RESEARCHES CONCERNING THE WOVEN FABRICS BEHAVIOR UNDER AXIAL TENSILE STRESS

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REZUMAT. În această lucrare se studiază influența caracteristicilor de structură asupra comportării țesăturilor la solicitări de întindere axială. Parametrii de structură, care au fost modificați pe parcursul programului experimental, sunt finețea firelor de bătătură și desimea in bătătură. Evaluarea comportării țesăturilor s-a efectuat prin analiza și interpretarea modului in care au variat indicatorii specifici: forța de rupere, alungirea la rupere, lungimea de rupere, rezistența specifică, coeficientul de utilizare a forței de rupere a firului in forța de rupere a țesăturii, diagramele forță-alungire și modulul de elasticitate. Indicatorii folosiți la analiza și interpretarea rezultatelor permit o apreciere corectă și completă a comportării țesăturilor la solicitări de întindere. Acest gen de evaluare este recomandat pentru țesăturile cu destinație tehnică (dar nu numai), care în timpul utilizării sunt supuse la solicitări de tensionare și au funcții impuse în acest sens.

Cuvinte cheie: fire tip bumbac, desimea bătăturii, forța de rupere a țesăturii, alungirea țesăturii, modul de elasticitate.

ABSTRACT: The paper studies the influence of the main structure characteristics on woven fabric behavior under axial tensile stress. The structure characteristics which have been modified within the experimental program are the fineness of weft yarns and the weft density. Woven fabric behavior was evaluated by controlling the modifications of all the specific indicators: breaking force (warp and weft directions), elongation, breaking length, specific resistance, coefficient of utilization of yarn load within the fabric load, the stress-strain diagram, and the woven fabric elastic modulus. The indicators used for analysis and interpretation of the results allow a correct and complete evaluation of woven fabrics behavior under axial tensile stress. This type of evaluation is recommended for technical textiles (but not only for them), because during utilization they are highly tensed, that is why they have imposed functions in this regard.

Keywords. type cotton yarns, weft density, fabric breaking force, fabric elongation, elastic modulus.

1. INTRODUCTION

A major problem of textile engineers' concern is designing fabrics according to their exploitation properties. Structural characteristics chosen by the specialist must lead to the realization of a product whose utilization value must satisfy customer's requirements.

During the exploitation, most of the fabrics are subjected to axial or biaxial elongation under simple or repeated strain stress. The stress level can be close to the breaking force or to smaller values. It is mandatory that the designer anticipate textile behavior to such stresses. Fabric tensile properties are not only determined by the properties of the constituent yarns, but also by the structure geometry, weaving conditions, finishing treatments and many other factors .

Besides these factors, the specialists also investigated the manner in which the tensile stress is applied (as deformation mechanism) under the conditions of axial, biaxial or random stress at small values of the applied stress or near the breaking force, studying the way in which the breakage appears and propagates.

All these aspects have been studied on geometrical or mechanic-geometrical models, and a series of theories on the mechanisms resulting in textile tensile destruction have been elaborated. Behavior to axial tension differs in terms of direction, because the textile fabric is anisotropic and asymmetrical [1] [2].

Any stress in a direction differing from the warp or weft direction implies another deformation mechanism. For example, the stress acting along a direction that makes an angle of 45° with warp or weft is a gliding stress, because no yarn from the superior clamp reaches the inferior clamp.

Table 1. **Structural characteristics for woven fabrics**

Variant	Nm_u	Nm_b	Warp yarns density, yarns/10cm	Weft yarns density, yarns/10cm				Weave
				1	*2*	*3*	*4*	
I	50/2	20/1	220	200	180	160	120	plain
II	50/2	27/1	220	200	180	160	120	plain
III	50/2	34/1	220	220	200	180	160	plain

In principle, the tensile stress occurs according to the following stages:

- in the first stage, the stress applied to the woven fabric is consumed in some re-arrangements and frictions between yarns and fibers;
- changes in textile geometry follow; yarns from stress direction gradually diminish their crimping degree until they straighten, while the yarns from the opposite direction crimp to a maximum degree;
- during the last stage of the stress, the yarns on the tested direction stretch to destruction; in this stage is consumed the biggest part of the stress.

