Mechanical Properties of Multifilaments in Different Measurement Conditions

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SYNOPSIS

Starting from Zhurkov's and Bartenev's theories and connecting them with Bailly's theorem and the structural analysis based on the rheological model, a method of determination of parameters describing the durability of multifilament is presented. Experiments carried out on polyester and polyamide filament yarns confirmed proposed method.

INTRODUCTION

Mechanical properties of multifilaments are affecting their behavior during manufacturing them into half-products (for example, into plied yarns) and into fabrics. The properties of final products are also influenced by mechanical properties of multifilaments.

In order to check a quality of multifilaments, an immediate strength is measured on tensile testers. As a characteristic, a mean value of maximal forces registered during the stretching of the assumed number of samples and a mean value of strain at that maximal force are always given.

It is a simplification, because, during the utilization of textile products (also multifilaments), the stresses imposed on them are lower than critical. These stresses have changeable values and a period of time for their application. The use of traditional methods of an immediate strength measurement is based on an assumption that greater strength assures a better fiber durability during its utilization, or that the fulfilling of a given minimal value of strength assures the manufacturing of multifilaments into fabrics without difficulty.

More accurate results can be achieved by using fatigue investigations of multifilaments (periodical stretching). The weak point of such kinds of measurements is their laboriousness, so that they are justified only in research (when the new types of multifilament or their treatment is checked) but they have a limited application during routine measurements.

ASSUMPTIONS

As mentioned, the traditional parameters used for quality assessment of fibers, yarns, and fabrics are a maximal force carried out by an examined sample and a strain of sample in the same moment. They are generally the critical values at which the sample is broken on traditional tensile testers, having pendulum type dynamometers.

Goodbrand produced tensile testers for stroke measurements, but then (19th and 20th century) they were not spread out. Now, there is a need to build the analogical machines, but requirements concerning the speed of stretching are greater than they were before (for example, to measure the strength of seat belts). In that case a rupture work is a characteristic value because the finding of relationships between stress and strain is very difficult as well as the determination of the critical values of both characteristics.

Finally, moving to the requirements of users, an immediate strength (tenacity) and strain are measured using determined parameters of measurement (sample dimensions, time of stretching up to break or stretching speed, a way of sample straightening—an initial load).

Development of the theory of polymer (fiber) material durability and critical analysis of the results of multifilament strength measurement suggest the

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possibility of expanding a research approach and using fully the results obtained, especially during the carrying out of untypical research (examining of the new types of multifilaments and their modification, or of the changes which have taken place during the use of different measurement conditions and so on).

The starting point here is Żhurkov's equation[1] combining a sample lifetime (time of stress acting up to break) with a stress. Starting from the Arrhenius' equation, Żhurkov obtained the following equation:

$$\tau = \tau_0 \exp[(U_0 - \gamma Q)/RT] \tag{1}$$

where τ = a sample lifetime, τ_0 = a period of oscillation of molecule chains (10^{-13}–10^{-12} s) taking part in breaking or rebuilding the crosslinking, U_0 = an activation energy of the process of the mechanical destruction of fiber material, γ = a structural coefficient, Q = a sample stress, R = Boltzmann's constant, and T absolute temperature (K).

Bartenev[2] made this equation more precise by introducing into it a minimal stress Q_0, below which a sample has an infinitely long lifetime and a second value of Q_{cr} at which a sample is broken with a speed of the spreading of crack in the material. The general relationship between the durability and stress is illustrated in Figure 1. Żhurkov's equation concerns samples which are loaded statically by stress Q.

Bailly[3] analyzing the durability of glass multifilament found that for each load (stress) there is a characteristic value (which agrees with Żhurkov's theory), and it does not matter if the sample is loaded monotonously or if some breaks exist during the loading. Based on this, he assumed that a sum of ratios of time of the stress acting $\Delta t(Q)$ and a sample lifetime under such a load $\tau(Q)$ is equal to 1:

$$\sum_{j=1}^{n} \frac{\Delta t(Q_j)}{\tau(Q_j)} = 1 \tag{2}$$

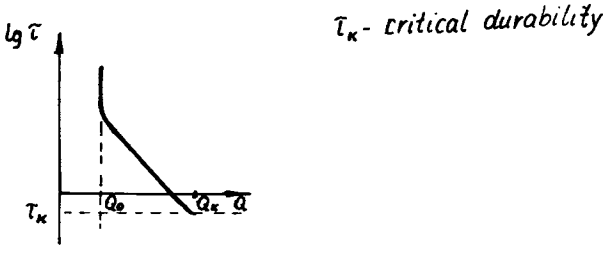

Figure 1 A general relationship between a durability and stress.

If time of the stress Q acting decreases in such a way that it can be replaced by the differential, then the following expression is obtained as a limit:

$$\lim_{\Delta t(Q_j)\to 0} \sum_{j=1}^{n} \frac{\Delta t(Q_j)}{\tau(Q_j)} = \int_0^{t_r} \frac{dt}{\tau[Q(t)]} = 1 \tag{3}$$

where $\tau[Q(t)]$ = a sample lifetime under stress Q and $Q(t)$ = a value of sample stress in moment t (measured from the beginning of loading).

When samples are stretched on tensile testers having a constant rate of strain, then an elongation of the sample is

$$\lambda = ct \tag{4}$$

and the strain of the sample is

$$\epsilon = \lambda/l_0 = c_1 t \tag{5}$$

where c, c_1 = successively absolute and relative stretching speed and l_0 = an initial sample length. From eq. (5) we have

$$t = \epsilon/c_1 \tag{6}$$

which after inserting this into eq. (3) gives

$$\frac{1}{c_1}\int_0^{\epsilon_r} \frac{d\epsilon}{\tau[Q(\epsilon/c_1)]} = 1 \tag{7}$$

Replacing τ by the value calculated in eq. (1), we have

$$\frac{1}{c_1}\int_0^{\epsilon_r} \frac{d\epsilon}{\tau_0 \exp[(U_0 - \gamma Q)/RT]} = 1 \tag{8}$$

In the case of carrying out research in constant temperature (T = const), values of τ_0, U_0, and γ ought to be constant as well as the value of R. Therefore, eq. (8) can be written in the following way:

$$[1/(Ac_1)]\int_0^{\epsilon_r} \exp(bQ)\, d\epsilon = 1 \tag{9}$$

where $A = \tau_0 \exp(U_0/RT)$ and $b = \gamma/RT$.

To be able to use this equation, a stress–strain relationship $Q = f(\epsilon)$ is needed.

Żhurkov's equation combines a sample lifetime with a stress Q based on a difference between the activation energy U_0 and a product of γQ_1.

