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Tensile Strength of Untwisted Blended Cotton/Flax Fibre Streams

Abstract
An estimation of the tensile strength of untwisted blended cotton/flax fibre streams with flax content from 10% up to 50% was carried out. Slivers with a linear density of 3 ktex after the second drawing machine were the objects of investigation. The tensile strength tests were carried out with the use of a tension tester by means of the static method in accordance with Polish Standard PN-88/P-04771. The results obtained were compared with the results obtained by the means of dynamic method with the use of the F 460 Stick-Slip Friction Tester apparatus.

Key words: *sliver, blended sliver, cotton-flax sliver, cotton-flax yarn, tensile strength of sliver, specific tensile strength of sliver, cohesion of fibres.*

RESEARCH AND DEVELOPMENT

Introduction

An untwisted fibre stream has a certain tensile strength thanks to the cohesion of fibres. The cohesion of fibres which form the stream is a characteristic feature of these fibres. The value of cohesion is influenced by the kind of fibre materials, by the fibre slenderness and the surface properties of the fibres [1].

Żurek [2] has analysed the stretching of a segment of an untwisted stream of fibres with a segment length greater than zero but smaller than the length of fibres. The tensile strength of the fibre stream is the resultant of two values: the tensile strength of fibres locked in both clamps, and the cohesion forces of the remaining fibres. The contribution of both kinds of fibres can be determined on the basis of the schema shown in Figure 1 [2]. This presents a segment of the fibre's stream of an ideal regular structure, in which every element contains the same number of fibre ends of fibres of the same length. Evidently, the linear density of such a stream of fibres has the same value along its whole length. The lines which identify the gripping of the fibres fall in the positions of the cross-sections A-A and B-B displaced by the distance x. As can be seen from the schema presented in Figure 1, a certain number of fibres are locked in both clamps; these fibres are marked by continuous lines. Fibres which are locked only in one clamp are marked by dashed lines, whereas those which are unlocked (the so-called 'swimming' fibres) are marked by dotted lines [2].

The forces that join the fibres mutually together depend on the pressure acting in the direction perpendicular to the fibre stream axis and on the friction coefficient between the fibres. These forces come to light during drawing the fibre stream.

The fibres locked in both clamps transmit a force which is approximately equal to the force necessary for breaking a fibre bunch formed from the same number of fibres and stretched to break between clamps positioned at the same distance.

Independent of the tensile forces, the forces of cohesion also stand in opposition to the drawing of a fibre stream. These fibres which determine the cohesion forces can be divided into two groups. The first group consists of fibres with a length longer than the distance between both clamps, and which are locked only in one clamp (marked by dashed lines in Figure 1). These fibres penetrate the fibre stream drawn with its whole segment which protrude outside the limit of the locking line; the above-mentioned fibres transmit a force which is equal to *hx*, where h is the unit cohesion of fibres. The length of penetration of these fibres in average equals *x/2*, which means that the force transmitted by one fibre in average equals *xh/2*. The second group of fibres which influences the cohesion forces are fibres with a length smaller than *x*, but longer than *x/2* $(x/2<l<x)$. One part of these fibres consists of fibres locked only in one clamp, the second are the so-called 'swimming' fibres. The 'swimming' fibres transmit forces at the outmost only within the range of half the fibre length. As for the second part of these fibres, at least half of their length must be located between the remaining fibres.

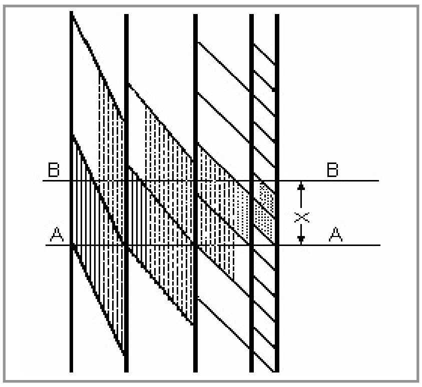

Figure 1. *The content of locked and unlocked fibres in the clamps A-A and B-B.*

Table 1. *Irregularity parameters of the sliver's linear density (CVm - irregularity of linear density, CV(0.4m) - irregularity of linear density for 0.4 m segments - 'CV " Inert', CV(1m) - irregularity of linear density for 1 m segments, CV(1.4m) - irregularity of linear density for 1.4 m segments - 'CV Inert', I - Huberty coefficient).*

