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DEVELOPMENT OF ENERGY-SAVING TECHNOLOGY MAINTAINING THE FUNCTIONING OF A DRYING PLANT AS A PART OF THE COGENERATION SYSTEM

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На основі математичного та логічного моделювання у складі когенераційної системи розроблена технологія функціонування сушильної установки на рівні прийняття рішень щодо виробництва пелетного палива. Запропонована інтегрована система оцінки зміни вологовмісту повітря в сушильній камері, що дозволяє виконувати зміну витрати повітря, що подається на підігрів, на основі зміни частоти обертання електродвигуна повітряного вентилятора, при вимірюванні температури повітря на виході із сушильної камери

Ключові слова: технологія, сушильна установка, вологовміст повітря, математичне та логічне моделювання, когенераційна система

На основе математического и логического моделирования в составе когенерационной системы разработана технология функционирования сушильной установки на уровне принятия решений для производства пеллетного топлива. Представлена интегрированная система оценки изменения влагосодержания воздуха в сушильной камере, которая позволяет изменять расход воздуха, подаваемого на подогрев, на основе изменения частоты вращения электродвигателя воздушного вентилятора, при измерении температуры воздуха на выходе из сушильной камеры

Ключевые слова: технология, сушильная установка, влагосодержание воздуха, математическое и логическое моделирование, когенерационная система

1. Introduction

Due to the opportunity of selling energy at "the green tariff", the use of the bio fuel as a renewable energy source is a stimulating factor for producing both electricity and heat from one energy source [1, 2]. In the production of the pellet fuel, the costs of timber drying make up to 25 % of the total costs. The moisture content should not exceed 10–12 %, and raw timber, for example, may contain about 50 % of water. In order to support the energy-saving temperature and the aerodynamic regimes, drying must take place in the approved interactions which is possible to obtain with using the cogeneration technologies, which have a primary engine, an electricity generator, a heat utilization system and a system of the control and management. Moreover, the measurement of the temperature and the air humidity as a drying agent in the drying chamber and the humidity of the dried timber, are not always used appropriately to support timber drying due to the complexity of measurements, which makes it impossible to use the measurements in the coherence to prevent the influence on the change in the parameters of drying for ensuring the continuous production of the pellet fuel. All these facts substantiate the relevance of this work.

2. Analysis of scientific literature and the problem statement

The means of improving the timber drying technology is based both on the intensification of the heat exchange processes in the drying chamber and on the improvement of the management systems of the drying process. In [3], for example, the advantage of mechanical activation of the dried material is determined, but at the expense of the extra costs in electricity. In the work [4] it was determined that the quality of drying is influenced by the structural parameters of a drying chamber, but the assessment was made with the measurement of the drying parameters in the drying chamber. In the work [5], the influence of the modes of drying parameters on the quality of drying was defined without coordinating the thermal and the aerodynamic modes of drying of the material. In the work [6], the recommendations on the intensification of the heat exchange in a drying chamber, but without the possibility of their use in the actual operating conditions of the drying chamber, were given. The most important indicator of raw materials drying is the drying capacity, which must be more than 1 and present the quantitative ratio of the moisture content of raw materials to its balanced moisture content.

The balanced moisture content of timber is almost equal to the stable moisture content, which depends on the temperature of the air and its relative humidity [7]. To support the capacity of the timber drying, the expert systems are used, which are based on the measurement of air temperature and the humidity in a drying chamber with measuring the timber humidity. The complexity of the measurements and the impossibility of using them in coherence can lead to the accumulation of the moisture by timber or the termination of the drying process [8, 9]. To maintain the quality of drying, it is necessary to coordinate the temperature and the aerodynamic timber drying modes on the basis of the prediction of the air moisture content change in a drying chamber by measuring the air temperature at the outlet of a drying chamber to notice the change of heater air consumption, on the basis of changes in the rotation frequency of the electric engine of the air blower.

3. The purpose and objectives of the study

The aim of the work is to develop energy-saving technology of the drying plant functioning as a part of a cogeneration system.

