THE SINTERING OF HIGH-ALLOY MATERIALS
BASED ON IRON AND NICKEL

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Below are given the results of an investigation into the sintering and structure of high-alloy iron-base materials used in frictional units operating under conditions of restricted lubrication or dry friction and in the presence of moisture. Such materials must possess good corrosion resistance, which is achieved by alloying them with molybdenum and nickel. So far nothing appears to have been published in the literature on the sintering behavior of materials such as iron–molybdenum, iron–molybdenum–graphite, and iron–nickel–molybdenum–graphite, which were chosen for investigation in the present work.

The composites contained 15% of molybdenum and 3% of graphite, the remainder being iron or a mixture of equal parts of iron and nickel. The following powders were used: PZh2M2 fine reduced iron (to GOST 9849-74), PNK carbonyl nickel (GOST 9722-74), MCh grade molybdenum (TsMTU 4784-56), and Jzs graphite (GOST 7478-57). The experimental procedure employed in this work was similar to that used in an earlier investigation into the sintering of materials based on iron–nickel–graphite composites [1], and involved studying the kinetics of the sintering process at temperatures of up to 1200°C and determining the phase composition of the test materials.

It was established that in the temperature range 20-600°C dilatometric curves obtained for all the mixtures investigated were identical, and the relative change in specimen length, \( \Delta l/l \), was a linear function of temperature. At higher temperatures the quantity \( \Delta l/l \) for the Fe–Mo mixture became constant right up to 1100°C. The addition of graphite to this mixture had no effect on the shape of dilatometric curves up to a temperature of 950°C, but above this temperature it increased \( \Delta l/l \). A similar increase in \( \Delta l/l \), but at 850°C, was observed also with the Fe–Ni–Mo–C mixture. On further heating, compacts began to shrink owing to the presence in the mixture of nickel [1].
Fig. 1. Kinetic sintering curves obtained at various temperatures for composite materials, Fe-Mo: 1) 1000; 2) 1050; 3) 1100; 4) 1150; 5) 1200°C. Fe-Mo-C: 6) 1000; 7) 1050; 8) 1100°C. Fe-Ni-Mo-C: 9) 1000; 10) 1050; 11) 1100; 12) 1150; 13) 1200°C.

Fig. 2. Temperature dependence of changes in linear dimensions of Fe-Mo (1), Fe-Mo-C (2), and Fe-Ni-Mo-C (3) composite materials.

Fig. 3. Temperature dependence of changes in volumes of Fe-Mo (1), Fe-Mo-C (2), and Fe-Ni-Mo-C (3) composite materials and specimens of Fe-Mo-C material sintered in vacuum furnace (4).

Fig. 4. Distribution of x-ray line intensities over width for Fe-Mo-C alloy after sintering at 1100°C (a); Fe-Mo alloy at 1200°C (b); Fe-Ni-Mo-C alloy at 1200°C (c) and 1100°C (d) for 3 (1), 10 (2), 30 (3), 60 (4), and 120 min (5).

Fig. 5. Histograms of microthermo-emf in metallic phase after 2-h sintering of Fe-Mo alloys at 1000 (1), 1100 (2), and 1200°C (3); Fe-Mo-C alloys at 1000 (4), 1050 (5), and 1100°C (6); and Fe-Ni-Mo-C alloys at 1000 (7), 1100 (8), 1150 (9), and 1200°C (10).

During isothermal soaking compacts usually shrank, and subsequent cooling was accompanied by thermal contraction. Slight inflections were detected on ΔI/I vs T curves, caused by γ → α transformation in the iron.

Kinetic curves (Fig. 1) show that with all the composites studied shrinkage was greatest during the first minutes of isothermal holding. In the case of solid-phase sintering (temperature range 1000-1100°C) the addition of graphite to the Fe-Mo mixture decreased its shrinkage by almost two-thirds, while the addition of nickel increased the shrinkage, in spite of the presence of carbon (Figs. 1 and 2).

The sintering of the Fe-Mo-C material at temperatures above eutectic melting point took place in the presence of a liquid phase, as a result of which appreciable shrinkage was observed. Thus, at ~1100°C compacts experienced almost instantly such large changes in volume and shape that it proved impossible to follow their shrinkage kinetics, although sintering at 1080°C produced only very slight changes in compact dimensions and volume (Figs. 2 and 3).