NEW TESTING INSTRUMENT WITH A FLOAT DYNAMOMETER

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Instruments with dynamometer mechanisms suitable for measuring relatively large deformations in a sample, which are produced by small external forces, are required for evaluating the rheological properties of elastoplastic and dispersed materials. Such measurements are necessary not only because plastics exhibit in their liquid-flowing condition a nominal plastic strength which is almost a million times smaller than that of metal, but also because they are preferable for determining the rheological parameters of certain types of plastics. It is known [1] that polymers exhibit their elasticity and viscosity patterns more clearly in sufficiently diluted solutions than in their solid state, since in the first instances stresses are determined with the masking of intermolecular interactions almost completely eliminated. Thus, the testing carried out with sufficiently small, mainly sheer, stresses, i.e., without destroying the structure, is suitable for evaluating and calculating a whole series of rheological parameters.

Existing tensile test machines and instruments for experimenting with plastics have imperfect dynamometer mechanisms and, therefore, provide low precision and restrict the range in testing samples which deform at low stresses.

Electrical viscosimeters [2] have an adequate precision, but they have a very complicated circuit and a large over-all size, which limits their wide application, especially in factory laboratories.

Test instrument PPS-1 with a float dynamometer designed by the author of this article and V. I. Tarasov, and made and tested at the All-Union Scientific Research Institute of New Building Materials (VNIINSM) is relatively simple and has several advantages.

The instrument is intended for evaluating the rheological parameters of plastics with various viscosities and consistencies, starting with 0.3 and up to $10^5 \text{N} \cdot \text{sec/m}^2$. These parameters include deformations in simple and plastic shears, dynamic viscosity and velocity gradients with respect to shear stresses, nominal plastic strength (maximum shearing strength), cohesion, adhesion, surface tension, tensile strength, elongation, compression et al.

The kinematic schematic of the instrument is shown in Fig. 1. Feed screw 11 is rotated by motor 9 through belt drive 8 (i = 2, 1, 0.5) by means of worm gear 7 (i = 60). The feed screw has a keyway with a key fixed to the casing, as well as a bracket connected through bottom roller 13 to the cord of the drum.

The screw is displaced vertically with its table 6 along cylindrical guide 10.

Rod 12, which is coupled to the table and, hence, to the source of power through the tested sample, is suspended at its upper end from a float, with its lower end resting against a Teflon roller on frictionless bearings and engaging by means of its rack with gear 14.

In the absence of deformations in the sample, i.e., in the absence of reversible (elastic) and irreversible deformations (elastoplastic yielding), the friction-force vector which passes through the effective axis of the device with the sample is directed towards the loading-force application point. In such a case the friction force does not affect the precision of the dynamometer. When a load is applied to the sample, producing in it elastic deformations or yielding, the friction-force vector is still directed towards the loading-force application point, whereas the rod with the sample which is fixed to it is affected by a force pointing in the opposite direction. Thus, the friction force produces a measurement error when the rod is being displaced and, therefore, it is necessary to make this force constant and reduce it to a minimum.

The dynamometer mechanism implements this task in addition to its main objective [3]. The mechanism consists of float 1 (see Fig. 1), tank 2 with knob 3, Teflon bearings 19, guide 20 and lid 21.

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The recording mechanism consists of a light drum 4 rotated on frictionless bearings by a flexible cord taken over a roller which is mounted on the axle of gear 14, a roller fixed to axle 16 of the drum, dial 5, two pointers 22, and carriage 18 with pen 15 and counter-balance 17. The pen is connected by flexible cords with the rod and the table.

The operation of the float dynamometer used in this instrument consists essentially of the following. The float which is suspended on the rod in the liquid balances its own weight, that of the moving components connected to it and of the sample-carrying device. It also compensates various errors due to the friction produced by the displacement of the rod. Thus, at the beginning of testing the load on the sample and, hence, the stresses in it are equal to zero, which is very important in testing with small loads. The float is submerged by the action of the motive power through the tested sample. The resulting Archimedian force reacts on the sample by pushing the float upwards. The float is displaced along the guide with a minimum liquid friction, since the float bearings are subjected to a load parallel to the rod, and not to a radial load which would have produced Coulomb friction whose value depends on the normal force. The design of this dynamometer is of particular interest, since even the smallest friction produced by the displacement of the float does not depend on the loading of the rod. Thus, the friction in the bearings at various load produces a constant systematic measurement error, which can easily be excluded in the processing of measurement results. Moreover, another advantage of the float dynamometer consists of the possibility of exerting on the sample a continuous, smooth and inertialless load which varies linearly.

The force acting on the sample and measured by the dynamometer can be represented as

\[ P = Sh \rho g - \sigma - F_f, \]

where \( S \) is the effective area of the float, \( h \) is the immersion depth of the float under the effect of an external force, \( \rho \) is the density of water, \( \sigma \) is the surface tension of water, \( F_f \) is the liquid friction force due to the displacement of the bearings with respect to the guide.

The instrument's constant error is \( \sigma = 82.5 \cdot 10^{-4} \) N for a float diameter of 7.5 cm, bearing diameters of 1-2 cm and a coefficient of surface tension of water of 72.8 \( \cdot 10^{-3} \) N/m. Force \( F_f \) also forms part of the constant error, but it is of even a lower order than \( \sigma \). Therefore, taking into consideration the constants of the instrument, we find that force \( P \) depends only on \( h \).

The instrument's technical data are: maximum loading force of \( \sim 3 \) N; rates of loading the sample of \( 8 \cdot 10^{-4}, \ 16 \cdot 10^{-4} \text{ and } 21 \cdot 10^{-4} \text{ m/sec}; \) error in measuring the force of \( 0.7-0.8\% ; \) a threefold amplification for the recording scale; motor type AOLB12-4, \( N = 80 \) W, \( n \approx 141 \text{ rad/sec}; \) overall size of \( 582 \times 565 \times 1300 \) mm and a mass of 60 kg.

The instrument's equipment includes a control desk for starting and stopping the instrument and controlling the heating of the sample. The instrument operates with special devices for gripping the tested sample. These devices are fixed to the table and the rod. Let us examine the instrument's operation in particular types of testing.