

The Influence of Knitting Structure on Mechanical Properties of Weft Knitted Fabrics

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In various knitting structures knitted fabrics are characterized in different extensibility (in a course and wale directions) and maximum force to rupture. Various combinations of stitches, tucks, and floats give also different width and length of knit. The goal of this study is to investigate the influence of different knitting structure elements and their position in the knit on deformation properties of plain weft-knitted fabrics. An investigation was carried out with the fabrics knitted on a basis of rib 1×1, rib 2×2, and rib 1×1×1×2 on a flat V-bed knitting machine in a gauge 10E. It has been established that extensibility and strength of the knitted fabrics are immediately concerned with knitting structure. In case of transverse deformation, the maximum elongation and strength characterized knitted fabrics, which have in a structure just stitches or in different order ranged stitches and short floats. In case of longitudinal deformation, the maximum elongation and strength characterized knitted fabrics which have in a structure tucks.

Keywords: weft-knitted fabric, knitting structure, deformation, extensibility, strength.

1. INTRODUCTION

Special claims are raised for knitted fabrics used for technical applications. In comparison with woven fabrics, knitted fabrics have much more extensibility, particularly in a transverse (course) direction. The structure of knitted fabric is a system of yarns, bent out into stitches. Integrity and a friction of a yarn stretching stitch by stitch determine the form of a knitted fabric stitch. The friction appears because of stitches interdependent relations. The ties of the second type are flexible and allowing changes of a stitch form and width-height dimensions [1].

A change of dimensions of strained knitted fabric can be defined by increasing dimension in one direction as dimension in other direction is decreasing. In many cases, it is important to know how much the knit will deform in one or another direction. On the other hand it is known, that in various knitting structures knitted fabrics are characterized in different extensibility (in a course and wale directions) and maximum force to rupture [2]. Processes of deformation of knitted fabrics are described in concept of extensibility of knitted fabric.

In the literature, papers discussing, works of several authors designed for investigation of deformations of plain weft-knitted fabrics are found. In [3] Čiukas and other experimentally investigated the parameters of two colours double Jacquard fabrics – the coefficient of stitch density, the stitch length, the surface density, and the extensibility of fabric. It has been established that extensibility decrease by increasing of number of standing needles in a back needle bed (i. e. by increasing of floats). The theoretical method for calculation of structure parameters of knits introduced by Čiukas can be used for calculation of thrust deformation of knits [4–6].

Gravas and others [7] have investigated prediction of fabric weight per unit area of single and double knitted fabrics using the appropriate software. In this work the

structure parameters of knitted fabric that determine the geometry and mechanical properties of knitted fabric have been applied.

De Araújo and other authors have investigated mechanical behaviour of weft-knitted fabrics for technical applications [8–11]. It has been established that knitted fabrics with longer floats were distinguished for improved extensibility. Thus, combining the stitches and floats of different length can be obtained the rigid or flexible structure.

The aim of this study is to investigate the influence of different knitting structure elements and their position in the knit on deformation properties of plain weft-knitted fabrics.

2. EXPERIMENTAL

Investigations were carried out with the plain fabrics knitted on a basis of rib 1×1, rib 2×2, and rib 1×1×1×2 on a flat V-bed knitting machine in a gauge 10E from PAN yarns with a linear density of 28 tex×2×3. The characteristics of tested knitted fabrics are presented in Table 1, and the knitting structure – in Figure 1.

All experiments were carried out in standard atmosphere conditions for testing according to the standard ISO 139. Structure parameters of plain knitted samples were analyzed according to the British Standard BS 5441. Tensile properties of the yarns were determined using universal testing machine ZWICK/Z005. The stress-strain characteristics of studied fabrics were obtained following the standard ISO 2062. The samples (100×200 mm) were stretched in two directions: in longitudinal (wale) and in transverse (course) directions. The stretching was prosecuted in step principle, i. e. wale spacing (*A*) and course spacing (*B*) were measured in every 20 % elongation by then sample is breaking.

