Selection of the structural scheme of the control line for finishing products from natural wood

Stanislav Gorobchenko[1], *Dmitriy* Kovalev[1], *Viktoriia* Sokolova[2*], *Ramil* Zagidullin[2], *Stanislav* Akhmetshin[2], *Yuri* Belenkiy[1], and *Aleksey* Teppoev[3]

[1]Saint-Petersburg State University of Industrial Technologies and Design, Saint-Petersburg, Russia
[2]Kazan Federal University, Kazan, Russia
[3]Saint-Petersburg State Forest Technical University, Saint-Petersburg, Russia

Abstract. The issues of choosing structural control schemes for finishing lines for products made of natural wood are considered. A literature review is given. In the block diagrams of these systems, single-level, two-level and three-level systems can be used, depending on the complexity of the control object and control tasks. The criteria by which it is necessary to choose structural control schemes and TCA tools are shown. Block diagrams of direct (direct) digital control of the process can be considered optimal. For these purposes, an algorithm for the direct control process is given.

1 Introduction

The choice of the control structure of the automation object affects how efficiently the system will work, as well as reducing its cost. Today, the problem of choosing a structural control scheme is solved practically normatively or on the basis of an approach traditionally used in a particular industry. At the same time, the number of block diagrams that can be applied on one control object can be several, and their choice can represent a separate task. One of the important problems associated with the choice of block diagrams of automation is the selection of block diagrams for automatic production lines, for which their various configurations can be applied.

The article aims to clarify the features of configuring block diagrams for various control objects and to propose an optimal block diagram for a line for finishing natural wood products.

Consider the state of the issue, based on recent publications on this topic. The article [1] presents structural and functional diagrams of spraying technological installations, tables of controlled parameters, a block diagram of the automation of the spraying technological process, and a diagram of the algorithm for the operation of an automation device. Particular attention is paid to the block diagram of the automation device and its operation algorithm. The article [2] discusses the main stages of the life cycle of transport and technological machines to be automated, and also provides a description of the block diagram of an integrated automated system for supporting the life cycle of a fleet of transport and technological machines.

* Corresponding author: sokolova_vika@inbox.ru

A new approach may be an approach based on energy information models. Using energy-information models to describe circuits of various physical nature and the apparatus of parametric block diagrams, it is possible to represent the whole variety of relationships between quantities and parameters in the form of a complex graph. In [3], this graph contains elements that reflect dynamic processes in operator form (parameters and quantities). With the advent of powerful computing tools, it became possible to automate the targeted process of synthesizing structural circuits, to study their dynamic characteristics, both existing and synthesized structural circuits [4].

2 Block diagrams

A graphic representation of the control structure is called a block diagram. The control structure is understood as a set of parts of an automatic system into which it can be divided according to a certain attribute, as well as ways of transferring influences between them. The block diagram of the automation system is shown in Figure 1 [5].

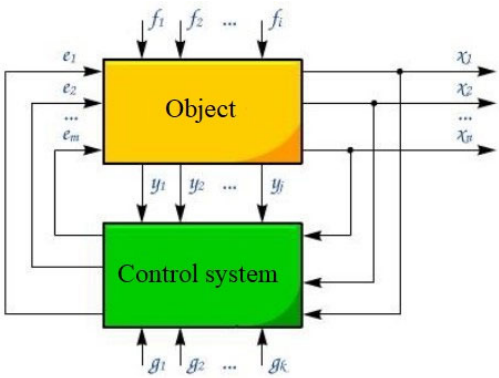

Fig. 1. Block diagram of automation x_1, x_2, ..., x_n – output parameters; y_1, y_2,...y_i – auxiliary parameters; f_1, f_2,... f_i disturbing influences; g_1, g_2,..., g_k – given values; E_1, E_2,…, E_m – control actions.

The automation system includes an automation object and a control system for this object. Thanks to a certain interaction between the automation object and the control system, the automation system as a whole provides the required result of the object's functioning.

