OPERATION ALGORITHM AND STRUCTURE OF AN ELECTRONIC SYSTEM FOR CONTROL OF ENERGY FLUXES IN THE SECTIONAL HEAT EXCHANGERS

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Abstract: The specifics of the process of the material moisture-heat treatment in the sectional heat exchangers have been analyzed. An operation algorithm of an electronic system for control of energy fluxes in the sectional heat exchangers has been created. An algorithm for modeling the process of moisture-heat treatment of the material in the sectional heat exchangers has been developed. Based on the presented algorithms, a specialized software product in the Visual Studio 2010 environment has been developed. A structure of the electronic system for control of energy fluxes in the sectional heat exchangers has been developed.

Keywords: model, algorithm, electronic system, sectional heat exchangers

1. INTRODUCTION

There are a number of known electronic systems for sectional heat exchangers control [1- 3]. They maintain a certain process parameters, but do not account for the dynamics of energy fluxes. It is determined by the unit heat-exchange and inertial properties defined by its structure.

The main goal of the electronic control systems is to determine the necessary control actions which provide the required product quality at lower energy consumption [4- 8]. To solve this problem the systems can calculate their control actions based on a process simulation through a model. Using the simulation results and taking into account the current parameters of the process, it is possible to determine the control actions which provide the necessary product quality at lower energy consumption.

2. METHODOLOGY

2.1. The aim of this research is to develop an operation algorithm and structure of an electronic system for control of energy fluxes in the sectional heat exchangers based on a mathematical model of the process.

2.2. The object of control is the process of the material moisture-heat treatment in the sectional heat exchangers. The specifics of the process is characterized with the necessity for humidification and heating of the material during it's entry in the sectional heat exchangers. The humidification could be accomplished by either cold water or steam. The heating is accomplished with the humidifying steam and with the steam entering the exchanger sections. One of the main prerequisites for accomplishing low product cost is the correlation between the energy fluxes entering the heat exchanger with the humidifying steam and with the heating steam. After condensation, the heating steam is brought back for a second heating. The steam for humidification and

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simultaneous heating is not reused, which requires the use of additional amount of softened water. During the steam humidification, it is important to take into account that the initial humidification could lead to a fast heating up of the material, which would comply with the criterion for minimal heating time.

2.3. Control criteria

In order to provide the required product quality, it is necessary to comply with the control criteria during the process control. The main criteria for the control of the process of the material moisture-heat treatment in the sectional heat exchangers are the minimal heating time, the maximal heating speed, the maximal heating value, the time for the material processing, the parameters values at the exit of the device etc. [9].

3. OPERATION ALGORITHM OF AN ELECTRONIC SYSTEM FOR CONTROL OF ENERGY FLUXES IN THE SECTIONAL HEAT EXCHANGERS

An operation algorithm of an electronic system for control of energy fluxes in the sectional heat exchangers is based on a model describing the process of moisture-heat treatment of the material. It is developed using the finite elements method [10-12]. The theoretical substantiation of the model is presented in [13]. The problem which the algorithm has to resolve is to simulate the process with a model and to determine the optimal correlation between the energy fluxes of steam used for heating and for humidification. The algorithm for control of the energy fluxes in the sectional heat exchangers is shown in Figure 1.

The initial conditions are set in block 1. A check if there is a request to set the parameters follows in block 2. If there is, a dialog window is shown (block 3). The process parameters from the sensors are measured and the data from the monitoring system are stored in block 4. The time interval (τ_{req} , s) required to fill in the 1st section of the heat exchangers is calculated in block 5. Depending on this interval, the maximal simulation time (τ_{max} , s) is calculated. It is assumed that the maximal simulation time is equal to multiple filling cycles, to pass the initial conditions transients during the modeling (block 6). The filling in period is also used to determine the time interval for estimation of the process criteria τ_{crit} . It is done in block 7.

