Simulation model of an automated system of wood drying process in the VisSim dynamic programming environment

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Abstract. The relevance of the use of simulation in the VisSim dynamic programming for the design of an automated control system for drying wood is indicated. The method of iterations of comparison of experimental and theoretical data, designing in a VisSim dynamic programming, environment was used in the work. A software product has been developed for controlling the heat-humidity regime in the drying chamber. A phased description of the implementation of the wood drying algorithm is given. Development results can be used in the design of automated control systems.

1. Introduction

Design and development of automated control systems (ACS) involves the determination of the dynamic properties of the control object or its mathematical model (the algorithmic structure of the object and the values of its parameters). The process of developing a generalized mathematical model and determining its parameters is a structural and parametric identification.

In the practice of synthesizing automatic control systems by technological processes, two methods of experimental determination (identification) of static and dynamic characteristics of automation objects are used. They are active and passive.

In the first case, the test effect of the standard form is set artificially, in the second case, the object is examined by comparing the output and input values under normal operation of the object.

The choice of the method of the object identification is determined by the task, experimental conditions, operational disturbances and deviations of the studied quantities admissible by technological requirements.

Static equations describe the behavior of an object in a steady state, i.e., show the relationship between the input \( x(t) \) and output \( y(t) \) coordinates, when all derivatives of the functions \( x(t) \) and \( y(t) \) are equal to zero.

2. Materials and Methods

To determine the static characteristics of the drying chamber for lumber drying, a relationship between the flow rate (pressure) of steam through the control valve and the air temperature at the midpoint of the chamber is established with the steam supply. In this case, the temperature is measured after stabilization of the structure temperature regime.
Figure 1 shows the results of experimental studies of the main parameters of the technological process of wood drying [1].

![Graph of changes in the main parameters of the drying process.](image)

Figure 1. Graphs of changes in the main parameters of the drying process.

In order to identify the control object (drying chamber) in this work, we used an algorithm for calculating the value of the objective function using experimental data presented in pulsed form, implemented in a VisSim dynamic programming environment [2,3,4].

3. Results and discussions

From the practice of designing process control systems it is known that there is a large class of control objects that are described in the form of one or more aperiodic links of the first order and possibly of a time delay link:

\[ W(s) = \frac{k}{T_1s + 1}e^{-st}. \]

The result of the calculation are the optimal values of the transfer function parameters:

\[ k_1 = 11.2; \quad k_2 = 15.1; \quad T_1 = 20500. \]

In this case, the minimum value of the objective function (identification error), corresponding to the calculated values of the parameters, is \( Z = 4.247 \).

Figure 2 shows the result of parametric identification (temperature-time relationship) at a preset value of steam pressure in heaters of 0.6 MPa in the form of a graph of the transfer function of the control object

\[ W(s) = 11.2 \frac{15.1}{20500s + 1}. \]
Based on the obtained results, it can be concluded that the theoretical model of heat transfer processes in the drying chamber is quite adequate to the real object, since the experimental data and the theoretical curve in the heating mode are well correlated. It can also be argued that the parameters of the mathematical model are determined quite accurately.

Based on the obtained data and the well-known algorithm, a simulation model of an automated system for controlling the wood drying process was developed (Figure 3).

The main blocks of the model in expanded form are shown in Figures 4–7.

**Figure 2.** The results of parametric identification in the form of transfer functions of the control object.

**Figure 3.** The simulation model of the temperature control system in the drying chamber in block form.

**Figure 4.** Model of the control object (drying chamber).
The controller model is shown in Figure 5.

![Figure 5. Controller unit.](image)

In the controller unit, the program for controlling the technological process of the wood drying process is recorded (a sequence of technological operations, i.e., phases of the wood drying process). In production and in some literary sources [5, 6, 7], the control program is usually called a technological map of the wood drying process.

The control program is shown in Figure 6.

