11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

MICRO-SCALE HEAT TRANSFER. IDENTIFICATION OF RELAXATION AND THERMALIZATION TIMES USING THE SEARCH METHOD

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Key Words: *Micro-Scale Heat Transfer, Dual Phase Lag Model, Inverse Problems, Numerical Methods.*

The thermal processes proceeding in micro-domains can be described, among others, using the dual phase lag model (DPLM). According to the newest opinions the DPLM constitutes a very good description of the real heat transfer processes proceeding in the micro-scale, in particular on account of extremely short duration, extreme temperature gradients and the very small geometrical dimensions of domain considered. The base of DPLM formulation is a generalized form of Fourier law

$$\mathbf{q}\left(r, z,\ t+\tau_q\right)=-\lambda \nabla T\left(r, z, t+\tau_T\right) \tag{1}$$

where $\mathbf{q}$ [W/m^2] is the heat flux, ∇T [K/m] is the temperature gradient, λ [W/(mK)] is the thermal conductivity, while τ_q, τ_T denote the relaxation and thermalization times, respectively, and $\{r, z\}$ are the geometrical co-ordinates (the axially-symmetrical problem for domain oriented in cylindrical co-ordinate system is considered – Figure 1).

The acceptation of the formula (1) leads to the following energy equation [1, 2]

$$(r,z)\in\Omega: \quad c\left[\frac{\partial T(r,z,t)}{\partial t}+\tau_q\frac{\partial^2 T(r,z,t)}{\partial t^2}\right]=\nabla\cdot\left[\lambda\nabla T(r,z,t)\right]+\tau_T\frac{\partial\nabla\cdot\left[\lambda\nabla T(r,z,t)\right]}{\partial t} \tag{2}$$

where c [J/(m^{3}K)] is the volumetric specific heat.

In this paper the thermal processes proceeding in the homogeneous thin metal film subjected to an external heat source are considered. The equation (2) is supplemented by the Neumann boundary condition for $z = 0$ and the external heat flux is the function dependent on the spatial co-ordinates and time. On the remaining parts of the boundary the no-flux conditions are assumed. The initial conditions are also known (initial temperature of domain and initial heating rate).

The aim of considerations is the estimation of above parameters using the algorithm basing on the search method, at the same time the numerical solution of the task discussed is treated as the results of measurements necessary to solve the identification problem.

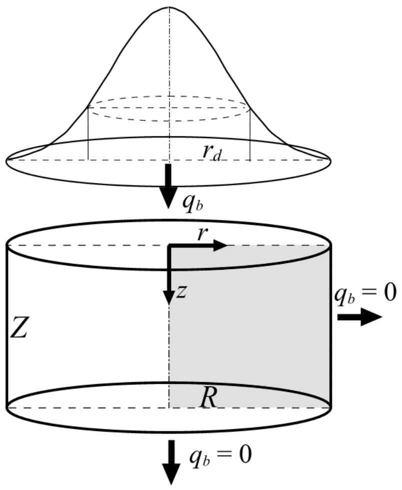

Fig. 1. Domain considered

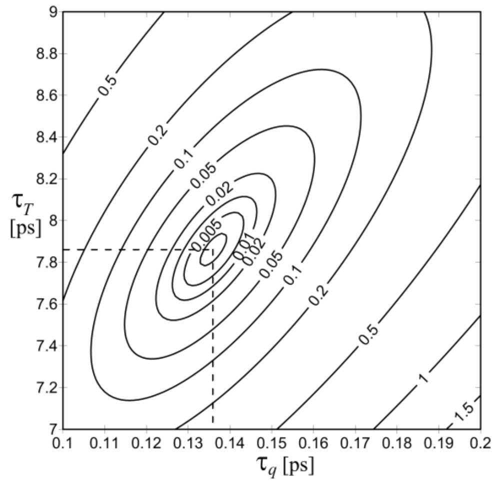

Fig. 2. Solution of inverse problem

The search method of the inverse problem solution used here consists in the division of the possible ranges of times τ_q and τ_T into sub-intervals, next for each pair τ_{qi} and τ_{Tj} the direct task is solved. The quality of the solution obtained results from the value of functional J corresponding to least squares criterion.

$$\mathrm{J}\left(\tau_q, \tau_T\right) = \frac{1}{M\,F} \sum_{m=1}^{M} \sum_{f=1}^{F} \left(T_{\tau_q, \tau_T}\left(r_m, z_m, t_f\right) - T_d\left(r_m, z_m, t_f\right) \right)^2 \tag{3}$$

where M is a number of sensors, F is a number of times steps, T_{τ_q, τ_T} is the calculated temperature corresponding to assumed values of lag times, T_d is the 'measured' temperature. The optimal values of τ_{qi} and τ_{Tj} arises from the minimal value of J (Figure 2).

The numerical model of the process discussed bases on a certain variant of finite differences method [3]. In the final part of the paper (full version) the examples of computations will be shown.

The work was done as a part of Project 2012/05/B/ST8/01477.

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