Adriana Mustata

Faculty of Textiles and Industrial Management,
"Gh. Asachi" Technical University of Jassy,
Blvd. Prof. Dimitrie Mangeron, No.53, 700050, Jassy, Romania
E-mail: amustata@tex.tuiasi.ro

Mechanical Behaviour in the Wet and Dry Stage of Romanian Yarns Made from Flax and Hemp

Abstract
Flax and hemp yarns will constantly be used in the clothing field and in different technical applications. Deformation during stretching in the dry and wet states of flax and hemp yarns obtained from boiled or bleached roving was studied. Structure modifications of the yarn and fibre components as a result of tension were highlighted by load-extension curve analysis. The following specific characteristic quantities were measured and calculated on the diagrams: the limit of proportionality, the tensile yield stress, the breaking limit, the mechanical breaking work, and the mechanical work factor. The study of these data established maximum values of the processing tension that dry and wet flax and hemp yarns could stand without breaking. Moreover, analysis of the mechanical work factor enabled the estimation of the strain capacity of the yarns studied and their ability to support a tension impact load. The load and displacement at which the first breaking destruction phenomena of the yarn fibres appear are those corresponding to the tensile yield stress. Thus, it is possible to establish the maximum tensions that the yarn could support during processing without fibres breaking. An original evaluation of the tensile properties of flax and hemp yarns was developed.

Key words: *flax yarn, hemp yarn, tensile yield stress, load-displacement diagram, breaking mechanical work.*

Introduction

Due to the favourable conditions of the climate and soil, flax and hemp have been cultivated on Romania territory since ancient times; in the beginning for household needs, and in modern times for industrial processing.

Between the two World Wars, the area cultivated with these technical plants was no more than 30,000 hectares. During the communist period this area was doubled.

Since the year 2000 the area yearly cultivated with flax has decreased to 400 hectares. This decrease was caused by modifications appearing in the structure of agricultural properties due to the abolition of cooperative properties. The manufacturing units of flax and hemp harvested stems have changed in their activity profile. In 2007 only 20% of flax and hemp rettings functioning in Romania before 1990 were active.

Worldwide one can notice an increased tendency to use flax and hemp fibres in the field of technical textiles as a consequence of the fact that these fibres show high resistance at streching, friction, reduced elongation at break, a high spinning capacity and high length of technical fibres [1 - 11]. Owing to increased air permeability, hygroscopicity and antiseptic properties, flax and hemp fibres will constantly be used in the clothing field [12, 13].

Practical application of flax and hemp yarns requires knowledge of the deformation and relaxation of fibres and yarns during processing, [14 - 21].

Flax and hemp fibres are made of elementary fibre bundles and are of a cellulose nature. The cells are of an exterior shape and different dimensions; they are bound by the middle lamella, which contains hemicelluloses, pectic substances, and lignin [6, 12]. If the cells of the elementary fibres are thin, the adhesion forces between them are reduced [22, 23]. This fact determines the slow division of the bundles without cell degradation, which allows to obtain thin fibres. Under the action of certain exterior mechanical forces [15, 16, 21], the amorphous and crystalline zones of the cell fibres undergo displacements, which are recovered or become permanent.

The water absorption in flax and hemp fibres modifies their mechanical properties [2, 25]. In the case of flax and hemp, it is important to know the transfer mode of the fibre properties in the yarn characteristics.

In the present paper stretching deformation during the dry and wet states of flax and hemp yarns obtained by boiled or bleached roving was studied. Structure modifications of yarn and component fibres as a result of stretching application were highlighted by load-displacement curve analysis (the load-displacement curve is the equivalent of the load-elongation curve). The study of these data established maximum values of the tension that dry and wet flax and hemp yarns could support without breaking during processing.

Experimental

Material

The flax and hemp yarns used in this study, wet spun from bleached or boiled roving, came from the Falticeni Spinning Mill (Romania). The flax and hemp yarns investigated, of linear density listed in ***Table 1*** (see page 8), were conditioned in a standard atmosphere for 48 hours [28]. For serial testing in the wet state, the yarns were stressed after one minute of moistening and then dried between two sheets of absorbent paper.