To use eq. (9) for prediction of an elongation at

the moment of break at assumed stretching conditions, it is necessary to know a relationship between the stress and strain of a sample. It can be found based on rheological models,[4] which lead to equations of the following form,

$$Q = M\epsilon + Nc_1[1 - \exp(-K\epsilon/c_1)] \quad (10)$$

where M, N, and K are coefficients, values of which depend on parameters of the rheological model, and c_1 = rate of strain, or based on empirically determined mean shapes of these relationships.

Based on the rheological model, curves shown in Figure 2 are obtained. The shape of these relationships is similar for the effective samples (of fibers or yarns). In both cases, when the unit (specific) speed of stretching increases, the stresses take higher values for the same values of strain.

If the right side of eq. (10) is inserted into eq. (9), then an integration cannot be done. To illustrate the direction of quantitative changes, it can be assumed that, in a range of elongation, where the creep of sample is predominant, the stress–strain relationship has a linear shape [according to the equation which is close to the asymptote equation in eq. (10)] according to the approximation proposed by Platt[5]:

$$Q = G + H\epsilon \quad (11)$$

where values of G and H are determined experimentally for given multifilament; the value of G according to eq. (10) is a function of speed of stretching and the value of H should be approximately constant.

If we insert eq. (11) into eq. (9), then we obtain

$$\int_0^{\epsilon_r} \exp[b(G + H\epsilon)]\, d\epsilon = (1/bH)[\exp(bQ_r) - \exp(bG)] \simeq Ac_1 \quad (12)$$

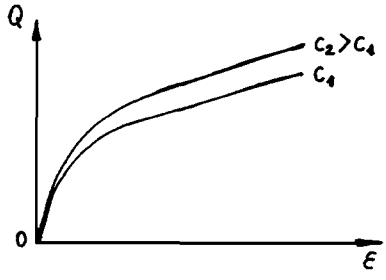

Figure 2 Curves representing fiber stress vs. strain based on the rheological model.

Substituting the values of G, H, and ϵ_r obtained from the experiment, the values of b and next A can be found.

AN INTERPRETATION OF RESULTS OF MEASUREMENT IN A LIGHT OF MODEL SOLUTIONS

In the previous section, the theoretical relationships between polymer lifetime and its internal properties characterized by an activation energy U_0 and a structural coefficient γ as well as lifetime dependence on sample stress were presented. Next, a possibility of the connection material lifetime with immediate measurements by using the rheological models was indicated, and then a way of simplifying them for the purpose of calculation was shown.

Material strength—its lifetime—is a basis of prediction: first, a strength of filament, next, of multifilament, and, finally, of fabrics made of this multifilament.

If Bartenev's theory is taken into account, then the boundary value of stress which does not lead into the sample (filament) destruction, even in an infinitely long period of time, is an elasticity limit of sample. Beyond this limit, changes in shape of the stress–strain relationship are observed. These changes lead to sample destruction in different periods of time. The bigger stress is acting, the shorter period of time up to break is observed. The breaking stress of a sample is influenced by its local weak places, which have a different genesis and form. They can be caused by strange bodies not connected with a filament material or only weakly connected with it—they have then a hole character; in other cases, they can be caused by damages of a surface in form of transversal or skew cracks.

Summing up the above considerations, we can conclude that there are two aspects of mechanical fiber properties:

(1) their lifetime as internal (intrinsic) feature of material,
(2) their strength as an accident.

If we knew all the parameters needed to determine the material lifetime, we would be able to predict the lifetime as well as the other sample parameters (strength or breaking strain) for the assumed shape of the sample made from this material and for given measurement conditions. The determination of parameters characterizing the lifetime of sample material is somewhat difficult, especially if we want to

use the data obtained from standard measurements of mechanical properties. It must be remembered that filaments have a skin and core having different structural and mechanical characteristics.

In eq. (1) on the material lifetime, there is only one constant—Boltzmann's constant. The temperature T was assumed constant during the experiment. Stress Q has a value assumed by the person leading the experiment. Therefore, there are only three parameters to determine: τ_0, U_0, and γ. In that experiment the value of lifetime τ is measured as a function of the other parameters.

In the case of such bodies like fibers, we can find the real value of stress, which is constant because of the constant value of force acting on a sample, just after a sample breakage, when the area of cross section at the place of breakage has been measured. Then we have generally different values of Q for each sample. Consequently, we still assume that U_0, γ, and τ_0 have a constant value in all samples made from a given material.

Let us come back to eq. (1). After logarithming it by sides, we have

$$\ln \tau = \ln \tau_0 + (U_0 - \gamma Q)/RT = \ln A - bQ \quad (13)$$

On the basis of the following equation we can see that, at different values of Q, only the entire value of $\ln A = (\ln \tau_0 + U_0/RT)$ and the value of $b = \gamma/RT$ can be found as mentioned previously. If we wanted to check the adequacy of Żurkov and Bartenev's theory as well as Bailly's theorem, we would have to look for a solution leading to achieve a real value of the stress in moment of a sample breakage.

As is commonly known, during the breaking of individual filaments the populations of results of breaking force F_r and breaking strain ϵ_r are obtained. As previously found,[6] the stress–strain relationship of samples made from the nonuniform material having a different value of area of cross section (a specimen has changeable thickness along its length) is given by the following equation:

$$\epsilon = \int_{A_1}^{A_2} f(F/A)\phi(A)\, dA \quad (14)$$

It was also proved that a thickness distribution $\phi(A)$ has an insignificant influence on the strain–stress relationship $\epsilon = f(F/A)$. Very significant for the critical (breaking) value of strain is the ratio of A_2/A_1 (A_2 = the area of cross section in the thickest sample place; A_1 = the area of cross section in the thinnest sample place). As a result, if the relationship $\epsilon = f(F/A)$ for the uneven sample has been determined and in a special experiment a value of the breaking force of very short elements near the place of breakage has been found, then an approximate form of relationship $\epsilon = f(F/A)$ for the sample material can be obtained and a critical value of breaking strain can be determined.

There is a basis for judging that the strength of very short elements (for example, 1 mm between jaws) corresponds to the strength of the undamaged fiber elements (having the area of cross section equal to A_2 in a long sample) and that the sample breakage has taken place in the thinnest place (A_1). Therefore, the breaking force of the long sample is

$$F_{r1} = QA_1 \quad (15)$$

and the breaking force of the short sample is

$$F_{r2} = QA_2 \quad (16)$$

Dividing these equations, we have

$$A_2/A_1 = \mathrm{F}_{r2}/F_{r1} \quad (17)$$

Knowing that value and assuming a type of thickness distribution inside sample elements being broken, an approximate shape of the stress–strain relationship of even samples as well as their potential elongation in moment of breakage can be determined.

It is very time-consuming work and it can be done in special cases with some eventual modifications concerning determination of a real value of the breaking force or stress of filaments.[7] For technical purposes it seems to justify using a simplified method.