The set goal requires solving the following tasks:

– to develop a structural scheme of the complex mathematical simulation of the dynamics of a drying plant to obtain the standard assessment of the changes in the moisture content;

– to develop structural schemes of the logical simulation for obtaining the functional information for decision-making to maintain the operation and the identification of a drying plant state as a part of cogeneration system;

– to offer the integrated assessment of changes in the moisture content of the air in a drying chamber concerning the energy-saving technology of the drying plant functioning;

– to evaluate the practical relevance of the obtained results.

4. Energy saving technology for the operation of a drying plant as a part of the cogeneration system

On the basis of the methodological and mathematical substantiation of the architecture of technological systems [10], the architecture of the cogeneration sysem that is based on a dynamic basis – the integrated dynamic subsystem, and contains the cogeneration and drying plants, was developed (Fig. 1). A drying chamber, a heat exchanger of the air heated by the cogeneration plant and an air fan were suggested to be included to the drying plant. The other units in the structure of the cogeneration power system are the unit of reducing and increasing the rotations frequency of the electric engine of the air fan, the unit of unloading the dried wood and loading the fresh material and the unit of the functional efficiency assessment (Fig. 1).

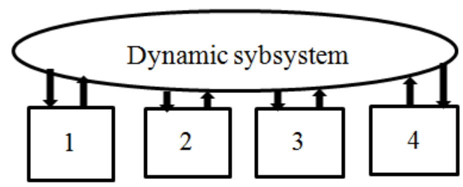

Fig. 1. Architecture of the cogeneration power system: 1 – the unit of reducing the rotations frequency of the electric engine of the air fan; 2 – the unit of increasing the rotations frequency of the electric engine of the air fan; 3 – the unit of unloading the dried wood and loading the fresh material; 4 – the unit of the functional efficiency assessment

Using the formula (1), the mathematical substantiation of the cogeneration system architecture was described:

$$CS=\left\{\begin{matrix}\left[D(P(\tau)\langle x_0(\tau),x(\tau),f(\tau),K(\tau),y(\tau),d(\tau)\rangle,R(\tau),P(\tau))\right]\\ Z(\tau),(P_i(\tau)\langle x_1(\tau),f_i(\tau),K_i(\tau),y_i(\tau)\rangle)\end{matrix}\right\}, \quad (1)$$

where CS is the cogeneration system; D is the dynamic subsystem (cogeneration and drying plants); P are the properties of elements of the cogeneration power system; ι is the time, s; x are the influences; f are the diagnosed parameters; K are the relations if D, CS respectively. Indices: i is the number of elements of the cogeneration power systems; 0, 1, 2 are the initial stationary mode, external, internal character of influences.

The foundation for the maintenance of the temperature and the aerodynamic regimes of timber drying regarding obtaining both standard and functional information is a mathematical model of the drying plant dynamics. The system of nonlinear differential equations includes the equation of the state as a physical model of the heat exchanger, the equation of energy of the transmission medium – the heater fueled by the cogeneration power plants, the equation of energy of the accepting environment – the air, in which the change in the air moisture is estimated both by time and along the spatial coordinate of the axis of the heat exchanger, which coincides with the flow direction of the medium movement, and the equation of thermal balance for the wall of the heat exchanger. As a result of the implementation of the mathematical model, the transmission function for the channel: "moisture content of the air – consumption of the air» was obtained:

$$W_{w-G_{i1}}=\frac{K_i(\beta-1)}{L_i K_w \beta\gamma}\left(1-e^{-\gamma l\xi}\right), \quad (2)$$

where

$$K_i = \frac{m(\theta_0 - \sigma_0)}{G_{i0}};\ \ \beta = T_m S + \varepsilon^* + 1;\ \ T_m = \frac{g_m C_m}{\alpha_{i0} h_{i0}};$$

$$\varepsilon^* = \varepsilon(1 - L_e^*);\ \ \varepsilon = \frac{\alpha_{e0} h_{e0}}{\alpha_{i0} h_{i0}};\ \ L_e^* = \frac{1}{L_e + 1};\ \ L_e = \frac{G_e C_e}{\alpha_{e0} h_{e0}};$$