3 Choice of structural control scheme

Control sections can be physically represented as separate installations, units, etc., or as local control channels for individual parameters of the same installations, units, etc. The control system, depending on the importance of the adjustable parameters, the number and role of the operating personnel who need to know the parameter values for optimal control of the object, in the general case, should provide different levels of control of the automation object, i.e. should consist of several control points, to some extent interconnected with each other.

Based on this, the control structures of the automation object can be, in particular cases, single-level centralized, single-level decentralized and multi-level. Single-level control systems, in which the object is controlled from one control point, are centralized, and single-level systems, in which individual parts of a complex object are controlled from independent control points, will be decentralized [6].

Structural diagrams of one-level centralized and decentralized systems are shown in Figure 2, in which the arrows show only the main flows of information transfer from the control object to the control system and the control actions of the system on the control object. In Figure 2, separate parts of a complex control object, controlled from CP1 - CP3, respectively, are separated by dashed lines.

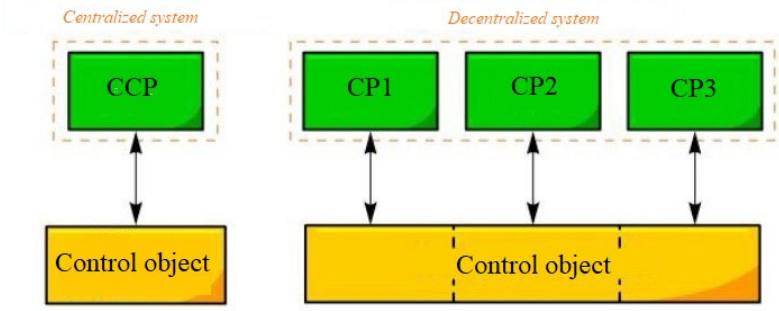

Fig. 2. Examples of single-level control systems.

Single-level centralized systems are mainly used to manage relatively simple objects or objects located in a small area. Most industrial facilities are currently complex complexes, some parts of which are located at a considerable distance from each other. Systems in which individual parts of a complex object are controlled from independent control points are decentralized [7].

Structural diagrams of one-level centralized and decentralized systems are shown in Figure 2, in which the arrows show only the main flows of information transfer from the control object to the control system and the control actions of the system on the control object. In Figure 2, separate parts of a complex control object, controlled from CP1 - CP3, respectively, are separated by dashed lines.

Figure 3 illustrates an even more detailed hierarchical structure of the automation system, with clearly defined levels, provided with their own technical, software, information, and other means to ensure the operation of the automated control system.

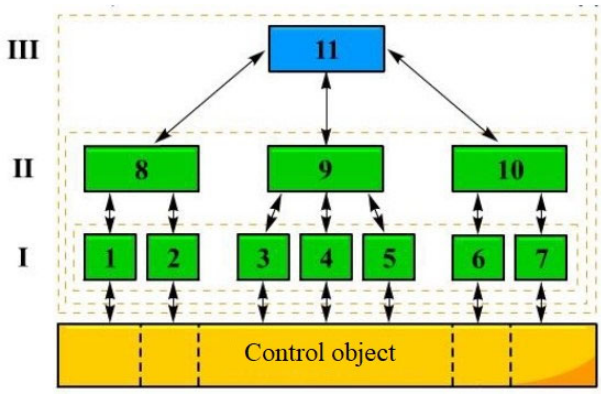

Fig. 3. An example of a three-level control system: I - III – control levels.

In general, the block diagram may have more levels, depending on how many levels of coverage of the regulator (ASR), technological process (ASTP), operational dispatch control (ASODU) or various layouts involving various departments (MES, ERP, etc.) can be included in the overall system.