There is noticed, when wale spacing is approached to the maximum value the course spacing is approached to the minimum value (Fig. 2).

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Table 1. Characteristics of tested knitted fabrics

Samples code	Pattern	Mean stitch length, mm	Initial wale spacing (A_0), mm	Initial course spacing, (B_0), mm	Breaking force, N	
					in wale direction	in course direction
R1×1-I	Rib 1×1	12 ±1	3.26	2.38	421 ±10	1490 ±37
R1×1-II	Half cardigan rib	12 ±1	5.26	3.03	703 ±25	781 ±11
R1×1-III	Full cardigan rib	11 ±1	5.88	2.70	748 ±17	775 ±23
R2×2-I	Rib 2×2	11 ±1	2.78	2.27	402 ±14	1435 ±18
R2×2-II	Tuck-rib stitch	11 ±1	3.57	3.57	419 ±8	1015 ±31
R2×2-III	Tuck-rib stitch	10 ±1	3.67	3.03	658 ±11	899 ±12
R1×1×1×2-I	Rib 1×1×1×2	10 ±1	3.45	2.06	501 ±9	1588 ±16
R1×1×1×2-II	Tuck-rib stitch	11 ±1	4.35	2.94	718 ±6	1009 ±22
R1×1×1×2-III	Tuck-rib stitch	11 ±1	4.26	2.56	682 ±9	721 ±20