We assume that, in all measurement variants, all kinds of fibers belong to the same population (when we examine the same multifilament in different conditions). The multifilament consists of the same number of filaments having analogical structural–morphological imperfections. When the multifilament has been stretched, the individual filaments are broken successively and, as a result, the graph of a staircase stress–strain curve as an illustration of the relationship between a tensile force of multifilament and its strain is obtained (Fig. 3).

According to that what was said before, for the purpose of characterizing the immediate strength parameters, a maximal force W_r and a corresponding strain ϵ_r are given. As results from probabilistical–

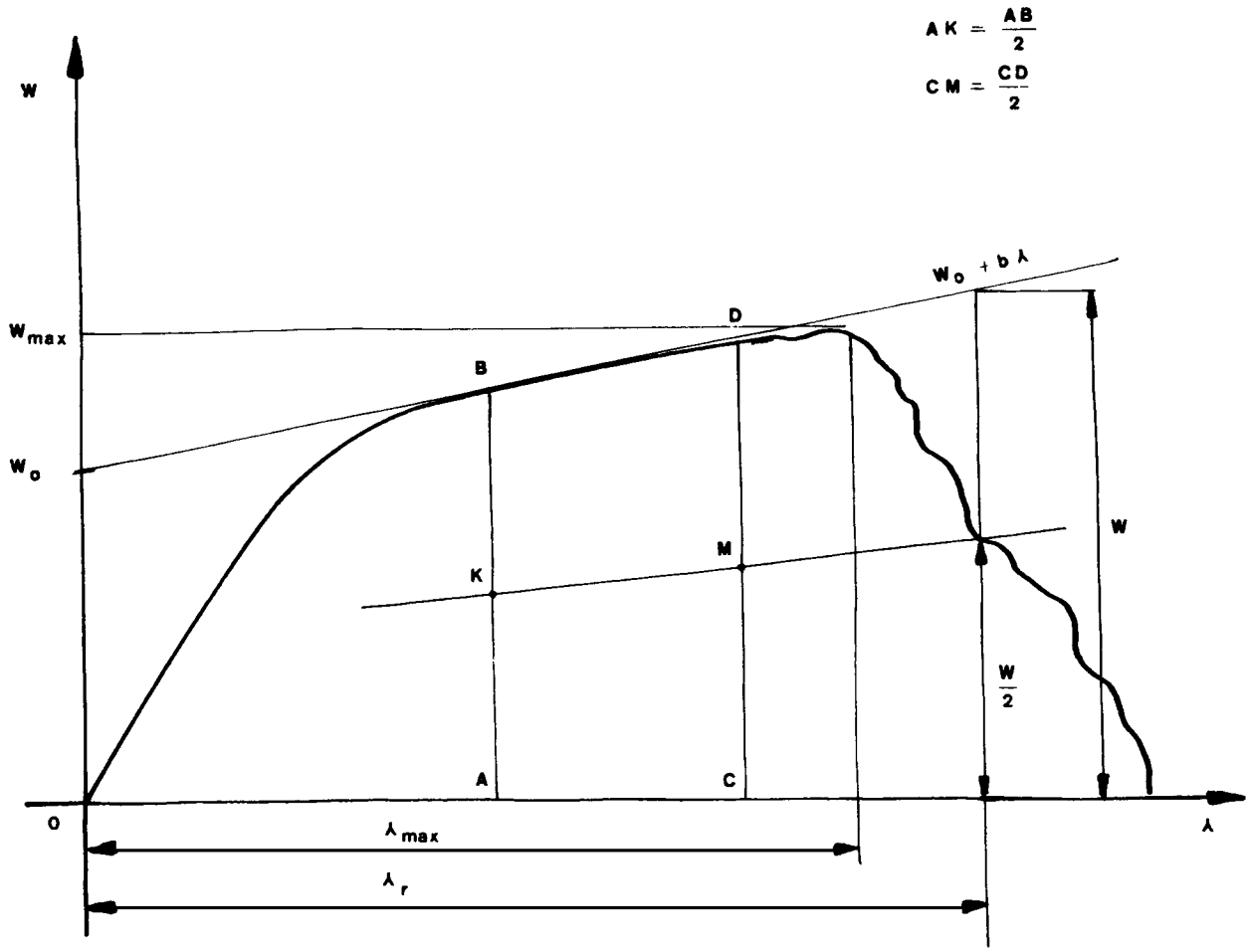

Figure 3 The relationship between a tensile force of multifilament and its strain.

mechanical considerations, these parameters are characteristic for the moment of break of the first, second, or third filament.[6] If the number of filaments is more than 20, a thread carries the lower load during further stretching.

If the graph of the force–elongation curve is done up to the break of the last filament, then an approximate value of the mean breaking force of the individual filament and the analogical value of the strain can be determined based on this graph. For that purpose we draw a tangent BD at the end of curve (near ϵ_r, but before the place of breakage of the first filament). Through points B and D we draw ordinates (down) to cross the abscissa axis at points A and C. Then we divide these ordinates in half, obtaining points K and M. Through these points we draw a straight line crossing an experimental curve. In such a way we obtain a point $(\epsilon_1, W'/2)$, which gives us a value of half of the force loading a bundle (W') made from (potentially) unbroken fibers. It is an approximate mean value of the breaking force of filaments in the stretched multifilament.

Moreover, coordinates of force and elongation in points B and D are used to find equations of the linear regression between a force (or stress) and a strain:

$$Q = G + H\epsilon \tag{18}$$

which are needed for calculations according to eq. (12).

According to that equation, we have

$$A_1 \simeq [\exp(bQ_r) - \exp(bQ_0)]/bH \tag{19}$$

where Q_r = a mean value of stress calculated based on the ordinate of the point where the straight line crosses an experimental curve (W'), Q_0 can be substituted by the value of an appropriate stress (tenacity) found on the ordinate axis (force W' divided

