BREAKING PROPERTIES OF DIFFERENT COTTON FABRICS AS AN IMPORTANT PREREQUISITE FOR THEIR PRACTICAL USE

DJORDJEVIC Suzana[1], MICIC Aleksandra[2], KRSTIC Radica[3], DJORDJEVIC Dragan[4]

[1,2] Higher Technological and Artistic Professional School Leskovac, Textile Department, Vilema Pusmana 17, 16000, Leskovac, Serbia, E-Mail: szn971@yahoo.com

[3,4] University of Nis, Faculty of Technology, Textile Department, Bulevar oslobodjenja 124, 16000, Leskovac, Serbia, E-mail: drdrag64@yahoo.com

Corresponding author: DJORDJEVIC, Dragan, E-mail: drdrag64@yahoo.com

Abstract: *In this paper, the ability of fabrics of different weaves and approximate fineness and density of threads to resist external forces of stress and deformation was investigated. An analysis of the influence of fabric construction on load behavior, i.e. on the behavior in use where the fabrics will be exposed to different types of stresses, is given. Two fabrics in plain and satin weaves were used. It was found that the structure and construction of fabrics directly affect the behavior during external stretching. The fabric in the plain weave has higher values for breaking strength and breaking elongation compared to the fabric patterns in satin weave. The pattern in the atlas weave has higher values for breaking elongation, which is related to the structure of the intertwining of the warp and weft and the residual stresses in the fibers, i.e. yarn. The fabric in the plain weave has higher values for the modulus of elasticity in both directions compared to the fabric in satin weave, which means that the initial deformation of the fabric in the plain weave requires a higher applied force compared to the fabric in satin weave. According to the results of work of rupture, the fabric in satin weave showed higher resistance to deformations compared to the fabric in plain weave. By modeling the force-elongation curve, using the second-order polynomial model, a very good coverage-fitting of the experimental data for both fabrics in the warp and weft direction is determined. Based on the model equations, the behavior of the same or similar fabrics in terms of mechanical characteristics can be predicted with sufficient reliability without practical measurement of breaking force and breaking elongation.*

Key words: *cotton, plain weave, satin weave, mechanical properties, work of rupture, modulus of elasticity.*

1. INTRODUCTION

The production of fabrics in the world is constantly growing due to increasing consumption, which is the main reason for the increased standard of clothing. Extended consumption purposes should be added here, such as household equipment, technical purposes, or industrial needs [1].

The structure of the fabric depends on its purpose. It is determined by several structural parameters, such as: raw material composition, types and properties of applied yarns, width and length, thread density of individual yarn systems, contraction of warp and weft threads, weight of running meters and square meters of fabric, etc. [2, 3].

Mechanical processing of fabrics must enable dimensional stability, constant mass, appropriate density, strength, and elasticity, required surface appearance, feel and similar properties.

Chemical finishing of fabrics, on the other hand, gives color fabrics, visual effects, beauty, changed the desired appearance of the surface, wearing comfort, softness and stiffness, fullness, heaviness, etc. [4, 5].

Accurate prediction of fabric properties is a very complex issue that can be difficult to solve without simplification. The complexity of the problem stems from the fact that the properties of the fabric depend on the construction and technological parameters. Construction parameters include fineness and properties of warp and weft threads, warp and weft density, and weaves. Technological parameters are the type of weaving loom and weaving conditions, i.e. the tension of the warp and weft, the speed of picking, the force of beating-up motion, etc. [6, 7].

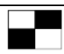
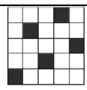
By comparing the results of the breaking characteristics of cotton fabrics in this paper, the behavior and ability of fabrics of different weaves and similar fineness and density of threads to resist external forces of stress and deformation were investigated. An attempt to explain the influence of the constructive solution of fabrics on the load behavior is presented, i.e. on the behavior in use where the fabrics will be exposed to tensile forces. The structure and construction of the fabric directly affects the behavior under various external factors, i.e. as diameter, thickness, density, etc. so the weaves react to the external load.

2. EXPERIMENTAL PART

2.1 Materials

In this paper, raw fabrics were used, made of 100% cotton yarn with close values for fineness and thread density in the direction of the warp and weft, but with different weaves. The basic properties of the tested fabrics are shown in Table 1.

