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Automation control system creating a microclimate chamber for storing fruits and vegetables

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The mathematical description of the processes produce storage using machine cooling, and developed an automated control system that implements pulse cooling.

Refrigeration equipment, storage for fruits and vegetables, storage, automatic control.

Increasing demands to reduce losses in terms of produce farms producing cause the urgent need to spread the use of the engine cooling air - refrigeration systems [1-3]. But the use of creating a microclimate with engine cooling air costly energy, which leads to increased production costs.

One of the ways that reduce specific energy storage refrigeration processes are automated control of temperature and humidity conditions [4].

Common - positional automatic temperature control system does not provide a satisfactory efficiency as technologically and in terms of energy because they do not take into account the change in heat load time (day, month, year).

The purpose of research - to create automatic climate control system in the chamber for storing fruits and vegetables.

Materials and methods research. In this paper, as the main method of investigation of dynamic properties of storage used analytical method followed by experimental verification Mathematical description. Analytical method for the synthesis automation systems can be used in the presence of the mathematical description of the process under study produce storage.

Results. In describing the physical processes in the refrigerator for storage of fruits and vegetables, the following simplifying assumptions and preconditions. The air volume in the chamber for storing fruits and vegetables well mixed and evenly washes the heat and mass surface. Thermal parameters of the premises, biological objects, as well as heat transfer coefficient values are independent of temperature, humidity and is constant in time. Thermal bearing protections of environmental parameters are independent, heat radiation inside absent. The influence of solar radiation outer surface considered when determining the conditional external temperature [5]. Specific heat and allocation of water linearly dependent on temperature. The temperature of the process equipment is temperature.

linear representation system of differential equations that describe the transient processes in the refrigerator for storage of fruits are as follows:

- Evaporator for:

$$m_x c_x \frac{dt_{x2}}{d\tau} = 2G_x c_x \left(t_{x1} - t_{x2}\right) + k_o F_o \left[0.5(t_{v1} + t_{v2}) - 0.5(t_{x1} + t_{x2})\right] \quad (1)$$

- For air cooler:

$$m_v c_p \frac{dt_{v2}}{d\tau} = 2G_v c_{vp} \left(t_{v1} - t_{v2}\right) - k_o F_o \left[\left(t_{v1} + t_{v2}\right) - (t_{x1} + t_{x2})\right] \quad (2)$$

- For luggage:

$$\left(m_n c_n + m_k c_p\right) \frac{dt_{k2}}{d\tau} = k_z F_z \left[t_z - 0.5\left(t_{k1} + t_{k2}\right)\right] - G_v c_p \left(t_{k2} - t_{k1}\right) \quad (3)$$

If you add dynamic equation (1) - (3) in increments $t_{x1} = t_{x1}^0 + \Delta t_{x1}$; $t_{x2} = t_{x2}^0 + \Delta t_{x2}$; $t_{v2} = t_{v20} + \Delta t_{v2}$; $t_{k2} = t_{k2}^0 + \Delta t_{k2}$; $G_x = G_x^0 + \Delta G_x$; $G_v = G_v^0 + \Delta G_v$, subtracting equation statics and ignoring the members of the second degree of smallness and resulting equations to canonical form, we obtain a system of ordinary differential equations:

$$T_x \frac{d\Delta t_{x2}}{d\tau} + \Delta t_{x2} = k_1 \Delta t_{v1} + k_1 \Delta t_{v2} - k_2 \Delta t_{x1} + k_3 \Delta G_x; \quad (4)$$

$$T_v \frac{d\Delta t_{v2}}{d\tau} + \Delta t_{v2} = k_4 \Delta t_{x1} + k_4 \Delta t_{x2} - k_5 \Delta t_{v1} + k_6 \Delta G_v; \quad (5)$$

$$T_k \frac{d\Delta t_{k2}}{d\tau} + \Delta t_{k2} = k_7 \Delta t_z - k_8 \Delta t_{k1} - k_9 \Delta G_v. \quad (6)$$