The temperature variations of the material before it enters the heat exchanger are controlled in block 8, 9 and 17, and the heating steam debit is controlled in blocks 10, 11 and 16. The kinetic curves are simulated through the created model in block 12 using the control action combination. The values of the quality criteria are calculated and stored in block 13. After the simulation ends, a matched kinetic curve is chosen, so that all the criteria are met and the energy expense is minimal. The corresponding control actions are set in block 19, in a dialog regime with the operator or automatically.

The most important part of the algorithm for the control of the energy fluxes in sectional heat exchangers is the process modeling (block 12) which uses the finite elements method.

4. ALGORITM FOR MODELLING THE PROCESS OF MOISTURE-HEAT TREATMENT OF THE MATERIAL IN THE SECTIONAL HEAT EXCHANGERS

In order to model the process, the time and space are divided into small intervals. Considering the process specifics, it is assumed that the material properties in one section are identical all over it [13]. This is possible because of the good mixing of the material in the section. The modeling is carried out by describing the energy and material balance in the sections for every moment of time. The algorithm for modeling the process of moisture-heat treatment of the material in the sectional heat exchangers is shown in Figure. 2.

The initial conditions are set in block 1. After that, the parameters are calculated which are constants for the duration of the process (block 2). The time scale is organized in blocks 3, 4 and 13. Considering the object specifics, the incoming energy in each of the device sections is calculated. For this reason, it is taken into consideration that the steam at entry in the separate sections is distributed in proportion to the maximum energy that would be consumed by each section. The calculation of the energy streams in each section is carried out in block 5, without debit limitation. The energy streams distribution through the sections is calculated in block 6. If the steam stream is less than the maximal one, it is considered that the heating stream is proportional to the correlation between the maximal steam for a certain section and the steam for all sections. The modeling of the filling in of the first section of the device is carried out in blocks 7, 8, 9 and 10. The emptying of the first section (considering the material stream is $G_{mat} = 0$) is verified in block 7 using the mass balance. If this requirement is met, the filling in of the material is modeled in block 8 ($G_{mat} = G_{mat}^{in}$). In block 9 is verified if the section has been filled and after that the material entry is canceled. The parameters of the first section for every moment of time are calculated in block 11. The calculation of the parameters for the next section of the device is shown in block 12. The calculation stops when the maximal time is reached (block 13) and the results are displayed in block 14.

