The present paper is a continuation of the investigation reported in [1-3].

The sintered materials selected for the investigation, iron-nickel (10% nickel, balance iron) and bronze-graphite (9% tin, 3% graphite, balance copper), were produced by the technique described in [2, 3]. Tests were carried out at temperatures of 78, 175, 230, and 293° K in a BLW-30 universal testing machine using the procedure described in [1, 2].

Determinations were made of the tensile strength, as well as the reduction of area and elongation after rupture. The specimen dimensions after the tests were measured on specimens reheated to room temperature. Mechanical property determination was performed by the procedure employed for dense materials (GOST 1491-61 standard). Four or five specimens were tested for each plot point, and the average values are quoted in this report.

The experimental results obtained for the iron-nickel, bronze, and bronze-graphite materials are shown plotted against porosity in Fig. 1. At room temperature, the dependence of strength on porosity is represented by plots which are not straight lines, although in the cases of the bronze and bronze graphite materials the curves deviate only slightly from straight lines. Similar regularities were observed earlier in [4, 5] for copper-base materials at normal temperature. With decreasing test temperature, the plots remain curved, but the whole curves shift upward and their curvature increases.

The plots of the room-temperature ductility characteristics of the materials investigated are in the form of curves rather than straight lines, and this type of dependence is retained as temperature decreases. However, in contrast to the regularities observed in the case of the strength characteristics, the curvature of the ductility characteristics vs porosity plots decreases with lowering temperature. With decreasing temperature, the ductility of the materials drops. The only exception occurs in the case of bronze, when a temperature drop to 230° K raises the whole curve of the reduction of area, and the curve shows a more marked dependence on porosity. When temperature

![Fig. 1. Effect of porosity on strength and ductility characteristics at various temperatures: a) iron-nickel; b) bronze; c) bronze-graphite.](image-url)
drops further, however, the change of this characteristic obeys the general regularity observed for the other materials.

The strength of the iron-nickel material at all temperatures and porosities is higher than that of bronze or bronze-graphite. In the case of iron-nickel, the mechanical properties are more strongly influenced by porosity. However, the ductility of bronze is much higher than that of iron-nickel.

It follows from Fig. 1b and c that the addition of graphite to the charge substantially lowers the strength and ductility characteristics of bronze. This is probably chiefly due to the shape of graphite inclusions (Fig. 2), namely, the fact that they are elongated and have sharp edges. This shape is acquired during compaction, and is associated with the easy sliding of graphite layers along the cleavage planes in the crystalline lattice. The sharp edges of the inclusions promote high stress concentration, and are thus responsible for the premature generation of rupturing stresses and limiting strains in substantial volumes, while the stresses in the remaining part of the material are much lower. Graphite particles of this shape, like those in gray cast iron [6], lower the strength and ductility characteristics of bronze-graphite.

Figure 3 shows the effect of temperature on the mechanical properties of iron-nickel, bronze, and bronze-graphite. With decreasing temperature, the strength of the materials steadily increases, the decrease at low porosity values being greater than at high porosities. The temperature dependence of the strength at low porosities is represented by a curve, but at high porosities is almost a straight line. The change in the ductility characteristics of the materials investigated does not follow a single pattern.

A specific temperature dependence is exhibited by the ductility characteristics of bronze. As temperature drops to 230° K, the reduction of area of the material increases, depending on its porosity, by a factor of about 1.22-1.61. However, subsequent temperature decrease substantially reduces this characteristic. At the same time, with increasing material porosity, the maximum on the reduction of area vs temperature curve becomes flatter. The fracture elongation steadily decreases with decreasing temperature. As the specimen porosity increases, the dependence of the percentage elongation on temperature becomes less pronounced and more nearly linear.

The ductility of iron-nickel and bronze-graphite steadily decreases with decreasing temperature, the extent of the drop being greater at low porosity values. The dependence, which is represented by curves at low porosities, gradually changes to linear at high porosities.

Fig. 2. Shape of graphite particles in bronze-graphite material.

Fig. 3. Effect of temperature on strength and ductility characteristics at different specimen porosities: a) iron-nickel; b) bronze; c) bronze-graphite.