Methods

Measurement of the breaking strength of the yarns

Measuring the breaking strength of the yarns was performed according to ISO 2062 on a TINIUS OLSEN H5 K-T yarn tester (England) by the automatic registering of the load–displacement curve. The initial length of the tested sample was 500 mm. On these curves the following characteristic quantities were measured:

- limit of proportionality at which the force is proportional to the displacement;
- tensile yield stress to which the binding molecules were stressed that were

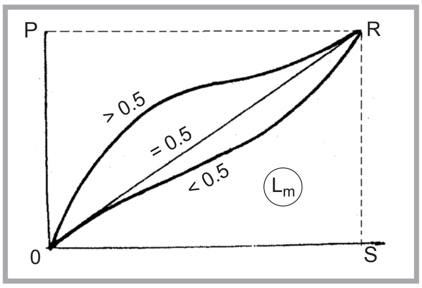

Figure 1. Ratio of mechanical work, Lm – real mechanical work.

still intact between the non-crystalline and crystalline zones of the fibres; with which the crystalline field orientation is associated;

- the breaking limit, which is defined by load and yarn displacement (elongation) during the breaking moment, is marked out by the final point on the curve;
- the mechanical work of breaking is defined as the load necessary for yarn displacement up to the breaking moment. This energy is given by the area enclosed under the load-displacement curve. Five load-displacement curves were analysed for each yarn studied.

The capacity of yarn deformation and its ability to support strains was evaluated by the ratio of mechanical work. This parameter was established according to Hooke's law. In this case the load-displacement curve is a straight line which crosses the origin of the axes and divides the entire area restricted by the axes into two parts, see ***Figure 1*** [29]. The theoretic mechanical work is given by the area restricted by axes (the surface OPRS, see ***Figure 1***). The theoretic work is the productof bracking force and elongation at break. For the ideal curve, according to Hooke's law, the factor of mechanical work has 0.5 value.

The mechanical work factor was calculated as a ratio of the real mechanical work and the theoretic mechanical work.

$$f_L = Lm_{real}/Lm_{theoretic} \qquad (1)$$

where:

f_L - the ratio of mechanical work;
Lm_{real} - real mechanical work;
$Lm_{theoretic}$ - theoretic mechanical work.

Measurement of the water weight degree

The measuring of the water weight degree of the yarn section tested was established using the standard method presented in SR ISO 6741-1/1998, [30].

Table 1. *Samples codification; *conditionated yarn, **after one minute moisten and drying between two sheets of absorbent paper.*

Yarn type	Fineness of the yarn, tex (Nm)	Spinning type and the treatment applied in roving	Yarn stage in breaking time
Flax yarn	103 tex (Nm 9.7)	Wet spinning from boiled roving	dry yarn*
			wet yarn**
	66.6 tex (Nm 15)	Wet spinning from bleached roving	dry yarn*
			wet yarn**
	25.3 tex (Nm 39.5)	Wet spinning from bleached roving	dry yarn*
Hemp yarn	100 tex (Nm 10)	Wet spinning from boiled roving	dry yarn*
			wet yarn**
	93 tex (Nm 10.7)	Wet spinning from bleached roving	dry yarn*
			wet yarn**

***Table** 2. Tenacity of hemp and flax yarns from boiled roving in the dry and wet stages.*

Characteristics	Flax yarn 103 tex from boiled roving:		Hemp yarn 100 tex from boiled roving:	
	tested in dry stage	tested in wet stage	tested in dry stage	tested in wet stage
Breaking strength, cN	2307	2633	642	915
Breaking tenacity, cN/tex	22.4	15.6	7.5	10.4
Change of tenacity in wet stage in comparison with dry stage, %	-	-30.3	-	+38.6
Degree of water permeation, %	-	68.2	-	50.6

***Table** 3. Tenacity of bleached yarns from flax and hemp in the dry and wet stages.*

Characteristics	Flax yarn 66.6 tex from bleached roving:		Hemp yarn 93.5 tex from bleached roving:	
	tested in dry stage	tested in wet stage	tested in dry stage	tested in wet stage
Breaking strength, cN	1668.4	1640	1100	1881
Breaking tenacity, cN/tex	25.44	15.61	11.7	13.5
Change of tenacity in wet stage in comparison with dry stage, %	-	-38.6	-	+15.4
Degree of water permeation, %	-	76	-	76

Results and discussions

Sample codification

The yarns submitted for analysis are presented in ***Table 1***. The load–displacement curves for the yarns studied are shown in ***Figures 2 - 10***.

Breaking strength of flax and hemp yarns in the dry and wet states

The forces applied to the yarns during the breaking moment overcome the friction forces between fibres, the compressive forces between the fibre layers, and the binding forces between the macromolecular chains which comprise the fibres of the weakest cross section of the stressed yarn. The network changes and slips, and permanent displacements take place.

