botechnical properties of iron–graphite materials. However, simultaneous alloying with copper and sulfur (2.5 and 0.4%, respectively) imparts to these materials good tribotechnical qualities, as a result of which they can be employed at higher sliding speeds (2–3 m/sec).

LITERATURE CITED


IRREVERSIBLE DEFORMATION OF A SINTERED POROUS BODY OF WORK-HARDENING PLASTIC METAL

PART I

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In recent years the growing prospect of constructional powder metallurgy materials being processed by plastic working methods has generated interest in research into the theory of the deformation behavior of porous bodies. The practical value of such research is that it may make it possible to determine optimum process parameters for working sintered materials from knowledge of the latter's plasticity reserve.

A number of works published in the 1970s [1–5] represent attempts to formulate, on the basis of the mechanics of plasticity, theories capable of satisfactorily describing the deformation changes experienced by porous bodies in various kinds of stressed state. The difficulties arising in the solution of problems of this nature are linked with certain characteristic features of the irreversible deformation of porous bodies whose origin lies in the possible substantial difference between the macroscopic tensor of stresses acting on a body and a local form of stressed state for some arbitrarily chosen element of a porous body. Because of this, rigorous calculations are possible only with models of very limited applicability, such as that of Fishmeister and others [3]. Some authors [1, 5] resort to preliminary experiments on porous sintered specimens and make use of the finding that Poisson's plastic ratio is independent of the previous history of the attainment of a given porosity, but this applies only to a small number of materials and over a limited range of presintering temperatures [1]. Of particular interest, in the authors' opinion, is Green's theory of plasticity of porous bodies [4], even though the assumptions involved in it greatly restrict its application.

It has already been shown by the authors [6] that the densification of a porous body of a non-work-hardening plastic metal in the range of medium and low porosities (≤40%) is satisfactorily described both by Green's theory and by the rms viscous stress hypotheses put forward in [7]. Clearly, it would be desirable to expand these theoretical considerations so as to obtain a description of the strain densification of real porous bodies with allowance for the work-hardening (strain strengthening) of their matrix metal. In view of this, the present work was undertaken with the aim of deriving an analytical expression for the relationship between the porosity of a sintered body of a work-hardening plastic metal and external pressure at a given type of macroscopic stress tensor.

First of all, let us find a function expressing the relationship between isostatic bulk compressive stress and porosity for the model used by Green, i.e., spherical voids of the same diameter uniformly distributed in a matrix. In this body let us consider an element in the form of a thick spherical shell of porosity equal to the porosity of the body as a whole and examine its behavior under the action of an isostatic compressive stress \( \sigma \).
Fig. 1. Variation of porosity with pressure in uniform isostatic compression for nickel specimens of 0.51 (a), 0.37 (b), and 0.31 (c) starting porosities sintered for 1 h at 1000°C. Curves: 1) calculated for spherically symmetrical model; 2) calculated from rms stresses and strains with allowance for strain strengthening.

We will assume that the densification of such a model object is similar to the densification of the body as a whole. Unlike Green, we will regard the material of the matrix as being work-hardening according to the parabolic law \( \sigma_y = \sigma_0 + \sigma_1 \frac{\epsilon}{2} \), where \( \sigma_y \) is the compressive yield stress, \( \sigma_1 \) a constant, and \( \epsilon \) the logarithmic compressive strain. Densification in the model under consideration is due to a radial isotropic displacement of the material, resulting in a decrease in the size of the void.

If \( r_0 \) is the length of a vector radius drawn through any point in the body before deformation and \( r \) the length of the vector radius after deformation, then, from the condition of constancy of the volume of the material, we have

\[
r^3 - r_0^3 = \frac{R_1^3 (\theta - \theta)}{1 - \theta},
\]

where \( \theta \) and \( \theta \) are the starting and instantaneous porosities of the body, respectively, and \( R_1 \) and \( R_2 \) are the outer and inner radii of the spherical shell, respectively.

Let us put

\[
r_0^3 - r^3 = a^3.
\]

In spherical coordinates the condition of constancy of volume of the material is expressed as

\[
\epsilon_r + 2 \epsilon_\varphi = 0.
\]

The condition of equilibrium is

\[
\frac{\partial \sigma_r}{\partial r} + 2 \frac{\sigma_r - \sigma_\varphi}{r} = 0,
\]

and the law of work-hardening in invariant form is given by the expression

\[
\sigma_r - \sigma_\varphi = \sigma_0 + \sigma_1 \left[ \frac{2}{3} (\epsilon_r - \epsilon_\varphi) \right]^{1/2}.
\]

Solving simultaneously Eqs. (1-2), (1-3), and (1-4) and introducing the designations adopted, we obtain

\[
\sigma_r = -2\sigma_0 \ln \frac{R_2}{R_1} + 2 \sqrt{\frac{2}{3}} \sigma_1 \left[ \sqrt{\ln \left(1 + \frac{a^2}{r^2}\right)} \right] dr.
\]