Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird
Annals of DAAAM International

MODELING OF TEMPERATURE AND NON-STATIONARY HEAT FLUX THROUGH A FLAT WALL

SELIMAJ, R[exhep] A[zem]; OSMANAJ, S[abrije] & SAHITI, N[aser]

Abstract: *In this paper is analyzed and modeled non-stationary heat flux through the one-layer flat wall. During this analysis are presented the formulas which express the dynamics of temperature changing and also the thermal flux being taken into account the temperature of the interior ambient and the temperature of interior surface of the wall. Important are time constants which are depended on wall structure and influence to the thermal parameters of the wall. Achieving the desired analytical parameters is done by Laplace's transformations and some other necessary replacements.*

Key words: *Non-stationary thermal conductivity, specific thermal flux, temperature of ambient air, temperature of wall surface. Laplace Transformations*

1. INTRODUCTION

Two groups of non-stationary problems that we encounter in technique are: heating and cooling. Non-stationary problems of heat transfer can be divided into two major groups, periodicals and not-periodicals (Bejan, 1988). Periodic changing occurs through harmonic functions (i.e. functions of sinus, cosine, tangent function, etc.). While the non-periodic changing of temperature or thermal flow, the change may appear, in general cases, by a linear function of time (Bixler, 1989) (for example $e^{\pm t}$).

2. SPECIFIC THERMAL FLUX AND TEMPERATURE ON THE SURFACE OF FLAT WALL

Wall thermal capacity by non-stationary thermal conductivity is appear as the variable parameter. Thus, the wall temperature θ_m varies not only depending on time t but also on the distance x from the surface of the wall (Figure 1), i.e. (Burmeister 1993): $\theta_m=\theta_m(t,x)$.

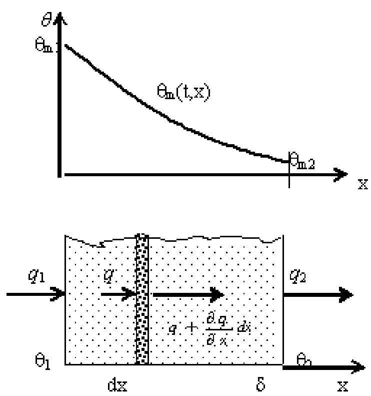

Fig. 1. Non-stationary thermal conductivity through the wall

Thermal balance equation for the provided layer, as in Fig. 1, is:

$$q(t,x)-\left[q(t,x)+\left(\frac{\partial q(t,x)}{\partial x}\right)dx\right]=\frac{\partial}{\partial t}\left[c_m\rho_m\theta_m(t,x)dx\right] \quad (1)$$

Where:

θ_m, ^0C – temperature through the wall surface, c_m, J/(kgK) - specific heat of the wall structure, and ρ_m - density of the wall material. Since the specific heat and density of the wall do not vary with time, then in equation (1) we have:

$$-\frac{\partial q(t,x)}{\partial x}=c_m\rho_m\frac{\partial\theta_m(t,x)}{\partial t} \quad (2)$$

In view of elementary layer of the wall, according to J. Fourier's law on thermal conductivity, we have (Dincer & Al-Muslim, 2001):

$$q(t,x)=-\lambda\frac{\partial\theta_m(t,x)}{\partial x} \quad (3)$$

First we converted these variables by parameter t in Laplace transformations (Keey, 1972). Using boundary conditions, the last equations get in the form:

$$-\frac{dQ(s,x)}{dx}=c_m\rho_m s\Theta_m(s,x)$$
$$Q(s,x)=-\lambda\frac{d\Theta_m(s,x)}{dx} \quad (4)$$

Where: Q(s,x) dhe $\Theta_m(s,x)$ - Laplace Transformations for q(t,x) and θ_m (t,x).

The Equation that describes the heat exchange of convection from the interior wall is (Kotas, 1985):

$$Q_{1i}(s)=\alpha_{1i}\left[\Theta_1(s)-\Theta_{m1i}(s)\right] \quad (5)$$

Considering equations (4) and (5) and some transformations and required replacements obtained the thermal flux and temperature through the wall layer (Moran, 1989):

$$q(t,x)=-\frac{2\alpha_1\lambda\theta_1 e^{-t/T_j(x)}}{\left(2\lambda+x\alpha_1\right)\left(1-e^{-t/T_j(x)}\right)}+\frac{q_1(t,x)}{1-e^{-t/T_j(x)}} \quad (6)$$

$$\theta(t,x)=\frac{1}{1-e^{-t/T_R(x)}}\left[\theta_1(t,x)-\frac{q_1(t,x)}{\alpha_1}\left(1+\frac{x}{\lambda}e^{-t/T_R(x)}\right)\right]-q_1(t,x)\frac{x}{\lambda} \quad (7)$$

Where the time constants, in unit s, are:

$$T_j(x)=c_m\rho_m x\left(\frac{1}{\alpha_1}+\frac{x}{2\lambda}\right) \quad (8)$$

$$T_R(x) = \frac{c_m \rho_m x^2}{2\lambda} \quad (9)$$

Equations (6) and (7) can answer any kind of wall which means each of mathematical models that describe the dynamics of temperature and thermal flux through the wall.