The breaking strength and elongation produced by the breaking of yarn depend on the fibre properties and the structure of the yarn resulting from the technology applied. When spinning the yarn, fibres are fixed by twisting and adding their strength to that of the yarn, which depends on the fibre strength, the number of fibres fixed into the yarn, the fibre length, the density of the fibres in the yarn, the friction fibre-fibre coefficient, the adhesion coefficient, and on the twist applied to the yarn. Flax and hemp yarns produced by wet spinning, which are the subject of the study, have a structure different to other spun yarns. Fibres from the yarns analysed are totally fixed in the yarn section, which is caused by the quantity of binding substances between fibres which remains on the fibres after their exit from the humidification bath on wet spinning frame. After the drying that follows wet spinning, these substances fix the fibres into the yarn. After the humidification before stressing, flax yarn of 103 tex and hemp yarn of 100 tex recorded different water permeation degrees: 70 and 50% (***Table 2***). The following observations of

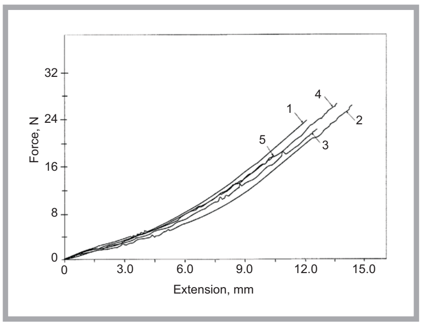

__Figure 2.__ Force-extension curves of the flax yarn 103 tex produced by wet spinning from boiled roving, tested in conditioned stage.

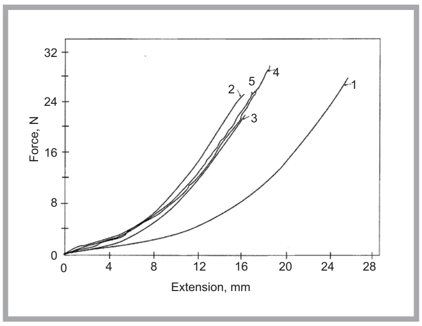

__Figure 3.__ Force-extension curves of the flax boiled yarn 103 tex, tested in wet stage.

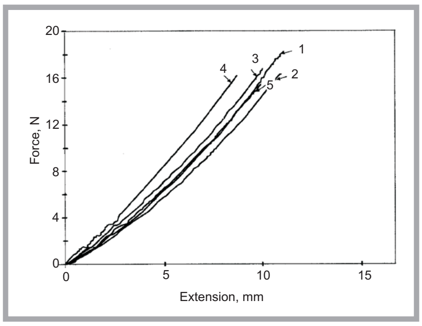

__Figure 4.__ Force-extension curves of the flax conditioned yarn 66.6 tex produced by wet spinning from bleached roving.

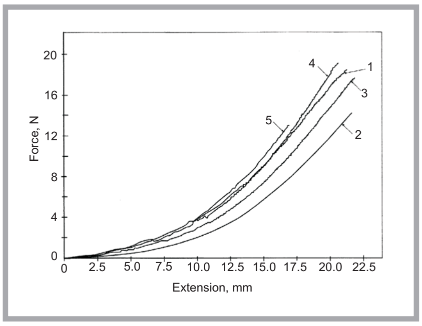

__Figure 5.__ Force-extension curves of the flax bleached yarn 66.6 tex tested in wet stage.

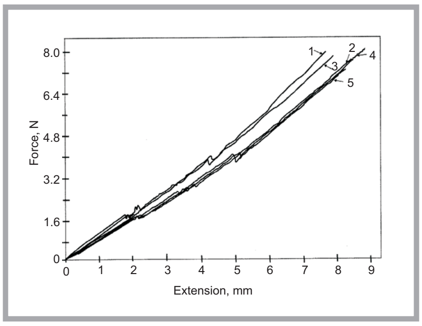

__Figure 6.__ Force-extension curves of the flax conditioned yarn 25.3 tex produced by wet spinning from bleached roving.

