Development of porous materials from spherical powders of refractory compounds and study of their properties are urgent tasks in view of the potential suitability of such materials for the thermal protection of components and walls of high-temperature installations.

Among the more important characteristics of porous materials is their gas permeability, which depends in the first place on the shape, size, and quantity of open pore passages. The gas permeability of sintered porous materials and its dependence on porosity have already been investigated by a number of authors [1-3, 5].

Of special interest is the dependence of gas permeability on the particle size distribution of starting powders at a given, fixed porosity of parts. Other conditions being equal, the sieve analysis of powders and the particle shape and surface condition to a large extent influence gas permeability. By correctly choosing the fractions of the starting powder, it is possible not only to achieve the required porosity and permeability, but also to secure the necessary uniformity of properties of porous components.

The influence of particle size distribution on the permeability of porous refractory compounds was investigated on specimens from TiC, WC, ZrC, TiB₂, and ZrB₂. In the present investigation, the air flow range and pressure drops employed secured a linear filtration law, as described by Darcy's formula:

$$V_f = \frac{K \Delta P}{\mu h},$$

where $V_f$ is the rate of filtration, $m^3/sec-m^2$; $K$ the coefficient of permeability, $m^2$; $\Delta P$ the pressure drop across the specimen, $N/m^2$; $\mu$ the coefficient of dynamic viscosity of air, $N$-sec/m²; $h$ the thickness of the porous specimen in the direction of filtration, m.

As an example, Fig. 1 shows results of hydraulic tests on two series of specimens—from TiC of about 54% porosity and from ZrB₂ of about 46% porosity, from which it can be seen that the particle size of the starting powders substantially affects the permeability of the porous materials. Thus, when the particle size changes from 60 to 600 μ, the permeability increases 5-10 times at the same material porosity.

Figure 2 shows the influence of particle size on the coefficient of permeability, determined from Darcy's formula, for specimens from titanium and zirconium borides, as well as from titanium, tungsten, and zirconium carbides, with mean porosities of 34, 46, and 54%. It can be seen from this graph that the influence of the specimen material on gas permeability is negligible, and lies within the limits of experimental error. On the other hand, increasing the particle size markedly increases gas permeability. At comparable particle sizes, gas permeability is greater from specimens of higher porosity. This is due to the number of interconnecting pores being increased as a result of a change in the type of powder particle stacking and the beginning of formation of bridges and arches at a porosity of more than 40%.

The widely employed empirical relationships between porosity and gas permeability [3,5] are valid only for those powder fractions from which the test specimens were prepared. The authors have attempted to find an empirical relationship describing the influence of porosity and particle size on the gas permeability of parts from refractory compounds. According to the data in Fig. 2, such a dependence of the coefficient of gas permeability on porosity and powder particle size may be approximately expressed by the formula:

Particle size, \( \mu \) | Compaction pressure, kN/cm\(^2\) | Sintering temperature, °C | Porosity (hydrostatic), % | Porosity (measured on structures), % | Curve No.
---|---|---|---|---|---
5-44 | Free pouring | 2300 | 57 | 60 | 2
44-74 | 10 | 2350 | 23 | 21 | 1
75-105 | 10 | 2200 | 47 | 48 | 3

![Fig. 1. Dependence of filtration rate on pressure gradient: a) titanium carbide, porosity about 54%; b) zirconium boride, II~46%. Particle size of powders, \( \mu \): 1) -74+44; 2) -177+149; 3) -420+177; 4) -750+420; 5) -1000+750.](image)

![Fig. 2. Dependence of coefficient of permeability on powder particle size. Porosity: I) about 54%; II) about 46%; III) about 34%. 1) ZrB\(_2\); 2) TiC; 3) TiB\(_2\); 4) ZrC; 5) WC.](image)

\[ K = \frac{D^2 + 0.06}{4.4 + 0.072D} \cdot 10^{-11}, \]

where \( D \) is the porosity, %; \( D \) the particle diameter, mm; \( K \) the coefficient of permeability, m\(^2\).

This formula is valid for porous materials prepared from spherical particles of refractory compounds (titanium and zirconium borides, and titanium, tungsten, and zirconium carbides) in the porosity range between 25 and 55%. It cannot be employed legitimately at component porosities above 55%, since at these porosities the principal part in gas permeability will be played by coarse pores generated by arches.

For processes associated with material transport, when the mechanism of transport is partly governed by the passage size, knowledge of the total porosity of the material is insufficient, and it becomes necessary to determine the quantity and size of interconnecting pores [6]. In this connection, in studies of the structural characteristics of porous materials, the principal aim is to obtain their differential pore size distribution curves [7, 8].

Measurements of pore size distribution were performed at the laboratory of the Institute of Electrochemistry, Academy of Sciences of the USSR, led by Professor R.Kh. Burshtein, using a mercury porosimeter suitable for pore radii ranging from 100 to 0.01 \( \mu \). Pore radii in the range 100-7 \( \mu \) were measured in a vacuum apparatus at pressures of 40-760 mm Hg, and those in the range 7-0.01 \( \mu \) in a high-pressure porosimeter at pressures of 1-801 atm gauge.

Test specimens were prepared from spheroidized particles obtained by granulating fine tungsten carbide powder by the process described in [4]. The specimen characteristics are listed in the table.

Because of the high sensitivity of the method, it is possible to evaluate not only the pore radius distribution (Fig. 3), but also the total porosity (Fig. 4) from the intersection of the integral curve with the axis of ordinates. The results obtained practically coincide with the porosity values measured by the method of hydrostatic weighing. The slight deviations (1-3%) may be attributed to error in the determination of porosity by hydrostatic weighing.