Based on the results of the experiments performed we may conclude that for the indicated values of the criteria K_{Tg}* and K_{Gg} the nonsteady state does not affect heat liberation [5], which permits us to treat the parameter change modes as quasisteady states.

The results obtained confirm the reliability and effectiveness of the method for determining heat liberation coefficients considered herein.

NOTATION

T, temperature; T_w, temperature of heat-sensing surface; T_f, heat exchange agent temperature; λ, thermal conductivity coefficient; c, specific heat; ρ, density; x, spatial coordinate; R, R_I, R_E, current, internal, and external radii of sensor; L, sensor length; ΔR, distance between approximation points along thermal sensor thickness; ΔL, distance between approximation points along thermal sensor length; V, volume of sensor element; F, area; α, heat liberation coefficient; τ, time; Δτ, step in the time; n, i, k, element numbers; j, time step number; λ_0, b_λ, c_0, b_c, coefficients of approximating linear temperature dependences of thermal conductivity coefficient and sensor material specific heat; q_w, thermal flux density on heat sensing wall; μ, dynamic viscosity; G, heat exchange agent flow rate; Cp, specific heat of heat exchange agent; d, channel diameter.

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DETERMINATION OF THERMAL FLUX DENSITY, MEDIUM TEMPERATURE AND HEAT LIBERATION COEFFICIENT BY SOLUTION OF THE CONVERSE THERMAL CONDUCTIVITY PROBLEM

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The converse thermal conductivity problem of determining temperature of the hot medium, heat liberation coefficient, and thermal flux density for asymmetic heating is solved using results of wall temperature measurements at three points located different distances from the hot surface.

In operation of high power equipment experimental determination of the temperature of the hot medium, the thermal flux density, and the heat liberation coefficient from the medium to the body wall under nonsteady state conditions is difficult, since thermal sensors will not tolerate the high thermal loads involved. In connection with this one can solve the converse problem of determining the basic parameters of the nonsteady state heat exchange between the hot medium and the body wall by using measurements of temperature over time at three points located at different distances from the heated (hot) wall surface.

We will consider the one-dimensional process of heat transport within a wall, one surface of which is heated by the hot medium, while the other is cooled by a cold medium in accordance with boundary conditions of the third type.

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The solution can be carried out by mathematical modeling with a specialized computer using resistance-capacitance networks. In performing the modeling all thermal parameters are considered known, with the exception of the temperature of the hot medium, the thermal flux density, the heat liberation coefficient, and their electrical analogs – the boundary voltage, resistance, and current of the model. The adjustable parameters of the model are calculated using thermal and construction data of the physical process, since these are related by the mathematical electrical circuit analogy [1].

Solution of the converse thermal conductivity problem with the specialized computer is performed by successive approximations. Initially the gas temperature is determined, then the heat liberation coefficient, and finally, the thermal flux density. This sequence is necessary because the medium temperature and the heat liberation coefficient affect the wall temperature regime differently.

Uniqueness of the solution is insured by specifying a temperature profile in the wall (temperature isochrons) in the form of a parabola of order n – an arbitrary real number.

Having established the arbitrary value of the model boundary resistance for the case of boundary conditions of the third sort or eliminating it for conditions of the first sort, by varying the voltage feeding the model the process of heat transport is modeled and agreement between the voltage of the corresponding model point and the experimental relative temperature of the (first) point closest to the heated surface is achieved to within the limits of a specified discrepancy.

Taking the voltage thus obtained as a first approximation and varying the boundary resistance, we again model the heat transport process and achieve agreement of the relative voltage at the corresponding model point to the experimental relative temperature of the third point to within a specified discrepancy. In doing this the previously obtained match of voltages and temperatures is maintained by minimizing the discrepancy.

Then establishing the voltage and boundary condition obtained in the first approximation in the model and varying them, we achieve agreement of the voltage at the corresponding model point and the experimental temperature of the middle (second) point to within the specified discrepancy.

