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MODELING OF THERMAL TIME CONSTANT OF THE ELECTROTHERMAL EQUIPMENT

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ABSTRACT
In this paper is analyzed and modeled the thermal time constant of the electro thermal-equipment. Moreover, the present paper illustrates the thermal parameters about thermal accumulation and inertia of the electro-thermal equipment. In analytical and graphical way are presented the heating temperature of electro-thermal equipment and the thermal time constant depending of increase of the heating temperature of electro-thermal equipment. The following results show the influence of optimization of the process.
Keywords: Thermal time constant, temperature, equipment.

1. INTRODUCE
Accumulation heat in the wall can be used for regulation of the heat into a local air, and in the thermal comfort condition it must be in the allowed limits. The equation of thermal balance for a local presents the heat of the heater that needed to compensate the heat that lost in the accumulation wall of local and from interior ambient to exterior via heat transmission of local wall [1, 2], respectively:

$$Q_0=Q_M+Q_T \quad \dots (1)$$

Where:

- Q_o, W – Thermal power of the heater;
- Q_M, W – Accumulation heat capacity in the wall of a local;
- Q_T, W – Heat flow that transmitted through the wall of a local.

2. THERMAL PARAMETERS OF A LOCAL AIR
In continuity of this paper are analyzed the parameters that influence in the thermal equilibrium of the heater and the interior temperature of a local [3]. In view of the exposed model in the equation (1), in continuity, are ensued these analytical expressions:

Thermal specific heat, in W/(m^{3}K),:

$$q_0 = \frac{k \cdot F}{V_j} \quad \dots (2)$$

Time thermal constant, in s:

$$\beta_M = \frac{F \cdot \delta \cdot \rho_M \cdot c_M}{2 \cdot Z \cdot q_0 \cdot V_j} = \frac{\tau}{\ln\left(\frac{t_0 - t_j - \frac{Q_0}{q_0 \cdot V_j}}{t_b - t_j - \frac{Q_0}{q_0 \cdot V_j}}\right)} \quad \dots (3)$$

Non-dimensional constant:

$$Z = 1 + \frac{q_0 \cdot V_j}{\alpha_j \cdot F} - \frac{q_0 \cdot V_j}{\alpha_b \cdot F} \quad \dots (4)$$

Interior temperature of a local [4], in ^{0}C:

$$t_b = t_j + \frac{Q_0}{q_0 \cdot V_j} + \frac{t_0 - t_j - \frac{Q_0}{q_0 \cdot V_j}}{e^{\frac{\tau}{\beta_M}}} \quad \dots (5)$$

Average temperature of the wall, in ^{0}C:

$$t_{mM} = \frac{t_1 + t_2}{2} \quad \dots (6)$$

Temperature on area of the interior wall surface, in ^{0}C:

$$t_1 = t_b - \frac{Q_0}{\alpha_b \cdot F} \quad \dots (7)$$

Temperature on area of the exterior wall surface, in ^{0}C:

$$t_2 = t_j + \frac{Q_0}{\alpha_j \cdot F} \quad \dots (8)$$

Transmission heat flow losses through the wall, in W:

$$Q_T = q_0 \cdot V_j \left(t_b - t_j\right) \quad \dots (9)$$

Accumulation thermal capacity in the wall, in W:

$$Q_M = Q_0 - Q_T \quad \dots (10)$$

Internal energy of the wall [5], in J/kg:

$$u = c_M \cdot t_{mM} \quad \dots (11)$$

Accumulation energy in the wall, in J:

$$E = m_M \cdot u \quad \dots (12)$$

Heat capacity coefficient, in J/K:

$$C_M = m_M \cdot c_M \quad \dots (13)$$

Thermal resistance coefficients, in K/W:

$$R_b = 1/(F \cdot \alpha_b);\ R_j = 1/(F \cdot \alpha_j) \quad \dots (14)$$

Where: k, W/(m^{2}K) – total coefficient heat transmission; F, 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; δ, m – thickness of the wall; α_b, α_j, W/(m^{2}K) – interior and exterior heat convection coefficient; ρ_M, kg/m^3 – density of the wall; c_M, J/(kgK) – thermal capacity of the wall; t_0, ^{0}C – interior temperature at the beginning moment; t_j, ^{0}C – exterior temperature; m_M, kg – mass of the wall; τ, s - time.

