EQUIPMENT FOR EVALUATING ELASTICITY CONSTANTS OF MATERIALS BY A STATISTICAL METHOD

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It is necessary for evaluating the deformation errors of high-pressure instruments (reference piston manometers, piezoelectric meters, viscosimeters, etc.), to possess precise values of elasticity constants for the measuring elements of these instruments. The available tabulated constants obtained by dynamic or static methods are unsuitable for these purposes, since the dynamic method does not account for the effect of stresses which arise in the operation of components [1], whereas the static method is insufficiently precise.

It is possible to obtain elasticity constants approaching their actual values by raising sufficiently the precision of the static method, which provides measuring conditions approximating most closely those existing in practice. We describe below an installation which has been developed on the basis of M. K. Zhokovskii's suggestion, and is suitable for measuring statically on one sample both Young's modulus and Poisson's coefficient with greater accuracy. It consists of an equipment for providing and measuring efforts (dynamometer) and a strain-gauge meter for measuring small transverse deformations of the sample.

Dynamometer

Precise measurements of the efforts acting on the sample are made by means of a hydraulic dynamometer with packless pistons, which has been successfully used in many instruments, including those of a reference type [2,3].

The schematic of the installation is shown in Fig. 1. The power piston system 3 consists of the upper (moving) and lower (stationary) pistons in a common cylinder. The system is fixed to upper beam 4 of frame 5 which, together with reversing gear 2 and grip 7 is mounted on pedestal 6 and is connected by means of a pipeline to piston manometer 9. Spherical stop 1 is used to prevent the rotation of the power piston. The transmission of vibrations and shocks to strain gauges 8, which are mounted on sample 17, is eliminated by separating that part of the installation from the remaining units. Piston manometer 9, reduction gear 15, pump 14, screw press 10, valve 6, and other auxiliary equipment are mounted on a separate table.

The more viscous pressure liquid (glycerine) is used in the power piston system of the installation, and the less-viscous liquid (transformer oil or benzene), in the manometer. The position of the boundary level between the two liquids, which is required to estimate the effect of the liquid column, is evaluated through an inspection window on the reading device of separator 11. In order to prevent any damage to the manometer in the case of a sample fracture and a sudden drop of the loaded piston, a shock-absorbing device in the form of blocking valve 12 is provided. The fracturing of the sample breaks the electrical circuit of electromagnet 13, thus closing the channel and disconnecting the manometer from the remaining parts of the installation.

The grips in the installation are provided with a new design which reduces friction between spherical surfaces by using ball bearings in a separator, thus reducing considerably the restoring moment of resistance in skewing.

This installation differs from normal hydraulic test machines by the fact that both its piston systems are rotated. The power piston systems are rotated, the power piston by a motor and the manometer piston by hand. This small difference improves considerably the properties of the installation, since dry and semidry friction is thus replaced by liquid friction.
Fig. 1.

The main parameters of the installation are: a power piston area of 100 cm$^2$, a manometer piston area of 1 cm$^2$, maximum pressure of $\sim 9.8 \cdot 10^6$ N/m$^2$, and the upper measurement limit of $\sim 10^5$ N.

The effort applied to the sample is evaluated from the formula

$$P = kmg,$$

where $k$ is the basic constant equal to the ratio of the effective areas of the power and the manometer pistons; $m$ is the mass of the weights on the manometer pan; and $g$ is the acceleration due to gravity.

Equation (1) is obvious and it holds, provided that the manometer piston with its pan is preset to balance the power piston system of an unloaded installation. The value of the basic constant was established experimentally by hydrostatic balancing of the power piston and the manometer piston.

The dynamometer error was evaluated by computation. The basic (instrumental) error and additional errors determined by the measuring conditions were taken into account. The values of additional errors were obtained from general theoretical equations for instruments with packless pistons [2].

An analysis of the installation error has shown that, even if all the component errors are considered to be residual and unexcluded, and are added arithmetically, the total error does not exceed 0.05% over the entire loading range. The actual error will be smaller, since some of the residual errors are systematic and can easily be eliminated by corrections. Thus, this dynamometer is at least 20 times more precise than ordinary machines, which have an error of the order of 1%.

**Strain Gauge**

For measuring longitudinal deformations in evaluating Young's modulus, it is possible to use an ordinary Martens strain gauge. In view of the absence of reliable strain gauges for measuring very small transverse deformations, the Poisson coefficient is normally evaluated indirectly from known values of moduli $E$ and $G$ by means of the relationship

$$\mu = \frac{E}{2G} - 1,$$

where $E$ is Young's modulus, $G$ is the shear modulus, and $\mu$ is the Poisson coefficient.