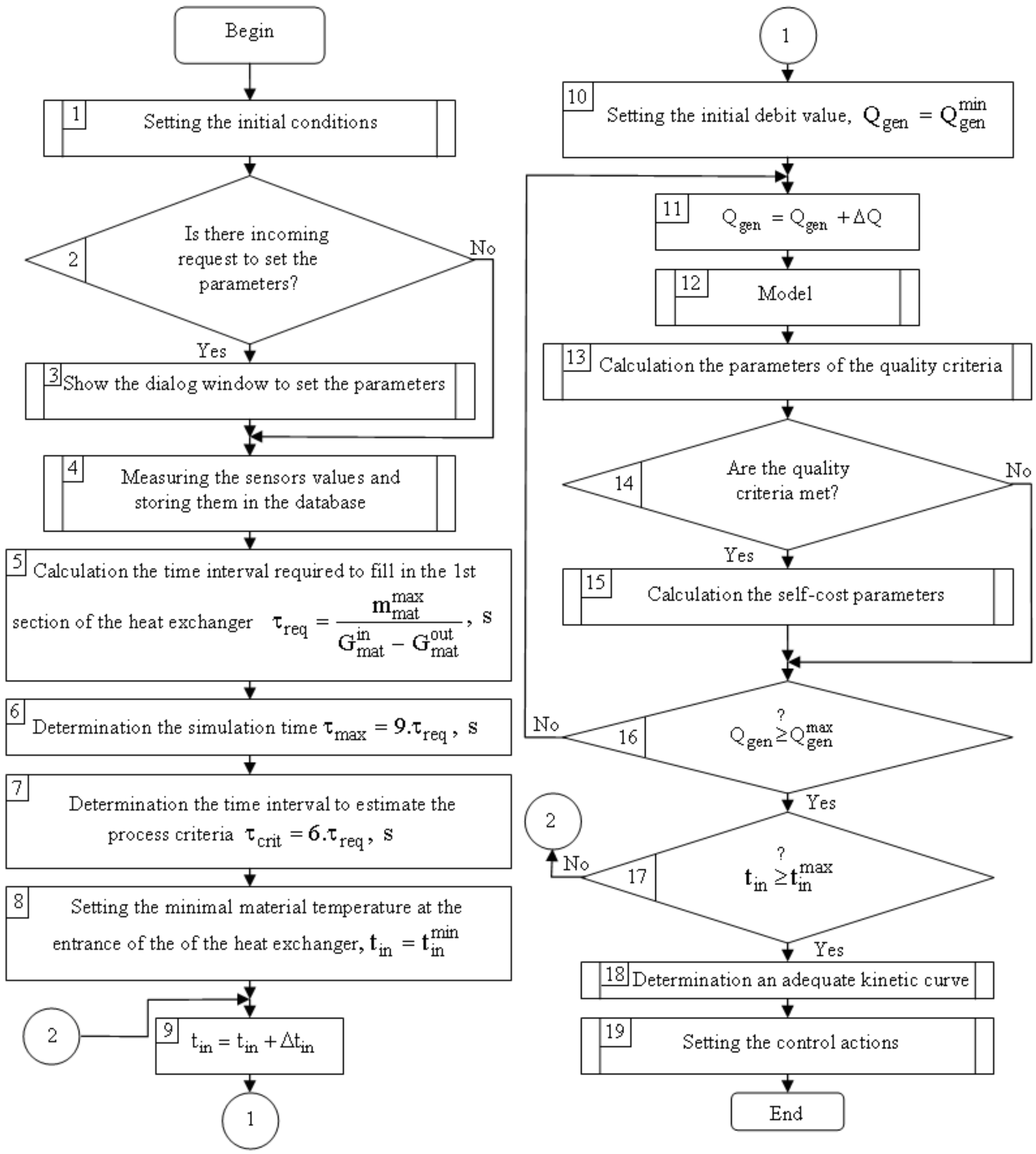


Fig. 1. Operation algorithm of an electronic system for control of energy fluxes in the sectional heat exchangers.