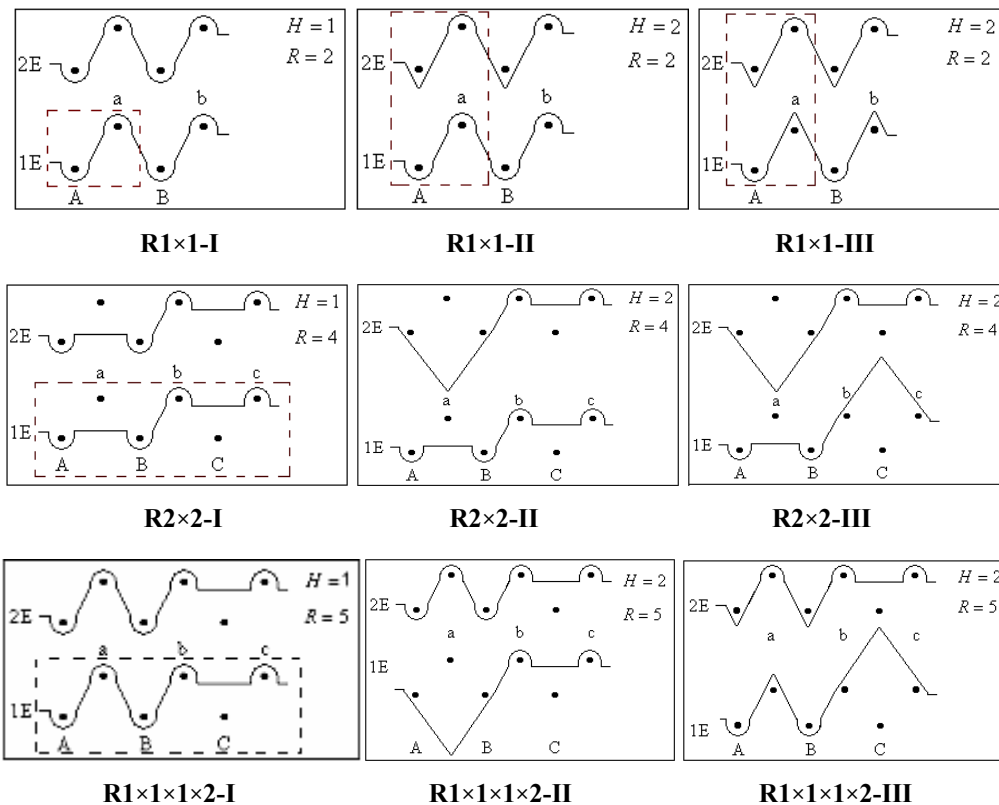


Fig. 1. Knitting structure of the tested knitted fabrics: R1×1-I – rib1×1, R1×1-II – half cardigan rib, R1×1-III – full cardigan rib, R2×2-I – rib2×2, R2×2-II – tuck-rib stitch on a basis of rib2×2, R2×2-III – tuck-rib stitch on a basis of rib2×2, R1×1×1×2-I – rib1×1×1×2, R1×1×1×2-II – tuck-rib stitch on a basis of rib1×1×1×2, R1×1×1×2-III – tuck-rib stitch on a basis of rib1×1×1×2

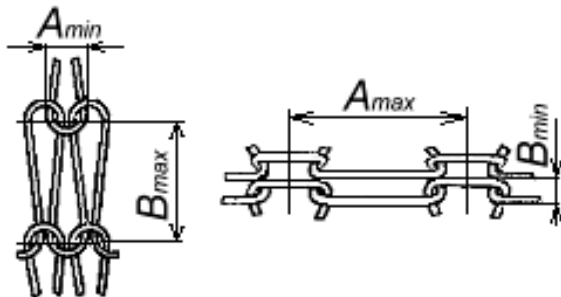


Fig. 2. Relation of wale spacing (A) to course spacing (B) in out-stretched state: $A_{\min}$ ($B_{\min}$) and $A_{\max}$ ($B_{\max}$) – respectively minimum and maximum value of wale (course) spacing

3. RESULTS AND DISCUSSION

3.1. The dependence of change of wale spacing (A) and course spacing (B) during stretching on knitting structure

The dependence of change of wale spacing (A) and course spacing (B) during stretching in wale direction to 60 % on knitting structure is presented in Figure 3. The value of 60 % is chosen in this case because to this elongation value no one sample is broken. The results demonstrate that dependence of wale spacing and course spacing on knitting structure persist the same just differ in ratio. The fabrics knitted in half-cardigan rib principle i. e.

those have tuck loops in every other course ($R1 \times 1-II$, $R2 \times 2-II$, $R1 \times 1 \times 1 \times 2-II$) have the greatest course spacing increase. For example the course spacing of $R1 \times 1-I$ fabric increased in 2.8 mm, $R1 \times 1-II$ – 3.5 mm, $R1 \times 1-III$ – 2.1 mm. The implication is that the elongation in wale direction of those fabrics (by 60 % deformation in wale direction) is the greatest. Respectively the wale spacing of those fabrics decreased at most (the wale spacing of $R1 \times 1-I$ fabric decreased 1.0 mm, $R1 \times 1-II$ – 2.1 mm, $R1 \times 1-III$ – 1.1 mm). Incidentally decreasing of wale spacing of fabrics knitted in a basis of rib2×2 was the least, as compared with the fabrics knitted in a basis of rib1×1 or rib1×1×1×2. The following dependences persist under the other deformation values as well.

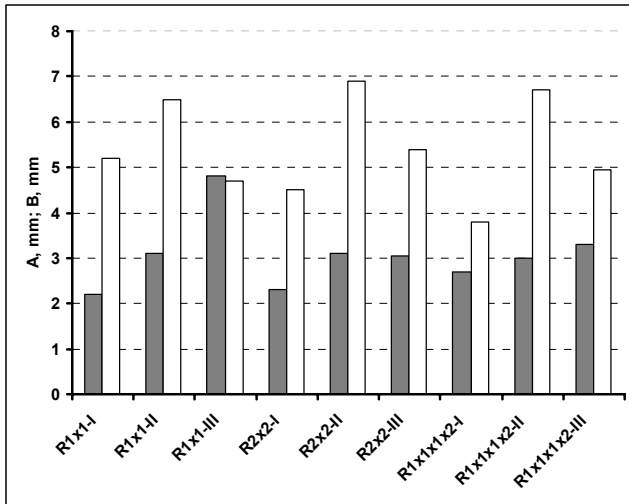


Fig. 3. Change of wale spacing – $\square$ (A) and course spacing – $\blacksquare$ (B) during stretching in wale direction to 60 % on knitting structure

The dependence of change of wale spacing (A) and course spacing (B) during stretching in course direction to 200 % on knitting structure is presented in Fig. 4. The

value of 200 % is chosen in this case because to this elongation value no one sample is broken.

