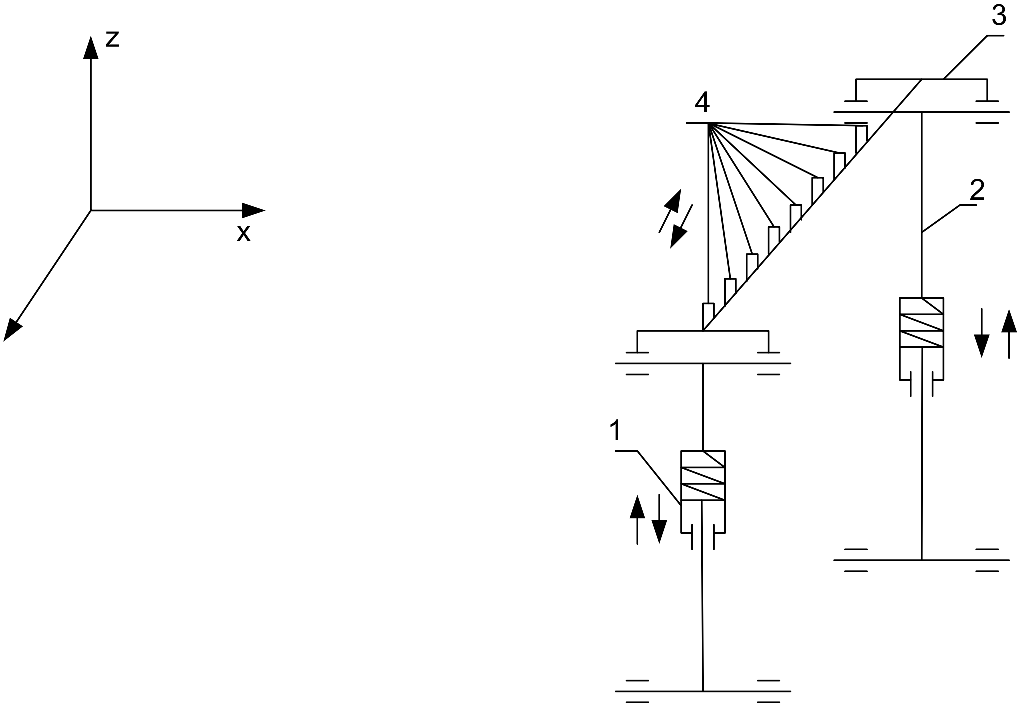

Figure 4 – Diagram Of The Preload Device

Trolls play the role of supporting and guiding structural elements. The absence of voltage on the trolls facilitates the maintenance of the coordinate reading system and eliminates the possibility of a short circuit under the influence of atmospheric precipitation.

The address elements on the X-axis are planks of delta wood. With the help of special (trolleybus) clamps, the slats are fixed on the trolleys. Metal plates are fixed to the slats in accordance with the position code, the size of which is determined by the type of selected sensors and its characteristics. The address elements on the Y-axis are metal plates located on the bridge of the gantry crane.

The system of reading elements is a series of inductive sensors of the BDP-2 type (non-contact motion sensors), mounted on a special preload device that provides the necessary gap between the sensor and the code plates.

The signal reception and processing unit remembers the position code coming from the sensors and stores the information until the next signal arrives and converts this signal to transmit it over the radio channel and to display it on the scoreboard (screen) in the crane operator's cabin. Figures 5 and 6 show the schemes for reading the code along the X,Y axis, which is an integral part of the signal reception and processing unit. The position code is sent to the memory register from sensors 1 7. Moreover, a signal is sent to the synchronization input from the "OR" element, i.e. the information is recorded if there is a signal at least on one of the outputs 1-6. From the register, it is transmitted to the decoder, and then to the input of the indicative devices.

The sensor system has the ability to offset on the Z-axis and a slight offset on the Y-axis. This offset must be calculated on a computer.