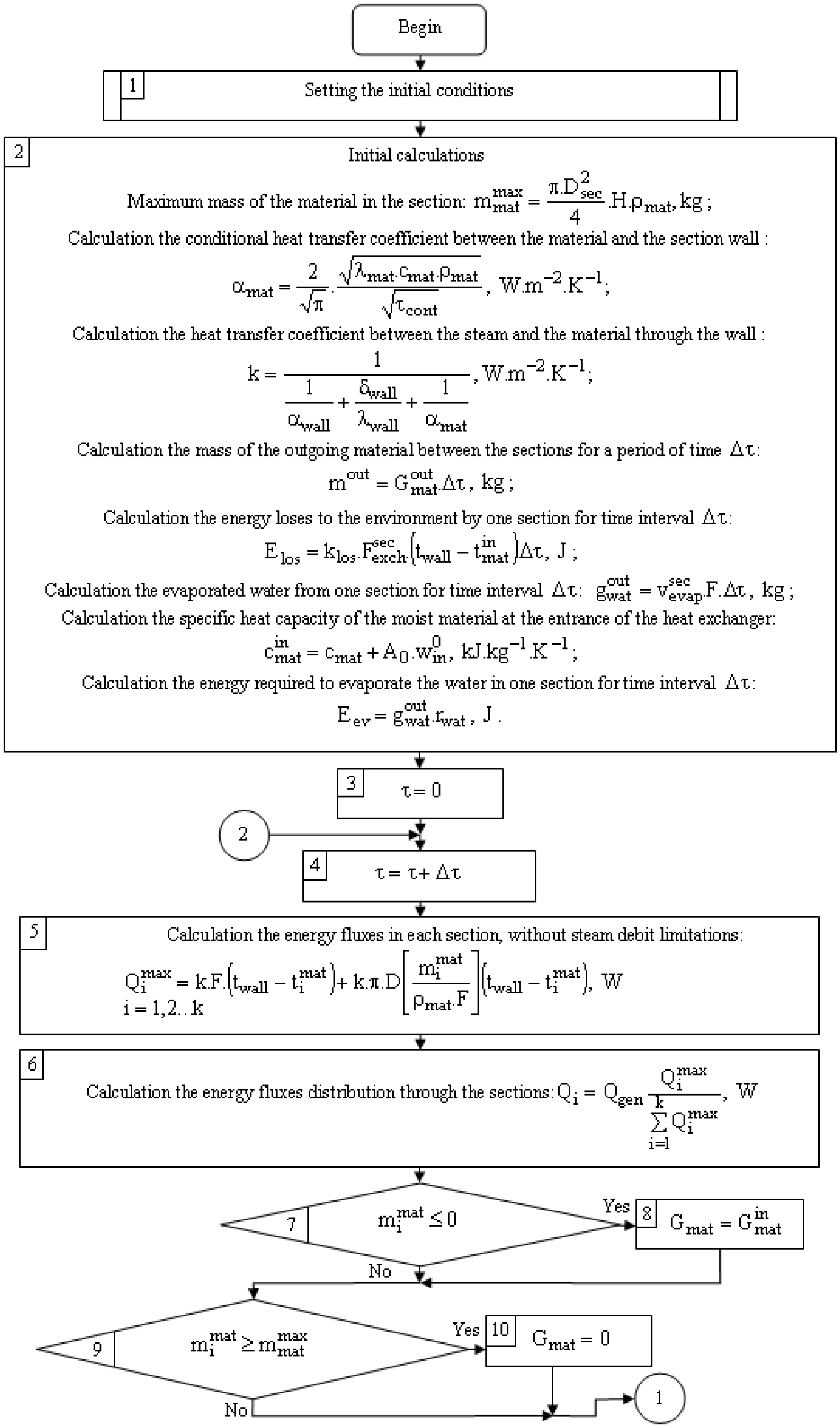


Fig. 2.a) Algorithm for modeling the process of moisture-heat treatment of the material in the sectional heat exchangers.