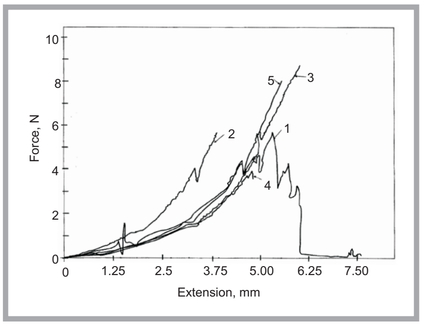

__Figure 7.__ Force-extension curves of the hemp conditioned yarn 100 tex produced by wet spinning from boiled roving.

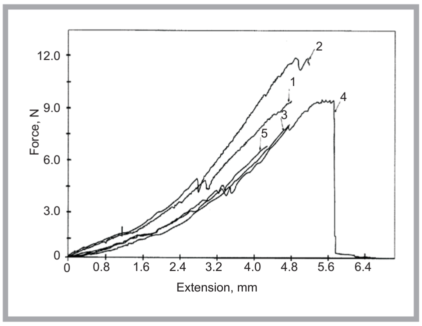

__Figure 8.__ Force-extension curves of the hemp boiled yarn 100 tex tested in wet stag.

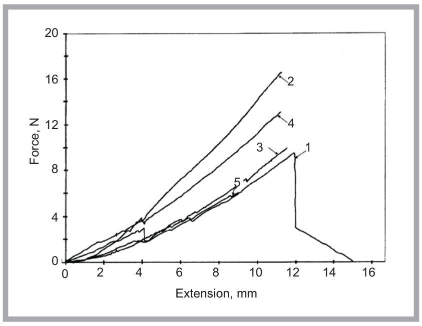

__Figure 9.__ Force-extension curves of the hemp conditioned yarn 93.5 tex produced by wet spinning from bleached roving.

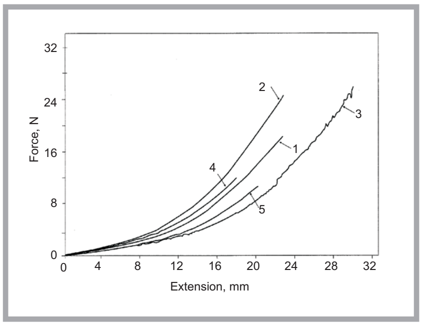

__Figure 10.__ Force-extension curves of the hemp yarn 93.5 tex produced by wet spinning from bleached roving, tested in wet stage.

the tenacity of the yarns tested in the dry and wet states were made:

- the breaking strength of yarn of 103 tex from boiled flax roving increases in the wet state by 14% in comparison with its strength in the dry state;
- the strength in the wet state of hemp yarn of 100 tex produced from boiled roving increases by almost 43% in comparison with that of dry yarn;
- the tenacity in the wet state in comparison with that in the dry state decreases by 30% in the case of yarn of 103 tex from boiled flax;
- the tenacity increases by 38% in the case of yarn of 100 tex from boiled hemp roving.

After one minute in water, bleached yarns of different fineness recorded the same mean degree of water permeation - 76%. (***Table 3***). The tenacity of bleached flax yarn of 66.6 tex decreases by over 30% in the wet state in comparison with that in the dry state. In the case of bleached hemp yarn of 93.5 tex, the tenacity increases by over 15% in the wet state in comparison with that of the same yarn tested in the dry state.

The various breaking behaviour in the dry and wet states can be related to a multitude of factors:

- internal structural transformation by water permeation;
- a different quantity of binding agents between fibres;
- different characteristics of the fibres of each type of yarn.

The analysis of the load-displacement curve allure made highlights structural transformations during the deformation of the flax and hemp yarns and fibres tested.

Behaviour of flax and hemp yarns in the proportionality area of the load and displacement

The form of the load-displacement curve shows that during stretching application

Table 4. *Limit of proportionality of flax and hemp yarns in dry and wet stage.*

Type of analysed yarn	Yarn stage in breaking time	Limit of proportionality					
		Minimum value		Maximum value		Mean value for five measures	
		Load σ, N	Displacement ε, %	Load σ, N	Displacement ε, %	Load σ, N	Displacement ε, %
Flax yarn 103 tex produced by wet spinning from boiled roving	dry yarn	1.6	0.24	4	0.98	2.7	0.5
	wet yarn	3	1.08	4	2.1	3.6	1.3
Flax yarn 66.6 tex produced by wet spinning from bleached roving	dry yarn	0.3	0.38	3	2.2	1.7	1.2
	wet yarn	1.9	1.25	1.9	1.7	1.9	1.4
Flax yarn 25.3 tex produced by wet spinning from bleached roving	dry yarn	0.16	0.005	0.4	0.06	0.29	0.04
Hemp yarn 100 tex produced by wet spinning from boiled roving	dry yarn	0.5.	1.16	1.1	1.9	0.8	1.6
	wet yarn	1.5	1.13	2.2	1.8	1.7	1.6
Hemp yarn 93.5 tex produced by wet spinning from bleached roving	dry yarn	1.1	0.4	2.4	0.8	1.7	0.6
	wet yarn	1.6	1.1	3.8	2.5	2.5	1.4

