BRIEF COMMUNICATIONS

EFFECT OF POROSITY AND TEMPERATURE ON THE THERMAL CONDUCTIVITY OF CERMETS

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The thermal conductivities of sintered specimens of iron powder, as functions of porosity, temperature, and powder particle size, were experimentally determined.

Odelevskii's formula [1] or the relationship $\lambda_{por}/\lambda_c = f(\theta)$, proposed by Skorokhod [2], is usually used to determine the thermal conductivity of cermets. Can these formulas, however, be used to determine the thermal conductivity of porous articles at high temperatures?

It was show in [3,4] that, at high temperatures, heat transfer by convection through a complex system containing a metal and pores can be neglected, since its role becomes of practical importance only at temperatures above 1000° K and in pores of diameter greater than 5000 μ. The value of the radiative thermal conductivity at T = 1300° K and h = 1000 μ (h is the pore diameter) is only $12.8 \cdot 10^{-2}$ W/m · deg) [5]. This value is negligibly small in comparison with thermal conductivity of metals and alloys, i.e., heat transfer by radiation in the pores at high temperatures can also be neglected.

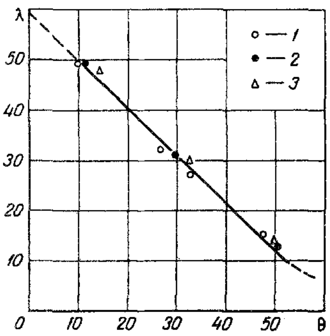

Fig. 1. Thermal conductivity vs. porosity: 1) fraction +160 μ; 2) fraction −120/+80 μ; 3) fraction −40 μ.

Thus, in real cermets, which have very small pores, conductive thermal conductivity is the dominant process at high temperatures.

The aim of the present work was to determine experimentally the thermal conductivity of sintered specimens of iron powder from the Sulinskii factory as functions of the porosity, powder particle size, and temperature.

The thermal conductivity was measured under steady-state thermal conditions. The cylindrical specimen of material of diameter 0.02 m was clamped between two standard specimens of Armco iron of known thermal conductivity. Oxidation of the specimens was avoided by heating them in an atmosphere of alcohol vapor.

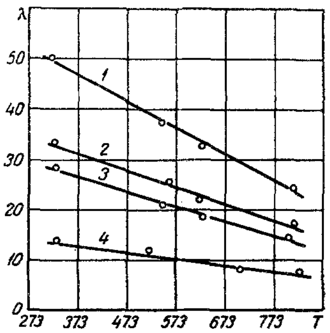

Fig. 2. Thermal conductivity vs. temperature and porosity: 1) θ = 9.6%; 2) 26.8; 3) 32.4; 4) 47.5.

The initial material for the specimens was iron powder with the chemical composition shown in the table. On being sintered in a nitrogen-hydrogen atmosphere, however, the chemical composition of the material was altered due to combustion of carbon, reduction of oxides, etc. Hence, the thermal conductivity

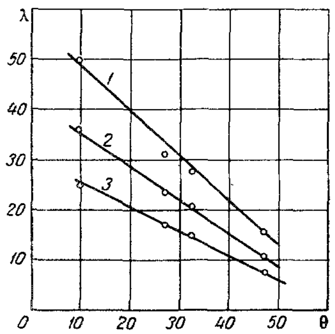

Fig. 3 Thermal conductivity vs. porosity and temperature: 1) T = 323° K; 2) 573°; 3) 773°.

Chemical Composition (%) of Iron Powder of Sulinskii Factory

Fe_{tot} not less than	Impurities, not more than				
	C	Si	Mn	S	P
98.0	0.15	0.25	0.5	0.04	0.04

of the material of the specimens was probably higher than that of steel 15 and less than that of Armco.

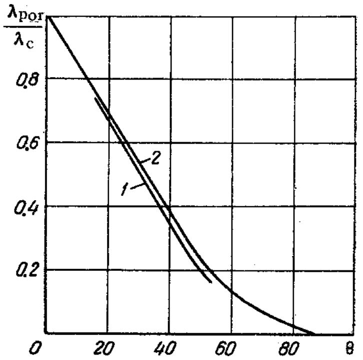

Fig. 4. $\lambda_{por}/\lambda_c = f(\theta)$: from author's data; 2) [2].

For investigation we took three powder fractions: +160 μ, −120/+80 μ, and −40 μ. The specimens were pressed at different specific pressures. The sintering conditions were as follows: sintering temperature 1473° K, isothermal holding time 7200 sec, atmosphere of purified and dried dissociated ammonia. Some of the sintered specimens were pressed a second time to provide specimens with lower porosity.

From the results of the experimental investigations, we plotted the relationships shown in Figs. 1–4.

Figure 1 shows the thermal conductivity λ as a function of the porosity θ for the three powder fractions. The mean temperature of the specimens was 323° K. Since the error of the measurements was 3–5%, the spread of the results for the different powder fractions lay within the region of error. As Fig. 1 indicates, the thermal conductivity was practically independent of the particle size of the powder.

The relationship shown in Fig. 1 is a straight line. Extrapolation of this line until it intersects the y-axis, thus giving the thermal conductivity λ_c of the compact (zero-porosity) metal, and calculation of the ratio λ_{por}/λ_c for each porosity clearly show that our relationship agrees with Skorokhod's postulated relationship [2] (see Fig. 4).

Figures 2 and 3 show the thermal conductivity as a function of the temperature for different porosities and as a function of the porosity at temperatures of 323, 573, and 773° K. These relationships are also linear.

Figure 2 shows that the straight lines have different angles of inclination. With reduction in porosity, the angle of inclination increases.

A calculation of the ratio $\lambda_{por}/\lambda_c = f(\theta)$ for each porosity, taking the values of λ_c and λ_{por} at 323°, 573°, and 773° K (Fig. 3), shows that these ratios are practically independent of the temperature.

Figure 4 shows the relationship $\lambda_{por}/\lambda_c = f(\theta)$ according to our experimental data and those of Skorokhod [2].

Thus, the thermal conductivity of sintered iron is practically independent of the particle size of the powder.

The effect of porosity on the thermal conductivity can be taken into account by Skorokhod's formula [2].

REFERENCES

1. V. I. Odelevskii, ZhTF, 21, 6, 1951.
2. V. V. Skorokhod, IFZh, 2, 8, 1959.
3. D. I. Boyarintsev, ZhTF, 7, 17, 1937.
4. D. I. Boyarintsev, ZhTF, 20, 9, 1950.
5. V. S. Smirnov, A. F. Chudnovskii, and M. A. Kaganov, Trudy LPI, no. 243, 1965.

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NONISOTHERMAL FILTRATION IN A CAPILLARY-POROUS BODY

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This paper gives a solution, obtained by the small-parameter method, for the equation of nonisothermal filtration of moist air through a capillary-porous body. It is shown that the shift of the temperature field caused by a change in the viscosity of the air differs by 15% from that calculated without consideration of the viscosity.

The differential equation of nonisothermal filtration when

$$k = k_0(1 + \beta t)$$

has the form

$$\frac{d^2t}{dx^2} - M\frac{dt}{dx} - M\beta t\frac{dt}{dx} = 0, \qquad (1)$$

where

$$M = \frac{\Delta p k_0 c_p}{\lambda\delta}.$$