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.

LITERATURE CITED

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SELECTION OF THERMOSENSOR INERTIA IN SOLVING THE CONVERSE THERMAL CONDUCTIVITY PROBLEM

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UDC 536.24

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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The process of heat propagation was considered in a single-layer wall of thickness δ, the inner surface of which is subjected to the intense thermal action of a hot gas, while its outer surface is cooled by air.

The analytical solution of this problem has the form:

$$T = A - Bx - (A - T_i)\left(\cos\mu x + \frac{\alpha_g}{\lambda\mu}\sin\mu x\right)\exp(-a\mu^2\tau),$$

where

$$A = \frac{\left(\alpha_a^{-1} + \frac{\delta}{\lambda}\right)T_g + T_a/\alpha_a}{\alpha_g^{-1} + \frac{\delta}{\lambda} + \alpha_a^{-1}};$$

$$B = \frac{\alpha_g}{\lambda}(T_g - A);$$

is determined by solution of the characteristic equation

$$\operatorname{tg}\mu\delta = \frac{\mu(1 + \alpha_a/\alpha_g)}{\mu^2\lambda/\alpha_g + \alpha_a/\lambda}.$$

Using the condition of thermosensor sensitivity threshold the maximum distance at which a sensor with specified inertia can be located (without risk of losing information on the input signal form) can be determined:

$$l = \frac{(1 - Y)[A - (A - T_i)\exp(-a\mu^2\tau)]}{B + [\alpha_g(A - T_i)\exp(-a\mu^2\tau)]/\lambda},$$

as well as the required inertia of a thermosensor located at a distance x from the hot wall surface:

$$\tau = \frac{1}{a\mu^2}\, ln\frac{(A - T_i)(X - Y)}{(1 - Y)A - Bx},$$

where

$$X = \cos\mu x + \frac{\alpha_g}{\lambda\mu}\sin\mu x.$$

If the sensor is located in the immediate vicinity of the hot wall surface, to determine its inertia a satisfactory degree of accuracy can be achieved with the approximate expression

$$\tau = \frac{1}{a\mu^2}\left[\frac{(A - T_i)(X - Y)}{(1 - Y)A - Bx} - 1\right].$$

Keeping in mind that the Biot criterion at the hot surface Bi_g and the relative thermal effect time K (or modified Fourier number) are defined by the expressions

$$Bi_g = \frac{l\alpha_g}{\lambda},$$

$$K = a\mu^2\tau,$$

and taking the temperature of the surrounding medium equal to the initial and introducing relative reckoning of temperature from the value T_i, we obtain

$$K = \ln\frac{\Theta(Bi_g + 1 - Y)}{Bi_g(\Theta - 1) + \Theta(1 - Y)}, \quad (1)$$

where $\Theta = A/T_g$.

From this last expression it follows that to determine the thermosensor inertia, i.e., K, tables with three entries Θ, Bi_g, Y can be constructed.

For an N-shaped change in the heat liberation coefficient use of this technique permits refining α_g to 30-40% in the initial stage of thermal loading. At the end of the heating the divergence between coefficients α_g obtained with high inertia sensors and an inertia calculated by Eq. (1) gradually decreases.

The character of the change in heat liberation coefficient exerted no marked effect on sensor inertia (signals of various form were considered: N- and П-shaped, trapezoidal and intermediate forms).

Mathematical modeling results indicate that if the deviation of instantaneous α_g values from the mean value comprises less than 15-20% the gain in accuracy achieved by use of sensors with the required inertia is not great.

Increase in the frequency of α_g change imposes more rigid limitations on the sensor inertia.

NOTATION

T, wall temperature; T_g, hot gas temperature; T_a, air temperature; T_i, initial wall temperature; α_g, heat liberation coefficient between hot gas and wall; α_a, heat liberation coefficient between air and wall; a, thermal diffusivity coefficient of wall material; λ, thermal conductivity of wall material; δ, wall thickness; A and B, steady state temperature field coefficients; x, coordinate; τ, time.

EFFECT OF TEMPERATURE MEASUREMENT ERRORS ON THE ACCURACY OF BOUNDARY CONDITIONS

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Results are presented from an evaluation of the accuracy of the solution of an inverse heat-conduction problem for an infinite plate with nonsymmetrical heat-transfer boundary conditions.

The accuracy of the determination of boundary conditions for heat transfer was analyzed in relation to the accuracy of the input data (temperature measurements), with application to the measurement of nonsteady heat flows by means of alpha calorimeters. Assuming that the temperature field within the sensitive element of the calorimeter is kept uniform, it is possible to reliably determine the coefficient of heat transfer between the end of the calorimeter core and the flow of heat carrier by using the solutions of the inverse heat-conduction problem for an infinite plate. Then the temperature field of the sensitive element of the gradient alpha calorimeter is described by the Fourier equation

$$\frac{\partial\Theta(X,\ \mathrm{Fo})}{\partial\,\mathrm{Fo}} = \frac{\partial^2\Theta(X,\ \mathrm{Fo})}{\partial X^2} \tag{1}$$

with the boundary conditions

$$\frac{\partial\Theta(1,\ \mathrm{Fo})}{\partial X} = \mathrm{Bi}(\mathrm{Fo})\,[\Theta_c(\mathrm{Fo}) - \Theta(1,\ \mathrm{Fo})], \tag{2}$$

$$\Theta(0,\ \mathrm{Fo}) = \Theta_0,\ \Theta(X,\ 0) = f(X). \tag{3}$$

Given experimental values of the temperature of the heat carrier $\Theta_c(\mathrm{Fo})$ and the temperature on the heated end of the sensitive element $\Theta(1,\ \mathrm{Fo}) = \varphi(\mathrm{Fo})$, the solution of the problem for these boundary conditions has the form [1]

$$\mathrm{Bi}(\mathrm{Fo}) = \{[\varphi(\mathrm{Fo}) - \varphi(0)] + 2\sum_{n=1}^{\infty}[\varphi(\mathrm{Fo}) - Y_n(\mathrm{Fo})]\}/[\Theta_c(\mathrm{Fo}) - \varphi(\mathrm{Fo})], \tag{4}$$

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