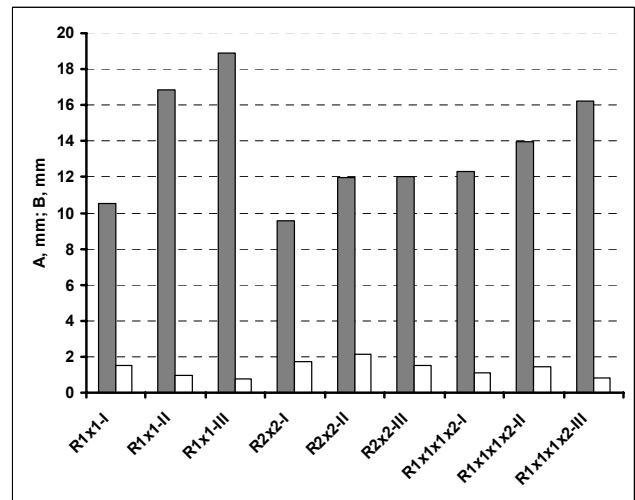


Fig. 4. Change of wale spacing (A) and course spacing (B) during stretching in course direction to 200 % on knitting structure (marked as in Fig. 3)

The results presented in Fig. 4 demonstrate that the wale spacing of fabrics knitted in full-cardigan principle i.e. those have tuck loops in every course ($R1 \times 1-III$, $R2 \times 2-III$, and $R1 \times 1 \times 1 \times 2-III$) changed in absolute value at most. Especially this difference is typical for fabrics knitted in a basis of rib1×1. For example the wale spacing of $R1 \times 1-I$ fabric increased in 7.2 mm, $R1 \times 1-II$ – 11.06 mm, $R1 \times 1-III$ – 12.02 mm. Equally, the elongation in course direction (by deformation in course direction) of fabrics knitted in full-cardigan rib principle is the greatest.

In Fig. 5 the dependence of the change of course spacing value ΔB on longitudinal deformation (in wale direction) is presented, and in the Fig. 6 the dependence of the change of wale spacing value ΔA on transverse deformation (in course direction) is presented.