3. ANALYSIS OF INTERIOR TEMPERATURE, THERMAL TIME CONSTANT AND OTHER THERMAL PARAMETERS

Analyzing the interior temperature of a local, it is shown that for:

$$\tau = 0 \Rightarrow t_b = t_0 = t_{min} \quad \dots (15)$$

$$\tau = \infty \Rightarrow t_b = t_j + \frac{Q_0}{q_0 \cdot V_j} = t_{max} \quad \dots (16)$$

$$\tau = \beta_M \Rightarrow t_b = 0{,}632 t_{max} + 0{,}368 t_{min};\ \text{or}\ t_b = 63{,}2\% t_{max} + 36{,}8\% t_{min} \quad \dots (17)$$

In view of the upper expressions, by means of the simulations respectively the diagrams which are presented in continuity, it is analyzed the interior temperature and the other thermal parameters for a modelling local. This local, with the walls of the brick composition, has these characteristics: width a=6m, length b=6m, and height c=5m; thickness of wall δ_M=0.3m; thermal power of heater Q_0=15000W; conduction coefficient χ=0.7W/(mK); convection coefficients α_b=8W/(m^{2}K); α_j=25W/(m^{2}K); density of wall ρ_M=1800kg/m^3; specific heat of wall c_M=920J/(kgK); total area of wall surfaces F=199,2m^2; interior volume of a local V_h=180m^3; exterior volume of a local V_j=243,936m^3; beginning temperature : t_0=15^{0}C; exterior temperature t_j=-20; -10; …30^{0}C; the time where the parameters are analyzed is τ=0,100,...,1000000s.

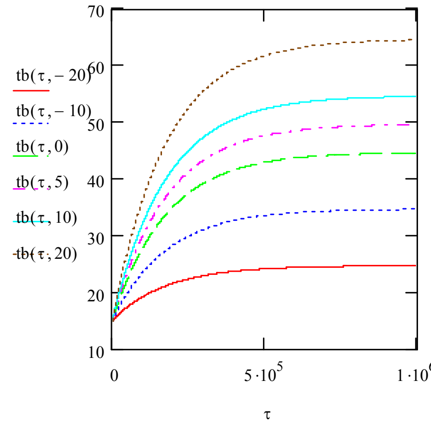

Figure 1. Change of interior temperature of a local in function of exterior temperature

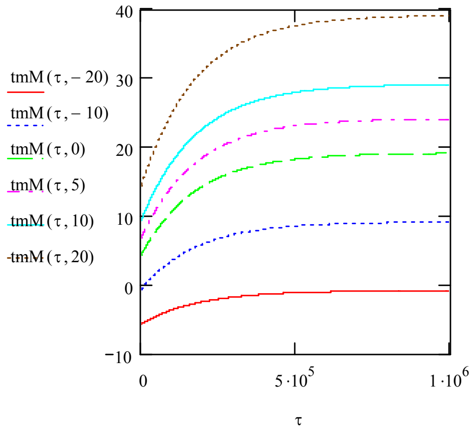

Figure 2. Change of average temperature of the wall in function of exterior temperature

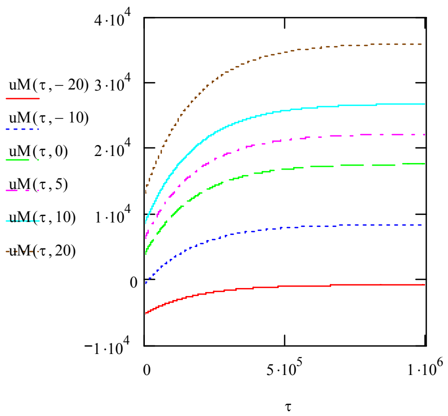

Figure 3. Change of internal energy of the wall in function of exterior temperature

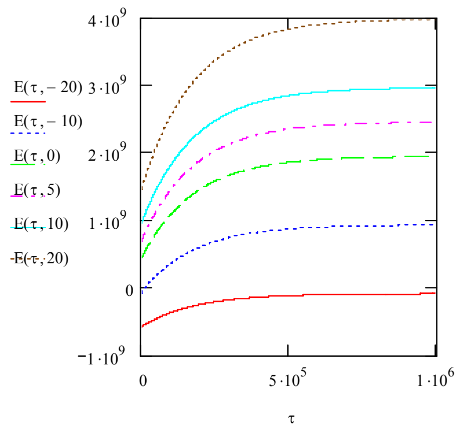

Figure 4. Change of accumulation energy of the wall in function of exterior temperature