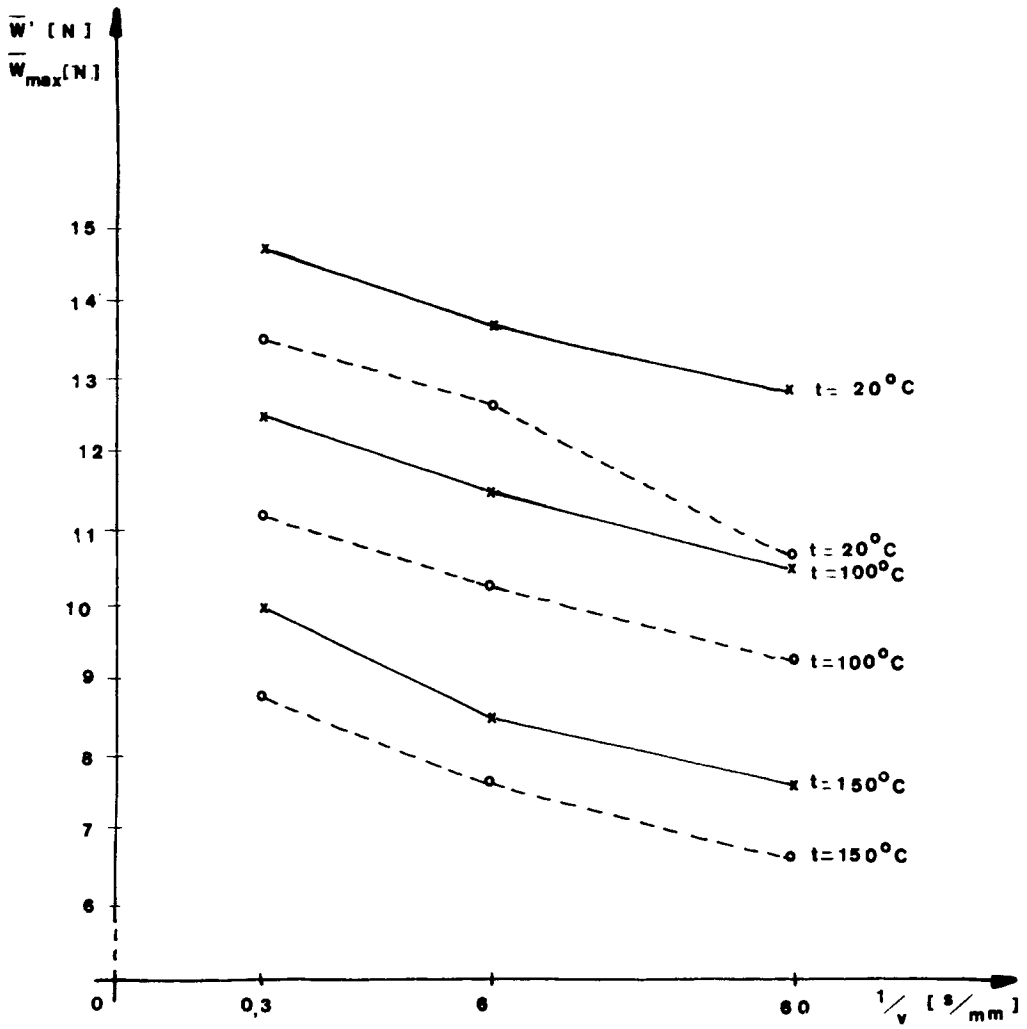

Figure 4 The mean values of breaking forces W_{max} and W' as a function of a reciprocal of speed of stretching in different temperatures in the case of polyamide multifilament.

by thickness of multifilament): $W'/Tt = Q_0 = G$, $H = (Q_r - Q_0)/\epsilon_r$, and ϵ_r = a breaking strain.

In eq. (19) we have two unknown values: $A_1 = Ac_1$ and b. As stated previously, coefficients A and b are almost independent of the stretching speed. Therefore, inserting values of Q_0, Q_r, and H in the successive experiment variants, we obtain

$$A = \tau_0 \exp(U_0/a)$$
$$\simeq [\exp(bQ_{ri}) - \exp(bQ_{0i})]/c_{1i}bH_i\dagger \quad (20)$$

where index i = 1, 2, 3 corresponds successively to the values obtained at speeds 1, 10, and 200 mm/min.

EXPERIMENTAL

Material and Measurement Method

Measurements tending to the verification of relationships presented previously are carried out for two multifilaments: polyamide of linear density 24 mg/m (tex)/24 filaments, and polyester of linear density 18 mg/m (tex)/32 filaments. Both multifilaments are without twist.

An analysis of the stress–strain relationship was received on an Instron tensile tester at three rates of strain: 1, 10, and 200 mm/min.

† It is assumed that there is no correlation between the fiber thickness and its elongation at the moment of break.

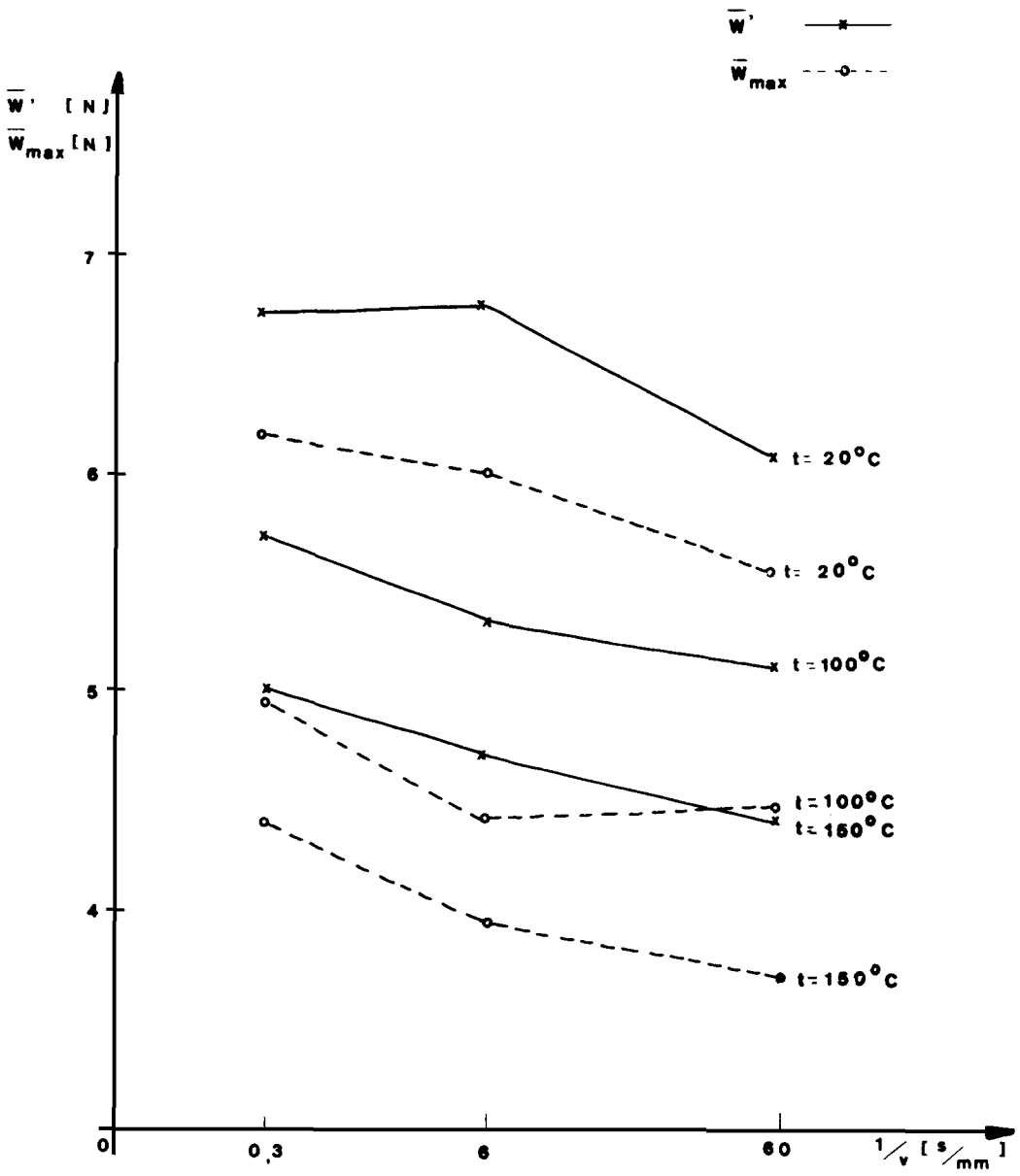

Figure 5 The mean values of breaking forces W_{max} and W' as a function of a reciprocal of speed of stretching in different temperatures in the case of polyester multifilament.