Table 5. *Tensile yield stress of flax and hemp yarns in dry and wet stage.*

Type of analysed yarn	Yarn stage in breaking time	Tensile yield stress					
		Minimum value		Maximum value		Mean value for five measures	
		Load σ, N	Displacement ε, %	Load σ, N	Displacement ε, %	Load σ, N	Displacement ε, %
Flax yarn 103 tex produced by wet spinning from boiled roving	dry yarn	3	0.5	8.8	1.4	5.2	0.9
	wet yarn	21.9	3.2	29.6	3.7	26.3	3.7
Flax yarn 66.6 tex produced by wet spinning from bleached roving	dry yarn	16.2	1.9	18.4	2.2	16.6	2.0
	wet yarn	1.9	1.3	17.4	4.3	9.9	3.0
Flax yarn 25.3 tex produced by wet spinning from bleached roving	dry yarn	1.7	0.4	4.1	0.9	2.4	0.6
Hemp yarn 100 tex produced by wet spinning from boiled roving	dry yarn	1.3	2.1	1.6	3.4	1.5	2.9
	wet yarn	4.4	2.8	4.7	3.6	4.5	3.2
Hemp yarn 93.5 tex produced by wet spinning from bleached roving	dry yarn	1.8	0.7	3.8	1.3	3.1	0.9
	wet yarn	3.5	1.9	25.0	4.5	15.8	4.0

Table 6. *Breaking strength of flax and hemp yarns in dry and wet stage.*

Type of analysed yarn	Yarn stage in breaking time	Maximum tensile load							
		Minimum value		Maximum value		Mean value for five measures		Coefficient of variation	
		Load σ, N	Displacement ε, %	Load σ, N	Displacement ε, %	Load σ, N	Displacement ε, %	CVσ, %	CVε, %
Flax yarn 103 tex from boiled roving	dry yarn	17.1	2.0	26.3	2.8	23.0	2.5	16.3	12.4
	wet yarn	21.9	3.2	29.6	5.1	26.3	3.7	10.9	20.6
Flax yarn 66.6 tex from bleached roving	dry yarn	15.4	1.7	18.4	2.2	16.6	2.0	6.7	9.1
	wet yarn	13.0	3.3	19.0	4.3	16.4	4.0	16.4	9.9
Flax yarn 25.3 tex from bleached roving	dry yarn	7.1	1.6	7.9	1.7	7.6	1.6	3.9	5.8
Hemp yarn 100 tex from boiled roving	dry yarn	3.9	3.9	8.7	6.04	6.4	5.13	30.4	15.7
	wet yarn	6.9	4.4	11.8	5.5	9.1	4.9	19.6	8.36
Hemp yarn 93.5 tex from bleached roving	dry yarn	5.9	1.7	16.5	2.3	11.0	2.1	36.2	11
	wet yarn	11.0	3.5	26.6	5.9	18.8	4.5	37.8	19.6

there is no instant elastic displacement (see ***Figures 2 - 10***). In the proportionality area, the yarn displacement is proportional to the load applied. In wet spun yarns, all the fibres are fixed together, which contributes to the yarn strength.

The behaviour of the test yarns in the proportionality area of the load-extension curve (***Figures 2 - 10***) is different in the wet state in comparison with that in the dry state. Thus, for the yarns tested in the wet state, in comparison with the dry state, there were recorded increases in load and longitudinal displacement corresponding to the limit of proportionality (***Table 4***).

The increases in the load along with displacement were smaller than in the case of the bleached yarns, as a consequence of the reduced quantity of binding substances. The highest mean value of the load at which it is proportional to the displacement was recorded in the wet state of flax yarn of 103 tex produced by wet spinning from boiled roving. This may be caused by the higher non-crystalline areas of fibres from boiled flax yarn and by the larger number of existent bindings between the non-crystalline and crystalline zones.

Behaviour of flax and hemp yarns in the flow area

The flow zone on the load-extension curve is characterised by a large displacement due to rather small loads (see ***Figures 2 - 10***). The slope of the load-extension curve has smaller values in this zone. At the tensile yield stress, the yarn tensions may determine the occuring of the first breaking fibres.

The load and displacement values corresponding to the tensile yield stress, presented in ***Table 5***, were quantified on load-extension curves recorded for each type of yarn analysed (***Figures 2 - 10***).

In the flow zone of boiled flax yarn of 103 tex and hemp yarn of 100 tex from boiled roving, the average load and displacement increase in the wet state in comparison with fibres in the dry state was higher in the case of flax yarn. The cellulose content of the yarn fibres and the occurrence of a great number of hydrogen bridges between hydrolytic groups may be taken into account.