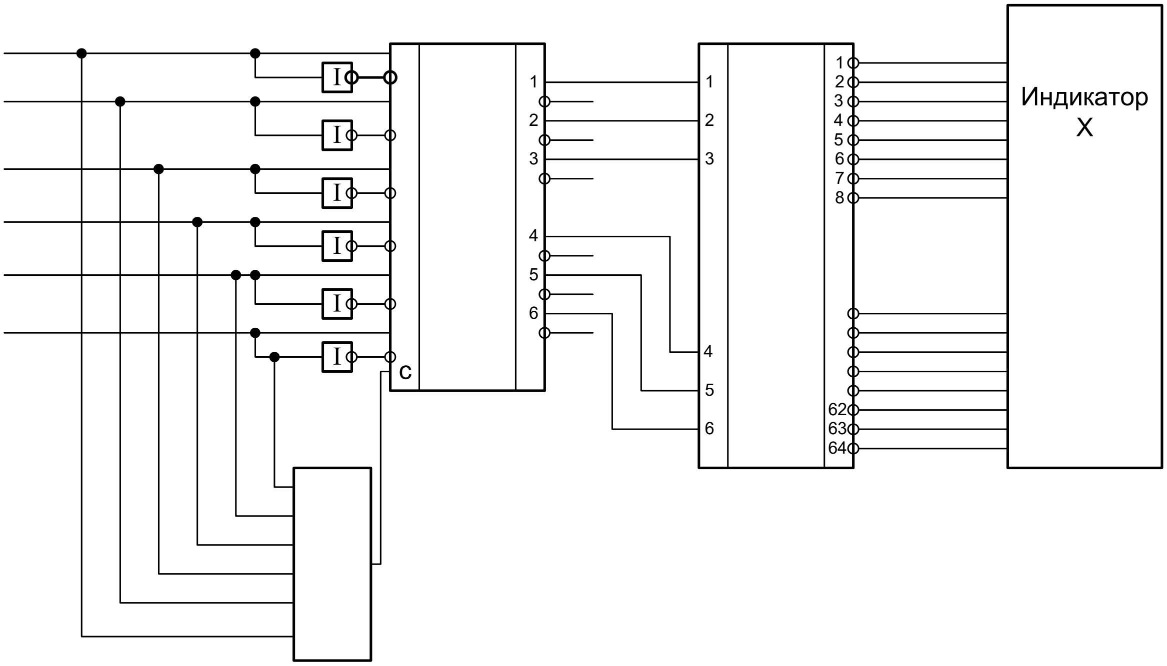

Figure 5 – X-Axis Code Reading Diagram

The trolleys serve as guides along which the trolley moves, with a sensor system installed on it. The trolley rests on the trolleys through four rollers, which allows for a constant gap between the sensors and the code bar. The preload of the trolley is carried out by the spring of the preload device. For a softer characteristic and constant pressure on the trolley, we take a long and small diameter spring. The spring acts on a four-link hinge, one link of which is extended and a trolley with a reader is attached to it.

There is a platform with a reading device under the maintenance platform of the current collectors.

The platform of the coordinate reading system is attached by two channels to the bridge of the gantry crane. The platform has a railing with a height of 1 m for safe maintenance. For passage to the SSC site, there is a hatch on the floor of the current collector service area. Thus, the relative location of system elements read (sensors) located on the straps code plates are not dependent on changes in the trolley with straps code relative to the gantry crane and is determined by the design code of the straps and the pressing device.

The design requirements for the code bars and the preload device are determined by the characteristics of the sensors. So, for the BDP-2 sensors selected by us, the gap between the plates and the sensors should be within 20 to 30 mm. Experimental data were obtained [31]:

Code plate size

$$S = (a + \Delta x)(b + \Delta y)$$

$$a \times b = 50 \times 60 \text{ mm}$$

$$\Delta x = \Delta x^{/} + \Delta x^{//} + \Delta x^{///} ,$$

where $\Delta y \Delta x^{/}$ - dimensional error;

$\Delta x^{//}$ - the error caused by the time difference between the interaction of address elements on the address receivers during parallel reading;

$$\Delta x^{///} = V \times t_c ,$$

where V – the speed of movement of the crane;

t_c – the delay of the reading equipment.

