ELECTRICAL RESISTANCE OF A FLUIDIZED BED OF GRAPHITE PARTICLES

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Experimental data on the electrical resistivity of fluidized beds of graphite particles are given. The dependence of the resistivity on the filtration velocity, particle size, temperature of the bed, and position of the electrodes is determined.

Passage of an electric current through a fluidized bed of electrically conducting particles is one of the possible methods of obtaining temperatures of up to 4000° C in the bed [1] and of effecting high-temperature processes of chemical and metallurgical technology [2]. Suitable materials for an electrothermal fluidized bed are graphite, certain kinds of coal and coke, and certain cermet compounds. The development of devices with an electrothermal fluidized bed will require reliable data on the electrical resistance of a fluidized bed in various hydraulic regimes.

Published information [3–5] on this question cannot be regarded as adequate. Moreover, the data of different authors for the conductivity of fluidized beds are contradictory.

This paper gives experimental data on the effect of the main parameters on the electrical resistivity of a fluidized bed of graphite particles.

The investigations were conducted on apparatus of diameter 67, 80, and 100 mm with copper, stainless steel, and graphite electrodes of various shapes. The resistance between the electrodes was measured with a Wheatstone bridge and in some cases was determined from Ohm's law. The material of the fluidized bed was technical electrode graphite (GOST 11256-65).

Preliminary experiments showed that the electrical resistance measured between electrodes immersed in a fluidized bed depended considerably on the material from which the electrodes were made. It should be borne in mind here that the total resistance measured between the electrodes consists of the resistance at the "electrode—bed" interface, the resistance of the particles, and the resistance at the points of contact of the particles with one another.

It is obvious that in the determination of the resistivity of a fluidized bed the contact resistance at the "electrode—bed" boundary must be made as small as possible, since this is "ballast" resistance and it is impossible to separate it from the total resistance. The total resistance in experiments with metal electrodes was several times higher than in experiments with graphite electrodes in the same hydrodynamic conditions. In addition, the total electrical resistance depended considerably on the state of the surface of the metal electrode. For instance, the presence of an oxide film on the surface of copper electrodes made the total resistance several times greater. Graphite electrodes, which have a much lower contact resistance, are most suitable for measurement of the resistivity of fluidized beds of graphite. All the results given in this paper were obtained with graphite electrodes.

We also found out in preliminary experiments if the conductivity of the bed depended on the composition of the fluidizing agent. In these experiments the bed was fluidized in turn by nitrogen, argon, helium, and air at 20° C and the resistance was measured with a Wheatstone bridge. The conductivity in all cases was the same. This result indicates that electric charges are transmitted by direct contact of the bed particles with one another. It should be borne in mind, however, that the result may be different when the electrical resistance is measured by passing a current through the bed. The fact is that at high voltages some of the electrical energy is transferred by microdischarges, whose rate of formation depends on the degree of ionization of the gas, as well as on the voltage. In this case the physical nature of the fluidizing agent may affect the electrical resistance of the bed.

The effect of gas velocity on the resistivity was investigated on an apparatus 100 mm in diameter and 300 mm high with a porous partition. The height of the bed at rest was 120 mm. We used 24 × 72-mm electrodes 2 mm thick with a distance of 82 mm between them. The total resistance between the elec-

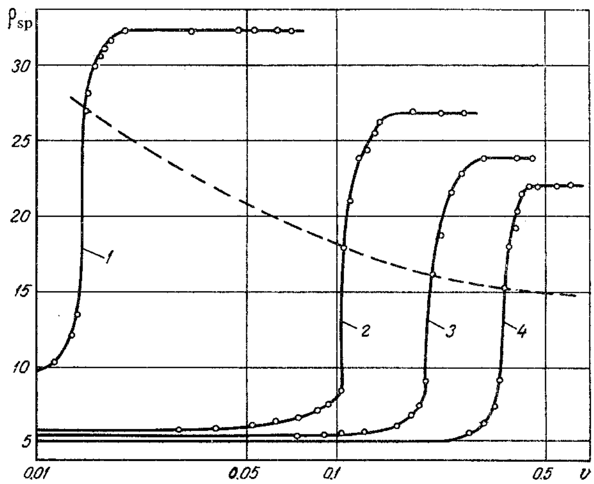

Fig. 1. Resistivity ρ_{sp}, ohm · cm, of different graphite fractions as function of gas velocity v, m/sec: 1) 0.07–0.14 mm; 2) 0.14–0.25 mm; 3) 0.25–0.5 mm; 4) 0.5–1.2 mm.

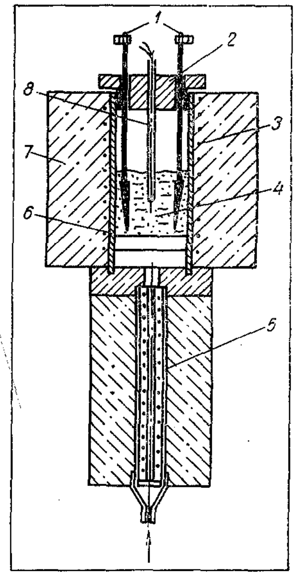

Fig. 2. Laboratory apparatus with fluidized bed: 1) electrodes; 2) case of refractory material; 3) heating coil; 4) fluidized bed; 5) gas heater; 6) porous partition; 7) heat insulation; 8) thermocouple in sheath.