$$\gamma_1 = T_i S;\ \ T_i = \frac{g_i C_i}{\alpha_{i0} h_{i0}};\ \ \xi = \frac{z}{L_i};$$

$$L_i = \frac{G_i C_i}{\alpha_{i0} h_{i0}};\ \ K_w = \frac{\partial i}{\partial w} / \frac{\partial i}{\partial t};\ \ \gamma = \frac{T_i S}{L_i},$$

where t, s, q are the air temperature, the temperature of the heat transfer agent, the temperature of the wall heat exchanger, K, respectively; G is the substance consumption, kg/s; C is the heat capacity, KJ/(kg·K); i is the enthalpy of the working body, KJ/kg; w is the moisture content of the air; a is the connective heat exchange coefficient, kW/(m^2·K); h is the specific surface, m^2/m; g is the specific mass of the substance, kg/m; z is the coordinate of the length of the heat exchanger, m; T_i, T_m are the constants of time, which characterize the thermal accumulative capacity of the air, metal, s, respectively; m is the indicator of the dependence of the heat transfer coefficient on the consumption; S is the parameter of the Laplace transformation; S=ωj; ω is the frequency, 1/s. Indices: i – inside flow – the air; m – the metal wall; e – external flow – the heat transfer agent; w – moisture content of the air; 0, 1 – input conditions, inlet into the heat exchanger.

To use the transmission function as a part of a complex mathematical simulation of the dynamics of the drying plant, a real part O (ω), which has the following form, was determined:

$$O(\omega) = (C_1 L_1 - D_1 M_1)(K_i / K_w). \tag{3}$$

For obtaining the coefficients as a real part O (ω), the following expressions were received:

$$C \quad \frac{A_1 A_2 \quad B_1 B_2}{A_2^2 \quad B_2^2};\ \ D_1 = \frac{A_2 B_1 - A_1 B_2}{A_2^2 + B_2^2};$$

$$L_1 = 1 - \cos(-\xi T_i \omega);\ \ M_1 = 1 - \sin(-\xi T_i \omega), \tag{4}$$

where

$$A_1 = \varepsilon^* - T_i T_m \omega^2;\ \ A_2 = -T_i T_m \omega^2;$$

$$B_1 = T_m \omega;\ \ B_2 = T_i \omega(\varepsilon + 1).$$

The temperature of the separating wall θ which is a part of the coefficient K_i:

$$\theta = \left(\frac{\alpha_i(\sigma_1 + \sigma_2)}{2} + \frac{A(t_1 + t_2)}{2} \right) \Big/ (\alpha_i + A), \tag{5}$$

where σ_1, σ_2 are the temperature of the heat transfer agent, heating at the inlet an the outlet of the heat exchanger, K, respectively; t_1, t_2 are the temperature of the air at the outlet and at the inlet of the drying chamber, K, respectively: α is the connective heat exchange coefficient, kW/(m^2·K); Index: i – inner flow – the air.

$$A = \frac{1}{\frac{\delta_m}{\lambda_m} + \frac{1}{\alpha_e}}, \tag{6}$$

where δ is the wall thickness of the heat exchanger, m; α is the connective heat exchange coefficient, kW/(m^2·K); λ is the thermal conductivity of the metal of the heat exchanger wall, kW/(m·K). Index: e – external flow – the heat transfer agent.

Using the integral of the transition from the frequency range to the time range, the change of the moisture content of the air both by time and along the spatial coordinate of the axis of the heat exchanger for heating the air, is defined as follows:

$$w(\tau, z) = \frac{1}{2\pi} \int_0^\infty O(\omega) \sin(\tau\omega / \omega) d\omega, \tag{7}$$

where τ is the time, s.

For the complex mathematical simulating of the drying plant dynamics, the block diagram that is presented, for example, for the input data of the pellet plant with the capacity of 680 kg/day of timber was developed (Fig. 2).

