EFFECT OF STRAIN RATE ON THE STRENGTH AND DUCTILITY

CHARACTERISTICS OF POLYAMIDES

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The main features are presented for dynamic tests in tension, compression, and shear with plastic strain rates up to $10^3$ sec$^{-1}$. An increase in strength characteristics and a reduction in ductility characteristics with an increase in strain rate are established with different forms of stressed state for the test materials. Experimental results confirm the necessity of studying the dynamic properties of polymer materials.

Use of structural thermoplastics instead of steels and light alloys is a promising way of reducing the metal content of engineering structures. Polyamides occupy a leading place among thermoplastics. The combination of properties, of which the main ones are high strength, elasticity, stable processability in mass produced articles, creates a priority for polyamides in the series of thermoplastics up to the year 2000.

Recently there has been development of polyamide grades PA 6 and PA 66 as the most utilized starting materials. By adding modifying additions to these materials it is possible to improve their impact strength and elasticity. Another promising direction for improvement of the properties of polyamides if filling them with glass fiber, and reinforcement of polyamides increases their strength properties to a greater extent than for other thermoplastics.

In this work the effect is considered of strain rate on the mechanical properties of polyamides PA 6 and PA 66 modified by introducing polyamide-forming additions (hexamethylene diamine and adipic acid salts) in the stage of polymer synthesis, and also of glass glass-fiber-reinforced composites prepared on the basis elastified polyamide matrices. The glass fiber content in the composites was 30 wt. %.

The following grades of polyamides were taken for the study: PA 6-LT-SVU2 (TU 6-05-211-1411-85), PA 66-2 (TU 6-05-211-1390-84), and PA 66-1-L-SV30 (TU 6-05-211-1424-86).

Blanks for specimens were prepared by casting under pressure in a DB-3328 casting machine with worm feeder plastification observing the specifications of GOST 12019-66.

The effect of deformation rate on the mechanical properties of the polyamides was studied with tests in tension, compression, and shear under room temperature conditions and a strain rate $\dot{\gamma}$ up to $10^3$ sec$^{-1}$ using the procedure and devices developed in the Institute of Strength Problems, Ukrainian Academy of Sciences [1-3].

Static tensile tests were performed in an Instron machine with a loading rate of 2 mm/min, and dynamic tests were carried out in a vertical impact machine with a falling load ($V = 12$ m/sec) and in a lever ($V = 0.88$ m/sec) loading device combined with it.

In the case of static and dynamic tests identical specimens were used with threaded heads M8 x 1 having a diameter and gage length of 4 and 6 mm respectively which made it possible to obtain comparable and reliable data in the test deformation rate range.

Not less than five specimens were tested under identical conditions. The calculated
error for strength characteristics did not exceed 5%, and for ductility it did not exceed 3%. The results were processed in accordance with GOST 11262-80 'Plastics. Tensile test methods'. Tests data in tension in relation to strain rate $\dot{\varepsilon} = V/\ell$, where $\ell$ is specimen gage length, $V$ is deformation rate, are presented in Fig. 1.

The dependence of nominal yield point $\sigma_{\text{nyp}}$ determined with a value of relative elongation $\delta = 1\%$ on semilogarithmic coordinates $\sigma_{\text{nyp}} = \log \dot{\varepsilon}/\dot{\varepsilon}_0$ ($\dot{\varepsilon}_0 = 4.4 \cdot 10^{-3}$ sec$^{-1}$ is strain rate with static tests) is almost linear in nature for all of the test materials. Apart from an increase in yield point, an increase in yield strength is also observed.

With an increase in strain rate all of the test polyamides are embrittled. Due to the marked scatter of values of relative elongation with brittle failure it was impossible to establish the dependence of ductility characteristics of polyamides on strain rate.

Static and dynamic tests in compression were carried out by a procedure (Fig. 2) in which a cylindrical specimen 1 with diameter 7.5 mm and height 15 mm was placed in a cylindrical bush 7 between the ends of a loading bar 2 and a mounted indentor 3. The latter rests against a force measuring element 4 which is a disk of aluminum alloy D16T slightly sensitive to strain rate which is set up on a base 5.

In the case of dynamic tests with a rate of 5 m/sec a specimen is loaded by impact of striker 6 over the spherical end of rod 2. The loading rod and indentor move in the direction of hole 8 of bush 7. As a result of specimen deformation the indentor is introduced into the force measuring element previously calibrated statically for the diameter of impression in relation to applied force. If it is required to limit specimen deformation, then disks 9 of different thickness are used. In static tests with rate of about $10^{-5}$ m/sec specimen loading is accomplished in a hydraulic press.

With both static and dynamic test in compression glass-filled polyamides PA 6-LT-SVU2 and PA 66-1-L-SV30 failed in a brittle fashion after single-stage loading with formation of a typical shear strain cone or cleavage at an angle close to 45°.

Modified polyamide PA 66-2 whose nominal deformation diagrams (stress-strain) are shown in Fig. 3 deform elastoplasticity (specimens were converted into a disk) both statically and dynamically.

Results of mechanical tests in compression (Table 1) point to an increase in the strength of polyamides with an increase in deformation rate, and the sensitivity of glass-filled composite based on polyamide PA 6 to strain rate is higher than for a composite based on polyamide PA 66.

Dynamic tests in shear with a deformation rate of 30-140 m/sec were carried out in a pneumatic impact machine by the procedure of continuous force recording in an elastically