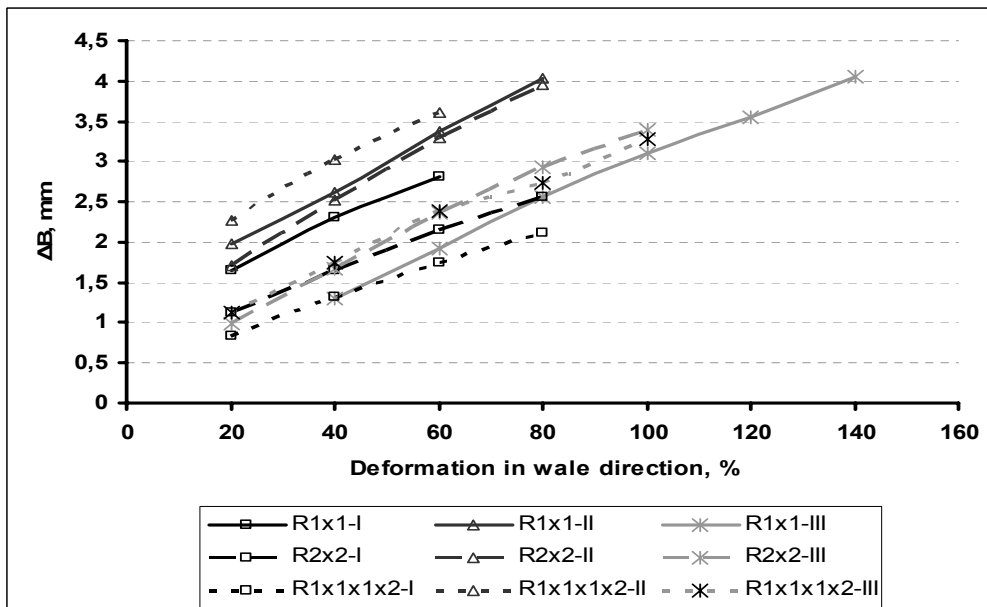


Fig. 5. Dependence of the change of course spacing value ΔB of fabrics knitted in different knitting structure on longitudinal deformation

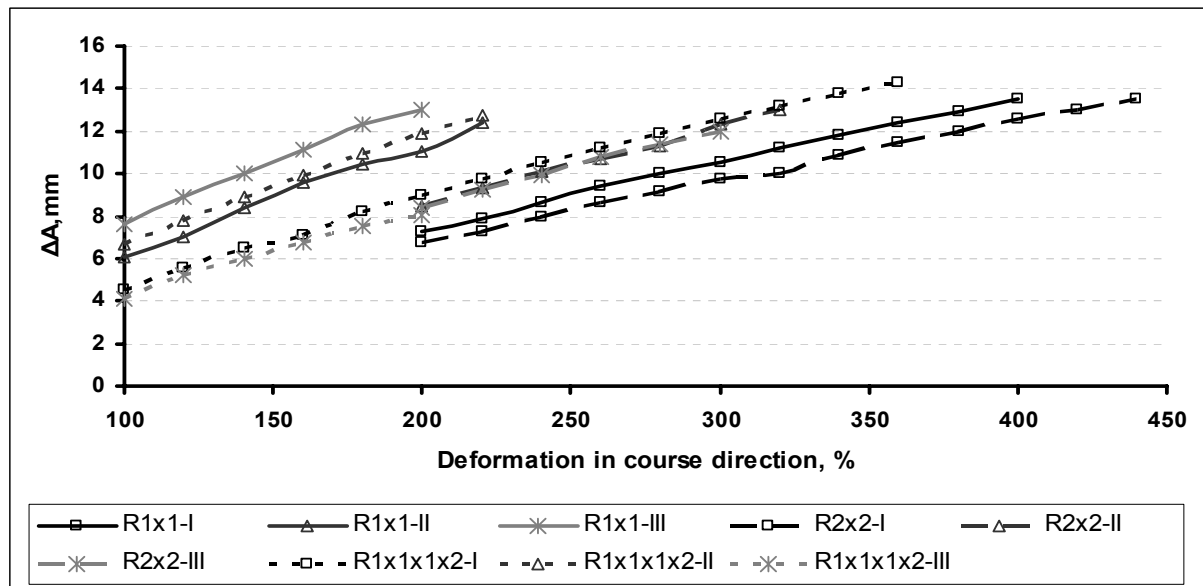


Fig. 6. Dependence of the change of wale spacing value ΔA of fabrics knitted in different knitting structure on transverse deformation (in course direction)

The change of wale spacing value ΔA is a difference between the wale spacing value after transverse deformation (in fixed value) A and the initial wale spacing value A_0 :

$$\Delta A = A - A_0, \text{ mm.} \quad (1)$$

The change of course spacing value ΔB is a difference between the course spacing value after longitudinal deformation (in fixed value) B and the initial course spacing value B_0 :

$$\Delta B = B - B_0, \text{ mm.} \quad (2)$$

The results presented in Fig. 5 and Fig. 6 demonstrate the run of the alteration of measurements of knitted fabrics during deformation to the breaking, in dependence to the knitting structure.