Examined samples were prepared in a special way. Random chosen segments of multifilaments were glued in paper patterns. The samples were stretched up to break of the last filament, registering the value of tensile force all the time. A maximal value of force, W_{max}, and corresponding to it the value of strain as well as values of W' and λ_F were read from the graphs after making the earlier construction described. The area limited by the stress–strain curve from point (0, 0), through points (W_{max}, λ_{max}), ($W'/2$, λ_r) to the last point ($W = 0$, λ = the elongation of the last broken filament) was measured using a planimeter.

The samples were broken into three temperatures: 20, 100, and 150°C in the thermic chamber.

The mean values of breaking forces W_{max} and W' are shown in Figures 4 and 5, whereas the mean values of strains λ_{max} and λ_r are shown in Figures 6 and 7. The graphs of rupture work are shown in Figures 8 and 9. On the abscissa axis the reciprocal of the ratio of strain in a logarithmic scale is used.

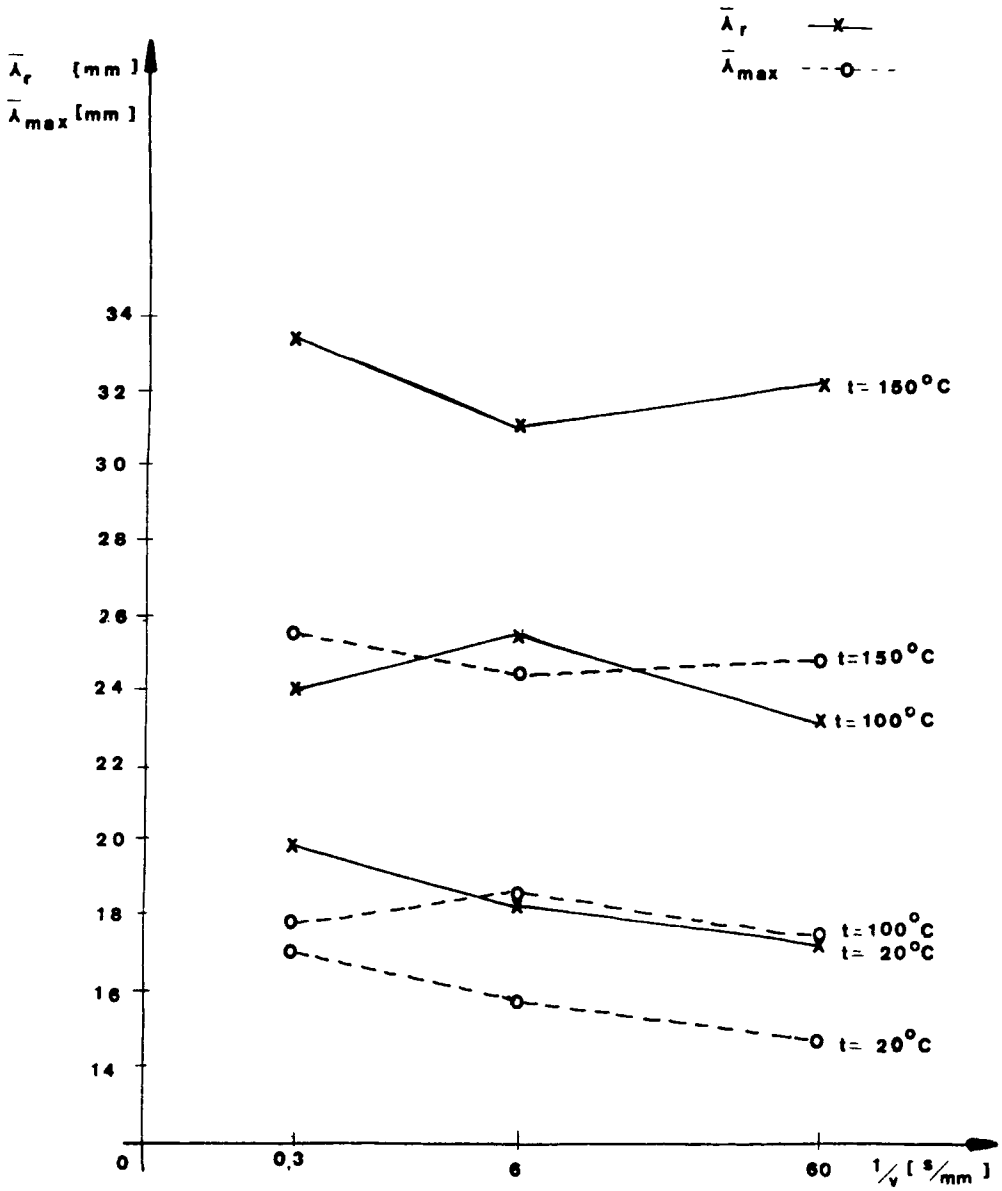

Figure 6 The mean values of elongations λ_{max} and λ_r as a function of a reciprocal of speed of stretching in different temperatures in the case of polyamide multifilament.

For each examined variant 10 measurements were done.

Interpretation of the Results

The graphs illustrate significantly the almost linear decrease of breaking forces W_{max} and W' with the decrease of ratio of strain (and so with the increase of time of stretching). The temperature increase causes a decrease in lifetime, but a linear character of the relationship between time of stretching and a breaking force is left approximately constant.

The elongations at moment of break of polyamide multifilaments decreased with the increase of time of stretching (the decrease of ratio of strain). They are growing significantly with the increase of temperature.

In the case of polyester multifilament the influence of the ratio of strain on value of elongation is not seen, but the influence of temperature is synonymously seen—with its increase, the breaking strain also increases.

