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Influence of the Elastane Fibre on the Woven Fabric Structural Mobility

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The woven fabrics structural mobility has some influence on the garment design and pattern construction. Deformation peculiarities during six textile fabrics extension were analysed in this work. Four of the tested fabrics had the elastane filaments in their structure. The method of parallelepiped shaped specimen uniaxial extension till fixed strain was used. The experiment was carrying out using a "Tinius Olsen HT10" tension machine. The specimens' deformation exceeds 14 %. The parallelepiped shape of specimen's was received by cut of its top and bottom edges with pitch of 16 degrees. The woven fabrics structure mobility was analyzed using strain-stress curves, numerical and graphical results. The results of this research work have shown that deformation peculiarities of the woven fabrics depend on their structural characteristics: density, thickness, wave and presence of elastane filaments. Taking into account the more considerable extensibility of elastane fibre the shearing phenomenon was not occurred finally during specimens' deformations. The results indicated that for the tested fabrics deformation till stated degree the force from 0.6 N till 9.4 N is necessary.

Keywords: elastane yarns, woven fabrics, structural mobility, extension, shear.

1. INTRODUCTION

The comfortable properties, performance factors of clothing and fitting to human body are very important for the wearer. Therefore fabrics with higher elasticity are more desirable for clothing designers and manufactures. In recent years the use of woven and knitted fabrics with elastane fibers has increased sharply. The elastane fibre containing at least 85 % polyurethane is capable of high stretch followed by rapid and substantial recovery to its unstretched length.

The elastane yarns can be: 1) twist with warp or weft yarn; 2) assembled with warp or weft yarn; 3) twist with warp and every second weft yarns; 4) twist with weft and every second warp yarns and etc. The elastane fiber is more resistant to aging than rubber and finer yarn is available. Since considerably resistant to high temperature, a heat setting can be achieved with other fibers simultaneously. However elastane fiber is non-attackable with alkali, yellowing with the action of chlorine and deterioration is accelerated with chlorine [1, 2]. The outstanding property of elastane is its very good stretch elasticity that can be as high as 500 %, while the elastic recovery reaches 95 %. The stretch and recovery of woven and knitted fabrics made from conventional yarns is limited, but due to elastane fibers presence a range of fabrics different degree of stretch and recovery is possible [3, 4]. The amount of elastane has a significant effect on dimensional and elastic properties of fabrics [1, 5]. Researches show that stress relaxation increases with the percentage of elastane in the yarn. It means that a higher relaxation time is typical for fabrics with a higher percentage of elastane in the yarn, which also have a higher deformation after loading in production processes [6]. It was also determined that the amount of elastane fibre in denim fabrics offers enhanced comfort properties. Therefore, as the elastane content increase, the tensile and tearing strength values decrease and increased amounts of elastane make denim fabrics stiffer [5]. It is known that properties of fabric depend not only on its stated structural parameters, but also on formation conditions of fabric. In [7] it was determined that small differences of technological parameters do not influence fabrics without elastane, but have great influence on fabrics with elastane, because the elastic component of yarn is very sensitive for various effects. Fabrics with elastane especially are suitable for fitted clothes with large areas of deformation. The influence of woven stretch fabrics properties on garment design and pattern construction were evaluated in [3]. In order to analyze the elastic fabrics behaviour during garment wearing the anisotropy of fabrics with elastane fiber due to their maximum strength and elongation was investigated and new method was proposed in [8]. During wearer's movements, some parts of the garment experienced extension into opposite directions. As a result of such type extension, the complicated deformation consisting of shear, extension and buckling of material named as fabric structural mobility took place [9]. Therefore in works [10, 11] the shear behaviours of fabrics are analyzed during the uniaxial tension of parallelepiped shape specimens whose top and bottom edges are cut with pitch of 16 degrees. This new method was used for coated and laminated fabrics investigation.

The aim of this research was to analyze the woven fabrics structural mobility using the above mentioned method of parallelepiped shaped specimen deformation.

2. MATERIALS AND METHODS

The six different woven fabrics were used in this study. Basic characteristics of the tested fabrics are shown in Table 1.