Blend content flax/ cotton, %	Variant W1				
	CVm, %	CV(0.4m), %	CV(1m), %	CV(1.4m), %	I
10L/90B	8.77	2.98	2.64	2.26	10.99
20L/80B	9.08	3.56	2.69	2.27	10.32
30L/70B	9.59	3.78	2.42	2.55	12.61
40L/60B	10.50	3.29	2.58	2.79	13.48
50L/50B	12.06	4.02	2.92	2.81	14.01
Blend content flax/ cotton, %	**Variant W2**				
	CVm, %	**CV(0.4m), %**	**CV(1m), %**	**CV(1.4m), %**	**I**
10L/90B	7.22	2.26	1.66	1.34	9.98
20L/80B	7.91	3.18	2.26	1.94	9.96
30L/70B	8.85	3.62	2.22	2.01	10.08
40L/60B	9.32	3.18	2.41	1.74	11.31
50L/50B	11.23	3.47	2.05	1.75	12.03

Table 2. *Tensile strength parameters determined by the static method (W_s - average specific tensile strength (cohesion) of slivers, s_w - standard deviation of the sliver's cohesion, V_w - variability coefficient of the slver's cohesion).*

Blend content flax/ cotton, %	Variant W1		
	W_s, cN/tex	s_w, cN/tex	V_w, %
10L/90B	8.33	2.11	25.3
20L/80B	6.87	2.48	36.15
30L/70B	6.54	1.86	28.39
40L/60B	4.87	1.19	24.44
50L/50B	5.07	1.49	29.41
Blend content flax/ cotton, %	**Variant W2**		
	W_s, cN/tex	s_w, cN/tex	V_w, %
10L/90B	5.13	1.59	31.06
20L/80B	4.72	0.77	16.33
30L/70B	4.0	0.84	20.90
40L/60B	4.25	0.61	14.48
50L/50B	4.20	1.41	27.13

Table 3. *Tensile strength parameters determined by the dynamic method (F - average breaking force of the sliver determined by the dynamic method, W_s - specific tensile strength (cohesion) of slivers, s_w - standard deviation of the sliver's cohesion, V_w - variability coefficient of the sliver's cohesion).*

Blend content flax/ cotton, %	Variant W1			
	F, cN	s_w, cN/tex	V_w, %	W_s, cN/tex
10L/90B	83.61	0.9	3.23	27.87
20L/80B	74.01	0.24	0.96	24.67
30L/70B	75.21	0.55	2.19	25.07
40L/60B	68.01	1.13	4.99	22.67
50L/50B	72.00	0.63	2.61	24.00
Blend content flax/ cotton, %	**Variant W2**			
	F, cN	s_w, cN/tex	V_w, %	W_s, cN/tex
10L/90B	75.39	1.21	4.80	25.13
20L/80B	71.79	0.43	1.81	23.93
30L/70B	74.01	0.71	2.87	24.67
40L/60B	65.40	1.26	5.79	21.80
50L/50B	63.00	0.23	1.11	21.00

The length of the effective working fibre part ranges from 0 to $l/2$, and on average equals $l/4$; this results in a value of the force transmitted by one fibre equal to $lh/4$. Such forces will be transmitted by all fibres placed in the fibre stream cross-section and whose length is smaller than $x/2$, and those of a length greater than $x/2$ and smaller than x $(x/2<l<x)$ which are not locked in any of the clamps.

When the segment x achieves a value equal to or greater than the doubled maximum of the fibre length ($x \geq 2l_{max}$) then the total force necessary to break the untwisted fibre stream will be:

$$F = 0.25 \cdot \overline{n} \cdot h \cdot \overline{l}, \ \text{cN} \qquad (1)$$

where:
- $\overline{n}$ - the average number of fibres in the fibre stream's cross-section,
- $\overline{l}$ - the average length of fibres in the stream in mm, and
- h - the unit cohesion of fibres in cN/mm.

The unit cohesion of fibres determines the force which should be applied to displace a fibre lying in an untwisted stream at a distance of 1 mm.

