Control of the mechanical characteristics of reinforcing fibers is important both during the fiber manufacture stage and in the production and investigation of composite materials (CMs), particularly those in which the fibers react with the matrix, as a result of which bonds are formed at their interfaces and at the same time the fibers experience a loss of strength, e.g., in CMs with metallic matrices [1, 2]. The mechanical characteristics of fibers can be assessed by three methods, namely by carrying out tests on: 1) individual fibers, 2) a "microplastic," and 3) a dry bundle. Fiber evaluation by results of random tests on elementary fibers gives the fullest information [3, 4]; thus, e.g., this method makes it possible to assess the mean values and standard deviations of key characteristics, construct flattening distribution frequencies, and employ various methods of statistical processing of results.

An understanding of the nature of fibers and a knowledge of the dependence of their properties on processing parameters enable the results of such tests to be employed for studying the influences exerted by various internal and surface defects on the strength and modulus of elasticity of fibers, the effectiveness of surface treatment, and the degree of interaction between fibers and matrix metal during the fabrication and operation of composite materials (for carbon fibers a method of conducting such an investigation is described in [3, 4]). However, as this technique is very laborious and yields widely scattered data, it is not likely to find extensive application, particularly in quality control testing.

A simpler method consists in determining mean values of strength and modulus of elasticity from results of tests on a "microplastic," i.e., a single bundle of polymer-bonded fibers [5]. In this case values calculated from properties of a "microplastic" with allowance for the volume fraction of reinforcing fibers are taken to be the mean values of fiber properties. Clearly, such data are more convenient for the analysis and prediction of properties of CMs, but experimentally determined values of characteristics of CMs are affected by the scatter of properties of single fibers, their distortion in the composite, matrix porosity, and the like — factors which must be allowed for by introducing suitable empirical corrections into fiber property formulas.

The simplest method of testing is the dry bundle method proposed in [6]. It consists in determining the specific work of fracture of a single unbonded bundle $A_{sp}$, with a prior determination of the mean modulus of elasticity of the fibers $E$ (e.g., from their electrical conductivity), and calculating the mean strength with the formula $\sigma = \sqrt{2A_{sp} \cdot E}$. This method is undoubtedly the least time-consuming, but in [6] no attempt is made to establish fully the validity of the formulas involved, and, apart from this, in the proposed form the method is not suited for the determination of parameters of the fiber strength distribution function.

In the present work the dry bundle method is provided with a scientific foundation and further evolved, so that it can be employed for determining parameters of the fiber strength distribution function. We assume that we are dealing with fibers having approximately the same cross-sectional area and modulus of elasticity and that their strength distribution is approximated by Weibull's distribution,

$$f(\sigma) = L\alpha \beta \sigma^{\beta-1} \exp(-L\sigma^\beta),$$

where $\sigma$ is the strength of the elementary fibers, $L$ is the gauge length, and $\alpha$ and $\beta$ are distribution parameters determining the mean fiber strength and the strength variation coefficient,

$$\bar{\sigma} = (\alpha L)^{-1/\beta} \Gamma\left(1 + \frac{1}{\beta}\right); \quad \kappa \approx \frac{1.2}{\beta}$$
Fig. 1. Variation of p*/S (ratio of maximum load to cross-sectional area of all fibers in bundle) and A_sp (specific work of rupture) with gauge length.

TABLE 1. Formulas for Calculating Parameters of Fiber Strength Distribution

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Mode of fiber loading in dry bundle</th>
<th>Simultaneous loading</th>
<th>nonSimultaneous loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weibull's distribution parameter $\beta$</td>
<td>From slope of exp. log $p*/S$ vs log $L$ straight line</td>
<td>From slope of exp. straight-line plot</td>
<td></td>
</tr>
<tr>
<td>Coeff. of fiber strength variation $\alpha$</td>
<td>$\alpha = \frac{1}{\beta} \left( \frac{p^*_1}{S_1} \right)^{-\beta}$</td>
<td>$\alpha = \frac{1}{L} \left( \frac{A_{sp}}{\Gamma(2/\beta)} \right)$</td>
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<td></td>
</tr>
<tr>
<td>Mean fiber strength on gauge length $L$, $\bar{\sigma}_L$</td>
<td>$\bar{\sigma}_L = \left( \frac{eL}{L} \right)^{1/\beta} \times \Gamma \left( 1 + \frac{1}{\beta} \right) \left( \frac{p^*_1}{S_1} \right)$</td>
<td>$\bar{\sigma}<em>L = \left( \frac{L}{L} \right)^{1/\beta} \Gamma \left( 1 + \frac{1}{\beta} \right) \times \left( \frac{A</em>{sp}}{\Gamma(2/\beta)} \right) \times \left( \frac{L}{L} \right)^{1/\beta}$</td>
<td></td>
</tr>
</tbody>
</table>

Form of fiber strength distribution

$$f(a) = L\alpha \delta^{\beta-1} \exp(-L\alpha \delta^\beta)$$

(here $\Gamma$ is the gamma function).

Let us consider two possible cases: the testing of a bundle with simultaneously and equally loaded fibers and the testing of a bundle whose fibers are not simultaneously loaded. The load on a bundle of total cross-sectional area $S$ is given by the expression $p = S \sigma(1 - F)$, where $F = 1 - \exp(-L\alpha \delta^\beta)$ is the integral function of Weibull's distribution. The maximum load on the bundle $p^*$ is calculated from the condition $dp/d\sigma = 0$, and is equal to $p^* = S(eL\alpha \delta)^{-1/\beta}$ ($e$ is the natural logarithm base). In logarithmic coordinates the variation of the maximum load with gauge length is expressed by a straight line with a slope equal to $(-1/\beta)$, so that the quantity $\beta$ can be determined experimentally from results of tests on bundles of different lengths. In the case of measurements on two gauge lengths $L_1$ and $L_2$ the analytical expression for $\beta$ will be

$$\beta = \frac{\log L_1/L_2}{\log \left( \frac{p^*_1}{S_1} : \frac{p^*_2}{S_2} \right)}$$

Expressing $p^*$ in terms of the distribution parameters and excluding $\alpha$ from the equation for the mean fiber strength on a gauge length $L$ we obtain

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