NOTATION

\( E \), electric field intensity; \( d_t \), \( m \), \( q \), diameter, mass, and charge of a particle; \( g \), acceleration of gravity; \( h \), interelectrode distance; \( Y \), dimensionless transverse coordinate; \( e \), local volume concentration of particles; \( \varepsilon \), \( \varepsilon_r \), dielectric permittivity of a vacuum, relative dielectric permittivity of gas; \( \rho \), density of material. Subscripts: \( t \), particle; \( y \), projection of vector on \( Oy \) axis.

LITERATURE CITED


SOME SPECIAL FEATURES OF THE MASS TRANSFER OF THE LIQUID PHASE IN COMPOSITE MATERIALS BASED ON TUNGSTEN AND TITANIUM CARBIDES

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UDC 532.546:620.22

We investigated the phenomena of absorption of molten cobalt by the triphase composite \((Ti, W)C\rightarrow WC\rightarrow Co\) and the moving forces of this process.

According to existing notions, mass transfer of metallic melts into sintered porous composites occurs under the effect of capillary forces [1, 2], and into nonporous ones under the effect of diffusion [3]. By the investigations of [4] it was proved that in sintered bodies consisting of high melting particles and a binder metal, a third kind of mass transfer is possible, viz., absorption of metallic melts by nonporous composite bodies induced by rearrangement of the high melting skeleton. This process was called migration of the liquid phase [5].

At present migration of the liquid phase is being investigated predominantly in biphasic materials. Special features of the kinetics of mass transfer of metallic melts in triphase composites, the mechanism and the moving forces were not studied much.

The present work is intended to shed light on some of these regularities.

The experiments were carried out with spherical specimens with 10 mm diameter and specimens \( 5 \times 6 \times 35 \) mm in size, made of a composite containing 40.0 vol.% tungsten carbide particles with a specific surface of 1200 mm\(^2\)/mm\(^3\), 52.2 vol.% particles of solid solution of titanium and tungsten carbides (Ti, W)C with specific surface of 1258 mm\(^2\)/mm\(^3\), and 7.8 vol.% binder metal cobalt. Residual porosity of the specimens did not exceed 0.1%.

In a vacuum furnace at a residual pressure of 0.1 Pa and a temperature of 1610\(^\circ\)K the spherical specimens were immersed in a cobalt melt containing 65.0 wt.% Co, 28.16 wt.% W, 4.0 wt. % Ti, 1.84 wt. % C, designated henceforth VTK65. At 1610\(^\circ\)K the binder metal in the prepared specimens was present in the form of a cobalt melt identical in composition with VTK65, and the particles of WC and (Ti, W)C formed two combined high melting skeletons. With constant temperature and pressure, which were ensured during the experiments, and also equal concentration of the elements (Co, W, Ti, C) in the liquid phase of the specimens and in the contacting melt of VTK65, we obtained chemical equilibrium of the system specimen-cobalt melt. Under the same conditions specimens \( 5 \times 6 \times 35 \) mm were brought with their \( 5 \times 6 \) mm side into contact with the melt of VTK65. The holding time was 300, 660, 1200, 1800, 2400, 3000 sec. Before being charged into the vacuum furnace, part of the specimens were subjected on their \( 6 \times 35 \) mm sides to uniaxial compression of 30 MPa.

In the subsequent experiments we investigated mass transfer of the liquid phase in the chemically nonequilibrium system specimen-molten metal. This was attained by adding to the melt of VTK65 up to 3 wt. % silicon or chromium which are surfactants for the carbides WC and (Ti, W)C. Under these conditions mass transfer of the liquid phase was effected both by diffusion and migration. The distribution of elements along the \( 6 \times 35 \) mm side was studied by the x-ray spectroscopic method on a device Camscan-'IVd, metallographic and stereological investigations were carried out with an optical microscope Neophot-24.

We established that in spherical specimens immersed in a melt of VTK65, after holding for 50 min the content of liquid phase increased 6 times and amounted to 60 vol.%, at the same time the volume of the specimens increased 2.2 times, and the carbide particles WC and (Ti, W)C were separated. In the initial state the following values were found: specific contact surface WC-WC \( S_{WC-WC} = 200 \) mm\(^2\)/mm\(^3\), specific contact surface (Ti, W)C-(Ti, W)C \( S_{(Ti,W)C-(Ti,W)C} = 267 \) mm\(^2\)/mm\(^3\), and specific phase boundary WC-(Ti, W)C \( S_{WC-(Ti,W)C} = 567 \) mm\(^2\)/mm\(^3\). The specific phase boundary WC-WC \( S_{WC-WC} = 233 \) mm\(^2\)/mm\(^3\). After penetration of molten cobalt the contact surfaces WC-WC, (Ti, W)C-(Ti, W)C and the phase boundary WC-(Ti, W)C practically vanished, the surfaces molten cobalt-carbide phase increased substantially, their specific values increased to \( S_{WC-Co} = 1120 \) mm\(^2\)/mm\(^3\), \( S_{(Ti,W)C-Co} = 1030 \) mm\(^2\)/mm\(^3\). Molten cobalt penetrated into the zone of contact of particles WC-WC, (Ti, W)C-WC, (Ti, W)C-(Ti, W)C, causing recrystallization of particles and rearrangement of the entire high melting skeleton. When the molten cobalt was absorbed, the content of liquid phase in the spherical specimens increased from 10 to 60 vol.%. In this volume of liquid the carbide particles WC and (Ti, W)C formed equilibrium shapes, correspondingly elongated prisms and spheres. The structure of the composite freed itself of the high-energy contact surfaces WC-WC, (Ti, W)C-(Ti, W)C, WC-(Ti, W)C and changed to a more stable state. It follows from these experimental data that in the investigated composite (Ti, W)C-WC-Co at a temperature higher than the melting point of the binder metal, the surfaces solid-solid are unstable, and under the conditions of unbounded volume of liquid phase in chemical equilibrium these surfaces are replaced by the energetically more stable surface solid-liquid. This replacement of surfaces is the moving force of the process of absorption of the liquid phase by the sintered composite. This replacement of surfaces is effected by recrystallization of particles through the liquid phase by the well-known mechanism dissolution-diffusion-precipitation [6].

The specimens \( 5 \times 6 \times 35 \) mm, being in contact through the \( 5 \times 6 \) mm side with the molten VTK65, absorbed the latter, and as a result the content of binder phase in them increased. The distribution of the content of binder metal along the specimens is described by a dependence that is close to hyperbolic (Fig. 1). After preliminary compression of the specimens, the depth of penetration of the liquid phase was 1.5 times greater than the depth of penetration of the molten VTK65 in comparison with uncompressed specimens (Fig. 1), and correspondingly higher were also the speeds of migration of the liquid in the specimens subjected to preliminary compression. The speeding up of mass transfer of the liquid phase in these specimens is connected with the weakening of the high melting skeleton. Under the effect of uniaxial compression there arose high stresses in the bulk of the specimens in the zone of contact of the high melting particles. This led to the disruption of some contacts, to the appearance of slip lines, to increased concentration of dislocations in the zone of contact.