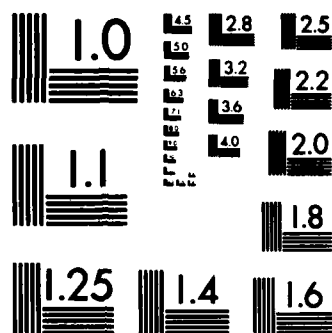MICROCOPY RESOLUTION TEST CHART
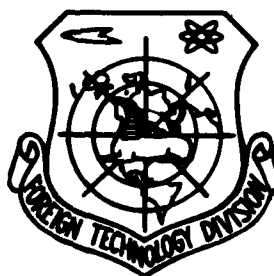
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FOREIGN TECHNOLOGY DIVISION

CREEP OF THERMOPLASTICS IN AIR AND IN PHYSIOLOGICAL SOLUTION

by

G.I. Roitberg, V.N. Kestel'man, R.Z. Rakhimov

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FTD-ID(RS)T-1272-85   14 Feb 86

MICROFICHE NR: FTD-86-C-001513

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English pages: 6

Source: Fiziko-Khimicheskaya Mekhanika Materialov, Nr. 5, 1972, pp. 81-84

Country of origin: USSR
Translated by: MSgt George Raikas
Requester: FTD/TQTD
Approved for public release; distribution unlimited.

Date 14 Feb 19 86

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Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yë or ë.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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CREEP OF THERMOPLASTICS IN AIR AND IN PHYSIOLOGICAL SOLUTION

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Creep of polymeric materials has been studied mainly under conditions of static monoaxial tension [1-4]. We have now established the existence of elastic, resilient-elastic (nonsteady-state) and viscous (steady-state) components of total creep. In this case, the full deformation under constant tensile load and at constant temperature, as well as the duration of load, are interrelated [2]:

$$\varepsilon_\eta = \varepsilon_y + \varepsilon_{y,}(\sigma) + v_t(\sigma)t, \qquad (1)$$

where ε_η - total creep; ε_y - elastic component; $\varepsilon_{y,}$ - resilient-elastic (relaxation) deformation; $v \cdot t$ - viscous deformation (v_t -rate of viscous deformation, t - time. Liquid mediums under these conditions do not alter the creep curves. We were interested to look into the possibility of using Equation (1) to describe the creep in structural thermoplastics under other types of stress in air and in liquid mediums.

We studied the creep of polymers under normal conditions in air and in a liquid medium - a physiological solution (0.9% NaCl solution in distilled water) under static bending and pressure. The subjects of the study were polyamide - 12 (P-12), a copolymer of trioxane with dioxalene (STD), fluorinated polymethyl methacrylate (PMMAF), and
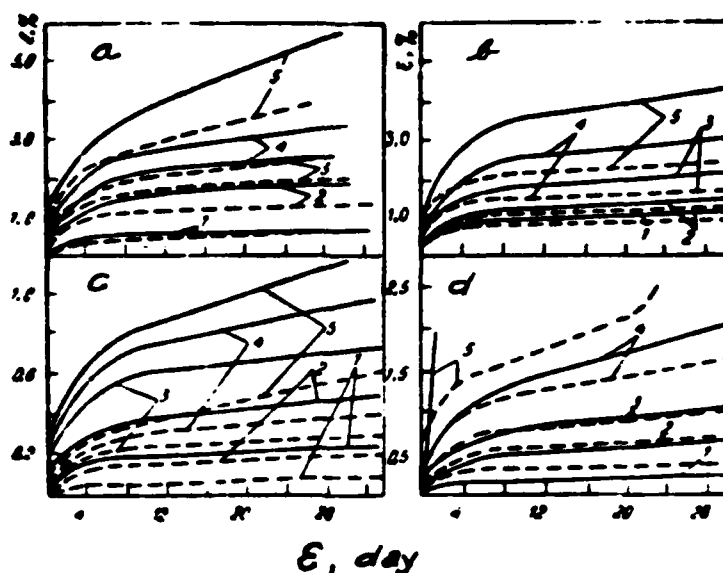
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Figure 1. Creep in P-12 (a), STD (b),
PETF (c), PMMAF (d) in air (broken lines)
and in physiological solution (solid lines)
under compression at different σ/σ_{kp}:

1 - 0.05; 2 - 0.1; 3 - 0.2; 4 - 0.03; 5 - 0.4

molding polyethylene terephtalate (PETF). Standard bars 10x15x120 mm
for bending and 10x10x15 mm for compression) were fabricated by
injection molding (P-12, STD, PETF) and machining from a block
(PMMAF). The experiments were conducted on special spring devices
under stresses σ constituting varying components of the short-duration
breaking load σ_{kp} for each material. The short-duration bending
strength of thermoplastics was determined at the rates of 50 mm/min
for compression and 15 mm/min for tension (Table 1). The creep was
determined with an accuracy of 0.01 mm on the basis of the results of
at least five experiments.

As is seen in Fig. 1, all obtained curves of creep consist of
two basic segments: nonsteady-state and steady-state creep (instan-
taneous elastic deformation is not shown). In form, these curves
coincide with known curves of creep under conditions of static tension
for the majority of hard polymer materials. Under static bending, the
picture was similar. In the physiological solution, intensity of
creep differs from that observed in tests conducted in air, although

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the nature of the curves remains unchanged.

Table 1. Short-term strength of thermoplastics (kg/cm^2).

(1) Материал	(2) При растяжении	(3) При сжатии	(4) При изгибе
П-12	112	586	740
СТД	650	980	1000
ПМША-Ф	800	1333	1350
ПЭТФ	180	1040	852

Key: 1 - material; 2 - tensile strength; 3 - compressive strength;
4 - bending strength.