The above presented equation (1) is in conformity with the Budnikov equation [3] proposed much earlier (in the 1950s). A standard which determines the conditions of drawing an untwisted stream of fibres [4] was elaborated taking into consideration the assumptions accepted for educing the principle (1). This standard recommends the use of a distance between the clamps of a tension tester equal to two and a half times the average or nominal fibre length. If information about the average length of fibres in the fibre stream is lacking, a locking distance of 100 mm for cotton system slivers should be accepted.

The Aim and Object of Investigation

The aim of the investigations carried out was to estimate and compare the tensile strength of blended cotton/flax slivers with a flax content of 10 to 50% as measured by means of the static and the dynamic methods. Slivers after the second drawing machine with linear density of 3 ktex were the objects of investigation.

A Ns4 flax tow was used as raw material for the tests. The tow was prepared by

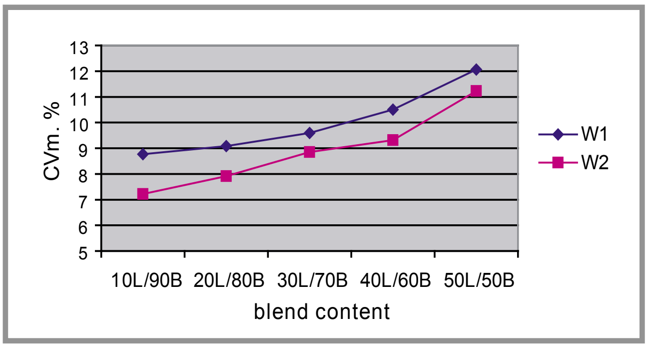

Figure 2. Irregularity of the linear density of slivers in dependence on the flax content in percent.

two mechanical methods marked as W1 for flax before tearing, and W2 for flax after carding.

The tensile strength tests were carried out with the use of a static tension tester working on the basis of a constant elongation increment in accordance with Polish Standard PN-88/P-04771 [4]. Every sliver segment was cut out (after break) in order to determine its linear density. The specific tensile strength W labelled as the sliver cohesion by standard [4] was calculated on the basis of knowledge of the breaking force and the mass (linear density) of the broken sliver segments. This method described above is a static method for estimating the fibre stream's strength parameters. The results obtained by this method were compared with the results obtained by means of the dynamic method with the use of the F460 Stick-Slip Friction Tester apparatus [5].

The Results Obtained and a Discussion of Them

The results of mass (linear density) irregularity obtained with the use of an Uster Tester 3 apparatus are listed in Table 1. The dependencies of irregularities of linear density on the blend composition prepared on the basis of the data listed in Table 1 are presented in Figure 2. An analysis of the data listed in Table 1 and presented in Figure 2 allows us to state that slivers of the W1 variant which include less well decomposed flax fibres ('elementarised') have a greater irregularity of linear density for short segments CVm than slivers of the W2 variant. A tendency to increase in irregularity (of the linear density) with a rise in the flax content is visible for both variants. For long segments, the differences in the irregularities of linear density of the slivers from variant W1 and W2 are smaller. With the increase in

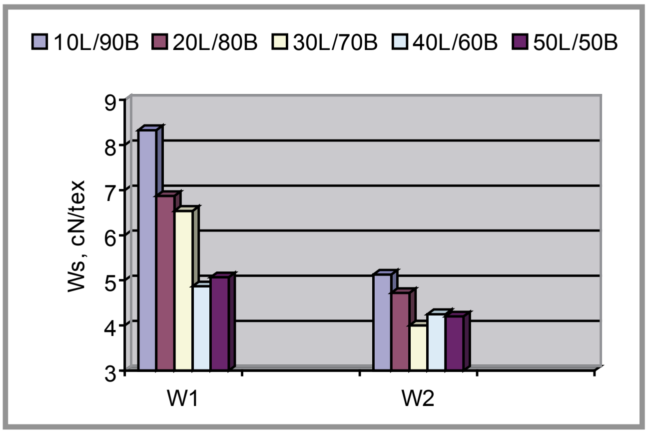

Figure 3. Average specific tensile strength of the slivers determined by the static method in dependence on the flax content in percent.