The mean value of displacement in the wet state for the flow zone of bleached yarns has comparable values: 3 - 4% for both types of yarns (***Table 5***). In the case of the bleached hemp yarn tested in the dry state, the difference between the maximum and minimum displacement recorded is double in comparison with bleached flax yarn in the same stress conditions. This may represent the more rigid chemical structure of the flax yarns compared with the hemp yarns of the bleached yarn component tested.

The load and displacement which the first breaking destruction phenomena of the yarn fibres show are those corresponding to the tensile yield stress. Thus it is possible to establish the maximum tensions that the yarn could support without fibres breaking. In this way, flax yarn of 103 tex from boiled roving could support tensions without breaking during the manufacture process until 2.9 cN/tex in the dry state and 21 cN/tex in the wet state. In the case of bleached flax yarn of 66.6 tex, the yarn tensions must not be over 2.8 cN/tex during wet state processing, and 24 cN/tex in the dry state. For boiled hemp yarn during dry state processing, it is advisable that the yarn tension not be over 1.5 cN/tex. In the wet state this tension should be lower than 3.6 cN/tex. For the bleached hemp yarn studied, the maximum values of the tension could be 1.9 cN/tex for dry yarn and 3.7 cN/tex for wet yarn. These limits were established considering the minimum values of the tensile yield stress, (***Table 5***).

Behaviour of flax and hemp yarns in the breaking area

The breaking area of the load-extension diagram (***Figures 2 - 10***) is characterised according to the accelerated breaking phenomena of the macromolecular chains resulting in fibres breaking i.e. the yarn breaking. This breakage occurs in the weakst part of the stressed section. The load and displacement values corresponding to the tensile yield stress for the flax yarns analysed are presented in ***Table 6***.

During the breaking process, irreversible displacements take place between fibres as well as between the macromolecular chains of the fibre compounds, in which the yarn supports a higher load increase than the displacement increase (***Figures 2 - 10***).

The spiral structure of cellulose macromolecules changes its orientation due to water absorption and an increase in intermolecular forces, causing an increase in the strength of the test yarns in the wet state.

The values of the coefficient of variation of the yarn strength recorded were over 40% for boiled hemp yarn and over 30% for bleached hemp yarn, (***Table 6***), due to the large irregularity of the fineness and length of the hemp fibres.

For the yarns studied in the breaking area, the bleached flax and hemp yarns tested in the dry state have a minimum longitudinal displacement, the cause of which may be the reduced content of non-cellulose substances remaining in the fibres. The flax yarns analysed are more uniform and have a strength variation between 6 and 17%. In the breaking area displacements take place at the yarn fibre level, where massive breaking of the macromolecular chains of the internal structure resulted in the yarn breaking.

Analysis of the breaking mechanical work of flax and hemp yarns in the dry and wet states

The breaking mechanical work represents the energy necessary for yarn displacement up to the time of breaking. The area enclosed under the load-extension curve is a measure of this energy. Values of the breaking mechanical work for the flax and hemp yarns analysed are presented in ***Table 7***.

The energy necessary for displacement up to the breaking of flax and hemp yarns is higher in the wet state than in the dry (***Table 7***). This is a fact determined for all the types of yarns tested, no matter the yarn fineness. These phenomena can be as a consequence of the water absorption of yarn fibres, which modifies the internal structure of the fibres due to hydrogen bridges arising between the macromolecular chains.

Factor of mechanical work

The study of the mechanical work factor allows to appreciate the yarn capacity to

Table 7. *Mechanical work of breaking; *J, Joule, 1 J = 1 N · 1 m.*

Yarn coding	Yarn stage in breaking time	Mechanical work of breaking , J*					
		Minimum value		Maximum value		Mean value for five measures	
		Energy, J	Range of absolute deformation ε, mm	Energy, J	Range of absolute deformation ε, mm	Energy, J	Range of absolute deformation ε, mm
Flax yarn 103 tex produced by wet spinning from boiled roving	dry yarn	0.0746	0 - 10.3	0.1425	0 - 14.4	0.176	0 - 13.8
	wet yarn	0.1155	0 - 16.2	1.2760	0 - 25.6	0.1647	0 - 18.8
Flax yarn 66.6 tex produced by wet spinning from bleached roving	dry yarn	0.0659	0 - 28.0	0.0877	0 - 36.0	0.0742	0 - 32.6
	wet yarn	0.0699	0 - 16.9	0.1272	0 - 21.4	0.1052	0 - 20.4
Flax yarn 25.3 tex produced by wet spinning from bleached roving	dry yarn	0.0274	0 - 8.23	0.0239	0 - 8.89	0.0297	0 - 8.22
Hemp yarn 100 tex produced by wet spinning from boiled roving	dry yarn	0.0058	0 - 4.8	0.0152	0 - 6	0.0162	0 - 5.6
	wet yarn	0.0126	0 - 4.4	0.0273	0 - 9.4	0.0196	0 - 6.5
Hemp yarn 93.5 tex produced by wet spinning from bleached roving	dry yarn	0.0222	0 - 8.89	0.0768	0 - 11.2	0.0519	0 - 12.438
	wet yarn	0.0721	0 - 20.1	0.2231	0 - 29.68	0.1377	0 - 22.556

