LETTERS TO THE EDITOR*

COLD-WORKING OF METALS UNDER HYDROSTATIC PRESSURE

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(Received 27 October 1957)

It is generally considered that the work-hardening, which determines the mechanical properties of cold-worked metal, depends mainly on the amount of cold deformation. The nature of the stressed state under which the metal is cold-worked, affects work-hardening to a very much small extent.

In our case an attempt was made to find the effect of cold-working by elongation under conditions of high hydrostatic pressure on the mechanical properties of certain metals. Such experiments apparently make it possible to estimate in a straightforward way the effect of the spherical stress tensor on the process of plastic deformation and work-hardening in metals, which is of considerable value not only for the further clarification of the theoretical ideas developed by Academician Davidenkov [1] but also for solving certain problems associated with the working of metals under pressure.

The tests were carried out on the metals and alloys for which the chemical compositions and heat treatment conditions are shown in Table 1.

The test-pieces were first cold-worked by elongating the metal under high pressure to various degrees of strain and were then tested in uniaxial tension under atmospheric pressure.

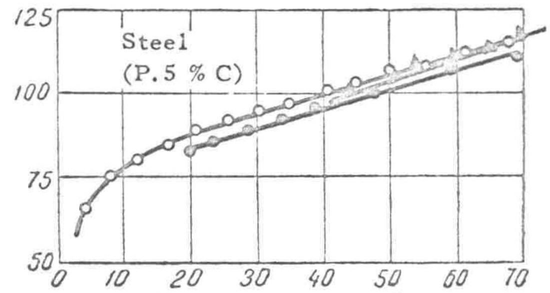

Fig. 1. Tensile test diagrams for St.50 specimens
●-●- after coldworking by elongation (e - 15 per cent) under 3500 atm, pressure;
0-0- no coldworking;
▲-▲- after coldworking by elongation (e - 40 per cent) under 3500 atm, pressure.

The cold-working under pressure was carried out in a special equipment for studying the mechanical properties of metals under high pressure [2]. The tests on the specimens under atmospheric pressure were carried out on a Type Im-4R machine. The diameter of the

TABLE 1

Material	Chemical composition %						Heat Treatment
	C	Mn	Si	Cu	Fe	Be	
Steel 50. . . .	0.45	0.60	0.05	—	—	—	Quench, temper at 700°C
Copper.	—	—	—	Ост.	0.05	—	Anneal at 600°C
Be bronze . .	—	—	—	Ост.	0.2	1.8	Water quench from 800°C

* *Fiz. metal. metalloved.*, 6, No.4, 761-768, 1958.

test-piece neck was measured with a dial-gauge indicator with an accuracy of up to 0.02 mm.

Fig.1, shows the tensile test diagrams for St.50 test-pieces. The total true strain is plotted along the abscissae and the true stress (in kg/mm^2) along the ordinate axis. As can be seen in Fig.1, after St.50 had been cold-worked under a pressure of 3500 atm, no notable change could be detected in the mechanical properties of the material. Analogous results were obtained for copper, cold-worked under pressure up to 2,500 atm.

In the case of beryllium bronze, as the degree of cold-work is increased, the capacity for concentrated plastic deformation increases notably, and the rupture strength is also raised. After cold-working specimens by 44 per cent under a pressure of 3200 atm, the rupture strength increased by 15 per cent, whilst the true reduction of area increased by 21 per cent. In normal conditions, beryllium bronze can only be cold-worked by elongation up to 80 per cent (according to our results) after which the test-piece ruptures. However, under a pressure of 3000 atm, we were able to cold-work beryllium bronze to 96 per cent in the neck; tensile testing following upon this showed that the limiting true strain in the test-pieces reached 120 per cent.

According to the results of X-ray structural analysis [3], cold-working of beryllium bronze under pressure is accompanied by a somewhat larger increase in the crystal lattice parameter than after normal cold-working by elongation. It would appear possible to conclude that the increased mechanical properties of quenched beryllium bronze after cold-working under pressure are associated with additional precipitation of the hardening gamma-phase. However, according to the Le Chatelier principle, an increase in hydrostatic pressure must retard a transformation which involves an increase in volume. Thus the marked change in the mechanical properties of the bronze after cold-working under pressure must apparently be associated not with the metastable nature of the alloy, but with anisotropy and residual stresses set up during working [4].

As for our tests on St.50 and copper it should be noted that preliminary cold-working in the range of hydrostatic pressures from 2000 to 3000 atm, produces no permanent changes whatever in the mechanical properties of the metals.

Translated by E. Bishop

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Job No. 4608

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AN INVESTIGATION OF THE STRENGTH OF THICK-WALLED PIPES

by
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Investigations of substances under a high hydrostatic pressure are usually carried out in thick-walled steel vessels -- pipes. In this research, when operating at pressures above 1,000 atm., the pipes used are of fairly large size. Theoretical calculations /1,2/ indicate that when the internal pressure is sufficiently high, the elastic stresses on the wall material, no matter how thick, can always exceed the permissible limit. Therefore, for every material there exists a definite limiting pressure above which the pipe cannot be used, as otherwise plastic deformation would begin, first, of the inner, and then of the outer pipe layers, culminating in the rupture of the pipe.

In many cases it is extremely important to determine the magnitude of the maximum internal pressure at which such a rupture occurs. The usual assumption is that the pressure at which a pipe ruptures depends mainly on the thickness of the pipe and the strength characteristics of the pipe material /3/. This assumption requires experimental verification, however.

For this purpose, the Laboratory of the Physics of Superhigh Pressures of the Academy of Sciences of the USSR has investigated the strength of thick-walled pipes subjected to superhigh internal pressures, up to 14,000 atm.

It should be noted that similar research on the strength of pipes made of carbon steel (0.28% C) under pressures as high as 7,100 atm was recently conducted at the University of Bristol by Crossland and Bones /4/.

1. Special apparatus was devised for rupture tests of thick-walled pipes subjected to internal pressures up to 14,000 atm. A schematic representation of the installation is shown in Fig. 1. The specimen-pipe 1 is held in split bushings 2 supported by the massive ring 3. The two ends of the pipe are connected to the cylinders 4 and 5 in which the high hydrostatic pressure is created.

The cavities of cylinders 4 and 5 and of the tube interior were first filled by a hydraulic compressor up to a pressure of 3,000 to 4,000 atm. The subsequent further rise in pressure was produced by the travel of piston 6 in cylinder 5; this travel was effected by feeding fluid to the lower cavity of cylinder 7. Fluid was fed to the upper cavity of cylinder 7 for the return strokes of pistons 6 and 8.

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