The equations T_x, T_v, T_k - time constants characterizing the dynamics $k_1, \cdots, k_9$ - constant coefficients, expressed in terms of design and technological parameters of the object:

$$k_1 = \frac{k_o F_o}{k_o F_o + 2G_x c_x}; \; k_2 = \frac{k_o F_o - 2G_x c_x}{k_o F_o + 2G_x c_x}; \; k_3 = \frac{2c_x \left(t_{x1}^0 - t_{x2}^0\right)}{k_o F_o + 2G_x c_x};$$

$$k_4 = \frac{0.5k_o F_o}{0.5k_o F_o + c_p G_v^0};\ k_5 = \frac{0.5k_o F_o - c_p G_v^0}{0.5k_o F_o + c_p G_v^0};\ k_6 = \frac{c_p \left(t_{v1}^0 + t_{v2}^0\right)}{0.5k_o F_o + c_p G_v^0};$$

$$k_7 = \frac{k_z F_z}{k_z F_z + 2c_p G_v^0};\ k_8 = \frac{k_z F_z - 2c_p G_v^0}{k_z F_z + 2c_p G_v^0};\ k_9 = \frac{2c_p \left(t_{k2}^0 - t_{k1}^0\right)}{k_z F_z + 2c_p G_v^0};$$

$$T_x = \frac{m_x c_x}{k_o F_o + 2G_x^0 c_x};\ T_v = \frac{m_v c_p}{0.5k_o F_o + c_p G_v^0};\ T_k = \frac{\left(m_n c_n + m_k c_p\right)}{k_z F_z + 2c_p G_v^0}.$$

Applying the Laplace transform to equations (4) - (6) we obtain analytical expressions peredatkovyh functions on channels that connect the temperature at the outlet of the chamber with its incoming air temperature, coolant temperature at the inlet and outlet of the air cooler and air parameters.

Transmission inertial elements in the system to ensure machine produce storage on major channels received in the form of:

$$W_1(p) = \frac{\Delta t_{v1}}{\Delta t_{x2}} = \frac{k_1}{T_x p + 1};\ W_2(p) = \frac{\Delta t_{v2}}{\Delta t_{x2}} = \frac{k_1}{T_x p + 1};\ W_3(p) = \frac{\Delta t_{x1}}{\Delta t_{x2}} = \frac{k_2}{T_x p + 1};$$

$$W_4(p) = \frac{\Delta G_x}{\Delta t_{x2}} = \frac{k_3}{T_x p + 1};\ W_5(p) = \frac{\Delta t_{x2}}{\Delta t_{v2}} = \frac{k_4}{T_v p + 1};\ W_6(p) = \frac{\Delta t_{x1}}{\Delta t_{v2}} = \frac{k_4}{T_v p + 1};$$

$$W_7(p) = \frac{\Delta t_{v1}}{\Delta t_{v2}} = \frac{k_5}{T_v p + 1};\ W_8(p) = \frac{\Delta G_v}{\Delta t_{v2}} = \frac{k_6}{T_v p + 1};\ W_9(p) = \frac{\Delta t_z}{\Delta t_{k2}} = \frac{k_7}{T_k p + 1};$$

$$W_{10}(p) = \frac{\Delta t_{k1}}{\Delta t_{k2}} = \frac{k_8}{T_k p + 1};\ W_{11}(p) = \frac{\Delta G_v}{\Delta t_{k2}} = \frac{k_9}{T_k p + 1}.$$

According to equations (4) - (6) and transmission functions of elementary units a mathematical model of dynamic processes of machine produce storage in the form of the block diagram (Fig. 1).

