Yarn Strength Dependence on Test Length

Pavol Lizák

University of Trencin,
The Faculty of Industrial Technologies

Department of Textile Technologies
in Ružomberok

Scota Viatora 2, 034-01 Ružomberok
Slovak Republic
e-mail: lizak@spsrk.sk

Abstract

Standard measurement of yarn strength is executed on a gauge length of 500 mm. Clamped yarn breaks in its weakest place. It is therefore important to measure the strength of 50-mm short links and to break them one after another lengthwise along the yarn. This allows us to observe how the strength changes along the yarn and to evaluate the auto-correlation functions of the strength of short yarn links. Some similar cotton yarns were analysed and compared by applying this methodology.

Key words: *yarn strength, yarn metrology, cotton strength, test length, weakest link, auto-correlation function.*

Theory

A stochastic model of yarn strength dependence on the gauge length is described in this work, for stochastic independent links (as a part of the yarn length between clamping jaws) and also for those links whose strength creates the accidental Mark process.

Standard measurement of yarn strength is executed on a gauge length of 0.5 m. A clamped yarn breaks in its weakest place according to the so-called principle of the weakest link [1], and this strength value is assigned to the whole length. Standard evaluation is the result of a measured strength file of the weakest links, while the strength of the other places situated on clamping lengths is not measured. The basic characteristics of distribution (average value, standard deviation and coefficient of variation) of the measured values are as a rule calculated but the order of the measured values and the relations between these values and the length of links are not usually examined.

For a better knowledge of the strength variability character it is necessary in some cases to measure and evaluate yarn strength by applying different methodology. It could also help us to understand the origin of achieved results. First of all, it is important to measure the strength of short links. However, the gauge length must be longer than the length of the longest single fibre in the yarn, since this longest yarn cannot be clamped in both clamping jaws of a tester at the same time.

Secondly, it is useful to break yarn links one after the other lengthwise along the yarn, as it enables us to watch how the strength changes along the yarn. In that way it is possible to evaluate the auto-correlation functions of the strength of short yarn links. To realise the subject of this work, similar cotton yarns were analysed from the point of view of their strength.

Experimental Methods

In standard testing of yarn strength, a test link of 500 mm is used [2], The yarn strength determined in such a testing procedure describes only the stress necessary to break the mechanically weakest place on this distance. It does not represent the distribution of strength on each link length. Strength values determined in such a way are logically worse correlated with technological and structural knowledge. For the purposes of this work, the strength of short (50 mm) yarn links has been examined.

Strength values were estimated by a standard statistical process (average value and variation coefficient of strength), and then an auto-correlation function of strength was evaluated.

Points of the auto-correlation function evaluated out from the experiments have been submitted by a regressive function of the following type:

$$r = ae^{-bx} + \left(1 - a\right)e^{-cx} \tag{1}$$

which means a sum of 2 exponential functions. Parameter r is the correlation coefficient, a, b, c are regressive coefficients, x is the distance in mm. For the purposes of the experimental data processing, special calculating software has been created.

Table 1. Basic statistical characteristics and experimental results of the measured strengths of yarn.

Yarn no.	1	2	3	4	5
Average strength $\overline{P}_{5cm}$ [N]	3.072	3.425	4.136	2.282	7.005
Standard deviation σ_{P5cm} [N]	0.432	0.387	0.433	0.351	0.815
Coefficient of variation ν_P [%]	14.069	11.319	10.468	15.395	11.631
Regressive coefficient a	0.4386	0.6098	0.5167	0.6117	0.4389
Regressive coefficient b	0.0197	0.01277	0.01426	0.21275	0.02537
1-a	0.5614	0.3902	0.4833	0.3883	0.5610
Regressive coefficient c	0.00026	0.00010	0.00012	0.00014	0.00048
Average tenacity $\overline{T}_{sim50cm}$ [N/tex]	0.13247	0.10225	0.10430	0.11252	0.12334
Standard deviation $\sigma_{Tsim50cm}$ [N/tex]	0.01833	0.01071	0.01027	0.01626	0.01355
Average tenacity $\overline{T}_{5cm}$ [N/tex]	0.15358	0.11610	0.11644	0.13831	0.14002
Standard deviation σ_{T5cm} [N/tex]	0.02158	0.01309	0.0122	0.02132	0.01625
Average tenacity $\overline{T}_{Pierce}$ [N/tex]	0.12011	0.09580	0.0976	0.01053	0.11484
Standard deviation $\sigma_{Tpierce}$ [N/tex]	0.01363	0.00826	0.00770	0.01345	0.01025
Average tenacity $\overline{T}_{żurek\,[}$N/tex]	0.12816	0.10068	0.10214	0.10031	0.12089
Standard deviation $\sigma_{TŻurek}$ [N/tex]	0.01554	0.00942	0.00878	0.01227	0.01170