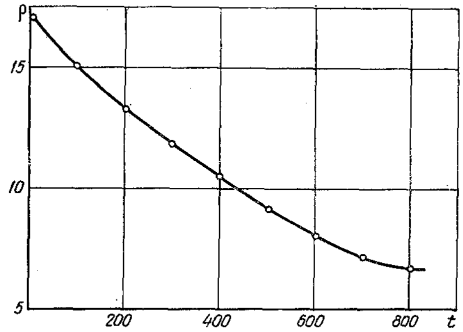

Fig. 4. Resistance ρ, ohm, between heating electrodes as function of bed temperature t, °C.

trodes was measured with a Wheatstone bridge. Figure 1 shows the resistivity of various fractions as a function of the velocity of the fluidizing agent (air, 20° C). The dashed curve in the figure denotes the boundary between the compact and fluidized bed. The figure shows that the conductivity varies nonlinearly with the gas velocity. Transition of the bed from the stationary to the fluidized state leads to a sharp increase in the resistivity due to the change in "packing" of the particles and reduction of the number of chains making contact between the electrodes. It is of interest that in developed fluidization the conductivity ceases to depend on the filtration velocity. This can be explained by the two-phase theory of fluidization, according to which an increase in gas flow rate in the fluidized bed does not lead to a proportional increase in voidage of the bed. This is why in developed fluidization the conductivity, which depends on the relative volume of the two "phases" in the bed, does not alter when the gas velocity increases. We also found that a fluidized bed of large particles had a lower resistance than a bed of small particles. This can be attributed to the fact that in a fluidized bed of large particles the chains which make contact between the electrodes consist of a smaller number of links, and hence, are less likely to be broken.

It is known that a fluidized bed is inhomogeneous in all directions. Mixing of the bed material in a vertical direction is more rapid than in the horizontal direction. It was to be expected that the resistivity of the bed would also show similar properties. To test this hypothesis we set up an experiment in which a pair of round electrodes 6 mm in diameter and 39 mm long were immersed at a distance of 35 mm from one another, first vertically, and then horizontally. The resistance between the vertical electrodes was lower than that between the horizontal electrodes. We think that this is due to the fact that vertical electrodes disturb the hydrodynamic regime in the fluidized bed less than horizontal electrodes.

To discover the relationship between the resistivity of the bed and the temperature we conducted experi-

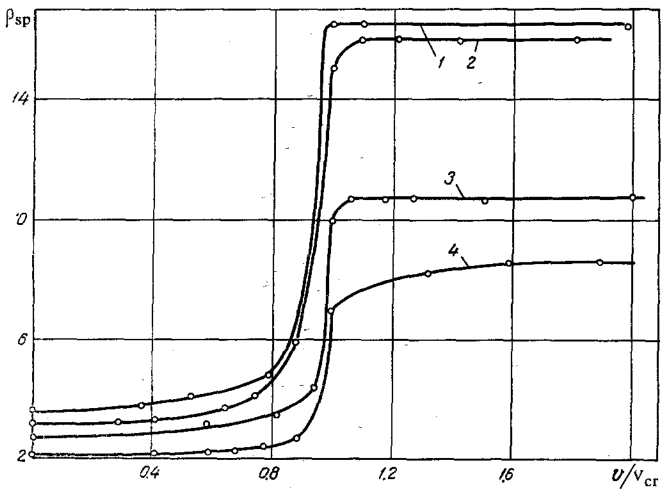

Fig. 3. Resistivity ρ_{sp}, ohm · cm, as a function of relative gas velocity at different bed temperatures: 1) 20; 2) 200; 3) 500; 4) 800° C.

ments in which the fluidizing nitrogen was preheated from 20 to 800° C on an apparatus (Fig. 2) 100 mm in diameter containing a bed of graphite particles of diameter 0.25–0.5 mm. The height of the bed was 120 mm. Figure 3 shows the results of Wheatstone-bridge measurements at different temperatures and velocities of the gas. The figure shows that the resistivity was almost halved when the temperature was increased to 800° C.

We also conducted experiments in which the bed was fluidized with argon and heated by passing an electric current through it. The apparatus consisted of a quartz tube 80 mm in diameter with a porous distributing screen and two electrodes of diameter 6 mm immersed at a depth of 50–80 mm in the bed. The bed, which was 100 mm high, consisted of particles 0.04–0.14 mm in diameter. The voltage on the electrodes was kept constant at 100 V during the experiment. The current was recorded as the bed was heated. The resistance of the bed, determined in this case by Ohm's law, decreased with temperature increase (Fig. 4).

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