Analysis and modelling of influence non-stationary exterior temperature in interior temperature and thermal heater capacity

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Abstract: - Task of this paper is to be analyzed and modeled the dynamics of thermal power by the heater located inside a closed environment, and the interior temperature in conditions when the heat exchange through walls is stationary and the exterior ambient temperature varies periodically. Modeling of interior temperature is based in thermal balance between thermal capacity of the heater, air heat accumulation and the heat losses through walls. So, in analytical and graphical way are presented the changes for interior temperature, accumulation heat and transmission heat. By means of corresponding diagrams there are presented the important results which show the practical side and possibilities to optimize the heater thermal capacity respectively the optimal time manipulation with the heater.

Key-Words: - Interior temperature, heater thermal power, heat losses, heat accumulation, optimization.

1 Introduction

The Equation of thermal balance for a space-local presents the heat capacity of the heater that needed to compensate the heat that accumulated into the interior ambient air of a local [1], and the heat that lost from interior ambient to exterior via heat transmission of local wall (fig.1), respectively [2]:

$$P = Q_a + Q_T \tag{1}$$

Where:

P, W – Thermal capacity of the heater;

Q_a, W – Accumulation heat capacity in the interior ambient air;

Q_T, W – Heat thermal capacity that transmitted via the wall from interior to exterior ambient air;

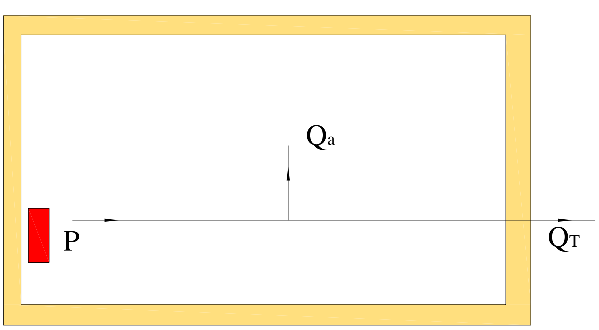

Fig.1 Heater thermal capacity and heat losses

2 Thermal parameters of interior and exterior ambient air

In continuity of this paper are analyzed the thermal parameters which influenced in thermal equilibrium of the heater and interior temperature of a local, in view of possibilities periodically variation of air exterior temperature (-20÷40 ^{0}C). So, there are ensued these analytical expressions:

Exterior air temperature:

$$t_j(\tau) = A_1 + A_2 \sin(\frac{2\pi}{\tau_d}\tau + \psi) \tag{2}$$

Air accumulation constant [3]:

$$\beta_a = \frac{c_a \cdot \rho_a \cdot V_h}{F_h \cdot k}\text{, in s;} \tag{3}$$

Interior air temperature:

$$t_b = t_0 \cdot e^{-\frac{\tau}{\beta_a}} + (1 - e^{-\frac{\tau}{\beta_a}})(\frac{P}{k \cdot F_h} + A_1) +$$

$$+ B_2(\sin(A_3\tau+\psi) - e^{-\frac{\tau}{\beta_a}}\sin(\psi)) + \tag{4}$$

$$+ B_3(\cos(A_3\tau+\psi) - e^{-\frac{\tau}{\beta_a}}\cos(\psi))\text{, in } ^0\text{C}$$

Transmission heat losses via the wall [4]:

$$Q_T = F_h \cdot k(t_b - t_j) = q_0 \cdot V_j(t_b - t_j)\text{, in W;} \tag{5}$$

Air heat accumulation:

$$Q_a = P - Q_T\text{, in W;} \tag{6}$$

Accumulation heat in interior ambient air:

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Where are:
k, $W/(m^2K)$ – total coefficient heat transmission; F_h, m^2 – total area of the wall surfaces of a local; V_h, m^3 – interior volume of a local; V_j, m^3 – exterior volume of a local; ρ_a, kg/m^3 – density of air; c_a, J/(kgK) – air specific heat capacity; t_0, ^0C – interior temperature at the beginning moment; τ, s – time; $B_2=A_2/((\beta_a A_3)^2+1)$; $B_3=-(\beta_a A_3 A_2)/((\beta_a A_3)^2+1)$; τ_d=T=24h – period; A_1 – vertical period shift; A_2 – amplitude; ψ – horizontal period shift ($\psi=\psi_{tj0}=\psi$(when $\tau=0$ and $t_j=0$)$=\arcsin(-A_1/A_2)=0.34$ [5]; $A_3 = 2\pi/\tau_d$.