3. ANALYSIS OF SPECIFIC THERMAL FLUX AND TEMPERATURE ON THE SURFACE OF FLAT WALL

Additional data are: x=0.1, 0.2, 0.3 m; α_1=8W/(m^2K); ρ_m= 2200; thermal specific heat c_m=879J/(kgK); λ=1.5W/(mK); θ_1=20^{0}C; θ_{m1}=0, 5,…, 20 ^{0}C. Using the above formulas we achieved below diagrams (figures 2, 3, 4, 5, 6 and 7).

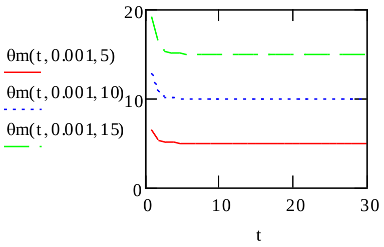

Fig. 2. Wall temperature changing, x=0.001; θ_{m1}=5, 10, 15^{0}C

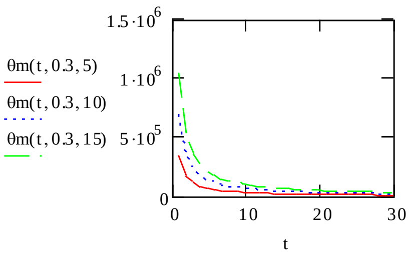

Fig. 3. Wall temperature changing, x=0.3; θ_{m1}=5, 10, 15^{0}C

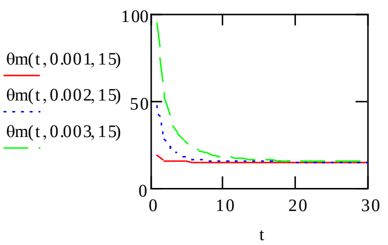

Fig. 4. Wall temperature changing, x=0.001, 0.002, 0.003; θ_{m1}=15^{0}C

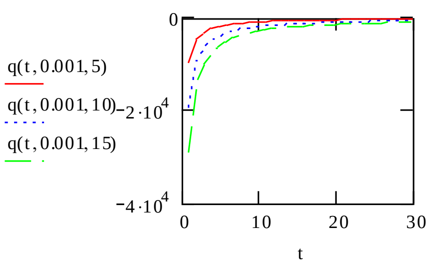

Fig. 5. Wall thermal flux changing, x=0.001; θ_{m1}=5, 10, 15^{0}C

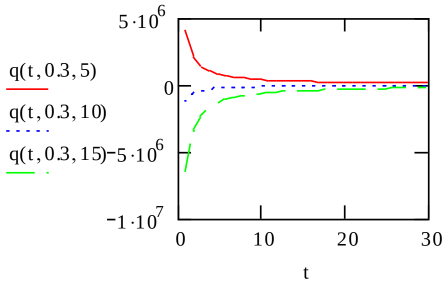

Fig. 6. Wall thermal flux changing, x=0.3; θ_{m1}=5, 10, 15^{0}C

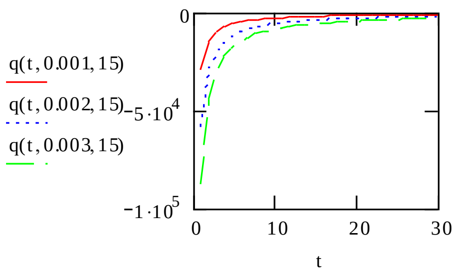

Fig. 7. Wall thermal flux changing, x=0.001, 0.002, 0.003; θ_{m1}=15^{0}C

4. CONCLUSION

Specific thermal flux and wall temperature, during non-stationary het conductivity of the wall, it seems that in the initial moment have large values. They depend on the composition of the wall and time constants. Then, with time, flux and temperature depended on thermal time constants, until after a certain time they reach the size to be constant.

In the above figures are shown that, depending on the temperature of the environment up to the surface of the wall, it depends on the change of thermal flow and temperature of the wall. By analyzing of non-stationary thermal conductivity of the wall achieved overall analyses of thermal losses.

Non-stationary thermal processes seem that are characteristic for short intervals of time (from several hours up to several days), in which represented the changing scale of other operations. Such heating and cooling problems can we see to residential buildings and other facilities with different destinations. They appear in many branches of industry and can easily be said that, as far as developing techniques as non-stationary thermal transfer processes current and become closer.

5. REFERENCES

Bejan, A. (1988), *Advanced engineering thermodynamics*, Wiley, New York

Bixler, N. (1989), *An improved time integrator for finite element analysis*, Comm. Appl. Numer Methods, Vol.5, pp. 69-78

Burmeister, L.C. (1993), *Convective Heat Transfer*, 2nd ed., John Wiley & Sons, New York

Dincer, I. Al-Muslim, H. 2001. *Energy and Exergy Efficiencies of Reheat Cycle Steam Power Plants*, Istanbul, Turkey.

Keey, R.B. (1972), *Drying-Principles and Practice*, Pergamon Press, New York

Kotas, T.J. *The Exergy Method of Thermal Plant Analysis*. Essex: Butterworths, 1985.

Moran, M.J. (1989), Availability analysis: *A guide to efficient energy use*, ASME Press, New York, US