
PROBABILITY NATURE OF THE SIZE EFFECT IN YARN STRENGTH

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In [1] the physical aspects of the scale factor (size strength effect) in strengthening man-made fibres were examined, starting from contemporary ideas about the kinetic nature of strength. Moreover, the size strength effect (SSE) can be examined from probability positions, which makes it possible to ascertain the principles of change in SSE during the process of yarn preparation and to evaluate the role of random and nonrandom factors in forming the SSE.

It must be noted that, in connection with the large length and small cross-section of man-made fibres in comparison with the parameters of other types of articles, the statistical laws governing SSE of yarns have their specific features. In its essence, the determination of the strength of a yarn at break comes down to a determination of its minimum value on a tested piece which has the length \( L_0 \) (the distance between the dynamometer clamps), and does not permit one to obtain information about the strength of the yarn in other sections. Therefore, as a result of the tests, we obtain information only about the minimum values of fibre strength.

In [2], from the positions of the statistical theory of extreme values [3], the statistical period of repeatability of the minimum values of fibre strength, which is a random quantity with the mean value \( L_s \), was examined. The manifestation of an SSE of yarns is connected with the existence of a statistical repeatability period and depends on the ratio \( L_0/L_s \), which is equal to the probability of incidence of a yarn section with minimum strength on a randomly chosen yarn piece having the length \( L_0 \) which is subjected to testing. The statistical dependence of strength on the length of the tested specimen has the form

\[
R_m = R_{\min} + \Delta R \frac{L_0}{L_s} ; \quad \frac{L_0}{L_s} \leq 1
\]

where \( R_m \) and \( R_{\min} \) are the mean and minimum values of yarn strength; and \( \Delta R \) is the amplitude of change in yarn strength.

On the SSE curve (Fig. 1), there is a critical point, corresponding to equality of the random period of repeatability in the minimum strength values and length of the tested yarn specimen (\( L_0/L_s = 1 \)). On further increase in the clamped length (\( L_0/L_s > 1 \)), the yarn strength hardly changes. In [2], a decrease in the dispersion of strength values on increase in clamped length was also noted (curve 2).

The repeatability period of minimum strength values can have a nonrandom (determined) character if, during the process of yarn preparation, periodic changes in technological pa-
parameters play an important role; for example, pulsation in the delivery of the spun mass through the spinneret, play in the transporting units, fluctuations in temperature, and the like [4, 5]. A determined character of the repeatability period considerably affects the strength distribution function. In [5], on the basis of theoretical and experimental evidence, the conclusion was drawn that deviation of the strength distribution function from the normal law is connected with periodicity in the change of yarn strength and a procedure is given for estimating this periodicity. The results of [5] show that the maximum information about nonuniformity in yarn strength can be obtained in the case where the clamped length in breakage testing is considerably less than the defect repeatability periods. A low value of yarn strength nonuniformity is often the consequence of the fact that tests are carried out at $L_0/L_s > 1$, which corresponds to a section of the SSE curve which is to the right of the critical point (Fig. 1).

The repeat period of yarn strength values can vary as a result of stretching. In Fig. 2, in the case of collagen and polyvinyl alcohol (PVA) yarns, we show the increase in repeat period (the critical point is shifted to the right) on increasing the stretch ratio. There are similar data for Polifen yarns [6]. It must be noted that the increase in repeat period is not always proportional to the stretch ratio, a result of nonuniformity in the heat-stretching process. In [7] a method was proposed for determining nonuniformity in yarn heat-stretching which makes it possible to estimate fluctuations in the local stretch ratio of yarn sections. In Fig. 3 we show experimental data on nonuniformity in the heat-stretching of individual yarn sections which were simultaneously present in the stretching zone. Along the abscissa in Fig. 3 we have plotted the relative deviation of the linear density of the yarn section from its mean value for the entire yarn ($B_s$); along the ordinate axis, the ratio of the actual local stretch ratio of this section ($\lambda_s$) to the mean value of the yarn stretch ratio ($\lambda_m$).

Thinner sections of Polifen or polypropylene yarns are stretched to a greater extent than the thickened ones, which leads to an increase in yarn nonuniformity during the heat-stretching process. The opposite relationship, which is characteristic of Kapron fibres, leads to a decrease in their nonuniformity during the stretching process. For Lavsan yarns, an approximately identical stretching of sections of different thickness is observed. For comparison, in Fig. 3 we give a curve for nonuniformity in stretching cotton roving, where, as a result of plastic deformation, nonuniformity in stretching roving sections of different