Sensors are triggered at a distance 38÷41 mm.

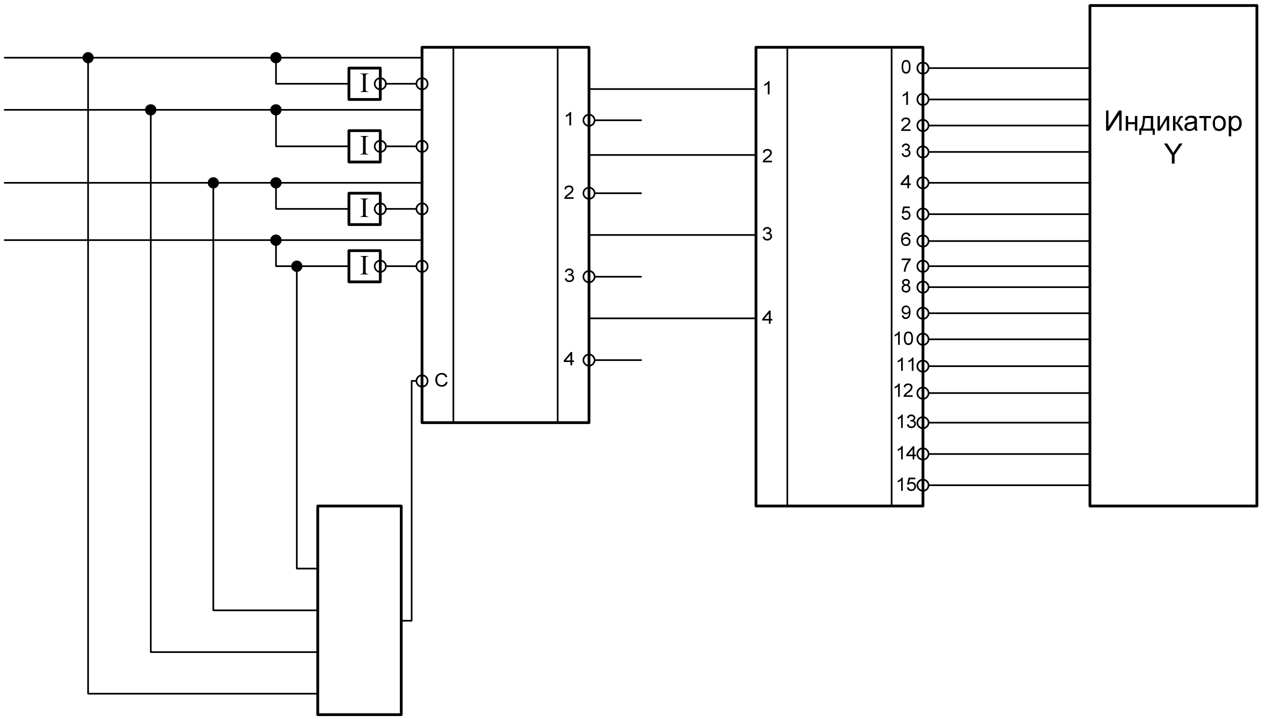

Figure 6 – Y-Axis Code Reading Diagram

6. CONCLUSION

Thus, the proposed crane operation positioning system (SPC) is based on the use of contactless inductive sensors as address receivers and metal screens as address carriers. The use of such a set of reading elements allows you to encode each position, which reduces the probability of an error reading the coordinate. In addition, the contactless elements of the system when operating in harsh weather conditions provide high reliability and ease of maintenance with high unification of the elements and their low cost. The layout of the system meets the requirements of long-term development, about the removal of system elements from the working area of the container platform, which provides less vulnerability, ease of maintenance and independence from the operation and maintenance of the track and transport zone.

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