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DETERMINATION OF ULTIMATE STRENGTH OF INDIVIDUAL FILAMENTS OF BASALT AND TAPARAN ARAMID FIBERS

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The results of processing of experimental data on strength of individual filaments of basalt and Taparan aramid fibers using new pentaparametric distribution are presented. Distribution enables determination of minimally and maximally possible (experimental) values for an experimental data array. Previously, this distribution was tested for steel strength determination results published by W. Weibull. The obtained results can be used for determination of fiber use potential for fabrication of composites. Initial experimental data on the strength of filaments and the results of their treatment are furnished.

Statistical treatment of results of measurement of strength of complex fibers and individual filaments of fibers in the practice of technological investigations almost always relies on three parameters, namely, average value, dispersion (or root-mean-square deviation), and coefficient of variation. These parameters do not depend on a specific distribution that is adequate for experimental data, but often confidence interval is given, as a complement to it, for average value, which is determined by using Student's distribution, and its use is proper only for quantities distributed in keeping with normal distribution.

The proof that normal distribution is adequate for experimental data, however, is almost never given. In review paper [1] specific data are cited, although commonly experimental data are not described by normal distribution and, consequently, numerical values of confidence intervals calculated by using Student's distribution will be erroneous in this case. Such a situation in fiber strength measurement data processing cannot be considered acceptable.

The technoeconomic costs for obtaining samples of high-strength fibers for tests and subsequent rectification of the technological process are high at present. Additional information may provide triparametric Weibull"Gnedenko distributions or gamma-distribution (provided it is proved that they are adequate) because they contain shear parameter, the physical meaning of which is minimum value of mechanical stress, at which the probability of fiber breaking is different from zero. It is an important parameter, but it shows only the lower theoretical strength limit.

In [2], a distribution was proposed for determination also of the upper theoretic strength limit, which is the mechanical stress upon attainment of which the probability of breaking is equal to unity. The distribution function in this case has the form

$$F(x) = \exp\left[-k\frac{(x_{\max} - x)^{n1}}{(x - x_{\min})^{n2}}\right]$$
$$F(x) = 0 \ldots \ if \ldots x \le x_{\min} \qquad (1)$$
$$F(x) = 1 \ldots if \ldots x \ge x_{\max}$$

where x_{min} and x_{max} – theoretically possible minimum and maximum strength values; x – measurement result (a series of parallel measurement results forms what is called *sample*); k, $n1$, $n2$ – adjustable parameters. Physical meaning of distribution function $F(x)$ – fraction of measurement results not exceeding a specific x value.

From the point of mathematical statistics, the sample is fully characterized by a *general set* (in the studied case, by a very large, almost infinite number of strength measurements). In practice, it is impossible to get such a number of

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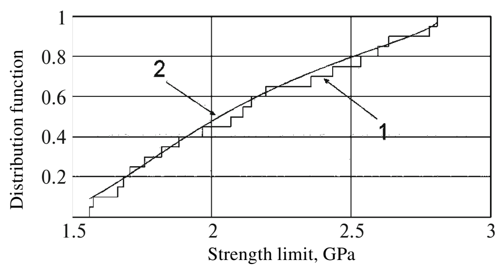

Fig. 1.

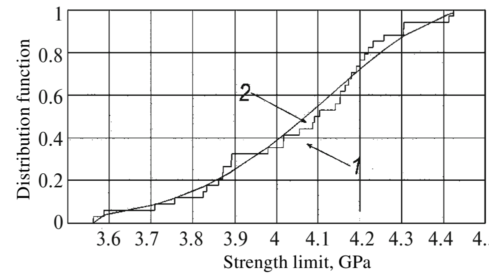

Fig. 2.

Fig. 1. Stepped curve *1* – empirical distribution function; *2* – curve calculated by equation (1) for filaments of basalt fiber.

Fig. 2. Multistep curve *1* – empirical distribution function; *2* – curve calculated by equation (1) for filaments of Taparan aramid fiber

Table 1. Values* of Strength Limit of Individual Filaments of Basalt Fiber (in GPa)

1.5634	1.5776	1.6634	1.6852	1.7078
1.7606	1.8224	1.8838	1.9679	2.0692
2.1138	2.1440	2.1953	2.3571	2.4340
2.5343	2.5958	2.6358	2.7805	2.8092

*Filaments were extracted from roving of continuous basalt fibers produced by OAO Stekloplastik (Fiberglass OJSC), Andreevka, Moscow District, Russia. The obtained data are based on 20 mm in quasistatic conditions.

Table 2. Values* of Strength Limit of Individual Filaments of Taparan Aramid Fiber (in GPa)

3.561	3.586	3.708	3.756	3.824	3.833
3.860	3.871	3.872	3.8914	3.893	3.979
4.016	4.017	4.054	4.087	4.091	4.103
4.140	4.152	4.153	4.164	4.172	4.180
4.191	4.200	4.210	4.220	4.231	4.25
4.303	4.305	4.412	4.424		

*The obtained data are based on 20 mm in quasistatic conditions. The sample of Taparan aramid fiber produced by Yantai Tayho Advanced Material Ltd., China, was obtained from agents of the company at the Interpolytech Exhibition, Moscow, 2016.

strength measurements, and there is a specific methodology of getting distribution parameters that actually are characteristics of the *general set*, based upon a limited set consisting of a real number of parallel measurements, i.e., of a *sample*. The procedure for determining distribution constants (equation (1); appropriate term of mathematical statistics is *estimation*) is described in [2]. Estimation of parameters was made in this work in accordance with the commonly accepted laws of *nonparametric statistics* [3] with due regard for the recommendations in [4].

The distribution parameters for the strength of filaments of basalt fiber (measurement results in Table 1) were x_{min} = 0.951 GPa, x_{max} = 2.823 GPa, k = 0.8928, $n1$ = 0.5262, $n2$ = 1.7558. The root-mean-square deviation was 0.0199. The results of analysis of strength of filaments of basalt fiber are plotted in Fig. 1.

For filaments of Taparan aramid fiber (strength measurement results are presented in Table 2 and Fig. 2), the following values of the constants of equation (1) were obtained: x_{min} = 3.574 GPa, x_{max} = 4.485 GPa, k = 4.0697, $n1$ = 2.0106, $n2$ = 0.0014. The root-mean-square deviation was 0.0397.

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