Table 1: *Nominal values of basic properties of cotton fabrics*

Thread linear density (tex)		Thread density (cm^{-1})		Fabric weight ($g \cdot m^{-2}$)	Weaves
Warp	Weft	Warp	Weft		
30	20	31	23	192	Plain 
31	19	29	23	178	Satin 

2.2 Methods

In order to determine the behavior of cotton fabrics under the action of forces that deform its structure, affecting the structural, mechanical and other properties of cotton material, the basic mechanical characteristics were analyzed: breaking force (F) and elongation (ε), according to SRPS ISO 5081; work of rupture, after integration of the deformation curve F–ε, with the help of mathematical software OriginPro; modulus of elasticity, E, by graphical method with the help of mathematical software OriginPro.

Each result of the examined parameter is the average value of 10 measurements for each fabric.

3. RESULTS AND DISCUSSION

Plain weave is the simplest and densest in the fabric (the most closed weave). The appearance of the fabric is the same on both sides of the fabric, i.e. the fabric is with two faces.

Satin is a weave in which the binding points do not touch each other, they are correctly distributed so that the surface of the fabric is smooth and even. There is a weft and a warp satin, based on which of the thread systems floats on the face of the fabric.

Tables 2 and 3 show the results for the breaking force and elongation of the analyzed fabrics. The breaking force in the plain weave in the direction of the warp and weft has the highest mean numerical value of 201 and 158 N, respectively. The cotton fabric in the satin weave has lower values of this mechanical indicator in both directions, for the warp direction it is 190 N, while for the weft direction the breaking force is 145 N.

According to statistical indicators, it can be stated that the results are fairly even, a slight advantage in uniformity is given to the fabric in the plain weave. There seems to be a lot of latent stresses in the fabric which relax under the action of the tearing force, causing greater variations in the measurement results [8].

Since the fabrics have very similar values of thread fineness and density, these differences in the results for the breaking force come from the weaves. This would be more visible if other types of weaves were taken for comparison.

The research also indicated that the breaking force is also affected by the distribution of binding points in the weave rapport, but the correlation of these parameters has not been determined with certainty due to the limited number of weaves with smaller weave rapport.

Table 2: *The results of the breaking force of fabrics in different weaves*

Statistical parameters	**Breaking force F, N**			
	Plain		**Satin**	
	Warp	**Weft**	**Warp**	**Weft**
Mean value, N	201	158	190	145
Standard deviation, SD, %	5.37	4.12	4.31	4.82
Coefficient of variation, Cv, %	2.67	2.61	2.27	3.32

According to Table 3, the breaking elongation of fabrics in all weaves varies from 6.9% (warp direction, plain weave) to 7.9% (weft direction, satin weave). The pattern in the satin weave has higher values for breaking elongation, which is primarily related to the structure of the interweaving of the warp and weft, although residual stresses in the fibers or yarns may also be affected.

The standard deviation for the results of breaking elongation varies from 0.37% (weft direction, satin weave) to 0.43% (weft direction, plain weave). The coefficient of variation has higher numerical values for all tested samples compared to the results for the breaking force and ranges from 4.63% (weft direction, satin weave) to 6.11% (warp direction, plain weave).

Table 3: *The results of breaking elongation of fabrics in different weaves*

Statistical parameters	**Breaking elongation ε, %**			
	Plain		**Satin**	
	Warp	**Weft**	**Warp**	**Weft**
Mean value, N	6.9	7.2	7.4	7.9
Standard deviation, SD, %	0.42	0.43	0.40	0.37
Coefficient of variation, Cv, %	6.11	5.98	5.40	4.63

Figure 1 shows the diagrams of the breaking force (F) – breaking elongation (ε) in the direction of the warp, the diagram in the direction of the weft is not shown. It is about the so-called deformation curves that explain the reaction of the fabric to elongation, i.e. on external deformations. At the beginning of stretching, both fabrics in different weave have a small increase in breaking force with increasing elongation, and later after 2.5% elongation there is a sharp increase in breaking force from 20 to 200 N.

The deformation curves differ in part in the right portion of the diagram, i.e. there is a separation of curves. In that part of the diagram, for the range of change of breaking elongation from 4.5 to 7%, there is a situation that a larger change of breaking elongation causes smaller changes of breaking force, which is especially noticeable with fabric in satin weave. This is particularly evident at the end of the deformation curve, after a breaking elongation of 6%. The reason should be sought in the type of weave, the number of bonding points, but also in the latent stress, the origin of the fibers and the accompanying substances and impurities present.