4 Selection of a block diagram for automation of a natural wood product finishing line

Wood and its modifications are used to produce furniture, joinery and construction products, industrial and consumer products. The main tasks and criteria of management here are:

- complex mechanization and automation of technological processes;
- reducing the complexity of operations;
- increase in labor productivity;
- increase in product removal from 1 m^2 of production area;
- reducing the cost of production;
- improving the quality of finished products;
- ensuring safe working conditions, protecting the health of workers, etc.

When finishing by pneumatic spraying using an Ecosprayer Easy W model finishing machine with Kremlin guns of the Airmix spray system, the following technological parameters must be maintained:

- air temperature in the room;
- relative humidity in the room;
- viscosity of working solutions, at a given temperature of the solution in the workshop;
- the specified distance from the nozzle to the conveyor belt;
- humidity of the parts coming for finishing;
- speed of movement of pistol carriages;
- the shape and orientation of the gun spray jet according to all the characteristics of the manufacturer of the spray guns;
- coating pressure.

It is required to provide the specified air pressure of the spray jet cocoon. The application of materials to all surfaces is automatic, the number of applications depends on the requirements for the finished surface [8].

Elements of local automation in accordance with the above criteria and requirements can be recommended as follows:

- an optical sensor reads the shape and size of the incoming product;
- the inductive sensor counts the pulses during the supply of the incoming product to the spray zone;
- a photocell detects the presence of a product exiting the conveyor and its entry into the next area of the production line.

The automation scheme provides for the control, registration and management of technological parameters through microcontroller control, Figure 4 [9].

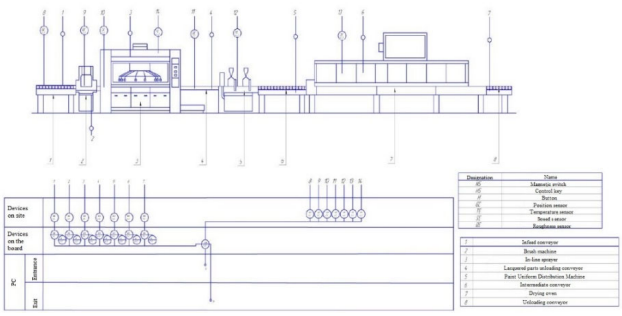

Fig. 4. Finishing line automation scheme.