The rupture work up to the break of polyamide multifilament decreases with the decrease of the ra-

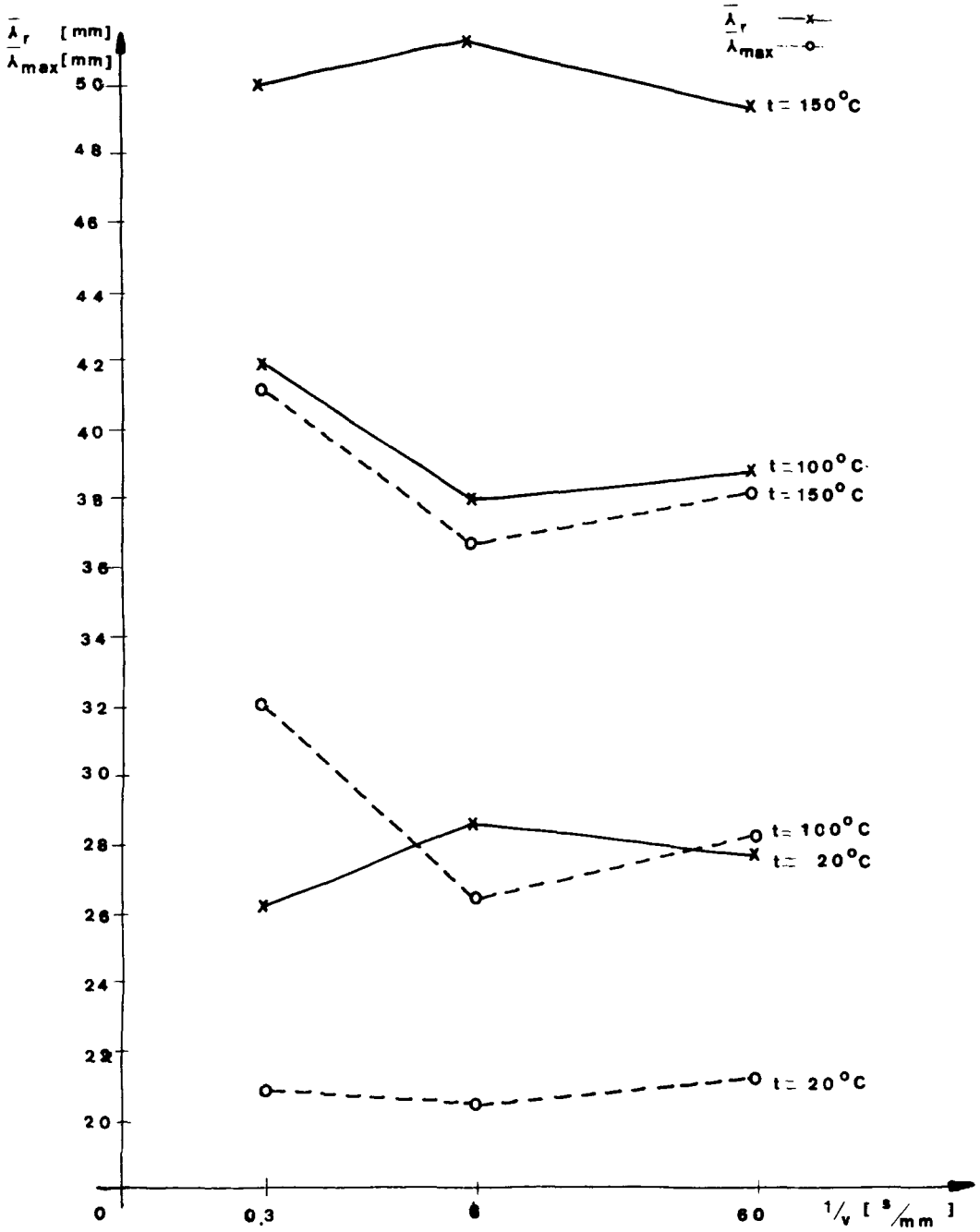

Figure 7 The mean values of elongations λ_{max} and λ_r as a function of a reciprocal of speed of stretching in different temperatures in the case of polyester multifilament.

tio of strain and the smallest values are obtained at temperature 20°C, a little bigger at temperature 100°C, and the biggest ones at temperature 150°C.

A similar arrangement of results is obtained for polyester multifilament with a restriction that the value obtained at temperature 20°C at speed 10 mm/min is a little bigger than at speed 200 mm/min.

Starting from eq. (12), trials for the determination of the values of A and b parameters were undertaken based on the determined values of G, H and ϵ_r (from stress–strain graphs). Remembering that