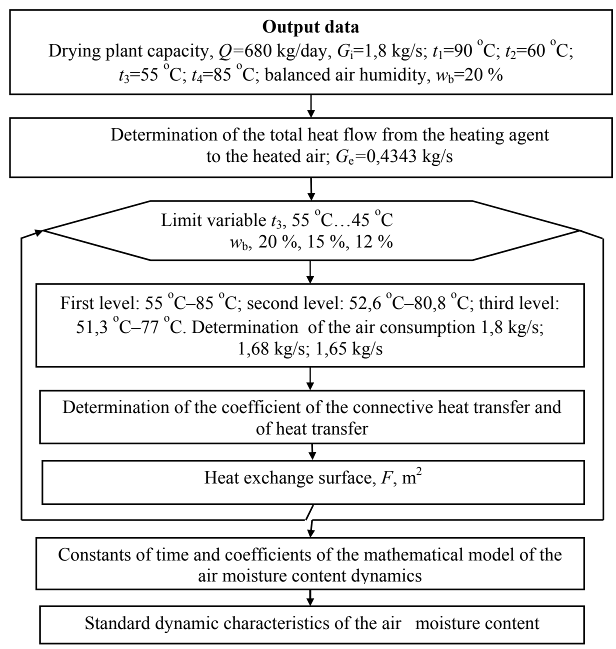

Fig. 2. The block diagram of a complex mathematical simulation of a drying plant: $G_{e.}$, $G_{i.}$ are the consumption of heat transfer agent, the air, kg/s, respectively; $t_{1,}$ t_2 are the temperature of the heat transfer agent at the inlet into the heat exchanger and at the outlet of the heat exchanger, K, respectively; $t_{3,}$ t_4 are the air temperature at the inlet to the heat exchanger and the outlet of the heat exchanger, K, respectively

According to the proposed block diagram (Fig. 2), within the limits of the defined cyclic structure, the following levels of the drying plant functioning regarding the changes of the air temperatures at the inlet to the heat exchanger and at the outlet of the heat exchanger were established: the first level: 55–85 °C; the second level: 52,6–80,8 °C; the third level: 51,3–77 °C, corresponding to the change in the balanced humidity of 20 %, 15 %, 12 % and the flow of air to 1.8 kg/s, 1.68 kg/s, 1.65 kg/s, regarding reducing the moisture content of the raw material from 40 % to 12 %. In Tables 1, 2, the results of the complex mathematical modeling of dynamics of the drying plant regarding the maintenance of changes in the moisture content of the air in the drying chamber are presented.

Table 1

Parameters of the heat exchange in the heat exchanger of the air heating

Functional level	Parameter		
	α_e, Wt/(m^2·K)	α_i, Wt/(m^2·K)	k, Wt/(m^2·K)
First level	3050,67	254,33	233,05
Second level	2912,86	242,84	222,59
Third level	2877,91	239,92	219,94

Note: α_e is the coefficient of connective heat transfer from the heat transfer agent that heats up the walls of the heat exchanger Wt/(m^2·K); α_i is the coefficient of heat transfer from the wall of the heat exchanger to the air, Wt/(m^2·K); k is the coefficient of the heat transfer, Wt/(m^2·K)

Table 2

Values of the constants of time and the coefficients of mathematical model of the dynamics of a drying plant

Functional level	T_i, c	T_m, s	ε	ζ	L_e, m	L_i, m	L_e^*	K_w
First level	0,0048	0,6149	14,547	0,146	33,26	483,89	0,029	–0,9646
Second level	0,0050	0,6440	14,547	0,136	32,51	472,99	0,030	–1,2848
Third level	0,0051	0,6518	14,547	0,134	32,32	470,19	0,030	–1,6060

The presented block diagram allows, having obtained the constants of time and the coefficients of the mathematical model of the dynamics of the moisture content of the air, determining the maximum admissible change in the moisture content of the air for the established levels of functioning [10]. For more information about (1)–(4) (Fig. 3) regarding making a decision on maintaining the operation of the drying plant, a logical model of the serviceability control of the drying plant based on the method of graph causal connections, was developed [2].