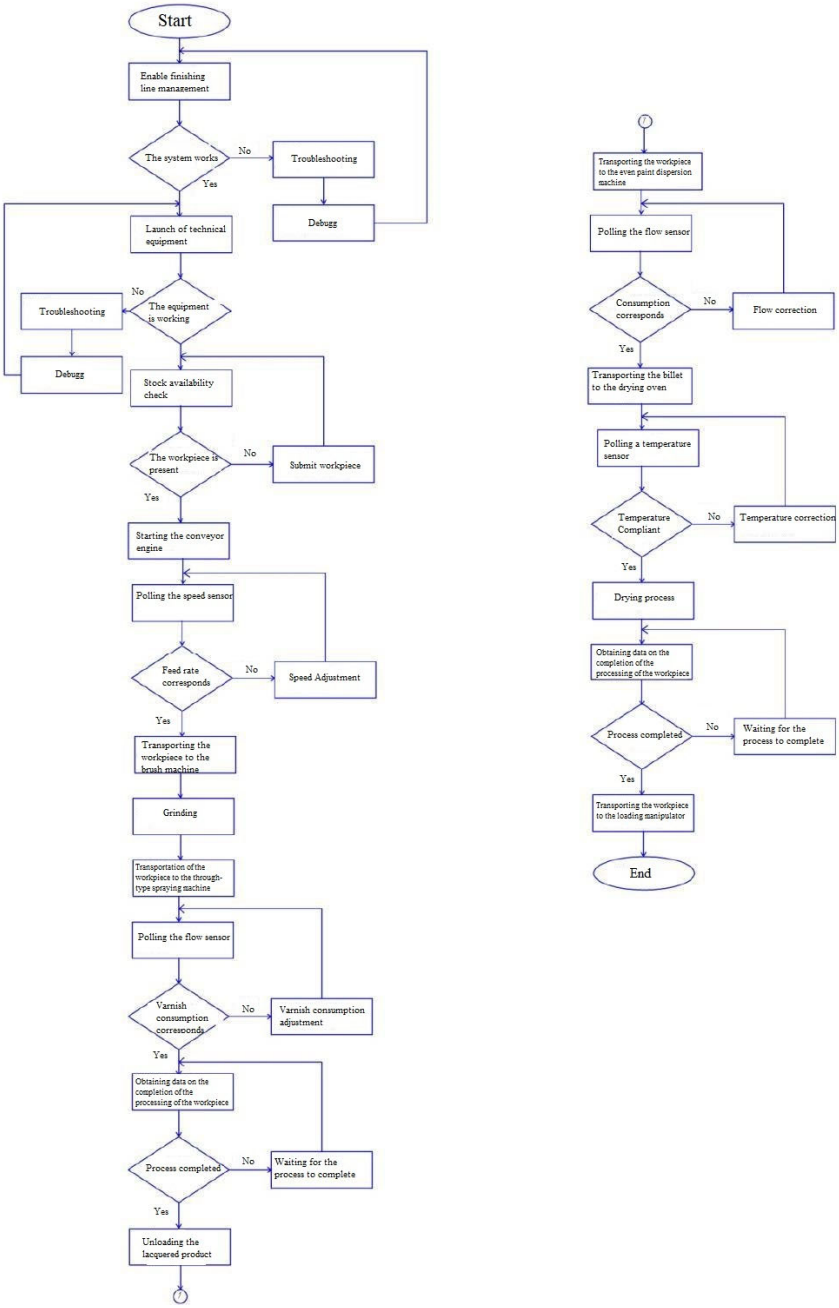

Fig. 5. Finishing line control algorithm.

The following sensors are provided as control devices in the finishing line automation system:

- sensor for surface roughness of parts supplied for finishing;
- a photo sensor that determines the presence or absence of a part on the working section of the line; as well as the photo sensor determines the linear dimensions of the workpieces to be finished;

- a pulse sensor that controls the movement of workpieces into the working areas of the line;
- conveyor speed sensor;
- pneumatic station that regulates the pressure in spray guns;
- varnish consumption sensor in a varnish-applying machine;
- varnish coating thickness sensor;
- temperature sensor in the dryer.

Information from the sensors is fed to the input of the controller located on the board. After analyzing the data, the controller generates a control action on the motors of the actuators [9]. Thus, the mode of direct digital control of the technological process is realized (Figure 5).

All data on the course of the technological process is fed to the input of the computer. The operator can participate in the technological process to reconfigure the equipment and control system of the finishing line. To start work, the equipment is started. The operator must set the speed of the infeed belt conveyor and place the workpiece on it. Next, information about the initial roughness of the workpiece is requested and, in accordance with the data obtained, the conveyor speed of the brush machine is set [10].

When the brush machine's photo sensor detects the presence of a workpiece in the working field, the brush mechanism is activated. It is necessary to trace the correct operation of the brushes. Further along the conveyor, the workpiece enters the varnishing machine [11]. After the photo sensor has fixed the workpiece, its linear dimensions are read. Based on these data, the varnish consumption in the control system is set. At the end of the polling cycle, the varnish supply stops [12].

Simultaneously with the flow, it is necessary to debug the pressure in the pneumatic station. The pressure in the spray guns is compared with the set pressure. If the pressure is greater than the specified one, it is necessary to suspend the process, if it is less, apply varnish to the guns. At the end of painting, the part is fed to an intermediate conveyor, where the thickness of the applied varnish is read [13].

According to the data obtained, the conveyor speed of the rubbing machine is set. According to the photosensor, the brushes from two asynchronous reversible motors are switched on. Further along the intermediate conveyor, the part enters the drying oven. When drying in an oven, two technological parameters must be simultaneously stabilized - temperature and humidity. At the end of the control cycle, the final quality of the coating is determined, and the workpiece enters the conveyor belt. The finishing line control algorithm is shown in Figure 5.