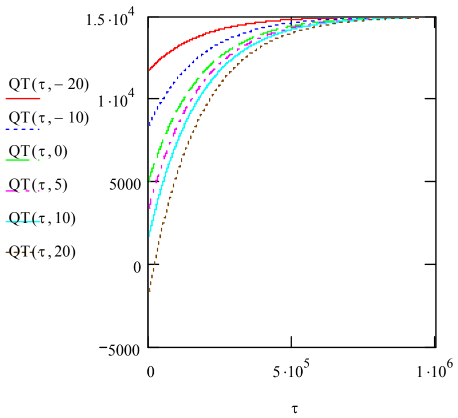

Figure 5. Change of heat transmission of the wall in function of exterior temperature

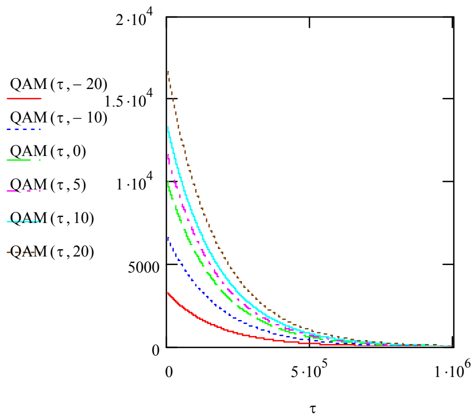

Figure 6. Change of heat accumulation of the wall in function of exterior temperature

For to=15^{0}C; tj=10^{0}C and βtb(τ,tb) achieved:

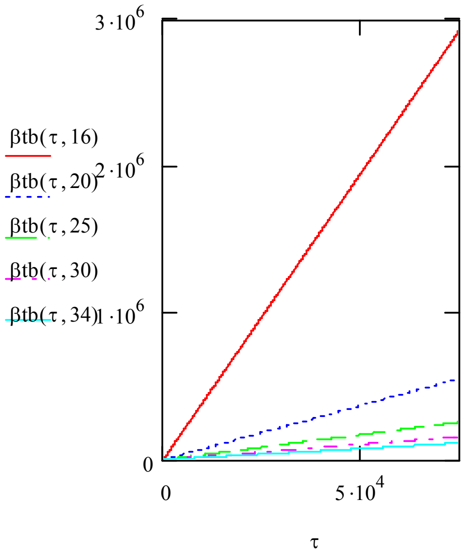

Figure 7. Change of time constant accumulation in function of interior temperature

All of parameters, as they seen upper on the schemes, are analyzed in function of exterior temperature and of the time.

4. CONCLUSION

Mathematical model, that upon is presented, describes the dynamic of air temperature into a local and the other thermal parameters which influence in the heat accumulation into the wall. From formulas and diagrams it is shown that after a determined time achieved to a constant heat exchange, respectively when $Q_M=0 \Rightarrow Q_T=Q_0$, expressed through the time constant accumulation. So, when the temperature difference t_b-t_j is evidently then also the time for achieving a constant heat exchange is too evidently. By increasing of exterior temperature the extremes temperatures rapport goes to increasing and that from 17% to 42%. From the last diagram it is shown that by saving lower interior temperature needed a higher heat accumulation, and go for conversely. The Thermal Time Constant for a thermal equipment presents the time required to change its body temperature by 63.2% of a maximal temperature and 36.8% of minimal temperature, and as is shown it is expressed and influenced by the environmental factors.

Achieved results consist in exactness and verity of practical side and also to secure the control of heating system and to bring to optimum using of the electrothermal equipment respectively to save the energy.

6. REFERENCES

[1] Demneri I., Shtjefni A., Karapici R.: Termoteknika, Tiranë, 2003;

[2] Mikles J., Fikar M.: Process Modelling, Identification, and Control, Springer-Verlag Berlin Heidelberg, 2007.

[3] Szirtes Thomas, Pal Rozsa: Applied Dimensional Analysis and Modeling, Vancouver, B.C., Canada, 2006;

[4] Sokolov J.: Toplifikacija i toplotne mreze, Beograd, 1985;

[5] Wayne Bequette B.: Process Dynamics -Modeling, Analysis, and Simulation, New Jersey, 1998;