3 Analysis of interior temperature and amounts of thermal capacities

In view of upon expressions, by means of the simulations respectively the diagrams that are presented in continuity, it is analyzed the interior temperature and the other thermal parameters for a modeling local. The local has these characteristics: width a=6m, length b=6m, and height c=5m; density of air $\rho_a=1.2kg/m^3$; specific heat of the air c_a=1005J/(kgK); total area of the wall surfaces $F_h=199,2m^2$; interior volume of local $V_h=180m^3$; exterior volume of local $V_j=243,936m^3$; beginning temperature: $t_0=10^0C$; the time where the parameters are analyzed τ=0,10,...,5000000s. So, in figure 2 is shown the changing of exterior temperature for ψ=0; 0.34; 100; 200, depending on time. In fig. 3 - air heat accumulation constant, depending of k, $W/(m^2K)$, in fig.4 – changing of interior temperature for ψ=0.34; k=0.8$W/(m^2K)$; P=1000, 2500, 5000W, in fig. 5 - changing of interior temperature for ψ=0.34; k=0.5, 1.0, 2.5 $W/(m^2K)$; P=5000W, in fig. 6 - changing of interior temperature for ψ=0.34; k=0.5, 1.0, 2.5 $W/(m^2K)$; P=5000W, in fig. 7 – heat that transmitted via the wall, for ψ=0.34; k=0.8$W/(m^2K)$; P=1000, 2500, 5000W, and in fig 8 – heat accumulation in interior air for ψ=0.34; k=0.8$W/(m^2K)$; P=1000, 2500, 5000W.

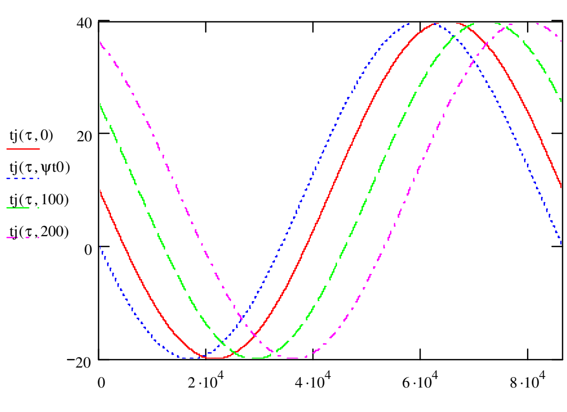

Fig.2 Changing of exterior temperature for ψ=0; 0.34; 100; 200, depending on time

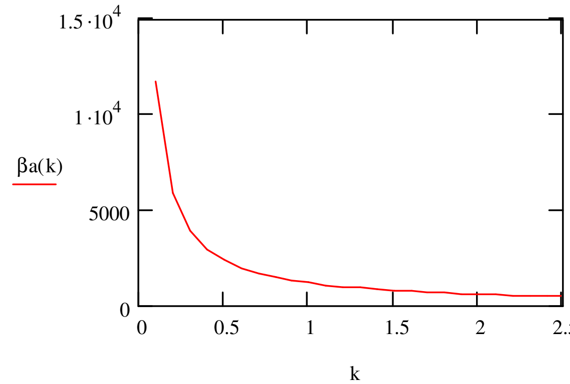

Fig.3 Air heat accumulation constant, depending of k, $W/(m^2K)$

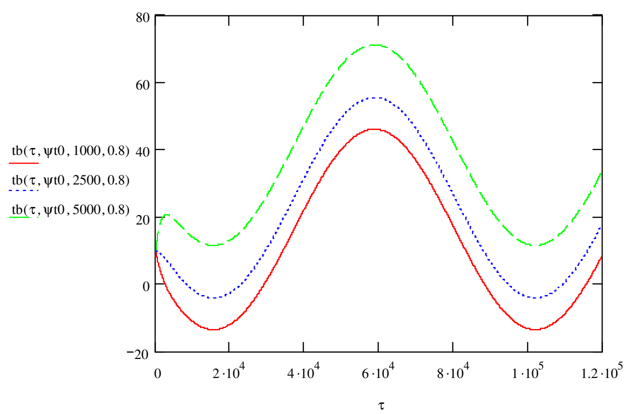

Fig.4 Changing of interior temperature for ψ=0.34; k=0.8$W/(m^2K)$; P=1000, 2500, 5000W, depending on time