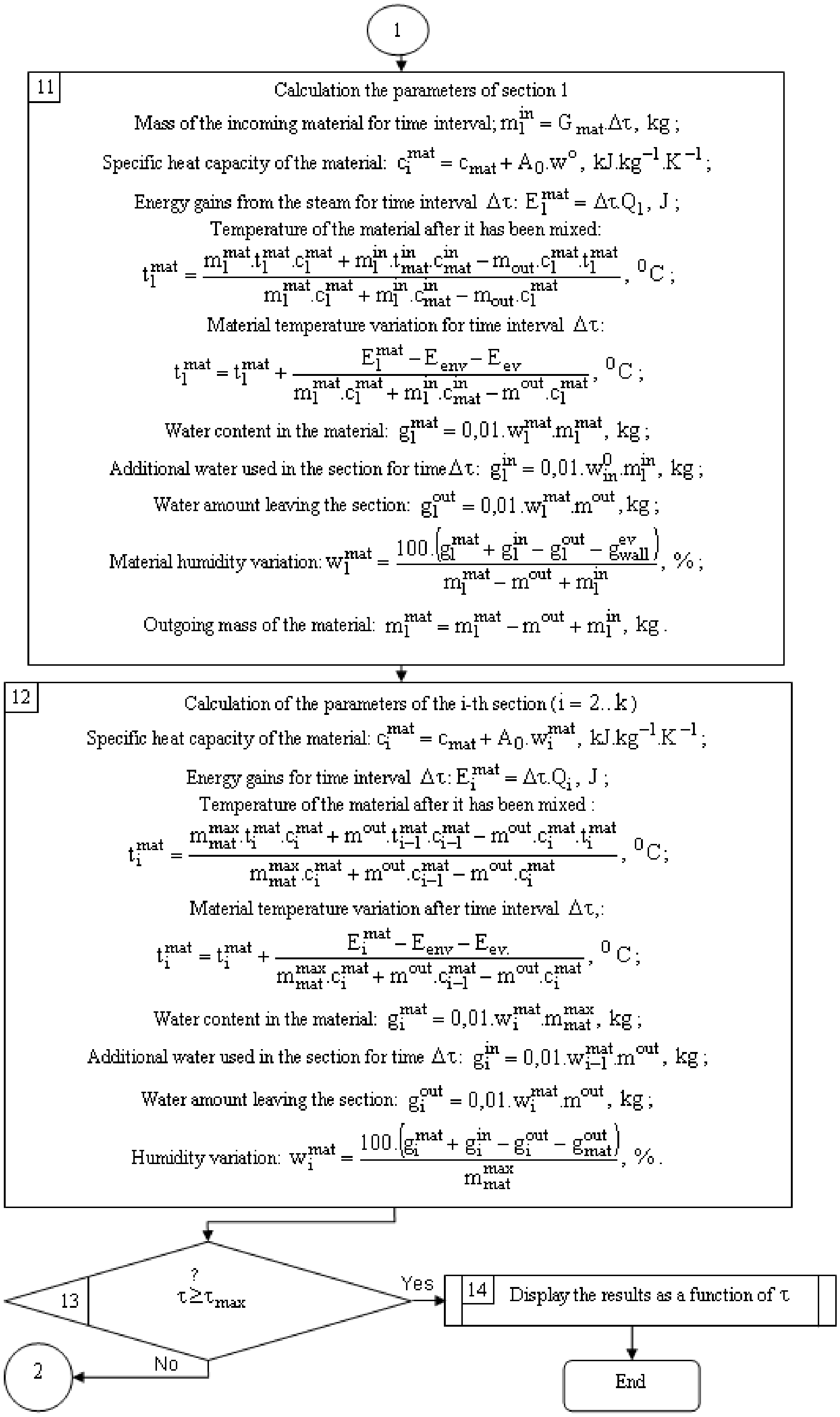


Fig. 2.b) Algorithm for modeling the process of moisture-heat treatment of the material in the sectional heat exchangers.

5. DETERMINATION OF THE CONTROL ACTIONS

Based on the presented operation algorithm of an electronic system for control of energy fluxes and the algorithm for modeling the process of moisture-heat treatment of the material in the sectional heat exchangers, a specialized software product in the Visual Studio 2010 environment has been developed. The main window of the program, the results of the simulation for the temperature and moisture variations, as well as the control actions for two different initial material temperatures (15 ^{0}C and 30 ^{0}C) are shown in Figure 3. In both cases, the determined heating temperature at the entrance of the device is t_Opt=78 ^{0}C.

As a result of the program calculations Figure 3), it can be noticed that the increase of the material temperature (tWH_ML) leads to a decrease in the steam debit (g_Para) for humidification and the water debit is increased. It can also be seen that for example when the material temperature at the entrance is tWH_ML = 15 ^{0}C, the steam debit is g_Para=0.044448, $kg.s^{-1}$, and when the temperature is при tWH_ML = 30, the steam debit is g_Para=0.035493 $kg.s^{-1}$.

The control actions in the installation are the steam debit for humidification (g_Para, $kg.s^{-1}$), the water debit for humidification (g_Voda, $kg.s^{-1}$) and the power of the steam flow for heating up the section walls (N-Para, W).

The economical effect from choosing one or another control action comes from the self-cost of the steam for humidification, the water for humidification and the temperature of the heating steam. The steam for humidification is more expensive because it is not reused which increases the water consumption. After losing some of its energy, the heating steam returns to the steam boiler and is heated again. The structure of the electronic system for control of energy fluxes in the sectional heat exchangers is presented in Figure 4.