During the second part of the stress, the structural geometric modifications occur with certain energy consumption, similar to that from the formation of textile element. This consumption can be more or less significant in relation with the breaking strength; yet, one cannot neglect them, because the modifications in structure geometry are significant [1], [6].

2. MATERIALS AND METHODS

This paper contains the study of the influence exerted by yarns count and weft density on textile behavior under axial stress. In the *Table 1* there are shown the structural characteristics of the fabrics obtained by applying the experimental program. The weft yarns from which the presented variants were produced were spun from the same cotton batch, their characteristics being presented in *Table 2*.

All variants of woven fabrics were subjected to axial tensile stresses. Determinations were made according to international standards on stripes having 5 cm width, at an initial distance of 200 mm between clamps.

It was used a METEFEM dynamometer, the moving clamp speed was set at 120mm/min. By using this equipment, it was drawn the strain-stress diagram for each variant of woven fabric [3].

Table 2. **Characteristics of the weft yarns**

No.	Nm	Twist, twists/m	*CV*, %	Breaking force, cN	*CV*, %
1	20/2	537	4.4	573	13.68
2	27/2	701	4.9	456	12.30
3	34/2	650	6.8	321	10.90

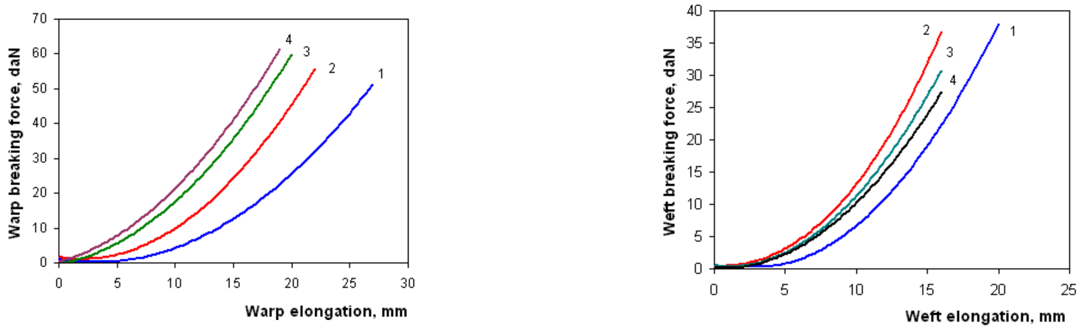
Table 3 presents the values of breaking force (Fr, daN), relative breaking elongation (Al, %), breaking length (Lr), specific breaking load (Rs), coefficient of yarn load utilization within the textile load (C), and tangential elastic modulus of woven fabric (E).