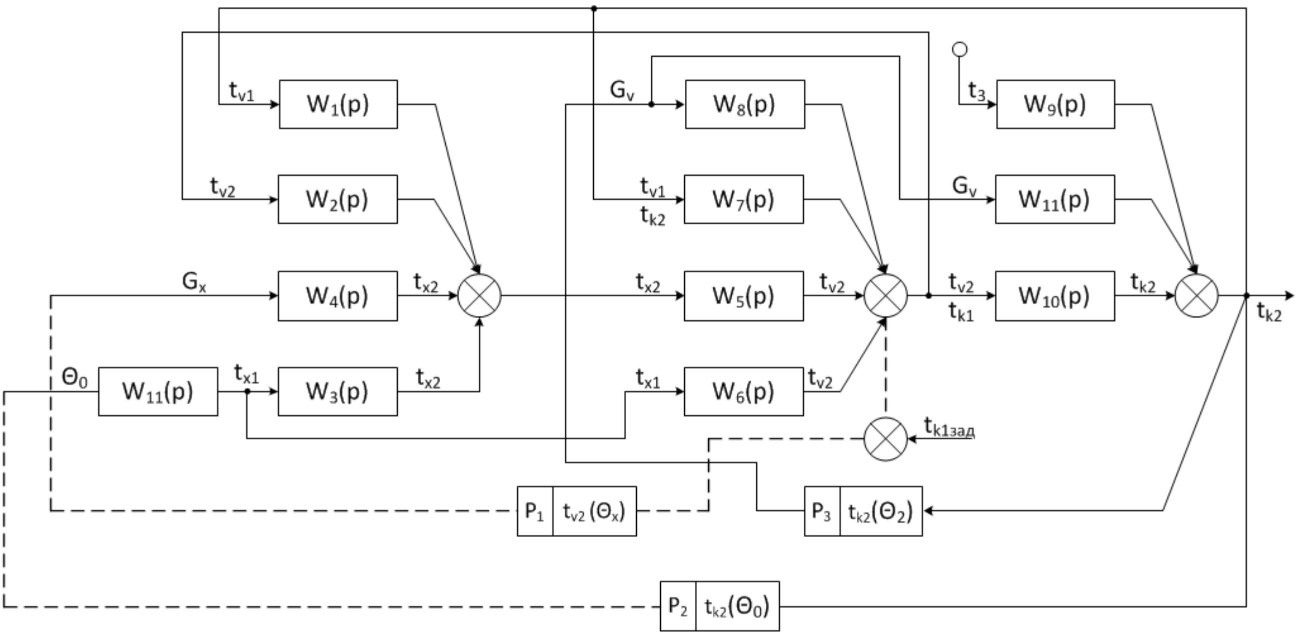
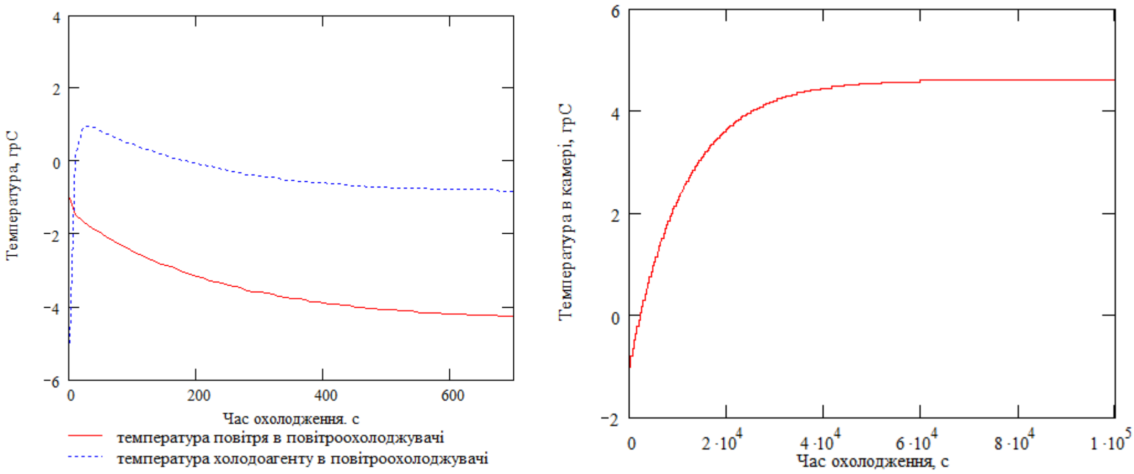


Figure 1. Block diagram of the automatic control mode cooling fruit products:

P1 - refrigerant flow regulator, P2 - control air flow, P3 - regulator cooling capacity (the revolutions of the compressor shaft)

Using equation (1) - (3), built transitional process chamber produce storage (Fig. 2).



a b

Figure 2. Transient's broadcaster storage of fruits and vegetables,

and - the air temperature in the air and coolant temperature;

b - the temperature of products stored

Conclusions.

Developed a closed mathematical model of thermal processes in the refrigeration unit that adequately describes the process based on the synthesized control system.

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