It is suggested to maintain the functioning of the drying plant as a part of the cogeneration power system with the continuous measurement of the air temperature at the outlet of the drying chamber, which is compared with a standard value of the level of functioning. Thus, the use of the logical structure within the cycle allows making decisions based on the information assessment (1), (2) to increase or decrease the air flow supplied to the heat exchanger of heating, with using the frequency changes of the electric motor rotation of the air fan, respectively. Obtaining the same summary information (3) indicates the completion of timber drying and requires a decision on the unloading the dried timber for further use in the technological process of the production of pellet fuel. Obtaining information (3) corresponds to the achievement of the air temperature at the outlet from the drying chamber of an extremely low level – 44 °C. Loading of the fresh raw materials occurs on the basis of the information assessment (4) when deciding on setting the temperature at the inlet to the drying chamber at the level of 85 °C regarding the air consumption of 1,8 kg/s (Fig. 4).

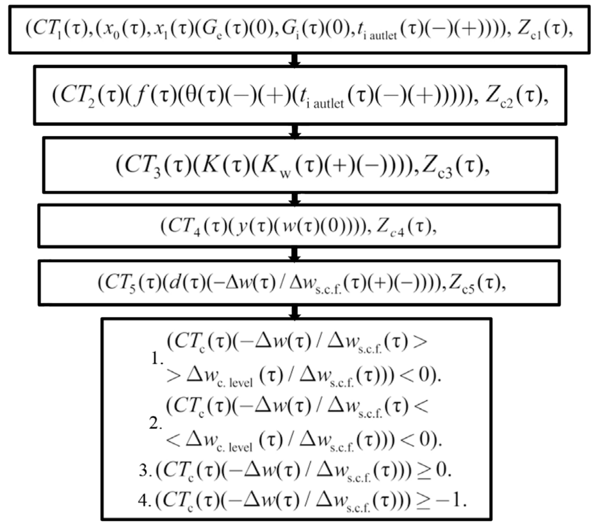

Fig. 3. Block diagram of serviceability control of the drying plant: CT is the action control; Z is the logical relationship; d are the dynamic parameters; w is the moisture content of the air; t is the air temperature, K; θ is the wall temperature of the heat exchanger, K; x are the influences; f are the diagnosed parameters; y are the output parameters; K are the coefficients of mathematical description; $K_w = \frac{\partial i}{\partial w} / \frac{\partial i}{\partial t}$ is the coefficient of the mathematical model of the dynamics of the drying plant where i is the enthalpy of the working body, kJ/kg; w is the moisture content of the air; G is the consumption of the heat transfer agent, kg/s; Indices: c – the serviceability control; outlet – outlet of the air from the drying chamber; i – the air: e – external flow – the heat transfer agent; s. c. f – sustainable calculated parameter value of the first level of functioning; c. level – calculated level; 0, 1, 2 – initial stationary mode, external, internal parameters; 3 – the coefficients of equations of dynamics; 4 – the essential parameters that are diagnosed; 5 – dynamic parameters

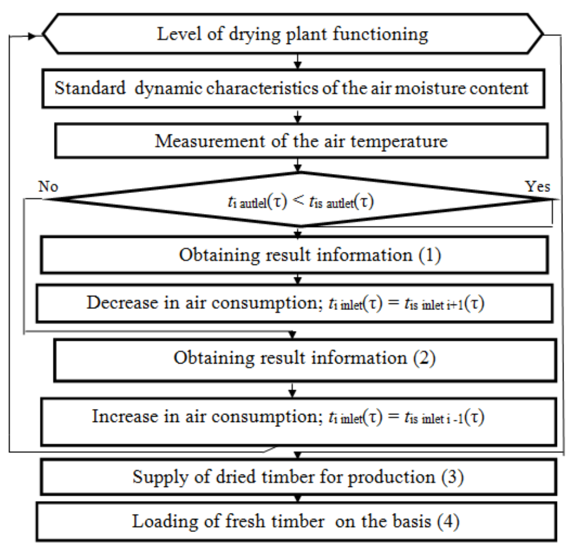

Fig. 4. Block diagram of the maintenance of the timber drying process at the level of decision-making, where $t_{i\ inlet}$, $t_{is\ inlet}$, $t_{i\ autlet}$, $t_{is\ autlet}$ are the functional and standard temperature at the inlet to the drying chamber and at the outlet of the drying chamber, respectively, K; i is the number of levels of functioning; τ is the time, s

Confirmation of the correctness of the made decisions is carried out on the basis of the proposed block diagram of the identification of the state of the drying plant as a part of a cogeneration system (Fig. 5), which was designed on the basis of the identification part of the graph of causal connections [2].