Table 8. *Factor of mechanical work.*

Type of analysed yarn	Yarn stage in breaking time	Factor of mechanical work		
		Minimum value	Maximum value	Mean value for five measures
Flax yarn 103 tex produced by wet spinning from boiled roving	dry yarn	0.377	0.422	0.399
	wet yarn	0.290	0.353	0.339
Flax yarn 66.6 tex produced by wet spinning from bleached roving	dry yarn	0.430	0.460	0.442
	wet yarn	0.291	0.322	0.310
Flax yarn 25.3 tex produced by wet spinning from bleached roving	dry yarn	0.463	0.484	0.470
Hemp yarn 100 tex produced by wet spinning from boiled roving	dry yarn	0.260	0,320	0.290
	wet yarn	0.330	0.459	0.398
Hemp yarn 93.5 tex produced by wet spinning from bleached roving	dry yarn	0.263	0.440	0.390
	wet yarn	0.281	0.344	0.318

support strains and deformations. Data centralisation regarding the mechanical work factor is presented in ***Table 8*** (see page 11).

The analysis of the factor of mechanical work (***Table 8***) allows the following conclusions to be drawn.

- The stretching behaviour of bleached yarns in the dry state approaches ideal behaviour according to Hooke's law. The mean value 0.47 of the factor of mechanical work of the thin flax yarn 25.3 tex, tested in dry stage is near to the same corresponding to the ideal behaviour according to Hooke's law.
- All the yarns tested in the wet state recorded a decrease in the mean deformation energy (ratio of mechanical work), showing deviations towards ideal behaviour. An exception was the hemp yarn of 100 tex produced from boiled roving.

The reduction into smaller values of the ratio of the mechanical work of bleached hemp yarn in the wet state can be explained by the existence of lignin in a higher proportion than in flax yarns. It is known that lignin is a chemical component which maintains an advanced orientation stage of the internal structure of the fibres [29].

Conclusions

In the case of the flax yarns studied: 103 tex, 66.6 tex, 25.3 tex and hemp yarns of 100 tex and 93 tex, the tenacity of all the fibres of the cross section contributes to the yarn strength. The strain of the mentioned yarns arises since the beginning of application of the axial tension. The form of the load-displacement curve shows that during the stretching, there is no instant elastic displacement.

For the bleached flax yarn 25.3 tex, tested in dry stage the experimental value of the factor of mechanical work tends to the theoretical value, for the ideal curve, according to Hooke's law. In this case, the load-displacement curve is a straight line, which crosses the axes origin and divides in two parts the entire area restricted by axes. The breaking mechanical work is given by the area enclosed under load-displacement curve. This area has half value of the surface restricted by axes. The theoretic mechanical work is given by the total area restricted by axes. The factor of mechanical work was calculated as a ratio between the real mechanical work and the theoretic mechanical work. This factor has 0.5 value for the ideal curve, according to Hooke's law.

Flax yarn of 103 tex from boiled roving could support tensions without breaking during the manufacture process until 2.9 cN/tex in the dry state and 21 cN/tex in the wet state. In the case of bleached flax yarn of 66.6 tex, the yarn tension must not be over 2.8 cN/tex during wet state processing, and 24 cN/tex in the dry state. For boiled hemp yarn during dry state processing, it is advisable that the yarn tension not be over 1.5 cN/tex. In the wet state this tension should be lower than 3.6 cN/tex. For the bleached hemp yarn studied, the maximum values of the tension could be 1.9 cN/tex for dry yarn and 3.7 cN/tex for wet yarn. It is advisable that adjustments to the machines that process the yarns be established so that the maximum yarn tension is smaller than the corresponding load of the tensile yield stress. Thus, one avoids yarn degradation because of yarns breaking.

For further processing in the wet state and the use of these yarns in a wet medium, it is important to know the deformation capacity of flax and hemp yarns after their water absorption. Hence, the tenacity of bleached flax yarn of 66.6 tex decreases by over 30% in the wet state in comparison with that in the dry state. In the case of bleached hemp yarn of 93.5 tex, the tenacity increases by over 15% in the wet state in comparison with that of the same yarn tested in the dry state. In a wet medium hemp yarns will have a good response.