![Figure 6. Control program block (temperature setpoint).](image)

In Figure 6, on the right side of the temperature control program in the drying chamber, temperature values are set that correspond to each stage of the wood drying technological process. On the left side in the time relay temporary temperature switching modes are set, that is the law of temperature-time relationship in the chamber in this process is formed.

Let us consider the algorithm of the controller of the temperature field control of the drying chamber.

The controller operates on the basis of a logical comparison device, which has two inputs and one output. Input signals are Test that is the set temperature value from the control program (desired temperature change law), and Tact is the value of the actual temperature in the steaming chamber.

The current values of the hysteresis $\Delta T$ are determined in the controller (mismatch between the values of the established temperature and the actual temperature) and an output control signal is generated.

- At $T_{est} - T_{act} > \Delta T$ the output signal takes the value “1”.
- At $T_{est} - T_{act} < \Delta T$ the output signal takes the value “0”.
Then, the generated signal is arrived to the actuator. In our case, this is a control relay and a solenoid valve.

Figure 7 shows the logic device, the signal from which is arrived to the control relay.

![Figure 7. Logic device.](image)

The control relay controls the operation of the electromagnetic valve and is presented in the form of a multiplier unit.

This unit has two inputs and one output. Steam flow rate is arrived to the one of the inputs of the multiplier, “0” or “1” are arrived to the other input.

Accordingly, if the output signal from the multiplier of the control relay takes the value “0”, then the power supply is cut off and the solenoid valve is closed. If the value is “1”, then the electromagnetic valve is open, and steam under pressure of 0.6 MPa and the set temperature value enters the drying chamber.

Figure 8 shows the technological flow chart (temperature-time relationship) of the process for a specific case of wood drying process, recorded in the controller's memory. This graph is a temperature setter in the automatic control system.

![Figure 8. Technological flow chart of the wood drying process.](image)

Figure 9 shows a graph of temperature-time relationship in the drying chamber. In the same coordinate system, a graph of the setpoint temperature is shown. Within the error set by the process ± 2 °C, the developed automatic control system reproduces with high accuracy the predetermined dependence of the setpoint temperature.
Figure 9. A graph of temperature-time relationship and a graph of the setpoint temperature.

As calculations show, the absolute error in the regulation of the temperature in the drying chamber is about 1 °C, or 1/70·100 = 1.4% at a maximum equilibrium temperature of 70 °C.

Then, according to the graph in Figure 10, we find the number of activation of the electromagnetic valve in 1 hour, at a temperature of 70 °C.

Figure 10. Solenoid valve activation schedule.

The graph shows that in 1 hour (from the time point, from 6 hours, to the time point of 7 hours), the solenoid valve made 5 starts. This complies with the operating requirements of electromagnetic devices.

The control program block is designed based on logic devices that control the operation of the steam solenoid valve. For this purpose, in the temperature control program in the drying chamber, temperature values are set that correspond to each stage of the wood drying technological process, and
in the time relay - switching modes temporary temperature, that is, it is formed a law of the temperature-time dependence in this technological process.

4. Discussions and conclusions
The developed simulation model is universal and, with some refinement, can be applied in the design and commissioning of similar systems for the automated control of heat and humidity processes in the drying process of various materials.

References
[1] Rasev A 2014 Wood drying process: study guide (Moscow)
[2] Gryzhov V, Korolkov V, Gryzhov E 2018 Modern science: actual problems of theory and practice. Series: Natural and Technical Sciences 12 pp 87-93
[3] Gryzhov V, Korolkov V 2010 Industrial automation 7 pp 17-19
[4] Gryzhov V, Korolkov V, Gryzhov E, Akshinskiy A 2018 Industrial automation 8
[5] Rasev A, Kosarin A 2010 Hydrothermal processing and preservation of wood (Moscow)
[6] Boldyrev P 2010 Wood drying process (Saint-Petersburg)
[7] Akinshenkov S, Korneev V 1992 Design of drying chambers and workshops (Saint-Petersburg)