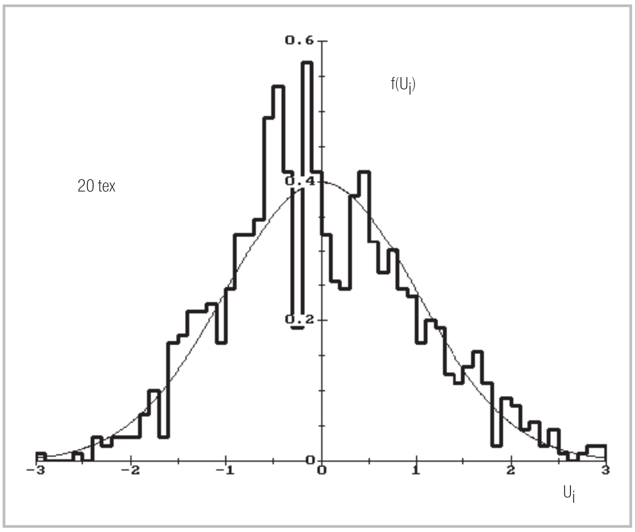

Figure 1. Distribution of standardised consistencies of probability of strength distribution by using gauge length l_0=50 mm for cotton 20 tex.

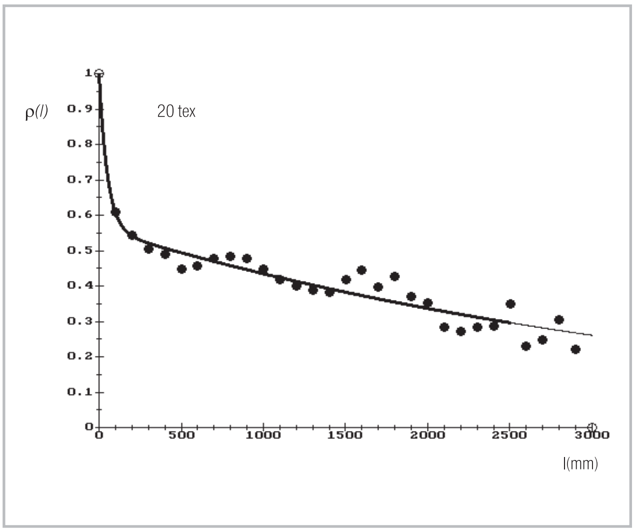

Figure 2. Auto-correlation functions for strength links of length l_0=50 mm in dependence on test length.

Measuring and Evaluating of Experimental Methods. Discussion of the Results

Material used in the tests

Samples of cotton yarn and cotton blends listed below have been examined:

Yarn No 1 - 100% cotton carded classic yarn	20 tex
Yarn No 2 - 100% cotton carded rotor yarn	29.5 tex
Yarn No 3 - 100% cotton carded rotor yarn	35.5 tex
Yarn No 4 - 100% cotton combed classical yarn	16.5 tex
Yarn No 5 - 100% cotton carded rotor yarn	50 tex

The experiments described in the next chapter were performed on all yarns.

Measurement results

The strength of carded and combed cotton yarns was measured on a non-standard gauge length l_0=50 mm. None of the single fibres could be held by both jaws of the dynamometer simultaneously. In randomly selected places of yarn from 6 cops, approximately 900 tears were executed in one file. The incorrect tears were excluded from calculation. The basic statistical characteristics of the measured strengths are specified in Table 1. Next, a general evaluation of the yarns mentioned on different test lengths was carried out. The main characteristics are average strength, standard deviation, and coefficient of variation. For this evaluation, the accumulative method has been used. We applied also used span selection, which helped to calculate the standard deviation. Other calculations were done using general statistical method. The values of distribution and correlation coefficients are described in Figures 1 and 2. The calculated coefficients characterise the standardised correlation function. Its course describes a regressive relation established as a sum of two exponential functions.

$$\rho_{P20}(l) = 0.438637 e^{-0.019696\, l[mm]} + \\ + 0.561363 e^{-0.0002558\, l[mm]} \qquad (2)$$

Simulation and discussion

Analytically there is no use in finding out the strength of long links, which is for example necessary when warping, so if we want to assess the yarn strength it is better to use the simulated process. The strength values in 10,000 pieces of yarn was simulated. The results for any length are listed in Table 2 (marked “simulation”). Each link was interpreted as a length of 5,000 mm consisting of 100 links of a length of l_0=50 mm. A standardised correlation function was used. Its simulated course is almost consistent with the standardised correlation function described by relation (2) and Figure 3, and confirms that the applied experimental procedure is correct.