Acknowledgments

The author is grateful to the staff of the Falticeni Spinning Mill (Romania) for supplying flax and hemp yarns.

References

1. *Dhakal H.; Composites Science and Technology, Vol. 67, No.7-8, 2007, pp. 16.*
2. *Ionescu-Muscel I.; Fibrele textile la sfarsit de mileniu, Editura Tehnica, Bucuresti, 1990, pp. 121.*
3. *Yuanjian T., Isaac D. R.; Composites Science and Technology, Vol. 67, No. 15-16, 2007, pp. 3300.*
4. *Muţje' P., Vatlejos M. E. et al.; Journal of Applied Polymer of Science, Vol. 102, No. 1, 2006, pp. 833.*
5. *Retegi A. et al.; Journal of Applied Polymer Science, Vol. 102, No. 4, 2006, p. 3438.*
6. *Gribincea V.; Fibre textile naturale, Editura Performantica, Iasi, 2007, pp. 139.*
7. *Sgriccia N.; Composites Science and Technology 67/9, 2007, pp. 1986.*
8. *Morley, N.; Advanced Composites Bulletin, - oct., 2007, p. 8.*
9. *Belletti G.; Selezione Textile, Vol. 45, No. 6, 2007, p. 30.*
10. *Tempesti A.; Selezione Tessile, Vol. 45, No. 4, 2007, p. 146.*
11. *Vallejos M. E., Lopez A., Mendez J. A. et al.; Revista de la Industria Tekstil -/456, 2008, p. 40.*
12. *Kostic M., Pejic B.,Skundric P.; Bioresource Technology, Vol. 99, 2008, p. 94.*
13. *Wilson A.; ATA Journal, Vol. 19, No. 3, 2008, p. 78.*
14. *Andersons J., Sparnins E., Porike E.; Journal of Composite Materials, Vol. 43, No. 22, 2009, pp. 2653-2664.*
15. *Andersons J., Sparnins E., Joffe R.; Journal of Materials Science Vol. 44, 2009, p. 57.*
16. *Andersons J., Porike E., Sparnins E.; Composites Science and Technology Vol. 69, 2009, pp. 2152-2157.*
17. *Bos H.., Oever V.., Peters O. C. J. J.; Journal of Materials Science, Vol. 37, No. 8/April, 2002, pp. 1683-1692.*
18. *Madsen B., Hoffmeyer P., Thomson A. B., Lilholt H.; Composites Part A: Applied Science and Manufacturing, Vol. 38, Issue 10, October, 2007, pp. 2194-2203.*
19. *Cierpucha W., Kozlowski R., Mankowski J., Wasko J., Mankowski T.; Fibres & Textiles in Eastern Europe, July/October, Vol.12, No. 3(47), 2004, pp. 13-18.*
20. *Czekalski J., Jackowski T., Krucinska I.; Fibres & Textiles in Eastern Europe, No. 2, 2000, pp. 24-28.*
21. *Curtin W. A.; Journal of Composite Materials, Vol. 34(15), 2000, p. 1301.*
22. *Schilling E.; Botanik and Kultur des Flachses. Technologie der Textilfasern, Vol. 5, Berlin, 1930, citated by N. Ceapoiu, 1958, p. 75.*
23. *Ceapoiu N.; Canepa, Studiu monografic, Editura Academiei, Bucuresti, 1958, p. 22.*
24. *Mustata A., Avram D., Slabu V.; Fibres and Textiles in Eastern Europe, Vol. 14, No. 3(57), 2006, pp. 29-32.*
25. *Mihailovic T. V.; International Journal of Clothing Science and Technology, Vol. 18, Issue 2, 2006, pp. 70-82.*
26. *Mustata A., Ph.D. Thesis, Technical University of Jassy, 1991, pp. 123.*
27. *Sedelnik N., Zareba S., Szporek J., Fibres & Textiles in Eastern Europe, January/ March, Vol. 14, No. 1 (55), 2006, pp. 22-26.*
28. *SR EN ISO 139/2005. Materiale textile. Atmosfere standard de condiționare şi incercare.*
29. *Mâlcomete O. et. al.; Cap. 1.2. Proprietatile generale ale fibrelor textile, din Manualul inginerului textilist, Vol. 1, (The Book of the Textile Engineer), AGIR Edition, Bucharest, 2003, pp. 54-55.*
30. *SR ISO 6741-1/1998. Umiditate.*

Received 22.04.2009 Reviewed 14.12.2009