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Table 1. The characteristics of investigated fabrics

Fabric	Surface density, g/m^2	Yarn content, %	Composition of yarn with elastane	Weave structure	Density P, cm^{-1}	
					Warp	Weft
M7	279	Wool (70 %), PES (27 %), EL (3 %)	Twist with weft yarn	3/1 Twill	40	30
M8	251	CV (50 %), PES (48 %), EL (2 %)	Assembled with weft yarns	1/2 Twill	37	18
M9	281	PES (97 %), EL (3 %)	Twist with warp and every second weft yarns	Pointed twill	31	27
M10	294	PES (96 %), EL (4 %)	Twist with warp and weft yarns	Plain	25	21
M13	230	Cotton (50 %), CV (50 %)	–	1/2 Twill	42	18
M14	200	Wool (100 %)	–	1/2 Twill	23	19

There are two principal methods used in the processing fabrics with elastane. One of them uses pure elastane yarns, which are worked or woven into fabrics made from other fibres, meanwhile in another method the elastane fibre is wrapped in a non-elastic yarns – either natural or man-made. The fabric manufactured by the first method (M8) and second method (M7, M9, M10) were tested in this work. The scanning electron microscope "FEI Quanta 200F" (SEM) for the analysis of yarns structure was used (Fig. 1).

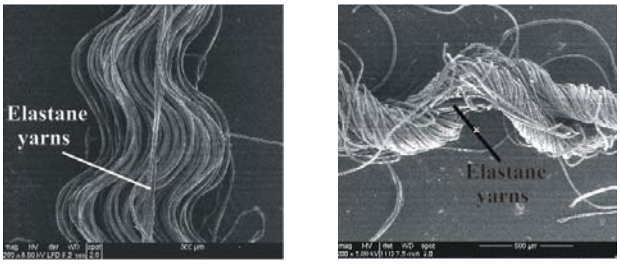

Fig 1. SEM photographs of fabric's M8 (a) and M9 (b) weft thread containing elastane filaments

For the evaluation at woven fabrics structural mobility the method presented in work [10] was used. The measurements of the parallelepiped shape specimen's were following: width $b = 50$ mm and distance between the clamps $l_0 = 100$ mm (Fig. 2, a).

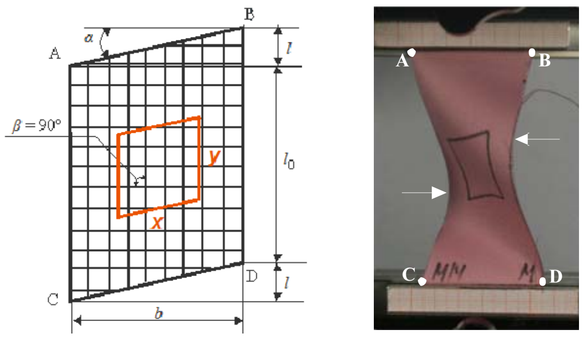

Fig 2. Initial specimen shape and its basic measurements (a) [10]; specimen shape after fixation in the clamps (b)

The specimen's upper (AB) and bottom (CD) selvages was cut at $\alpha_2 = 16°$ angle. Therefore the extension distance l, which is necessary to transform the parallelepiped specimen shape into the rectangular shape, was 14 mm or $\varepsilon = 14$ %. The whole specimen's length $L = 128$ mm was calculated as follows:

$$L = l_0 + 2l; \tag{1}$$

where L is the all the specimen length, mm; l_0 is the distance between clamps, mm; l is the extension distance ($l = 14$ mm).

In the middle of specimen a parallelogram was drawn with dimensions (30 × 30) mm^2, which sides are parallel to the specimen selvages A-B-C-D (Fig. 2, a). At the beginning of the experiment the angle β between weft and warp threads was 90° (Fig. 2, a). After the specimen selvages AB and CD were fixed in the clamps, it forms two waves in the bias direction (selvages AC and BD) (Fig. 2, b). The experiment was carried out using a "Tinius Olsen HT10" tension machine. The cross – head speed was kept at 50 mm/s.

The fabrics deformation force F_n (N) was evaluated from the tensile load-strain curves. The shear phenomenon and longitudinal yarns straightening that represents the woven fabric structural mobility was evaluated from the drawn parallelogram measurements x, y and angle α (°) (Fig. 3).

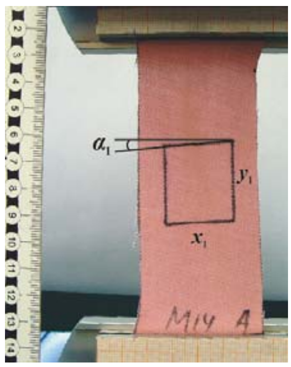

Fig 3. The specimen of fabric M14 cut in weft direction after ultimate extension $\varepsilon = 4$ %

The parallelogram sides' length alterations Δx and Δy (%) of drawn parallelogram were calculated as follow:

$$\Delta x = \frac{x - x_1}{x_1} 100\%; \tag{2}$$

where x is the drawn parallelogram sides length before stress (30 mm), %; x_1 is the drawn parallelogram sides length (%), after extension $l = 14$ mm.

$$\Delta y = \frac{y - y_1}{y_1} 100\%; \tag{3}$$

where y is the drawn parallelogram sides length before stress (30 mm), %; y_1 is the drawn parallelogram sides length (%), after extension $l = 14$ mm.

