THE BENDING STRENGTH OF SINTERED IRON-
AND COPPER-BASE MATERIALS AT LOW TEMPERATURES

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The investigation described is a continuation of an earlier work [1], in which the strength of copper-base materials was studied on bronzes of 5-25% porosity, containing various nonmetallic additions which did not react with the matrix. The relationships found between strength and porosity were linear, which was due to the narrow porosity range examined. For this reason, the authors failed to secure the characteristic curve of strength as a function of porosity at normal temperatures. However, the linear relationships obtained greatly simplified analysis of experimental results in the determination of general regularities. It was established that, with decreasing test temperature, the dependence of strength on porosity becomes more pronounced.

A hypothesis was put forward that this regularity probably applies to many porous sintered materials. It was therefore considered of interest to test the regularities arrived at on other materials, and do so both in a wider porosity range and with alloying additions which would not only react with the matrix, but also intensify the sintering process. The investigation was carried out on iron- and copper-base materials. Clearly, an intensification of the sintering process may be expected to be produced by alloying with nickel, which forms solid solutions with both iron and copper. When iron or copper particles are in contact with nickel, preferential diffusional flow will be directed, in accordance with a law of thermodynamics [2], from nickel toward iron or copper. As a result, diffusional porosity may be expected to be generated in the nickel particles, facilitating the propagation of diffusional creep.

The charge for the compaction of specimens was prepared by mixing iron (GOST 9849-61 standard, PZh-IM1 reduced, fine grade), copper (GOST 4960-49 standard, PM2 grade), and nickel (GOST 9722-61 standard) powders in the required proportions. Since alloy formation during the sintering of complex systems is realized as a result of diffusion, freshly-prepared powders were employed in order to increase the rate of propagation of heterodiffusion. In addition, the mixing of the powders in the barrel mixer was continued for 6 h. Compacting was performed at different pressures to obtain specimens of different porosity (Fig. 1). The iron specimens were sintered in a hydrogen atmosphere for 2 h at 1473°K. The iron-nickel and copper-nickel alloys were sintered in a hydrogen atmosphere for 8 h at temperatures of 1473 and 1273°K, respectively.

From Fig. 2, which shows the shrinkage of specimens of different compositions, it follows that an addition of nickel intensifies the sintering process. The porosity of the iron-base material containing nickel decreased by 5-10% in the case of high-porosity (40-50%) specimens and by 3% (absolute) for medium-porosity (20-30%) specimens.

During the microstructural analysis of a material sintered for 8 h, it was established that an addition of nickel resulted in a significant grain coarsening and some densification of the grain boundaries. As had been assumed, pores appeared on the nickel particles, their number decreasing sharply as sintering time increased from 2 to 8 h. Evidently, at longer holding periods, the process of coalescence of the diffusion pores begins to manifest itself. The microstructure of the sintered materials is presented in Fig. 3a-c.

Tests were carried out in a GM-250 bending machine (made in Eastern Germany) provided with a special device [3]. The rate of travel of the lower grip of the machine was taken to be 0.000167 m/sec. The strength of the materials was determined at 78, 175, 280, and 298°K. During the tests, load vs strain curves were recorded. By processing the bending diagrams by the procedure described in [4] and determining from these diagrams the ultimate strength using Nadai's formula, it was found that, in view of the substantial plastic strains preceding the rupture of the specimen, the limiting stress should be established from the plastic moment of resistance. Each plot point was obtained from results for 4-8 specimens. More specimens were employed for higher porosities and low temperatures. The mean values are presented below. The test results obtained are shown in the form of curves in Figs. 4-5.
Fig. 1. Effect of compacting pressure on specimen porosity.

Fig. 2. Change of specimen porosity during sintering.

Fig. 3. Microstructure of sintered materials from iron (a), iron-nickel (b), and copper-nickel (c) powders.

Fig. 4. Effect of porosity on strength of materials at different test temperatures: a) iron; b) iron-nickel; c) copper-nickel.