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INCREASING THE STRENGTH OF SINGLE FILAMENTS AND YARNS OF A PARAARAMID FIBER BY THEIR PROCESSING WITH AN AQUEOUS SUSPENSION OF CARBON NANOPARTICLES

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The paper presents the results of increasing the strength and modulus of single filaments and yarns of a paraaramid fiber by their processing with an aqueous suspension of carbon nanotubes in the production process

In [1], the prospect of modification of aramids using carbon nanotubes (CNTS) for the development of new composite materials is shown. In [2], the results of increasing the shear strength of a composite based on an aramid fiber fabric and epoxy resin are presented. The surface of finished fabric was first coated with CNTS. The properties of fibers determined in the process of introduction of CNTS before molding were unstable. In [3], the results of tests on paraaramid copolymer fibers [4], treated with an aqueous suspension of CNTS produced by “Nanotechcenter” (Russia, Tambov) [5], at the intermediate stage after molding is shown. The tests were conducted within a month after their manufacture. Test results for the same samples within 10 months of fiber manufacture are presented in this paper, and they coincide with the data given in [4]. Figure 1 shows the distribution histograms of the tensile strength of filaments of the original and CNT-treated samples. Table 1 presents the results of tests on filaments and yarns. The clamping length

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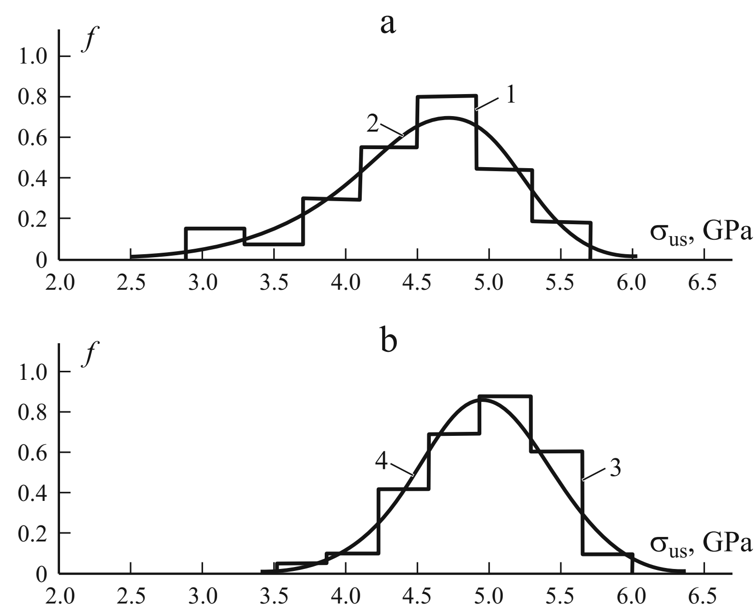

Fig. 1. Distribution histograms of the ultimate tensile strength σ_{us} of filaments and its distribution density functions *f* for the original (a) and CNT-treated (b) fibers: 1, 3 — experimental data and 2, 4 — the densities of Weibull distribution function.

of filaments during the tests was 20 mm, and the strain rate was 0.0041 s^{-1}. The test of yarns was carried out according to standard methods on the basis of 500 mm at the same strain rate.

The results obtained showed no increase in the aging rate of the CNT-treated samples during storage. The statistical scatter of their properties during the processing had decreased, and the properties had become more stable. The increase in the strength characteristics of fibers as a result of their processing with the suspension of CNTS was statistically significant.

The theoretical distribution was selected using the Kolmogorov–Smirnov criterion [6].

The adequacy of the normal

$$f(x\,|\,\mu_N,\sigma_N)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{(x-\mu_N)^2}{2\sigma_N^2}}, \tag{1}$$

lognormal

$$f\left(x\,|\,\mu_L,\sigma_L\right)=\frac{1}{x\sigma_L\sqrt{2\pi}}e^{-\frac{(\ln x-\mu_L)^2}{2{\sigma_L}^2}}, \tag{2}$$

and Weibull

$$f\left(x\,|\,a,b\right)=\left(\frac{b}{a}\right)\left(\frac{x}{a}\right)^{b-1}e^{-\left(\frac{x}{a}\right)^b} \tag{3}$$

distributions was checked. It is found that formally experimental data can be adequately approximated by either of them, but, according to the Kolmogorov–Smirnov criterion, there is a preferable one in each particular case.

TABLE 1.

Property	Distribution						N
	normal		lognormal		Weibull		
	μ_N	σ_N	μ_L	σ_L	*a*	*b*	
Filaments of the original fiber							
σ_{us} G1-G2	4.528 4.37-4.67	0.615 0.52-0.74	1.500 1.46-1.53	0.146 0.12—0.17	**4.782** **4.65-4.91**	**9.030** **4.91-10.87**	68
E G1-G2	115.54 114.3-116.7	5.016 4.29-6.03	**4.748** **4.73-4.79**	**0.0425** **0.036-0.051**	118.10 116.3-119.8	17.170 14.8-19.7	68
Yarn of the original fiber							
σ_{us}+CNT G1-G2	**4.970** **4.85-5.08**	**0.466** **0.39-0.56**	1.598 1.57-1.62	0.0969 0.082-0.11	5.175 5.06-5.28	12.196 5.28-14.74	61
E + CNT G1-G2	119.50 118.4-120.5	4.098 3.47-4.99	4.782 4.77-4.79	0.035 0.03-0.04	**121.18** **120.3-121.9**	**39.686** **32.7-48.1**	61
CNM treated yarn							
σ_{us} G1-G2	2.623 2.55-2.68	0.225 0.18-0.28	0.960 0.93-0.98	0.088 0.07-0.11	**2.721** **2.66-2.77**	**14.113** **11.3-17.5**	50
E G1-G2	**143.76** **143.0-144.4**	**2.539** **2.12-3.16**	4.968 4.96-4.97	0.0177 0.01-0.02	144.98 144.2-145.6	61.117 49.82-74.96	50
CNM treated yarn							
σ_{us}+ CNT G1-G2	**3.411** **3.36-3.45**	**0.154** **0.12-0.19**	1.226 1.21-1.23	0.0455 0.037-0.057	3.484 3.44-3.52	24.712 19.90-30.68	48
E + CNT G1-G2	**157.86** **157.3-158.3**	**1.729** **1.43-2.16**	5.061 5.05-5.1	0.0109 0.009-0.013	158.75 158.1-159.3	83.948 69.0-102.05	48

In Table 1, the parameters of the density distribution function of the tensile strength and modulus of single filaments and yarns of paraaramid copolymer fibers are presented: elastic modulus *E* (GPa), tensile strength σ_{us} (GPa), the upper and lower bounds, G1 and G2, of the confidence interval, and the number *N* of parallel experiments; confidence level 95%. The preferred distributions are shown in bold.

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