When introduced into the technological process, the automation system should provide:

- polling the performance of sensors for roughness, coating thickness, conveyor speed, varnish consumption, temperature in the dryer;
- survey of the operation of the main conveyor, varnish-applying and drying machine;
- reading information from the roughness, coating thickness, conveyor speed, varnish consumption, temperature gauges;
- turning on the drives of the conveyor, varnishing machine;
- control of the varnish level in the machine;
- measurement of varnish consumption;
- control of operation of metering pump drives;
- performing calculations using formulas, etc. [14].

The analysis of the control object - the finishing line for natural wood products shows that most of the signals in the installation are implemented between the sensors and the controller. At the same time, the consistency of the entire line as a whole remains an important element due to the continuity and high speed of the products passing along the line.

The role of transferring information to higher levels in this case remains in question, since the amount of information output to possible upper levels is not enough to organize the corresponding level and therefore is not economically feasible. The algorithm for connecting the controller with sensors (Figure 5) implements the interaction between the main levels on a budget and does not require the use of additional capacities. In this regard, the scheme can be strengthened by proposing to immediately use digital signal processing and the use of digital sensors. Thus, a block diagram with direct digital control from the line controller can be proposed.

5 Conclusion

The choice of the control structure of the automation object has a significant impact on the efficiency of its work, reducing the relative cost of the control system, its reliability, maintainability, etc. In the process of developing an automation project, first of all, the task is to understand from what places or from what sections control will be carried out, where it will be necessary to place control nodes, what kind of connection will exist between them. This makes it possible to obtain the main control loops and develop a block diagram that can optimally divide the entire set of parts of the automatic system according to a certain attribute, as well as ways to transfer influences between them. As an illustration, the choice of a block diagram of automation in the field of woodworking and its advantages when using direct digital control is shown.

The work is carried out in accordance with the Strategic Academic Leadership Program "PRIORITY-2030" of the Kazan Federal University of the Government of the Russian Federation.

References

1. A.M. Sharafutdinov, A.I. Akimov, Bulletin of scientific conferences **2**, 157-158 (2015)
2. GOST 24.701-86 Unified system of standards for automated control systems. Reliability of automated control systems. Basic provisions.
3. GOST 34.601-90. Automated systems. Creation stages.
4. GOST R 59792-2021 Types of testing of automated systems.
5. GOST 24.302-80. Technical documentation system for automated control systems. General requirements for the implementation of schemes.
6. D.I. Chistyakov, G.V. Skonodobov, Prospects for the development of information technologies, 89-93 (2017)
7. G.A. Dolin, Actual problems of radio and film technology, 40-45 (2018)
8. A.S. Sushkov, S.I. Sushkov, K.Ya. Yakovlev, Bulletin of the Voronezh State Technical University **10**, 179-182 (2010)
9. S.I. Polyakov, V.S. Esipov, Actual directions of scientific research of the XXI century: theory and practice **5-4**, 481-486 (2015)
10. Structural diagrams of automation systems [electronic resource] (2022). http://ani-studio.narod.ru/ (accessed 22.02.2022)
11. S.N. Basque, *Modern automation technologies* (Publishing Center of SUSU, Chelyabinsk, 2017), p. 41
12. I.Yu. Petrova, Yu.A. Lezhnina, O.I. Evdoshenko, Engineering and Construction Bulletin of the Caspian Sea **1**, 110-119 (2019)

13. V.S. Petrovsky, A.D. Danilov, *Automation of technological processes and industries in the woodworking industry* (Voronezh State Forestry Engineering Academy, Voronezh, 2010), p. 432
14. I. Maganov, E. Tihonov, A. Gaiduk, I. Kiyamov, L. Sabitov, V. Sokolova, E3S Web of Conferences **390**, 07041 (2023)