Table 3. **Experimental values of woven fabrics characteristics**

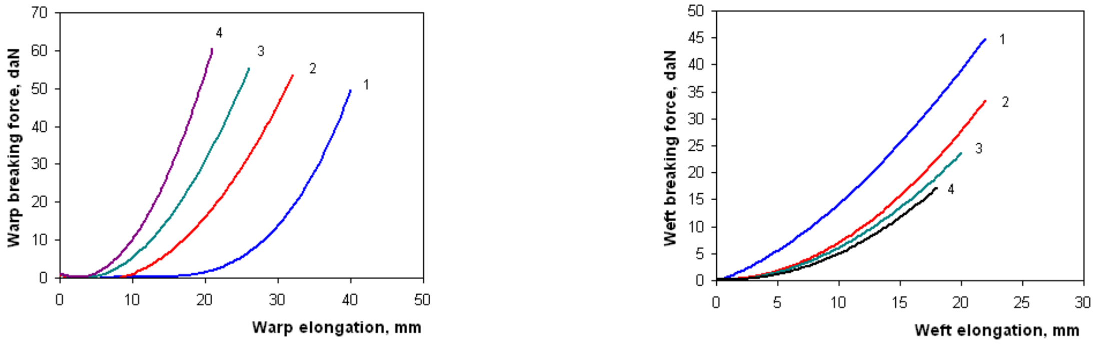
Nm	P_b / Parameter	220		200		180		160		120	
		Warp	*Weft*	*Warp*	*Weft*	*Warp*	*Weft*	*Warp*	*Weft*	*Warp*	*Weft*
20	Breaking force	-	-	48.83	62.12	50.90	51.18	53.46	47.41	54	36.53
	Elongation	-	-	23.16	12.05	23.30	10.65	20.15	10.65	15.27	9.33
	Lr	-	-	4.23	5.54	4.64	4.67	5.29	4.69	5.65	4.10
	Rs	-	-	-	12.47	-	11.37	-	11.82	-	12.17
	C	-	-	-	1.087	-	1.061	-	1.061	-	1.033
	Modulus *E*	-	-	1.38	1.65	1.42	1.32	1.88	1.31	1.94	1.03
27	Breaking force	-	-	57.03	51.64	56.83	41.16	59.57	35.18	59.03	23.25
	Elongation	-	-	21.27	13.05	18.16	11.72	16.30	10.15	13.25	8.25
	Lr	-	-	5.57	5.13	6.11	4.42	6.90	4.40	7.50	2.90
	Rs	-	-	-	13.95	-	12.36	-	11.88	-	10.47
	C	-	-	-	1.14	-	1.016	-	0.977	-	0.86
	Modulus *E*	-	-	1.6	1.60	1.69	1.37	1.84	1.30	1.94	0.98
34	Breaking force	57	43	58.87	36.31	58.20	30.44	59.67	28.16	-	-
	Elongation	17.8	11.77	15	9.23	13.90	8.85	12.50	8.05	-	-
	Lr	6.1	4.63	6.80	4.20	6.84	3.58	7.20	3.61	-	-
	Rs	-	13.41	-	12.34	-	11.30	-	11.96	-	-
	C	-	1.22	-	1.14	-	1.054	-	1.096	-	-
	Modulus *E*	1.79	1.66	1.88	1.83	1.86	1.53	2.08	1.38	-	-

Following data processing, the regression equations that model the dependence of load, elongation and modulus on weft yarn count are written.

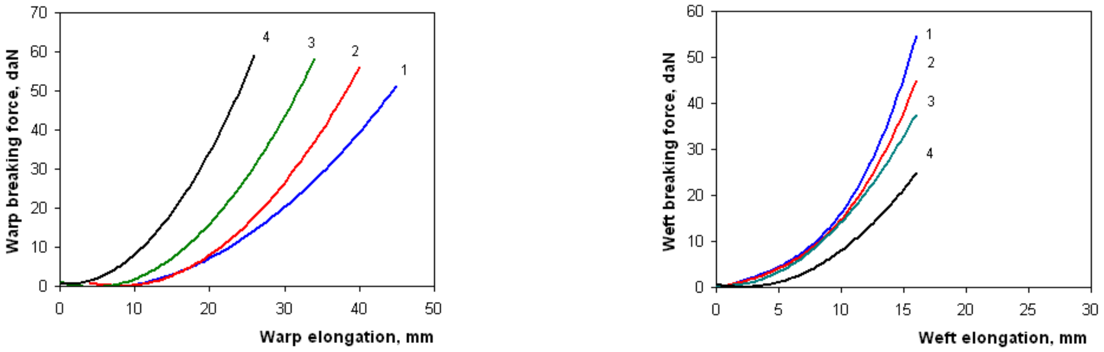
Figures 1, 2, 3 and *4* illustrate the aspect modification of the stress-strain curve vs. yarn count, as well as the graphic representations of the regression equations.



a. Nm$_b$ 34



b. Nm$_b$ 27



c. Nm$_b$ 20

Fig. 1. Aspect modification of stress-strain curve vs. weft density.