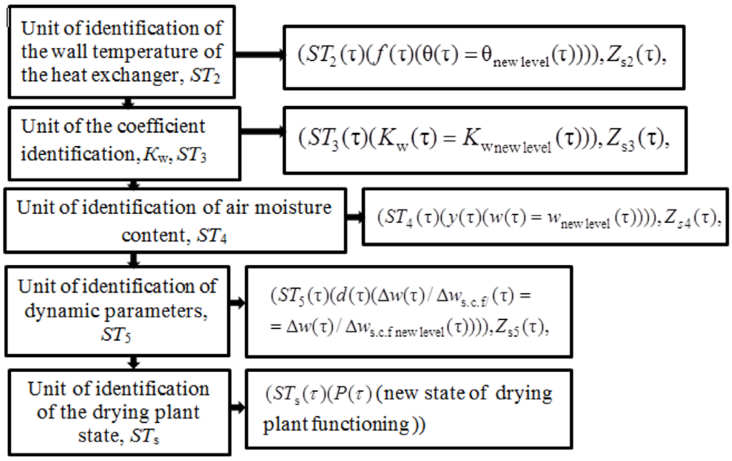

Fig. 5. Block diagram of logical simulation of the identification of state of the drying plant: ST is the identification of the state; P are the properties of the drying plant; Z is the logical relationship; d are the dynamic parameters; f are the parameters that are diagnosed; y are the outlet parameters; K is the coefficient of mathematical description; $K_w=\frac{\partial i}{\partial w}/\frac{\partial i}{\partial t}$ is the coefficient of mathematical model of the dynamics of the dryer, where i is the enthalpy of the working body, kJ/kg; w is the moisture content of the air; t is the air temperature, K. Indices: s – state; new level – a new level of functioning; s. c. f – sustainable calculated parameter value of the first level of functioning; 2 – internal options that are diagnosed; 3 – the coefficients of the equations of dynamics; 4 – the essential parameters that are diagnosed; 5 – dynamic parameters

On the basis of the proposed architecture of the cogenerating system (Fig. 1) and the developed structural diagrams (Fig. 2–5), which were tested for maintaining the drying chamber functioning for a fixed time interval [10], there was developed the integrated system of the drying plant functioning (Table 3), which provides the opportunity to make a decision on the power change of timber drying with the continuous measurement of the air temperature at the outlet of a drying plant.

The moisture content in the drying chamber at a definite time is determined as follows:

$$w_{i+1}(\tau)=w_i((\Delta w_{i+1}(\tau)/\Delta w_{s.c.f.}(\tau)- -\Delta w_i(\tau)/\Delta w_{s.c.f}(\tau))(w_2-w_1)), \qquad (8)$$

where w is the moisture content of the air in the drying chamber, %; w_1, w_2 are the moisture content of the air at the inlet to the heat exchanger of the air heating and at the outlet of the heat exchanger, %, respectively; i is the number of levels of timber drying; τ is the time, s. Index: s. c. f. – sustainable calculated value of the first level of functioning.

Thus, for example, in 4400 s after loading raw wood to the drying chamber, it was established that the aerodynamic mode of the drying chamber regarding the air supply of 1.8 kg/s into the heat exchanger does not correspond to the reduction of the air temperature at the outlet of the drying chamber to the level of 52 °C and requires to make a decision on the change of air consumption to the level of 1.68 kg/s regarding the coordination of aerodynamic and thermal regimes of timber drying. The absolute value of the air humidity in the drying chamber at this period of time was determined as follows:

$$18{,}87\,\%=17{,}46\,\%+((0{,}8048-0{,}7544)(40\,\%-12\,\%)).$$

Table 3

Integrated system of the drying plant functioning maintenance

Time, τ, 100 s	Change of the moisture content of the air in the drying chamber	$\Delta w(\tau)/\Delta w_{s.c.f.}(\tau)$	w(τ), %
11	Loading raw timber. Making decision on the air supply of 1.8 kg/s air: t_{outlet}=55 °C; t_{inlet}=85 °C	–1	12
22	Air supply of 1,8 kg/s. Timber drying: t_{outlet}=54 °C; t_{inlet}=84 °C	–0,9107	14,5
33	Air supply of 1,8 kg/s. Timber drying: t_{outlet}=53 °C; t_{inlet}=82 °C	–0,8048	17,46
44	Making a decision the air supply of 1.68 kg/s: t_{outlet}=52 °C; t_{inlet}=80,5 °C	–0,7544	18.87
55	Identification of the new conditions of functioning: air supply of 1,68 kg/s: t_{outlet}=52 °C; t_{inlet}=80,5 °C	–0,7532	18,87
66	Air supply of 1,68 kg/s. Timber drying: t_{outlet}=51 °C; t_{inlet}=76,6 °C	–0,5674	24,07
77	Making decision regarding the air supply of 1,65 kg/s: t_{outlet}=51 °C; t_{inlet}=76,6 °C	–0,5778	24,36
88	Identification of the new conditions of functioning: air supply of 1,65 kg/s: t_{outlet}=51 °C; t_{inlet}=76,6 °C	–0,5778	24,36
99	Air supply of 1,65 kg/s. Timber drying: t_{outlet}=50 °C; t_{inlet}=76 °C	–0,4801	27,10
110	Air supply of 1,65 kg/s. Timber drying: t_{outlet}=48 °C; t_{inlet}=75 °C	–0,3021	32,08
121	Air supply of 1,65 kg/s. Timber drying: t_{outlet}=45 °C; t_{inlet}=75 °C	–0,1277	36,96
132	Unloading dried timber for production of the pellet fuel: t_{outlet}=44 °C; t_{inlet}=74 °C	–0,0190	40

Note: t_{outlet}, t_{inlet} are the air temperature at the outlet of the drying chamber and at the inlet of the drying chamber, respectively, °C; w is the moisture content of the air in the drying chamber, %. Index: s .c. f. (sustainable calculated upper) – sustainable calculated value of the parameter of the first level of functioning

For further timber drying, it is necessary to control the air temperature at the outlet of the drying chamber by reducing the power of the air fan regarding the air supply of 1.68 kg/s, which in 6600 s, makes 51 °C, and to make the further timber drying to the air humidity in the drying chamber, for example, of 24.07 %, calculated as follows:

$$24{,}07\ \%=18{,}87\ \%+((0{,}7532-0{,}5674)(40\ \%-12\ \%)).$$

And if the air temperature at the outlet of the drying chamber decreased to 44 °C, which corresponds to the increase in the air humidity in the drying chamber up to 40 %, it is necessary to unload the dried timber to the pellet plant and load raw materials, ensuring setting of the thermal and aerodynamic parameters of the drying plant of the first level of functioning.

5. Discussion of the results of studying the energy-saving technology of maintenance of the drying plant functioning as a of part of the cogeneration power system

As a result of the research, there was developed an integrated system of changes in the moisture content of the air in the drying chamber, which allows maintaining the timber drying capacity based on the changes in the air consumption that is supplied to the heat exchanger, using changes in the rotation frequency of the electric engine of the air fan. There was obtained the analytical evaluation of changes in the moisture content of the air in the drying chamber due to the unreliable use of the measurements because of the difficulty of getting the measuring results in cohesion. It was suggested to measure the air temperature at the outlet of the drying chamber for making the objective decisions regarding the change in the air consumption for heating the air to maintain the drying capacity.

It makes it possible to objectively ensure the change in the air humidity in the drying chamber and prevent the reverse process of the moisture accumulation by the raw materials. The exact term of unloading the dried timber to the pellet plant and loading the raw materials to the drying plant was determined. The uninterrupted functioning of the cogeneration power systems for the additional production of energy, taking into account frequency regulation of the electric motor of air fan for drying raw materials allows reducing the cost of the production of electrical energy and heat. The presented results of the investigation are the continuation of working in the direction of harmonizing the production and the consumption of bio fuels [2]. The approbation of the results of the research under the conditions of using pellet plants of various capacities as parts of the cogeneration systems was planned.