Table 2. Approximate values of yarn (20 tex) strength.

Test length	Average strength $\overline{U^{\cdot}} = \frac{\overline{P^{\cdot}} - \overline{P}}{\sigma_P} = \frac{\overline{P^{\cdot}_{[N]}} - 3,072}{0,432}$		Standard deviation $\sigma_{U^{\cdot}} = \frac{\sigma_{P^{\cdot}}}{\sigma_P} = \frac{\sigma_{P^{\cdot}[N]}}{0,432}$	
l [mm]	simulation	approximation	simulation	approximation
50	0	0	1	1
100	-0.30	-0.32	0.95	0.95
150	-0.48	-0.50	0.92	0.92
200	-0.60	-0.63	0.90	0.90
250	-0.70	-0.72	0.89	0.89
300	-0.77	-0.80	0.88	0.87
400	-0.89	-0.92	0.86	0.85
500	-0.98	-1.01	0.85	0.83
600	-1.05	-1.08	0.84	0.82
800	-1.16	-1.19	0.82	0.80
1000	-1.24	-1.28	0.81	0.79
2000	-1.51	-1.53	0.77	0.74
3000	-1.67	-1.68	0.74	0.72
4000	-1.80	-1.77	0.72	0.70
5000	-1.89	-1.85	0.70	0.69

Table 3. Predicted values of yarn strength (20 tex).

Test length [mm]	Average strength $\overline{P}$ [N]	Average tenacity $\overline{T}$ [N/tex]	Standard deviation of strength σ_{P5cm} [N]	Standard deviation of tenacity σ_{T5cm} [N/tex]	Coefficient of variation ν_P [%]
50	3.072	0.1536	0.4320	0.0216	14.07
500	2.614	0.1310	0.3542	0.0177	13.55
5000	2.230	0.1115	0.2938	0.0147	13.18

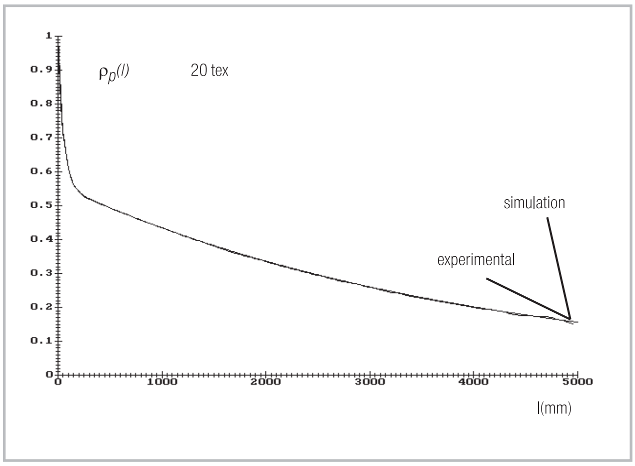

Figure 3. Simulated and standardised correlation functions yarn.

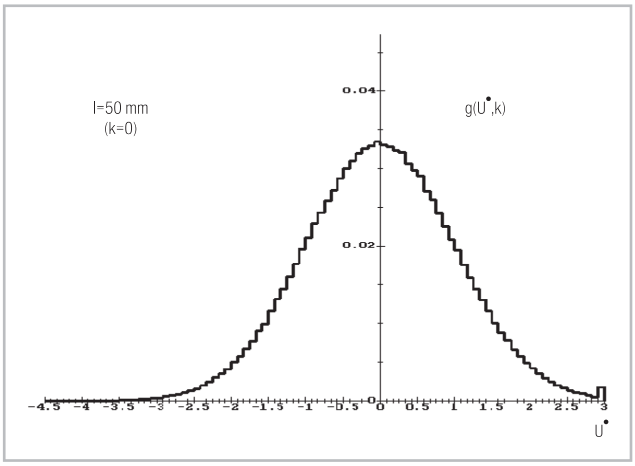

Figure 4. Distribution of transformed strength values on the gauge length l_0=50 mm.

