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Figure 1

Figure 1: Figure 1

Abstract

Full Text

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PHYSICS

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MEASUREMENT OF THE SHEAR STRESS OF A NUMBER OF SUBSTANCES AT PRESSURES UP TO 100,000 ATM

To determine the possibility of using graphite, silver chloride, pyrophyllite, and a number of other substances as lubricants in high-pressure apparatus, it was necessary to find out how their plastic deformation takes place. For this purpose, experiments were carried out to measure the shear force of various materials at hydrostatic pressures up to $\sim 100{,}000$ atm, and for graphite and silver chloride up to pressures on the order of 500,000 atm. The experiments were performed on an apparatus constructed at the Institute of High-Pressure Physics of the Academy of Sciences of the USSR ([1]). The specimen under study, in the form of a thin disk (0.1 mm thick) or in the form of a powder, was subjected to normal pressure between two pistons (made of hard metal-ceramic alloy of grade VK-6), one of which rotated about an axis perpendicular to the surface. The pressure on the pistons was produced by compressing them between the plates of a hydraulic press.

Fig. 1. Plot of the dependence of the shear stress τ on pressure p. 1 –AgCl; 2 –Mg; 3 –Armco iron; 4 –catlinite; 5 –graphite; 6 –pyrophyllite

The force required to rotate the piston was measured as a function of the normal pressure by means of a piston dynamometer with automatic recording of the dependence of the shear force on the angle of rotation, and the corresponding plots were constructed. Knowing the dimensions of the parts of the apparatus, it is possible to calculate the average shear force and the average hydrostatic pressure on the ends of the pistons. Thus, for the forces directly measured in the experiment, curves of the dependence of the average shear force on the average pressure were obtained. These curves consist of two substantially different parts (^{2}). Bridgman believes that the initial part of the curve corresponds to surface sliding between the material and the surface of the piston. Then, when the internal shear force reaches the value of the yield limit, internal sliding of the disk material begins along planes parallel to the ends, while the ends of the disk, owing to friction, "freeze" to the pistons. The authors have shown that the contact area changes sharply up to pressures on the order of 10,000–15,000 atm; therefore all tests were carried out beginning with pressures of 15,000 atm, when the contact area became more constant.

In most cases the shear force was measured for 10–15 pressure values equally spaced from one another. Each test was repeated 3–4 times, and average values were taken.

Usually the process of deformation in shear proceeded smoothly, without internal fractures, as evidenced by the absence of sharp clicks and explosions. The data obtained on the dependence of the shear force on pressure are presented in Table 1 and in Fig. 1. Examination of these data shows that the shear force increases linearly with increasing pressure up to 100,000 atm, and then increases sharply, becoming 3–4 times greater than the shear at 25,000 atm. This is explained by strain hardening of the material. Therefore such low-plasticity materials as pyrophyllite and graphite have the greatest shear value, while silver chloride and magnesium have the smallest. The shear force of pyrophyllite is 6 times greater than the shear force of silver chloride.

Table 1

Limiting shear force (in kg/cm^2)

Substance	Pressure in kg/cm^2	Pressure in kg/cm^2	Pressure in kg/cm^2	Pressure in kg/cm^2	Pressure in kg/cm^2
	25,000	50,000	75,000	100,000	500,000
AgCl	450	900	1300	1800	14,000
Mg	750	1250	1800	2500	
Soft iron	1850	3500	5150	6750	
Catlinite	1620	3800	3650	7600	
Pyrophyllite	1730	4500	7950	11600	
Graphite	2700	4800	6600	8200	135,000

For graphite and silver chloride, tests were carried out up to pressures of the order of 500,000 atm (Fig. 2). It turned out that the shear force of graphite after pressures of 100,000 atm begins to increase sharply, and the curve for the limiting

Fig. 2. Graph of the dependence of shear stress τ on pressure p. 1 –AgCl; 2 –graphite

Figure 2: Fig. 2. Graph of the dependence of shear stress τ on pressure p. 1 –AgCl; 2 –graphite

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1 –AgCl; 2 –graphite

shear force becomes convex with respect to the pressure axis. The shear force of graphite at 500,000 atm increases by a factor of 16 compared with the shear force at 100,000 atm. Apparently, at such high pressures the covalent bonds begin to prevail over the van der Waals bonds. One of the authors, together with S. S. Kabalkina (^{3}), showed that already at pressures of the order of 10,000-15,000 atm the compressibility of graphite is determined mainly by the compressibility along the c axis, which is a consequence of weak van der Waals interactions between the layers.

On the basis of the data obtained, one may conclude that in the pressure range up to 100,000 atm the shear force increases linearly with pressure. Pyrophyllite has the greatest shear force, and silver chloride the smallest. When the pressure is increased above 100,000 atm, the shear force of graphite begins to rise sharply and at a pressure of 500,000 atm reaches 135,000 kg/cm^2, which indicates a change in the interaction forces within the crystal lattice.

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Note: Figure translations are in progress. See original paper for figures.