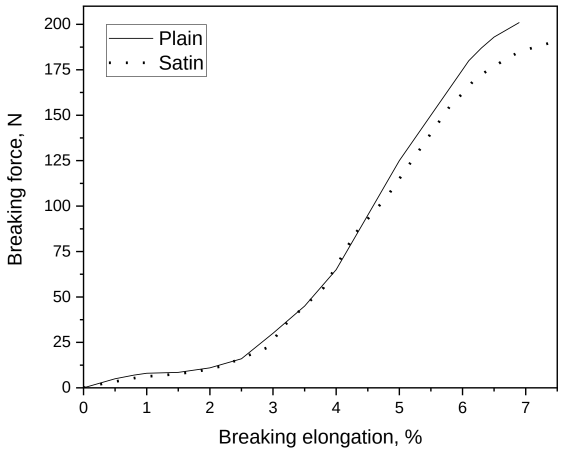


Fig. 1: *Deformation curves of the analyzed fabrics in the warp direction*

Table 4 shows the data for the modulus of elasticity of the used cotton fabrics by warp and weft direction. Also, the straight-line equations defined by the expression $\sigma = E \times \varepsilon$ are shown here. This expression in the mathematical sense represents an equation in which the modulus of elasticity is the coefficient of the direction of the linear part of the straight line (slope).

According to the results from Table 4, it can be noticed that the fabric in the plain weave has ~~the~~ higher values for the modulus of elasticity in both directions. This means that for the initial deformation of the fabric into the plain weave, a greater applied force (stress) is necessary compared to the fabric in the atlas weave.

Table 4: *Analytical expressions and calculated values of modulus of elasticity*

Weave		**Equation of a straight line in the region of elastic deformations**	**Coefficient of determination R^2**	**Modulus of elasticity, E, kPa**
Plain	Warp	$\sigma = 0.40 \cdot \varepsilon$	1	400
	Weft	$\sigma = 0.25 \cdot \varepsilon$	1	250
Satin	Warp	$\sigma = 0.30 \cdot \varepsilon$	1	300
	Weft	$\sigma = 0.24 \cdot \varepsilon$	1	240

Figure 2 shows a histogram of the results for the work of rupture of cotton fabrics of different weaves. Less work of rupture also means less resistance of fabrics to external deformations, i.e. to breaking elongation in this case. According to the results from this histogram, the fabric in satin weave has greater resistance to deformation in both directions of threads, although at the same time, it should be noted that the fabric in this weave has less breaking force in both directions, compared to fabric in plain weave. Thus, for example, in the warp direction, the fabric in satin weave has a 5.79% lower breaking force than the fabric in the plain weave in the same direction, but because it has a higher work of rupture by 12.84%. A similar result was found for the threads system in the weft direction.

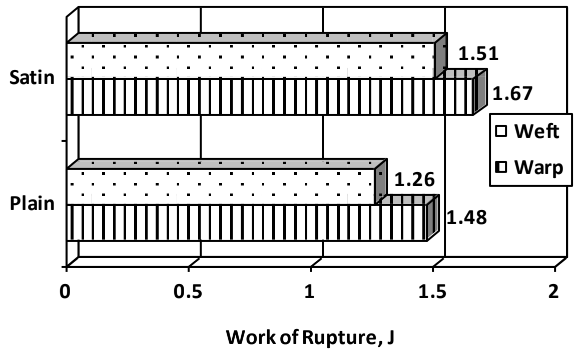


Fig. 2: *Work of rupture of cotton fabrics in different weaves*

Deformation curves, after nonlinear fitting of the breaking force–breaking elongation dependence, are presented by the diagram in Figure 3. This diagram can also be called a scatter diagram because it allows a pictorial representation of whether there is a relationship between the variables x and y or not, as well as its character and intensity.

Based on the appearance of the scattering diagram in Figure 3, it is concluded that it is a nonlinear dependence of variable parameters. It is a statistical (stochastic or random) dependence, which, based on experimental data, is expressed using a regression equation (approximate curve) or a second-order polynomial, in this case.