$$A = \tau_0 \exp(U_0/RT)$$

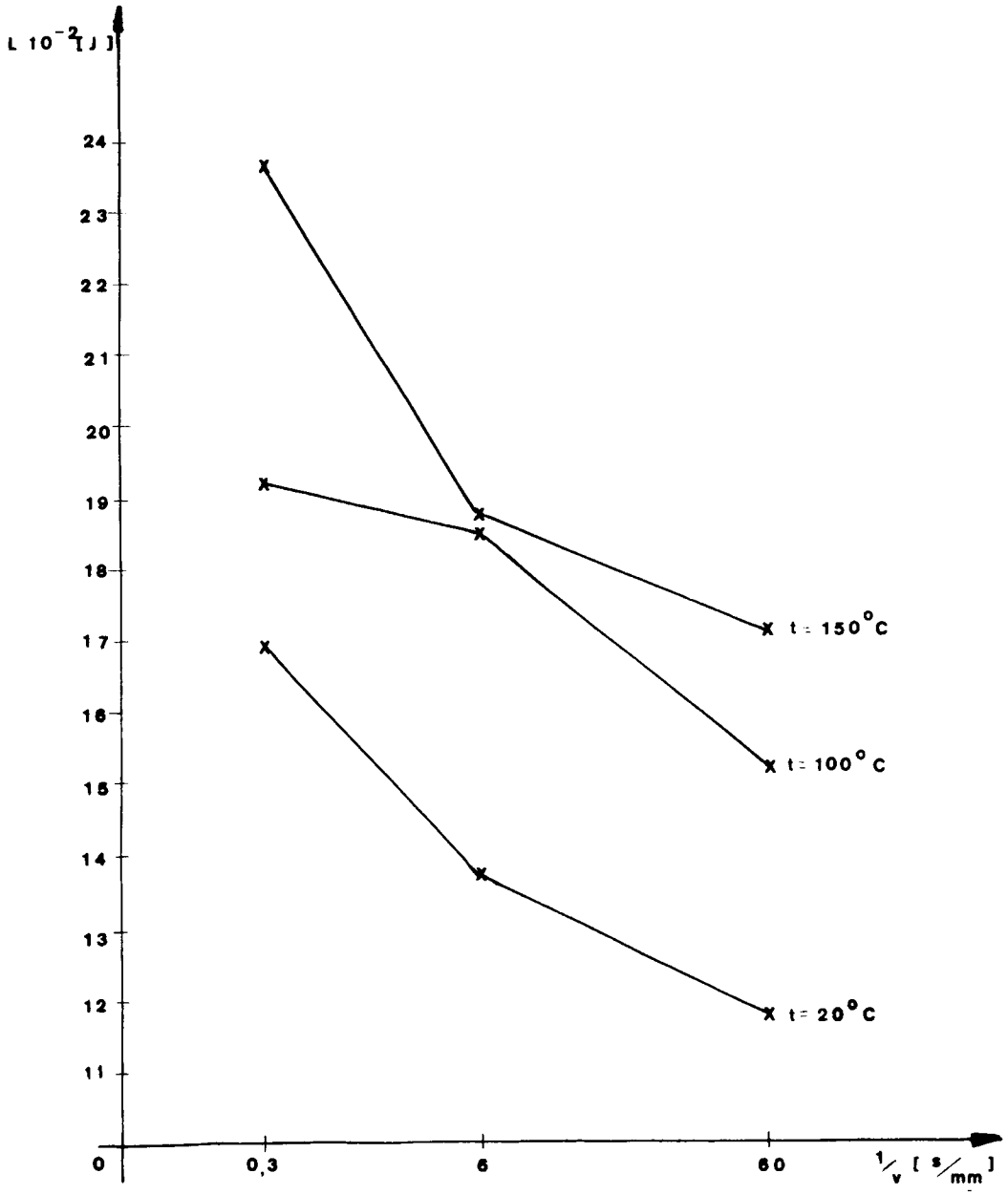

Figure 8 The mean values of rupture work as a function of a reciprocal of speed of stretching in different temperatures in the case of polyamide multifilament.

and

$$b = \gamma/RT$$

so that these two values are functions of the environment temperature during stretching, the values of the above-mentioned parameters G, H, and ϵ_r obtained in constant temperature at ratios of strain successively c_1 = 1 mm/min (1/60 mm/s) and c_2 = 200 mm/min (200/60 mm/s) were calculated. The values of these parameters are given in Table I.

Analyzing these data, one can state that values of the parameter $G = W_0/Tt$ (Tt = linear density of the multifilament) increase with the ratio of strain, which agrees qualitatively with results of analysis based on the rheological model.

The values of the parameter $H = (W_{max} - W_0)/Tt\epsilon$ do not show significant dependence on the ratio of strain (which also agrees with the rheological

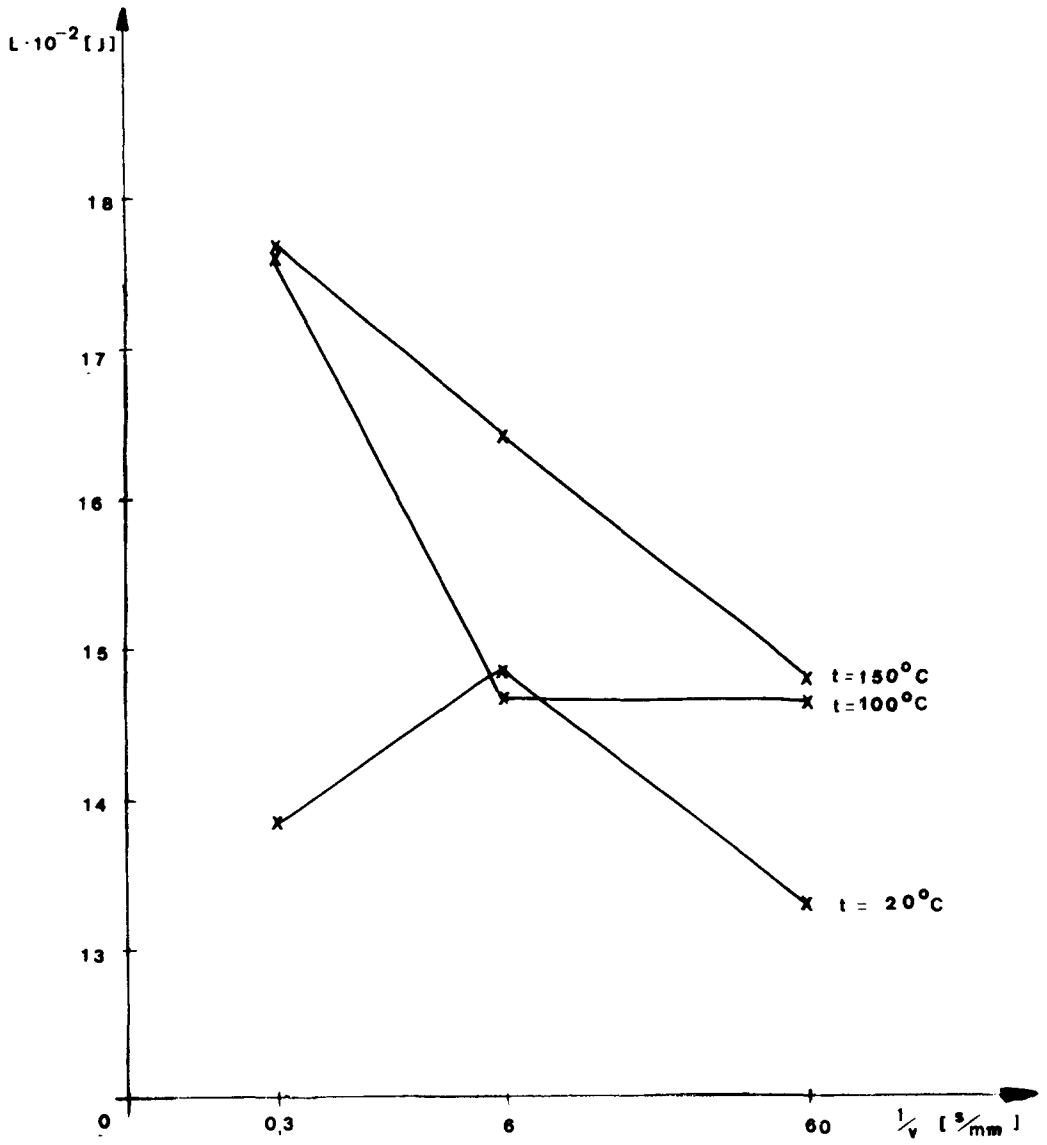

Figure 9 The mean values of rupture work as a function of a reciprocal of speed of stretching in different temperatures in the case of polyester multifilament.

model). At temperatures 20 and 100°C the values of H rather decrease with the increase of the ratio of strain, whereas at 150°C an insignificant increase of values of this parameter is observed for polyamide and polyester multifilaments.