It is generally assumed that in the region of steady-state
deformation, when the rate of the process is constant, we observe
viscous, and in the nonsteady-state region resilient elastic defor-
mation. To isolate resilient elastic deformation, some researchers
[5] have continued the linear curve segment within coordinates ε_π-t
until it intersects the ordinate ε_π, thereby disregarding the time
required to reach the limit of nonsteady-state creep. Under the
conditions we are assuming here, however, nonsteady-state creep time
is extremely important with respect to the total time the load is
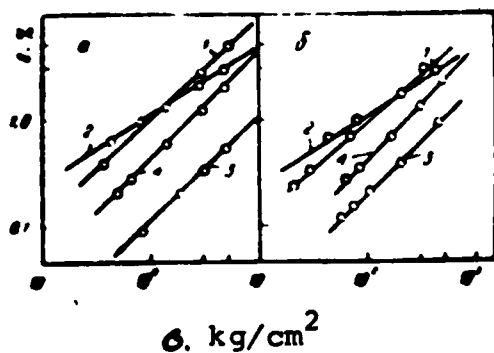applied and can therefore not be disregarded.

σ. kg/cm^2

Figure 2. Nonsteady-state creep
strength of P-12 (1),
STD (2), PETF (3),
PMMAF (4) as a function
of compressive stress
σ in air (a) and in
physiological solution
(b).

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Figure 2 shows resilient elastic deformation as a function of compressive stress σ in air and a model medium within a system of logarithmic coordinates. The rectilinearity of the curves confirms the earlier suggested exponential relationship between deformation and stress [5]:

$$\tag{2}$$

where A - parameter depending on the medium; k - coefficient determined by the type of load (Table 2). Lines of nonsteady-state creep in the physiological solution are located somewhat higher than the analogous lines obtained in tests in air.

Table 2.   Parameter values in creep equation for P-12.

(1)	(2)	(3)		(6)					
		(4)	(5)	(4)	(5)	(4)	(5)	(4)	(5)
II бенд (7)	39	2	3					0,0180	0,0154
	7я	3	5					0,0230	0,0416
	156	5	7	3,2·10	4,07·10	1,0	1,0	0,0454	0,0578
	2 4	4	11					0,0833	0,0920
	412	8	9					0,1010	0,1820
	340	10	9					0,1430	0,2040
Сжатие (8)	218	4	7					0,00067	0,00067
	516	10	12	2,46·10	3,62·10	0,85	0,85	0,00087	0,001270
	119	11	11					0,00120	0,001680
	17я	10	10					0,00240	0,00330
	363	8	10					0,00017	0,01000

* v_t for bending measured in mm/day, for compression [illegible]/day.

Key: (1) Type of deformation;   (2) stress kg/cm^2;   (3) time to limit of nonsteady-state deformation in days;   (4) Air;   (5) physiological solution;   (6) constants;   (7) bend;   (8) compression.
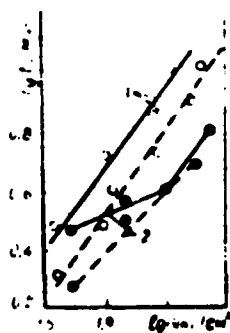
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Figure 3. Dependence of rate of steady-state creep on static bending stress σ for P-12 (1) and STD (2) in air (broken lines) and in model medium (solid lines).
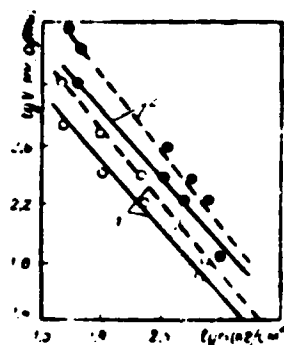
Figure 4. Dependence of time to limit of nonsteady-state deformation on static bending stress σ for P-12 (1), and STD (2) in air (broken lines) and in a model medium (solid lines).

Taking into account relationship (2) and the time required to reach the limit of nonsteady-state creep, Equation (1) can be written in the following form:

$$\varepsilon_{\eta} = \varepsilon_{y_9} + A\sigma^k + \tau_{1(\sigma)}(t - t_{1(\sigma)}), \tag{3}$$

where $t_{1(\sigma)}$ is the time within which the limit of nonsteady-state deformation is reached. Creep values obtained using Eq. (3) deviated from those arrived at experimentally by no more than 6% for P-12, 8% for STD, 6% for PMMAF, 9% for PETF.

In Formula (3) the rate of steady-state creep v_t and the time required to reach the limit of nonsteady-state deformation t_1 are also functions of stress. Under the conditions of our tests, time t_1, on account of the comparatively short total test time, cannot be disregarded. Considering this, we attempted to describe steady-state creep as a function of stress mathematically. It turned out that for thermoplasts P-12 and STD subjected to static bending, functions $v(\sigma)$ and $t_1(\sigma)$ in air and in the model medium are linear in logarithmic coordinates (Figs. 3 and 4), and consequently, are described by the exponential function:

$$v = B\sigma^m \tag{4}$$

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and

$$t_1 = C\sigma^n \tag{5}$$

where B, C, m and n are constants. For STD under bending stress in the model medium, the linearity is preserved up to $\sigma = 200$ kg/cm^2.

Thus, for thermoplasts with a high degree of crystallinity (P-12 and STD), the creep during static bending with low stress in air and in physiological solution can be described by the following equation:

$$\varepsilon_{\hat{u}} = \frac{\sigma}{E} + A\sigma^k + B\sigma^m (t - C\sigma^n). \tag{6}$$

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Received July 15, 1971

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