The control system uses a personal computer (PC), with connected sensors and a specialized controller to it through a serial interface. The sensors which control the temperature in the store (1) and the temperature of the air in the working room (2) are digital [14]. They are connected to the PC through a transmitter [15]. The specialized controller collects information from sensors with analogue outputs (4, 5) and from sensors with impulse outputs (6, 7). The controller controls the executive mechanisms -valves for steam for heating (10) and steam for humidification (13), with the digital outputs and relays (8, 9, 11, 12). The water for humidification is controlled through an analogue output, inverter (14) and a dozing pump (15).

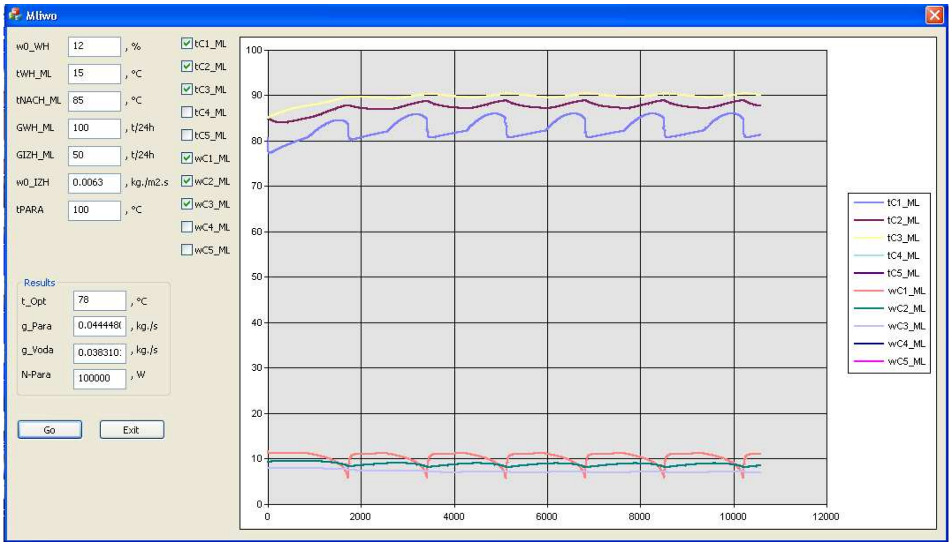
By reading information from the specialized controller and the sensors, the PC receives information about the process state. Software products for modeling of the process and for control of energy fluxes during the process of moisture-heat treatment of the material in the sectional heat exchangers are installed on the PC. The software products implement the suggested algorithms. After simulation of the process the software decides which control actions to use in order to optimize the energy expenses. The estimated values of control actions are sent over a serial interface to the controller which carries out the executive mechanisms.

6. RESULTS

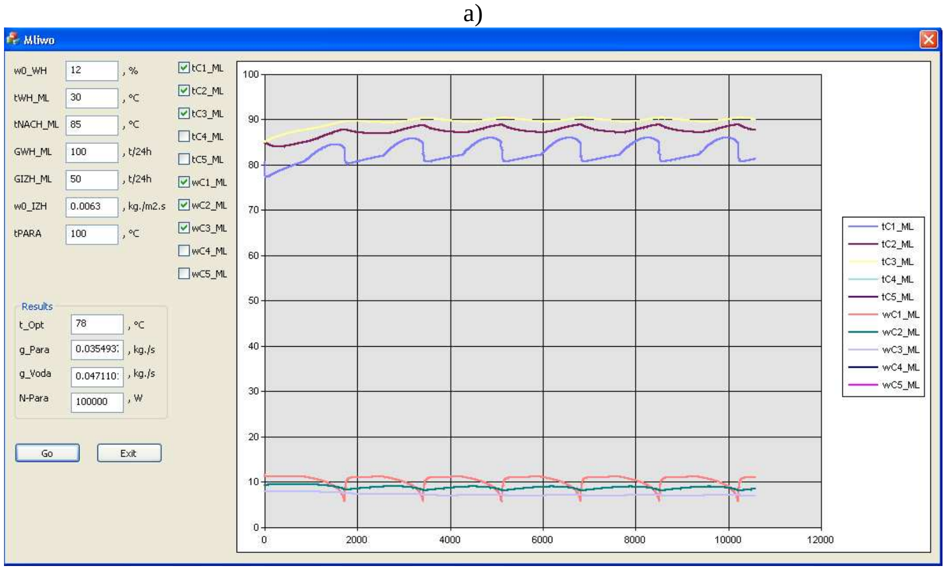
The specifics of the process of the material moisture-heat treatment in the sectional heat exchangers have been analyzed.