The parallelogram angle $\Delta\alpha$ (°) alteration was calculated as follows:

$$\Delta\alpha = 16 - \alpha_1; \quad (4)$$

where α_1 is the parallelogram angle after extension l = 14 mm.

All specimen results were evaluated in warp and weft directions. Since the tension machine "Tinius Olsen HT10" is computer-aided, the coefficients of variation of the F_n results were calculated automatically as average of three specimens and ranged from 0 % to 10 %. The average of geometrical characteristics Δx, Δy and $\Delta\alpha$ were calculated using six measurements: two sides and two angles of every drawn square on the specimen. The coefficients of variation of these results didn't exceed 5 %.

All measurements were performed after specimens had been conditioned in standard atmospheric conditions for 24 hours (20 °C ±2 °C temperature, 65 % ±5 % RH).

3. RESULTS AND DISCUSSIONS

The deformation force F_n, which represents the resistance of tested fabrics to the deformation, is presented in Fig. 4. It can be seen that fabric M13 can be characterized as most stable in both warp (F_n = 6.8 N) and weft (F_n = 9.4 N) directions. This effect may be related to the fabric's plain wave and composition of cotton yarns. It is known that cotton fabrics characterize for more significant friction between their yarns. Also, the threads system of plain wave structure is shorter than twill wave and has more influences to the friction between yarns [12, 13]. It is important to note that fabric M13 has no more extensible elastane yarns. The least deformation force F_n was determined for the fabrics containing elastane fiber in both warp an weft directions. Therefore the fabrics M9 and M10 structure are more mobile and these fabrics may be characterized as more flexible and stretchable. It should be noted that characteristic F_n for fabrics M7 and M8 was less in weft direction and twice larger in warp direction due to the elastane fibre in weft direction.

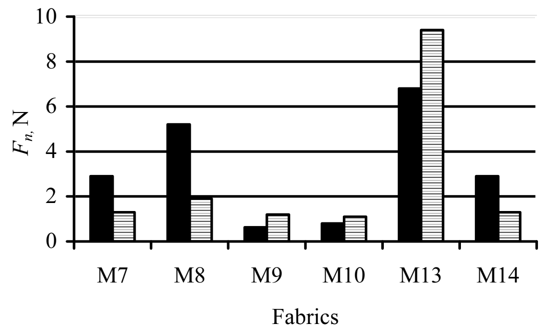

Fig 4. The deformation force F_n of tested fabrics after their deformation ε = 14 %: ■ – warp direction; ▤ – weft direction

The essence of the fabric's deformation used in this work is the non-uniform extension of the longitudinal yarns that courses their slippage with respect to each other. Together with the longitudinal yarns deformation the perpendicular yarns' are turning about intersection points and the angle between warp and weft yarns change from 90° to 90° + α. Additionally the warp threads not only slip in regard to each other but also extend. Extension degree depends on the warp thread tensile properties. The alteration of parallelogram allowed us to define what part of specimen's deformation depends on the yarns stretch and what part on the shear between warp and weft yarns occurs. In the case of free shear which can appear if the yarns of fabric are inextensible and non-flexible the $\Delta\alpha = \alpha$ = 16°. If $\Delta\alpha$ is less than α = 16°, it shows that part of the deformation occurs due to threads extension. During the investigation, it was found that $\Delta\alpha$ varied from 7° – 8° for fabrics with elastane fibre and $\Delta\alpha$ = 9° – 12° for fabrics without elastane fibre (Fig. 5).

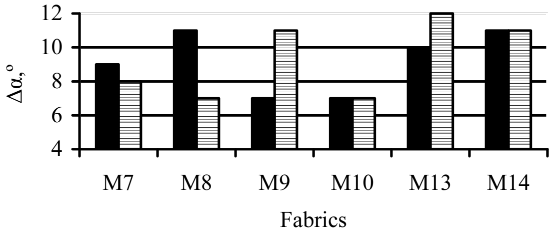

Fig 5. The change of angle $\Delta\alpha$ after specimens'deformation till ε = 14 %: ■ – warp direction; ▤ – weft direction

As a rule the higher value of $\Delta\alpha$ means that fabric's shearing deformation predominates over its longitudinal threads extension and vice versa. According to the results presented in Fig. 4, the higher extensibility of both warp and weft threads have shown fabric M10. Naturally the important role of this type deformation plays the elastane fibre, which is twist with warp and weft yarns. According to the received results the part of shear deformation for most elastic fabric M10 was calculated as 43 % ($\Delta\alpha$/16) meanwhile for comparably stabile fabric M13 in weft direction was calculated even till 75 %.