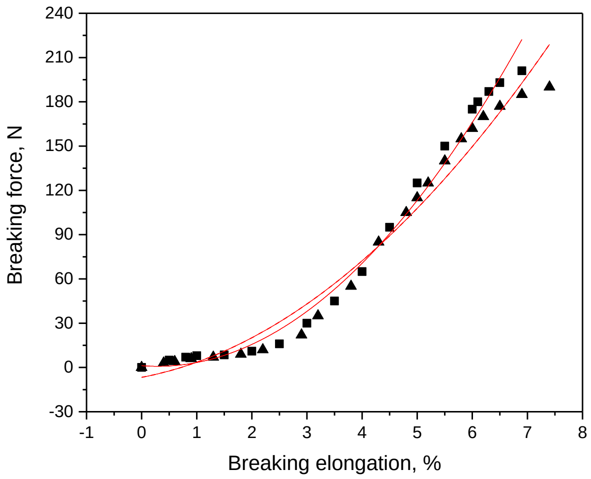


Fig. 3: *Deformation curves after nonlinear fitting in the warp direction*

Table 5 presents data related to the appearance of the second degree polynomial equations which very well describe the relation breaking force–breaking elongation for each of the examined fabrics of different interweaving in the direction of warp and weft. A good measure of the adequacy of a polynomial model is confirmed by the coefficient of determination, R^2.

Based on these equations, the behavior of the same or similar fabrics in terms of mechanical characteristics can be predicted with sufficient reliability without practical measurement of breaking force and breaking elongation.

Table 5: *Analytical expression of second-degree polynomials for modeling of deformation curves*

Weaves		**Second degree polynomial equation**	**Coefficient of determination, R^2**
Plain	Warp	$F = 1.22 - 2.93 \cdot \varepsilon + 5.07 \cdot \varepsilon^2$	0.988
	Weft	$F = -1.06 + 1.29 \cdot \varepsilon + 3.18 \cdot \varepsilon^2$	0.989
Satin	Warp	$F = -6.69 + 7.10 \cdot \varepsilon + 3.16 \cdot \varepsilon^2$	0.974
	Weft	$F = -6.48 + 11.64 \cdot \varepsilon + 1.17 \cdot \varepsilon^2$	0.987

5. CONCLUSIONS

From the obtained results, it can be concluded with certainty that the resistance to deformation of two cotton fabrics of different weave and other similar structural characteristics depends on several factors, primarily on the type of weave but also probably on residual stresses from the weaving process, origin of cotton fibers, impurities and dirt, etc.

All this should be considered when making new items as well as when choosing a fabric with a suitable weave for a special purpose where the ability of the woven pattern to withstand external stress forces should be demonstrated.

REFERENCES

[1] Z. Penava, D. S. Penava, Z. Knezic, *"Woven Fabrics Behavior in Pure Shear,"* J. Eng. Fiber Fabr., vol. 10, pp. 114-125, 2015.

[2] I. Jahan, *"Effect of Fabric Structure on the Mechanical Properties of Woven Fabrics,"* Adv. Res. Tex.t Eng., vol. 2, pp. 1-4, 2017.

[3] K. Nassar, A. A. Dawoud, *"Work of rupture as an indicator to abrasion resistance property of selected woven fabrics,"* IJARSE, vol. 5, pp. 69-83, Jan. 2016.

[4] B. Witkowska, I. Frydrych, *"A Comparative Analysis of Tear Strength Methods,"* Fibres Text. East. Eur., vol. 12, pp. 42-47, April/June 2004.

[5] C. Dongsheng, L. Hong, Z. Qiaoling, W. Hongge, *"Effects of Mechanical Properties of Fabrics on Clothing Pressure,"* Przeglad Elektrotechniczny, vol. 89, pp. 232-235, 1b/2013.

[6] Z. Penava, D. S. Penava, Z. Knezic, *"Determination of the Elastic Constants of Plain Woven Fabrics by a Tensile Test in Various Directions,"* Fibres Text. East. Eur., vol. 22, pp. 57-63, 2014.

[7] E. M. Abou-Taleb, *"Fabric toughness as an indication to clothing durability for selected blend pet and cellulosic fiber fabrics,"* IJESMR, vol. 5, pp. 1-7, Nov. 2014.

[8] S. H. Eryuruk, F. Kalaoglu, *"The effect of weave construction on tear strength of woven fabrics,"* Autex Res. J., vol. 15, pp. 207-214, Sept. 2015.