6. Conclusions

1. The production of pellet fuel requires the use of the integrated evaluation system of changes in the moisture content of the air in the drying chamber regarding the coordination of the temperature and aerodynamic modes of timber drying with the use of the cogeneration technologies to maintain the drying capacity.

2. There was suggested the structural scheme of the complex mathematical simulation of the dynamics of the drying plant which gives an opportunity to determine the tolerances on the change in the air moisture content in the drying chamber for the determined functional levels, which correspond to the change of the air temperature at the inlet to the heat exchanger of the air heating and at the outlet of the heat exchanger according to a change in the balanced air humidity in the drying chamber and a change in the air supply.

3. The structural scheme of the logical simulation regarding the drying plant serviceability for getting the final functional evaluation of changes in the air moisture content in the drying chamber was suggested. This scheme, which operates by the principle of causal connections, includes the following units: the unit of the evaluation of the changes of air temperature at the outlet from the drying chamber that are measured; the unit of the change of the temperature of the walls of the heat exchanger for heating air, the coefficient of the mathematical model of the dynamics of the air moisture content, K_{w}, the unit of the dynamic parameters of the change in the air moisture content, the unit of the serviceability control.

4. The structural scheme of maintaining timber drying at the level of decision-making was suggested. A special feature of this scheme is the comparison of the measured air temperature at the outlet of the drying chamber with a standard value and the determination of the summary information regarding making decisions to change the rotation frequency of the electric engine of the air fan or the change of the dried and raw wood.

5. The structural scheme of the logic simulation regarding the identification of the state of the drying plant for confirming the made decisions was suggested. It includes the following units: the unit of the change of the wall temperature of the heat exchanger for heating air, the coefficient of the mathematical model of the dynamics of the air moisture content, K_w, the unit of the dynamic parameters of the change in the air of the moisture content, the unit of the identification of the drying plant state and allows setting the new state of the drying plant functioning.

6. There was suggested the integrated system of the changes in the air moisture content that allows maintaining the timber drying capacity on the basis of the changes in the air consumption regarding the change in the rotating frequency of the electric motor of the air fan with the measurement of the air temperature at the outlet of the drying chamber, making the timely supply of the dried timber for the pellet fuel production and loading the raw wood.

7. Coordinating the temperature and the aerodynamic modes of the timber drying provides an opportunity, for example, for the production of 5.8 thousand tons of wood pellets per year to reduce the cost value of the electricity and heat production by 20–30 % and to get the 40 % savings of the financial resources with using pellet fuel for heating and hot water supply.

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EFFICIENCY IMPROVMENT OF SHIPS OPERATION BY WATER-FUEL EMULSION USING

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Досліджена технологія використання водопаливних емульсій під час роботи суден, що обслуговують нафтовидобувні платформи. При аналізі процесу паливопідготовки розглянуто основні теоретичні методи та результати моделювання горіння каплі водопаливної емульсії. Показано, що присутність води при певних умовах може позитивно впливати на процес горіння, що приводе до поліпшення характеристик одержуваного факела горіння і тепловиділення палива

Ключові слова: емульсія, двигун судна, суміш води і дизеля, диспергування, температура спалаху, концентрація води, концентрація компоненти

Исследована технология использования водотопливных эмульсий при работе судов, обслуживающих нефтедобывающие платформы. При анализе процесса топливоподготовки рассмотрены основные теоретические методы и результаты моделирования горения капли водотопливной эмульсии. Показано, что присутствие воды при определенных условиях может положительно влиять на процесс горения, приводя к улучшению характеристик получаемого факела горения и тепловыделения топлива

Ключевые слова: эмульсия, двигатель судна, смесь воды и дизеля, диспергирование, температура вспышки, концентрация воды, концентрация компоненты

1. Introduction

In most cases, when operating of ship power plants, the ships do not use clean fuel, but the fuel emulsion with the presence of the water component [1]. The presence of water in fuel in most cases cannot be avoided. The natural processes of moisture condensation from the environment, a technical failure in the sealing units and seals the fuel