Calculations of A and b values were done in the following way: We have two equations for two ratios of strain c_1 and c_2:

$$Ac_1 = (1/bH)[\exp(bQ_{r1}) - \exp(bG_1)]$$
$$= \{[\exp(bQ_{r1})]/bH_1\} \times \{1 - \exp[-b(Q_{r1} - G_1)]\} \quad (20a)$$

$$Ac_2 = (1/bH_2)[\exp(bQ_{r2}) - \exp(bG_2)]$$
$$= \{[\exp(bQ_{r2})]/bH_2\} \times \{1 - \exp[-b(Q_{r2} - G_2)]\} \quad (20b)$$

Analysis of experimental data shows that the expression $Q_r - G = H\epsilon_r$ has similar values for all speeds. Therefore, it can be assumed that, in the case of stretching of the samples at the same temperature,

$$1 - \exp[-b(Q_r - G)] \simeq \text{const} \quad (21)$$

Table I The Values of Tensile Forces F and $G(W_0)$, H Parameters in (cN/tex) in Different Measurement Conditions

L.p.	Multifilament	Ratio of Strain (mm/min)	Temperature (°C) 20 F	20 G	20 H	100 F	100 G	100 H	150 F	150 G	150 H
2.	Polyamide	1	53.2	24.5	1.67	43.3	25.1	0.829	31.3	19.6	0.380
		10	57.0	29.5	1.51	47.7	29.8	0.746	35.0	21.0	0.469
		200	61.2	34.5	1.39	51.9	33.8	0.796	41.4	25.0	0.488
3.	Polyester	1	19.0	21.1	0.412	15.9	14.9	0.372	13.8	10.9	0.281
		10	21.1	22.7	0.385	16.6	15.1	0.385	14.8	11.0	0.314
		200	21.0	24.6	0.500	17.8	16.9	0.215	15.6	12.4	0.318

so that, dividing previous equations, we have

$$c_1/c_2 = [H_2\exp(bQ_{r1})]/[H_1\exp(bQ_{r2})] \quad (22)$$

which after a simple transformation gives us

$$b = [1/(Q_{r1} - Q_{r2})]\ln[c_{11}H_1/c_{12}H_2] \quad (23)$$

After calculation of the value of b, the value of constant A can be found:

$$A = (1/c_1bH)[\exp(bQ_r) - \exp(bG)] \quad (24)$$

The values of coefficient b and constant A obtained based on the above equations and on experimental data are given in Table II.

Analyzing these data it can be noticed that a regular arrangement of parameters occurs in the case of the polyamide multifilament. The value of parameter $b = \gamma/RT$, under the assumption that γ has a constant value, decreases with the increase of temperature (but changes are greater than result from calculated values). The situation looks similar in the case of parameter A:

$$A = \tau_0\exp(U_0/RT)$$

Considering the polyester multifilament, similar re-

Table II The Values of b and A Parameters Calculated Based on Data Given in Table I

Multifilament	Temperature (°C)	Ratio of Strain, c (mm/s)	b	A (s)
Polyamide	20	1/60	0.639	3.26×10^{16}
		1/6		4.09×10^{16}
		10/3		3.25×10^{16}
	100	1/60	0.611	3.72×10^{13}
		1/6		5.98×10^{13}
		10/3		3.65×10^{13}
	150	1/60	0.549	8.33×10^{9}
		1/6		5.15×10^{9}
		10/3		8.32×10^{9}
Polyester	20	1/60	0.985	1.07×10^{16}
		1/6		12.81×10^{16}
		10/3		1.07×10^{16}
	100	1/60	1.763	2.45×10^{24}
		1/6		0.486×10^{24}
		10/3		2.49×10^{24}
	150	1/60	1.465	7.64×10^{17}
		1/6		288×10^{17}
		10/3		7.55×10^{17}

Table III The Values of $U/R + T \ln \tau_0$ and γ

Multifilament	Temperature (°C)	$U/R + T \ln \tau_0$	γ
Polyamide	20	11144	187
	100	11655	227
	150	9662	232
Polyester	20	10814	289
	100	20947	658
	150	17418	620

lationships are observed at temperatures 100 and 150°C.

Remembering that values of A and b are given by the above equations, the values of U_0/R and γ/R can be found from equations

$$U/R + T \ln \tau_0 = T \ln A \quad (25)$$

$$\gamma/R = bT \quad (26)$$

Calculated in such a way values are given in Table III.

For the polyamide multifilament we obtained results which do not differ too much from each other. For the polyester multifilament we can see some discrepancies between values obtained at temperatures 20, 100, and 150°C, which is connected with structural changes in the material at a temperature of about 100°C.

Comparing data shown above for polyamide multifilaments with Bartenev's data, one can state that values of the coefficient b are close to each other. Considering the value of parameter A, Bartenev starting from data pertaining to the fiber structure obtained $A = 2 \times 10^{21}$ s, wheras we obtained a value of A equal to 3.3×10^{16} s. This is due to the above-mentioned irregularity of multifilament thickness which causes the decrease in strength and durability. It is confirmed by different values of strength obtained by Bartenev (83 cN/tex) and us (57 cN/tex). This difference causes the decrease of lifetime (such a big one, because the stresses are exponential). It can be said that the method presented gives, in a relatively short period of time, data necessary to characterize durability parameters of multifilaments at different loads and different temperatures.

Knowing the values of A and b parameters, an approximate value of multifilament durability can be determined at known tenacity and temperature. In Table IV results obtained for examined multifilaments are shown. That kind of prediction enabled relatively fast designing of technical fabrics.

CONCLUSIONS

Starting from Zhurkov's and Bartenev's theories and connecting them with Bailly's theorem and the structural analysis based on the rheological model, a method of determination of parameters describing the durability of the multifilament loaded by different stresses at known temperatures is presented.

Based on the results obtained experimentally and on an analysis of these results the following conclusions can be drawn:

1. Having the stress–strain graphs for multifilaments done on tensile testers working at the

Table IV Predicted Value of Multifilament Lifetime (in s) at Constant Load

Multifilament	Q	Temperature (°C) 20	100	150
Polyamide	10	5.47×10^{13}	8.26×10^{10}	3.44×10^{7}
	20	9.18×10^{10}	1.83×10^{8}	1.42×10^{5}
	30	1.54×10^{8}	4.07×10^{5}	5.86×10^{2}
	40	2.59×10^{5}	9.04×10^{2}	2.42
	50	4.34×10^{2}	2.01	
Polyester	10	5.64×10^{11}	5.40×10^{16}	3.32×10^{1}
	20	2.98×10^{7}	1.19×10^{9}	1.44×10^{5}
	30	1.57×10^{3}	2.63×10	6.25×10^{-2}
	40	8.28×10^{-2}	5.79×10^{-7}	

constant rate of strain principle, the parameters necessary for the prediction of multifilament durability at assumed conditions can be determined.

2. For the purpose of characterization of a multifilament durability, it is better to base on approximate values of mean force and elongation at the moment of break obtained as a result of a simple geometrical construction.
3. The experimental results confirmed the influence of the ratio of strain on the values of stress (tenacity) at the moment of break and of the rupture work. The changes of strain are not too significant.
4. All measured parameters have been influenced significantly by the environment temperature.

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