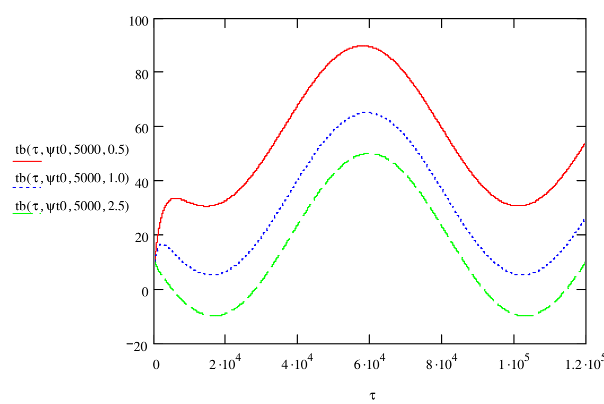

Fig.5 Changing of interior temperature for ψ=0.34; k=0.5, 1.0, 2.5 $W/(m^2K)$; P=5000W

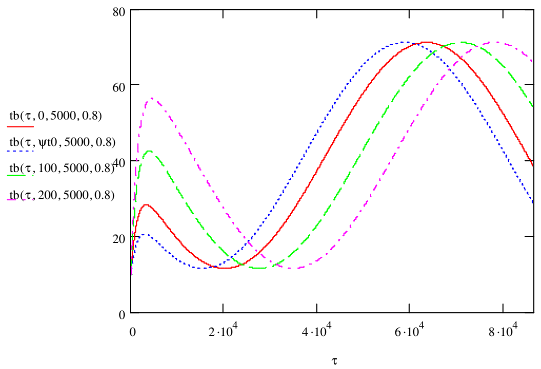

Fig.6 Changing of interior temperature for ψ= 0; 0.34; 100; 200; k=0.8W/(m^{2}K); P=5000W

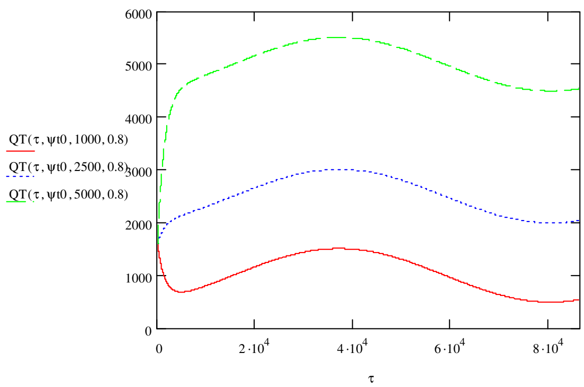

Fig.7 Heat that transmitted via the wall, for ψ=0.34; k=0.8W/(m^{2}K); P=1000, 2500, 5000W

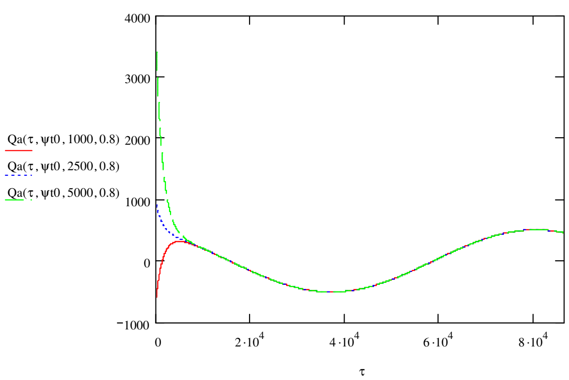

Fig.8 Heat accumulation in interior air for ψ=0.34; k=0.8W/(m^{2}K); P=1000, 2500, 5000W

All these upon diagrams are calculated in function of heater thermal capacity P and of time τ

4 Conclusion

Mathematical Model upon exposed describes the interior temperature, heater thermal capacity, heat losses through walls, air accumulation heat and the other thermal parameters in view of the periodically influence exterior temperature. The upon diagrams shown the changing of interior temperature, air accumulation heat capacity, heat transmission capacity and the heat that transmitted via the wall, depending on time, exterior temperature, total coefficient heat transmission, and from heater thermal capacity.

Taking in considerate the air accumulation heat and changing exterior temperature achieves the exactness and genuineness about the practical results, and also to secure the control for heating system, to regulate the process circle respectively to stabilize the state parameters. All of this leads to processes automatization and to optimize the managing of equipments, installations and systems respectively to save the energy.

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