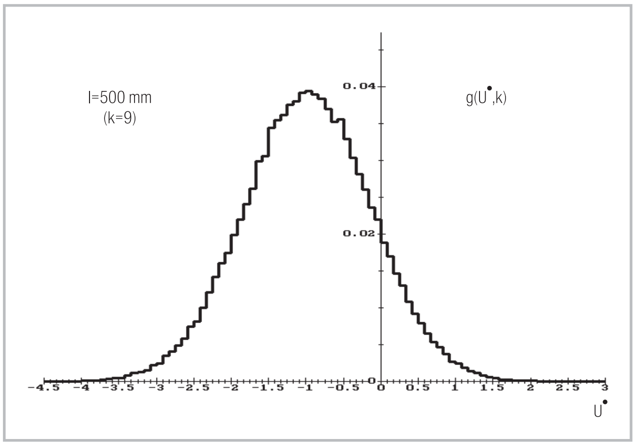

Figure 5. Distribution of transformed strength values on the test length 500 mm.

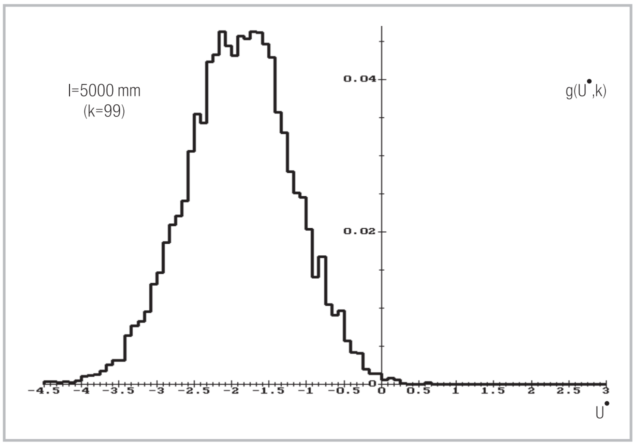

Figure 6. Distribution of transformed strength values on the test length 5000 mm.

Figure 4 describes the simulated distribution of transformed strength on the gauge length l_0=50 mm (k=0). Figure 5 show the distribution of transformed strength values on the test length 500 mm (k=9). It is obvious that the average value as well as the standard deviation diminished (the histogram is taller and slimmer). Figure 6 shows the distribution of transformed strength values on the test length 5,000 mm (k=99). The trend of the average value and the standard deviation diminishing continues. As we can see, some asymmetry occurs in the distribution (it is displaced a little to the left). The course of the distribution curve in Figure 6 is less smooth. This is caused by a lower number of simulated links.

For a 50-mm gauge length the strength values shown in Table 3 have been found. On test lengths 500 mm and 5000 mm, the strength values were predicted and are also presented in Table 3. Both values were predicted by the same procedure.

Conclusions

The average strength values for gauge length 50 mm (for cotton yarn examined in this work) lie in the range of 0.116-1.153 N/tex. Combed yarns have a higher coefficient of variation (15.41%) than carded yarns (around 10.47%). When calculating the strength of test length 0.5 m, we found that the relations shown in Table 1 approximately correspond to the Pierce relation together with the Żurek 1/7 exponent modification [3], From this, it is obvious that all the yarns have flat strength. Average strengths of 50-mm links are higher than average strengths of 10-mm links over 500-mm test length, which explains the principle of the weakest link by the larger number of yarn links.

As we can see, the absolute exponent value in the first component is higher for all yarn cases, so that the value of the first component is close to zero. On the contrary, the absolute exponent value of the second component is low, so that its value in the entire extent of measurement does not differ too much from the multiplying constant. The yarn of 29.5 tex best approaches our original hypothesis. We may consider that with increasing distance between two compared places, the correlation coefficient gives lower values.

We consider that the yarn strength should be a result of the sum of two independent components, of which the first one is an auto-correlation function itself. This function is in the shape of the first exponential, and the second one is in the shape of the second exponential. The final auto-correlation function thus represents the sum of two exponential functions. It looks as if the yarn strength is the sum of two links. The first strength link is characterised by a rapid decrease of the auto-correlation exponential. That means that a given value of this first link does not influence the strength in distant surroundings. This is probably caused by the influence of structural anomalies, such as yarn purity, etc.

In contrast, the second link of strength shows only a small decrease of correlation. This means that the value for this link in some places also marks the value in a place distant enough from the first one. This is probably caused by the influence of material unsteadiness on the yarn length. ❏

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References

1. *B. Neckar, Morfologie a strukturni mechanika obecnych vlákennych utvaru, skripta TU Liberec, 1998.*
2. *P. Lizák, Pevnost' priadze na kratkych useèkách, Proceedings of the 4th working seminar Strutex 1998, TU Liberec.*
3. *W. Żurek, Struktura przędzy, Warszawa 1971.*

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