SPECIAL FEATURES OF PLASTIC DEFORMATION OF POROUS METALS

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The use of powder metals and articles under conditions of considerable external loads and the use of cold treatment of sintered materials require knowledge of the dependence of their characteristics of plastic deformation on the structural parameters. For porous metals such dependences have a complicated form and have not been studied sufficiently well. In this connection, it is of interest to determine the special features of plastic deformation in metals with different porosities. The present work is a description of such an investigation for sintered iron.

Some special features of plastic deformation of porous iron have been considered in [1, 2].

In the present work the specimens to be tested were prepared by the method of [3] from PZhRV-2 powder with a mean particle size of 80 μm. In order to obtain different porosities we conducted a single pressing of the specimens to a specified density followed by their heat treatment. By changing the pressing pressure we obtained specimens with a porosity Po = 4 - 40%. The heat treatment included sintering of the pressed preforms in vacuum at 1180°C for 2.5 h. It should be noted that changes in the porosity lead to changes in the properties of the metal that are not related to the density under ordinary conditions.

Cylindrical specimens 10 - 12 mm high and 15 mm in diameter were subjected to uniaxial compression at room temperature with a degree of deformation ε ranging between 3 and 40%. For comparison, we studied commercial iron melted by the conventional method.

For a quantitative analysis of the structural characteristics of the porous specimens after deformation we measured the mean linear sizes of grains (Rg) and intergrain (Rg) intra-grain (Rp) pores. These characteristics were determined from micrographs separately along the deformation axis (R'g) and normal to it (R''g), which allowed us to evaluate the coefficient of anisotropy $K_a = R'g / R''g$. The microstructural analysis was conducted using a NEOPHOT-32 light microscope and a BS-300 electron microscope.

We investigated polished sections on cuts of the side surface of the cylindrical specimens. The cuts were polished before the deformation and then a reference grid with a cell of 50 μm was introduced on them by scratching. In order to evaluate the deformation strengthening we determined the microstresses $\Delta d/d$ and the mean sizes of the regions of coherent scattering D as a function of Po and ε. These characteristics were evaluated using a DRON-3.0 x-ray diffractometer (copper $K_\alpha$ radiation) from the physical broadening of the x-ray interference lines (110), (200), (211), (220) by the method of [4].

It was established (Fig. 1a) that the mean grain sizes in a nondeformed state and under a constant deformation decrease with growth of the porosity. This is so because with growth of the porosity the size (Fig. 1a) and concentration of the pores increase and impede the growth of grains in the process of recrystallization in sintering. With increase in ε in the case of a low-porosity material (P < 0.1) the mean grain size decreases (Fig. 1b). With growth of the porosity this effect decreases and at Po > 0.3 the grains are deformed very little, which indicates that the role of internal dislocation processes becomes less significant. Similar phenomena are characteristic for the grain anisotropy. The coefficient of anisotropy (at a constant deformation) becomes close to $K_a \approx 1$, which corresponds to a weakly deformed state (Fig. 1a). As the degree of deformation of a low-porosity material is increased, the anisotropy increases, whereas at a high porosity this change is insignificant (Fig. 1b).

It can be seen from Fig. 1a that the porosity exerts a substantial effect on the mean size of intergrain pores measured at a constant degree of deformation. As the degree of deformation of a low-porosity material is increased, the mean size of intergrain pores changes but little (Fig. 1b), which is associated with the predominant contribution of intragrain slip to the total deformation of the specimen. For a high-porosity material the growth of ε is accompanied by a considerable decrease in the mean size of intergrain pores caused by the ef-
The special features of plastic deformation of porous metals are discussed in the text. The effects of grain penetration into isomeric voids are noted, particularly at Po > 0.3 when the pores and grains have close sizes (at $R_{pi} \approx 30 \mu m$). The mean size of the intragrain pores ($R_{pi} \approx 3 - 4 \mu m$) depends on the porosity quite little, mainly due to the intraparticle porosity of the initial powder (mean size of pores in the particles is 5 - 8 \mu m) and interparticle pores that penetrate the grain body in the process of recrystallization [5]. The deformation also affects insignificantly the size of the intragrain pores. This shows that it is necessary to allow for the open and isolated porosities separately when analyzing the deformation of porous metals and their mechanical properties [6, 7].

An important feature of the microstresses and the sizes of regions of coherent scattering is their nonmonotonic variation with growth of the porosity (Fig. 2). At a low porosity (Po \leq 0.1) we observe a maximum in $\Delta d/d$, which is especially well defined at high values of $\varepsilon$; as the porosity increases, the microstresses decrease (Fig. 2a). The degree of deformation $\varepsilon$ exerts a substantial influence on $\Delta d/d$ in low-porosity specimens (Po < 0.1) and its influence on this parameter is insignificant in high-porosity specimens (Fig. 2b). The function $D = f(Po)$ has a minimum at Po \approx 0.1. The parameter $D$ is little dependent on the porosity in high-porosity specimens (Fig. 2a). The degree of deformation affects $D$ most markedly in a low-porosity material (Fig. 2b). The established anomalies in the dependences of $\Delta d/d$ and $D$ on the decrease in the degree of deformation and the porosity can be explained by the accumulation of considerable stresses on intragrain pores (local concentrators) under conditions where relaxation of these stresses due to the most efficient mechanism of grain motion as a whole [8] is hampered by the intergranular porosity and the relative strength of the intergranular boundaries. As the porosity increases, the stress gradients relax due to the participation of mechanisms of a rotation type [1, 9], which decreases the level of microstresses and increases $D$ due to the lower plastic deformation of intragrain regions. In this case the micrographs of deformed specimens (Fig. 3) exhibit a rotation of the lines of the reference grid, which are broken on intergranular boundaries due to grain boundary slip [10]. It should be noted that other authors have discovered anomalies in the internal friction [11] and some mechanical characteristics [12, 13] of powder iron in the range of low porosity.