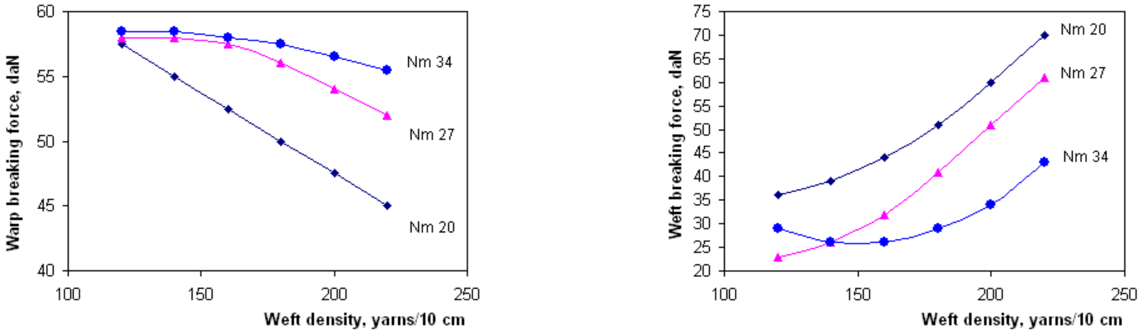


Fig. 2. Graphical representation of regression equations for fabric breaking force.

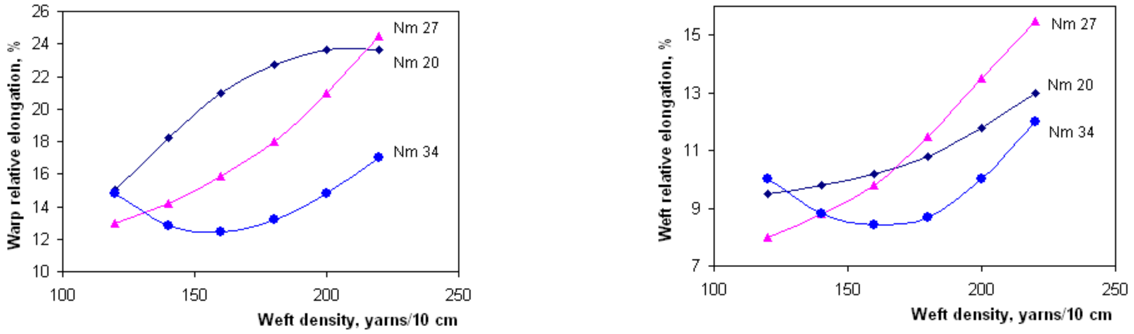


Fig. 3. Graphical representation of regression equations for fabric relative elongation.

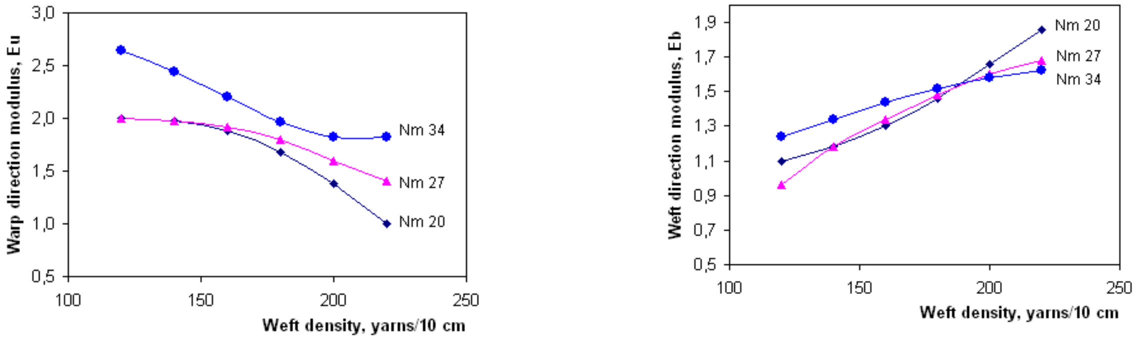


Fig. 4. Graphical representation of regression equations for fabric elastic modulus .