After successively matching electrical modeling results to the experimental data for all three points within the limits of specified discrepancies the modeling process is halted and the values of the supply voltage and boundary resistance and voltage are taken from the model. These values are taken as the final ones used to find the temperature of the hot medium and the heated wall surface as well as the heat liberation coefficient. The thermal flux density is then determined from the results obtained using Newton's formulas.

By carrying out the electrical modeling with the specialized computer at several points in time we can determine the change with time of hot medium and heated wall temperature, heat liberation coefficient, and thermal flux density.

To verify the reliability of the method the problem of determining gas temperature, heat liberation coefficient, and thermal flux density was solved for heat transport through a planar wall, using the data of [1, p. 143].

Commencing from the condition of location of the experimental data at node points of the electrical model, we choose the number of cells in the model and define the coordinate scale k_ℓ. Location of the experimental points at node points of the electrical model is insured by varying the number of model cells. Correspondence (coincidence) of the thermosensor location points and the node points of the electrical model decreases the uncertainty in result processing.

The electrical process time is chosen proportional to the thermal process time in accordance with available measuring equipment and the time scale k_τ is defined.

Knowing the thermophysical characteristics of the wall material, the heat liberation coefficient on the cooled surface α_c, the coordinate and time scales from the model equations we determine the ohmic resistance of the electrical cells r and the model resistance on the cooled boundary R_c:

$$r = \frac{k_l}{ac_e k_\tau}; \quad R_c = \frac{\lambda r}{\alpha_c k_l}.$$

After all modules of the specialized computer are combined the values obtained for r and R_c are established in the electrical model.

To solve the converse thermal conductivity problem the temperature scale k_T is specified and experimental values (levels) of temperatures at three points for the moment being studied are established on the screen of the oscilloscope. After matching these temperatures to the electrical model, values of the supply and boundary voltages u_b and u_s are measured together with the boundary resistance R_h.

Temperatures of the gas T_g and the hot surface T_s and the heat liberation coefficient are calculated with the functions $T_g = k_T u_b$, $T_s = k_T u_s$, $\alpha_h = \alpha_c(R_c/R_h)$. The data thus obtained permit calculating the thermal flux density from the relationship $q = \alpha_h(T_g - T_s)$.

Results of solving the converse thermal conductivity problem with the specialized computer were compared to data from an analytical calculation. Temperature divergences of 3-5% were found with thermal flux divergences of 7-12%.

The method described permits determination of hot medium temperature, heat liberation coefficient, and thermal flux density from wall temperature measurements obtained by simple means in regions where their values are relatively low.

NOTATION

a, thermal diffusivity coefficient; c_e, capacitance of electrical model cell; k_ℓ, k_T, k_τ, coordinate, temperature, and time scales; q, thermal flux density; r, ohmic resistance of electrical model cell; R_h, R_c, resistance of heated and cooled boundaries of electrical model; T_g, T_s, temperature of hot gas and body surface; u_s, u_b, supply and boundary (surface) voltages of electrical model; α_h, α_c, heat liberation coefficients on hot and cold wall surfaces; λ, thermal conductivity coefficient; τ, time.

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SELECTION OF THERMOSENSOR INERTIA IN SOLVING THE CONVERSE THERMAL CONDUCTIVITY PROBLEM

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An expression is presented for calculation of the inertia of the thermosensor whose indications are used to solve the converse problem of determining a rapidly changing heat liberation coefficient.

To solve the converse thermal conductivity problem of determining a rapidly changing heat liberation coefficient between the hot gas and a solid wall by temperature measurements within the wall it is necessary to choose the thermosensor position and inertia properly.

As the thermosensor is removed from the hot wall surface and as its inertial characteristics are degraded the temperature curve which it produces "smoothes out," and information on the character of the change in the heat liberation coefficient is lost, although the mean value α_g can be reconstructed from such data quite simply.

In order to choose the thermosensor inertial characteristics the problem was posed of determining the time over which the temperature at the given coordinate reaches a given fraction Y of the surface temperature (sensor threshold sensitivity).

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