As it is evident from Fig. 6 the dependency between deformation force F_n and angle $\Delta\alpha$ is not high but from the received curve shape we can suppose that lower force is necessary for the fabrics structure shearing than for the longitudinal threads extension.

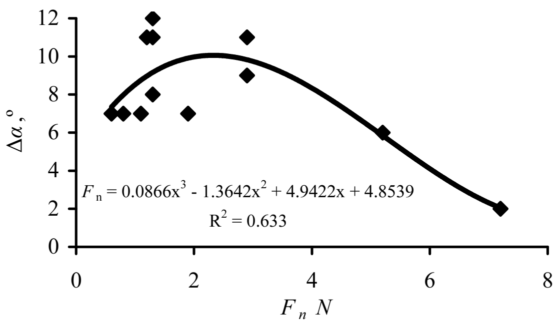

Fig 6. Dependency between maximum tensile force F_n and the change of angle $\Delta\alpha$

It is known that during woven fabric's extension yarns in direction of loading are straightened and denser meanwhile transverse yarns are waving and crimpled [13]. These deformations were determined using characteristics Δx and Δy. The crimp of fabrics specimens was evaluated using characteristic Δx (Fig. 7). It was found that smallest alteration of Δx was determined for fabric M14 (Δx = 0 %) in warp direction and 6 % in weft direction while fabric M10 parameter Δx exceeds even 67 %. Fabric M10 linear density in warp and weft direction is similar and it contains elastane fibre in both directions. Therefore fabrics are more tensile and their yarns stretch alike too. Fabric without elastane fibre (M14) is affected with larger friction forces, threads react against shear and characteristic Δ*x* changes not significant.

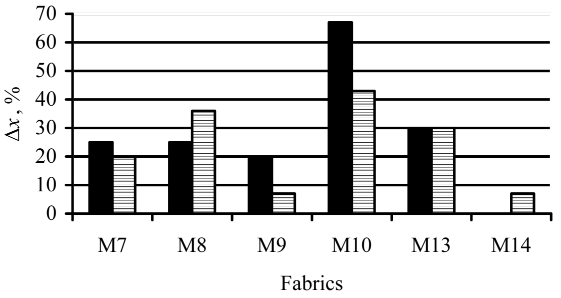

Fig 7. The change of Δ*x* after specimens‘deformation till ε_n = 14 %: ■ – warp direction; ▤ – weft direction

The part of longitudinal yarns straightening during specimens' deformation was determined using characteristic Δ*y*. The results have shown that Δ*y* values were almost equal in warp and weft directions for most tested fabrics (Fig. 8). The less result of Δ*y* for some specimens means that during their deformation the longitudinal yarns elongation occurs due to their extensibility but not due their straightening.

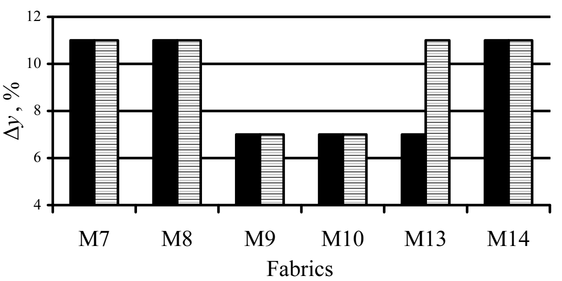

Fig 8. The change of Δ*y* after specimens‘deformation till ε_n = 14 %: ■ – warp direction; ▤ – weft direction

The received results were compared with coated and laminated fabrics results obtained using the same method [10]. The analysis have shown that for fabrics with elastane fibre deformation the force of their deformation F_n in the range of 0.6 N – 1.9 N is necessary while for the coated and laminated fabrics F_n = 3.8 N – 12 N. The determined F_n = 1.3 N – 9.4 N for one layer fabrics without elastane fibre characterizes them as medium mobile.

4. CONCLUSIONS

The known method of parallelogram shape specimen deformation which, is proposed for coated and laminated fabrics structural mobility evaluation, was used in this work for more elastic fabrics analysis.

The results of research work have shown that only elastane fibers in both directions may guarantee the high structural mobility of the fabric.

It was found that during woven fabrics deformation, when two opposite forces are acting, its structural mobility may be characterized by yarns shearing and extension. It was determined that fabrics without elastane fiber during deformation experienced more shear effect than longitudinal yarns extension and fabrics with elastane fibre vice versa, especially when elastane fibers are in both warp and weft directions.

It should be noted that deformation of specimens in cross direction depends not only on the fabrics elasticity bu ton the other their structural characteristics.

The analysis of fabrics deformation also have shown that after stated extension of ε_n = 14 % wrinkles in most specimens plane didn't disappear. It means that buckling phenomenon depending on the fabrics rigidity turns up.

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