An operation algorithm of an electronic system for control of energy fluxes in the sectional heat exchangers has been created. As a result of the implementation of the suggested operation algorithm, the optimal values of the control actions are estimated.

An algorithm for modeling the process of moisture-heat treatment of the material in the sectional heat exchangers has been developed. The suggested algorithm makes it possible to simulate the process of moisture-heat treatment of the material in time for different values of the environment parameters.



a)



b)

Fig. 3. Simulation of the temperature, moisture and the control actions at an initial material temperature: a) 15 ^{0}C; b) 30 ^{0}C.

Parameters: w0_WH - the required material moisture at the end of the process,%; tWH_ML -temperature of the material in the store, ^{0}C; tNACH_ML-initial material temperature in the sections before the modeling begins (the recommended one is 85 ^{0}C); GWH_ML-the mass debit of the material at the entrance of the device (set by the operator), $t/24h$; GIZH_ML-the mass debit of the material at the exit of the device, $t/24h$; w0_IZH - the evaporation speed from the sections surface, $kg.m^{-2}.s^{-1}$; tPARA-the steam temperature, ^{0}C; t_Opt – the set temperature of the material at the entrance of the device, ^{0}C; g_Para – the humidifying steam debit, $kg.s$; g_Voda - the humidifying water debit, $kg.s$; N-Para – the power of the steam flow for heating up the section walls, W.

Graphics: tC1_ML, tC2_ML, tC3_ML, tC4_ML, tC5_ML -variation of the material temperature for the different sections of the device, ^0C; wC1_ML, wC2_ML, wC3_ML, wC4_ML, wC5_ML - variation of the material relative humidity in the different sections of the device, %.

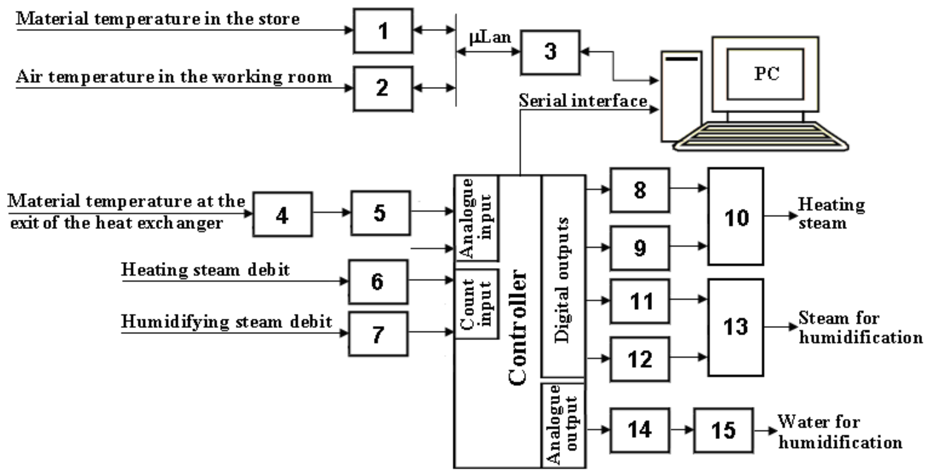


Fig. 4. Structure of the electronic system for control of energy fluxes in the sectional heat exchangers.

Based on these algorithms, a software product has been developed using the Visual Studio 2010 environment. The results are shown in graphical and table form.

A structure of the electronic system for control of energy fluxes in the sectional heat exchangers has been developed. It is based on a PC with the corresponding software. The suggested system has been implemented in the "Bonik EOOD" company, Ruse, Republic of Bulgaria.

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