THERMAL CONDUCTIVITIES OF METAL CASTING MOLD FACINGS

V. S. Serebro and A. I. Brener

UDC 536.212.3:621.744.3

An experimental method for the determination of the thermal conductivity in heat transfer between a cooling casting and a coated plate is described; the scope for use of the method is considered.

The nonmetallic materials in molds, including facings, are heterogeneous systems that consist of grains of refractory material almost out of contact and a matrix in the form of gas-filled pores and binding agent [1]. The thermal conductivity of such a material is substantially dependent on the metal being cast; the latter affects the temperature distribution within the mold and hence the gas conditions that apply, i.e., the gas composition in the pores. The thermal loading on the mold is complicated, on account of the rapid temperature change and the heat released by the phase transitions in the casting, and useful information on the thermal conductivities of the nonmetallic part for the mold can be obtained only by tests involving thermal interaction between the mold and the molten material. The electrical heater commonly used to measure thermal conductivities cannot provide the real thermal-loading conditions in a mold. These features make the method described below of some interest in determining the thermal conductivities of facings, since it is based on measuring the temperature distribution in a symmetrically faced plate in the mold.

To derive the temperature distribution symmetrical in a cross section of the plate, the latter is set in the mold in a vertical position, with identical cavities containing molten material on both sides; the plate is made up of two plates of equal thickness, which is convenient for inserting thermocouples at various points within the thickness. The system was coupled to a ÉPP-09 recording potentiometer.

The amount of heat transferred by thermal conductivity in time Δt may be compared with the amount of heat accumulated by the plate in this time to give

$$\lambda_1 = \frac{c_2\gamma_2 X_2(\theta_{2f}-\theta_{2i})}{(\bar{T}_1-\bar{T}_2)\,\Delta t}\, l_1.$$

This formula is correct for a linear temperature distribution within the coating. The thickness of this coating is restricted, and so the temperature distribution may be taken to be close to that assumed, as shown by Fig.1.

We used a copper plate, and the low thermal conductivity of the facing and high thermal conductivity of the copper meant that the plate was heated only at a low rate, so the temperature difference within the thickness of the plate was small (Fig.1). This simplified the determination of θ_2.

TABLE 1. Observed and Calculated Thermal Conductivities of Facing Materials

Composition, wt.%				λ_1, W/m-deg		calc. error, %
K016B quartz sand	zirconia concentrate	black graphite	bakelite powder	obs.	calc.	
97,0	—	—	3,0	0,275	0,321	+16,7
95,0	—	—	5,0	0,419	0,372	—12,6
96,5	—	0,5	3,0	0,414	0,362	—14,3
	98,0	—	2,0	0,384	—	—

Translated from Inzhenerno-Fizicheskii Zhurnal, Vol.21, No.5, pp.804–806, November, 1971. Original article submitted January 25, 1971.

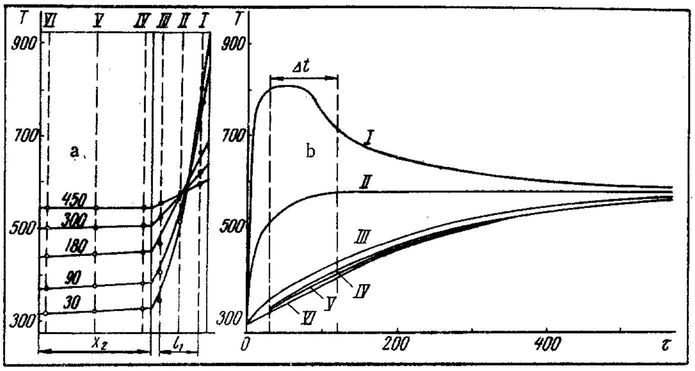

Fig. 1. Temperature distribution in a coated copper plate on contact with molten aluminum: a) temperature in coating (the numbers on the curves are times, sec); b) temperature variation in plate and coating in sections I–VI. T, °K; τ, sec.

We find $\overline{T}_1$ and $\overline{T}_2$ from the curves; also, Δt is chosen such that the difference $\theta_{2f} - \theta_{2i}$ is at least an order of magnitude greater than the possible error of measurement for the temperature.

In this way we measured the thermal conductivities of various facing materials (Table 1). The experiments were done on castings of technically pure aluminum, which was at 933°K on pouring. The facing thickness in all cases was 0.005 m, while the thickness of the copper plate was 0.020 m.

The matrix is a fibrous system consisting of two mutually interpenetrating components, the binding agent and the pores. In this connection, the structure of the facing as a whole should be considered as a complex granular–fibrous system. A method of calculation has been given for such a system [2], the essence of which is to calculate the thermal conductivity of the matrix as for a fibrous body, and then to calculate the thermal conductivity of the matrix as for a fibrous body, and then to calculate the thermal conductivity of the whole structure as for a granular body. Table 1 gives the results for λ_1 for these facings; the thermal conductivity of the matrix was calculated from Eq. (11) of [2], while that for the facing as a whole was calculated from Eq. (6). The conversion from the values of the concentration by weight for each component given in Table 1 to the concentration by volume, which is the quantity used in the formulas, is as follows:

$$p_i = \frac{k_i \gamma_0}{100 \gamma_i}.$$

The specific volume of the pores is related to the specific volume of the solid components of the mixture by the relation

$$p_n = 1 - \Sigma p_i.$$

Comparison of the calculated and observed λ_1 shows that the method of calculation gives a quite acceptable error as regards these coatings; in order to select a suitable thermal conductivity for each of the components, the arithmetic mean of the initial temperature of the plate and the temperature of the cast metal may be used.

NOTATION

λ_1	is the thermal conductivity of the coating material;
c_2, γ_2	are the specific heat capacity and density of the plate material;
θ_{2i}, θ_{2f}	are the initial and final values of the plate temperature averaged over the thickness;
$2X_2$	is the plate thickness;
$\overline{T}_1$, $\overline{T}_2$	are the values averaged over the time Δt of the temperature in cross sections a distance l_1 apart;
k_i, p_i	are the weight and volume concentrations of the i-th component;
p_n	is the volume concentration of pores;
γ_i, γ_0	are the densities of the i-th component and of the coating;
τ	is the time

LITERATURE CITED

1. Yu. F. Borovskii, B.B. Gulyaev, and I. M. Zubenko, in: Technical Properties of Molding Mixtures [in Russian], Nauka, Moscow (1968).
2. G. N. Dul'nev and Yu. P. Zarichnyak, Inzh.-Fiz. Zh., 12, No.4 (1967).