3. RESULTS AND DISCUSSIONS

As the result of the presented graphics and experimental data, there can be mentioned the following interpretations:

- Breaking force in the warp direction decreases when the weft density increases. The decrease is insignificant, of only 3% at Nm 34 and 27, and 9.5% for Nm 20. The explanation is related to the fact that warp tension increases at high densities. The cyclic stress at high tensions determines warp yarn fatigue. This phenomenon is more significant at Nm 20 because the weft density of 200 yarns/10cm is obtained with much higher stresses.
- The breaking force in the weft direction also increases, but not to the same extent for all the yarns, even if the weft density increase is the same. The increase is of 41% at thicker yarns Nm 20 and 27, and of 35% at Nm 34.
- At the same time, the coefficient of yarn load utilization increases at all the variants, and it has the biggest increase, of 24%, at Nm 27. The explanation consists in the fact that the variant with Nm 27 and density of 200 yarns/10 cm is the most balanced of all woven variants (P_u=200 yarns/10cm, Nm_u = 50/2).
- As one can see from the graphical representation, even if at the density of 120 yarns/10 cm the variants with Nm 20 and 27 are more spaced, at the maximum value of 200 yarns/10 cm the curves get closer to each other due to a better load utilization coefficient at the variant Nm 27.
- Breaking relative elongation increases on both warp and weft direction. It increases on the warp direction, first of all because the frequency of yarns crimping increases, and it increases on the weft direction due to the decrease of the number of structure phase from 6.17 to 4.5. This decrease means the increase of weft wave height. The modification of the aspect of stress-strain curve from the variants with higher count to those with smaller count is obvious in figure 1 a, b, c.
- Fabric modulus calculated as the slope of the tangent to the curve in the linear zone can be considered as the indicator which characterizes fabric behavior at this type of stress at the most general mode. *Figure 3* gives a graphical representation of the regression equations that model the modulus dependence on weft count. One can see clearly that the modulus in warp direction decreases with yarn count, because the warp crimping degree increases. The effort consumed to stretch the warp is bigger if the warp is more crimped.

Modulus in the warp direction is bigger at the variants with thinner weft yarn.

In *Figure 5*, which presents the stress-strain diagrams in warp direction for fabric variant with Pb = 180 yarns/10cm and Nm_b 34, 27, 20, one can notice very different behaviors.

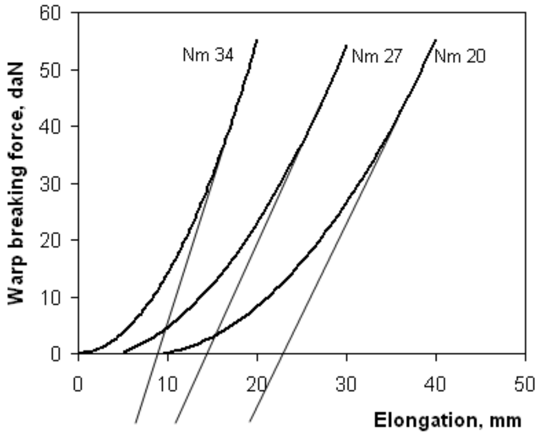


Fig. 5. Stress-strain diagrams in warp direction of the woven fabric.

Even if the load is the same, both elongations and modulus differ very much. The bigger modulus E is obtained for the variant with the thinnest weft yarn. Therefore, the utilization of a thicker weft yarn determines a diminution of modulus in warp direction. The stress consumed to straighten the warp yarns is bigger when the weft yarn is thicker.

Modulus on weft direction increases because the load increases, even if the elongation decreases. The increase of modulus in the weft direction is smaller at Nm 34, because the load increase is smaller for this yarn.

Related to the way in which yarn breakage occurs, it can be noticed a clear difference between the variants with bigger densities and those with smaller ones. At big values, there is a sudden strong breakage, which means that the effect of yarn unevenness disappears. At variants with smaller densities, there are isolated yarn breakages and a breaking area which growths until the catastrophic breakage. Depending on product destination, this can be very useful information [3] [4].

4. CONCLUSIONS

1. Fabric behavior under axial tensile stress can be completely estimated if one knows all the indicators for the estimation of this type of stresses.
2. Woven fabric modulus is a parameter that defines the tensile behavior in the most general manner, being important for both technical fabrics and common fabrics (for example those used for making clothes).
3. Yarns' fineness and weft density are structural characteristics that influence fabric behavior to such stresses, not only along one direction, but also as a whole ensemble.
4. For certain technical fabrics, the manner in which the breakage occurs is very important, and the structural characteristics, such as yarns density (especially) and fineness, have a deciding influence.

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