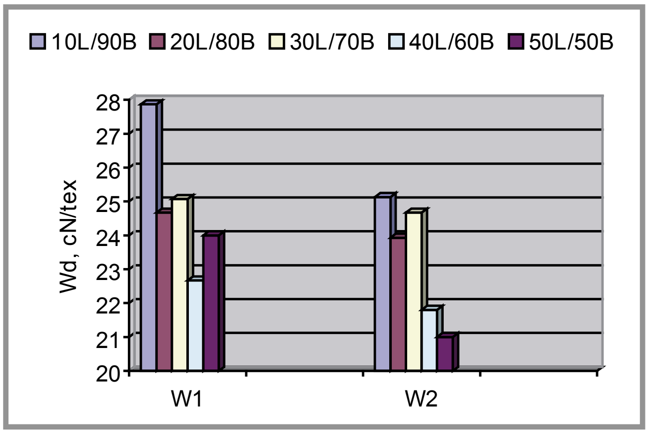

Figure 4. Average specific tensile strength (cohesion) of the slivers determined by the dynamic method in dependence on the flax content in percent.

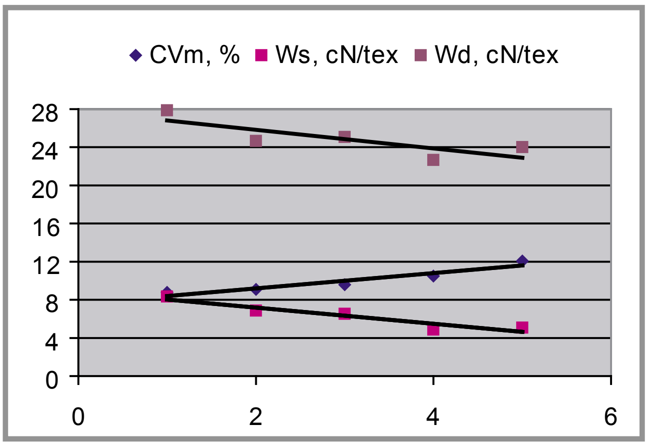

Figure 5. Comparison of the sliver parameters for variant W1; 1, 2, 3, 4 and 5 are related to the consecutive blends listed in Table 3 and Figure 4.

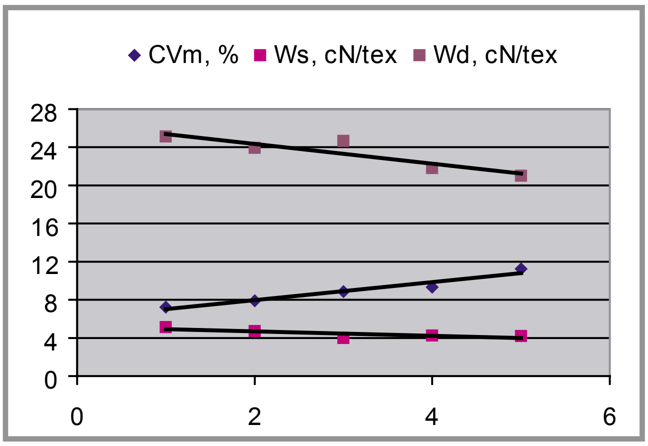

Figure 6. Comparison of the sliver parameters for variant W2; 1, 2, 3, 4 and 5 are related to the consecutive blends listed in Table 3 and Figure 4.

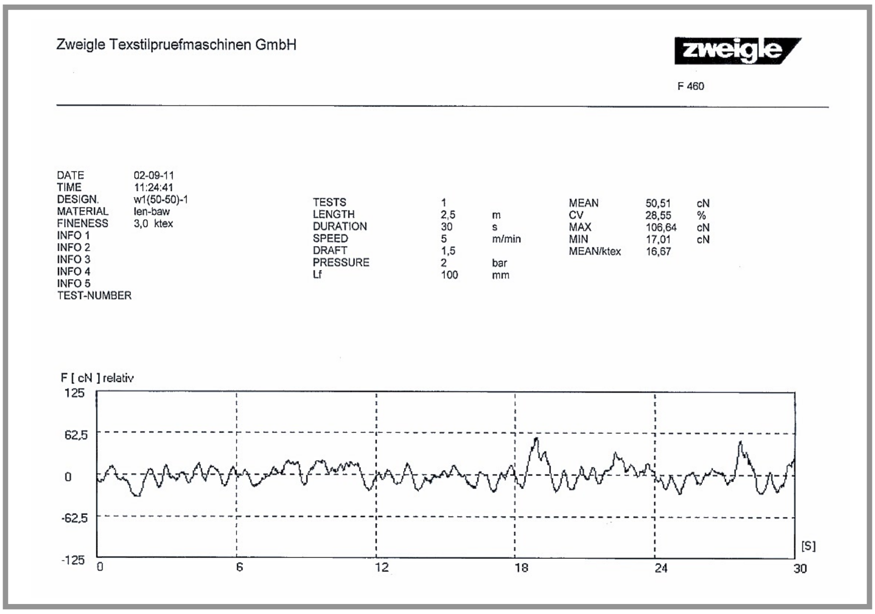

***Figure 7.** Computer print obtained with the use of F 460 Zweigle apparatus.*

the flax content in the sliver, a tendency to increase in the Huberty coefficient can also be observed.

The results concerned with the specific tensile strength of the slivers are listed in Table 2. Measurements were carried out with the use of an 1120 Zwick tester. The distance between clamps was 100 mm, and the velocity of the upper clamp was selected at 500 mm/min. Ten measurements were carried out for each of the variants.

A graph was constructed (shown in Figure 3) on the basis of the data from Table 2. The specific tensile strength (the cohesion) of the slivers determined by the static method has a tendency to decrease with the flax increase in the blended yarn. The cohesion of these slivers which contain flax fibres from variant W1 have higher values ranging within the boundaries of 4.87 to 8.33 cN/tex. The differences for variant W2 are smaller, and range from 4.0 cN/tex to 5.13 cN/tex.

The measurements of the sliver's tensile strength with the use of the F460 Stick-Slip Friction Tester were carried out by selecting the following parameters established in preliminary studies:

- drawing ratio - 1.5,
- velocity of sliver - 5 m/min,
- pressure - 2 bar (200 kPa),
- measurement time - 30 sec.

Five measurements were carried out for each variant.

The results of the average breaking force F obtained with the use of the F460 Stick-Slip Friction Tester and the specific tensile strength elaborated are listed in Table 3. On the basis of the data from Table 3, the graphs presented in Figure 4 were elaborated.

The specific tensile strength of the slivers from variant W2 is smaller than for variant W1 (21.00 cN/ktex - 24.67 cN/ktex for variant W2. and 22.67 cN/ktex - 27.87 cN/ktex for variant W1). A tendency of the sliver's strength parameters to decrease with an increase in flax content is visible. This tendency can create conditions for uncontrolled drawings by feeding the next machines with sliver.

Figures 5 and 6 present the trends of the analysed sliver parameters of both variants W1 and W2. The values of specific tensile strength (cohesion) of slivers obtained by the dynamic method are 3.5 to 5 times higher than those obtained by the static method. Such great differences can be caused by the drawing ratio of 1.5 used in the F 460 drawing apparatus. As has been established from tests carried out earlier, the drawing force has its highest value at a drawing ratio of about 1.5 [5]. A computer print obtained by the F 460 Zweigle apparatus for a blended L50/B50 sliver (50% flax and 50% cotton) is presented in Figure 7 as an example.

Summary

An increase in the flax content of a blended cotton/flax sliver from 10% up to 50% causes:

- an increase in the irregularity of linear density of the slivers for short and long segments.
- a decrease in the specific tensile strength (cohesion) of slivers measured by the static method, and
- a decrease in the specific tensile strength of slivers determined by the dynamic method.

The blended slivers of variant W1, characterised by application of flax after carding, have less irregularity of linear density and a higher specific tensile strength (cohesion) than those slivers which contain flax before tearing.

Conclusions

- The values of the specific tensile strength of slivers obtained by the dynamic method are 3.5 to 5 times higher than those obtained by the static method.
- The increase in flax content in the cotton/flax blended slivers from 10% to 50% causes an increase in the slivers' irregularity of linear density for short and long segments, and a decrease in the specific tensile strength (cohesion) of the sliver measured by means of the static method, as well as that estimated by means of the dynamic method.

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