The greatest changes of measurements during longitudinal deformation have the fabrics knitted in a full cardigan pattern (on basis of all rib patterns – 1×1 , 2×2 , $1 \times 1 \times 2$). This is because of volumes of tuck loops those enable deform knit in longitudinal direction more easily (as well as in [1, 2, 6]).

The greatest alterations of measurements during transverse deformation apparently have the fabrics knitted in basic patterns – rib 1×1 , rib 2×2 , rib $1 \times 1 \times 2$. This is because of short wale and rib floats, and loops those enable deform knit in transverse direction more easily (likewise in [1, 2, 6]).

3.2. The dependence of elongation at maximum force on knitting structure

The dependence of elongation at maximum force (elongation at break) on knitting structure of weft-knitted fabrics is presented in Fig. 7.

The results demonstrate that fabrics knitted in a basic structure distinguish for the greatest elongation at break (and similarly for the maximum force to rupture) in a course direction. It is because the loops have more possibilities to deform in course direction than tucks or floats. At first an elongation of stretched fabric proceeds

because of deformation of loops and beyond because of deformation of yarns.

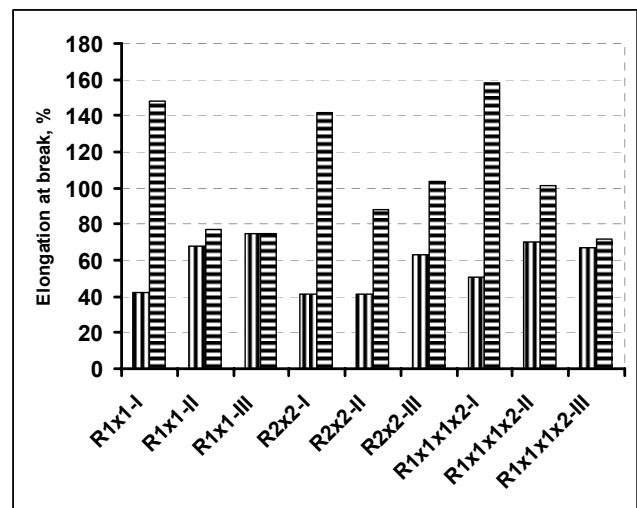


Fig. 7. Dependence of elongation at break on knitting structure during stretching in wale and course directions

On the other hand [4, 5], the rib knitted fabrics are about $3 \div 3.5$ times more tensile in course direction than in wale direction. Results presented in the Fig. 7 demonstrate that elongation at break in course of rib 1×1 fabric is ~ 3.6 , of rib 2×2 fabric ~ 3.5 , and of rib $1 \times 1 \times 2$ fabric ~ 3.1 times greater than in wale direction. Otherwise situation is in case of tuck-rib fabrics. It is interesting, the elongation at break in course and wale directions of full cardigan rib $R1 \times 1$ -III is equal. The elongation at break of tuck-rib stitch fabric $R1 \times 1 \times 2$ -III in course direction differs from elongation at break in wale direction barely ~ 1.1 times, same as of half cardigan rib $R1 \times 1$ -II fabric. But the elongation at break in course direction of tuck-rib stitch fabric $R2 \times 2$ -II and $R2 \times 2$ -III is about twice greater than in wale direction.

In case of deformation in wale direction the greater elongation at break (similarly maximum force to rupture)

demonstrates fabrics knitted in tuck-rib stitch patterns. A tuck deforms in wale direction quite easily. Obviously, the strength of deformed in wale direction knitted fabric is being reinforced with tucks [2].

CONCLUSIONS

It has been established that extensibility and strength of the knitted fabrics are related to the knitting structure.

The main conclusions from the experiment performed are as follows:

1. By deformation in wale direction the fabrics knitted in half-cardigan rib principle, i.e. those have tuck loops in every other course, have the greatest course spacing increase in absolute value. The elongation in wale direction of those fabrics is the greatest.
2. By deformation in course direction the wale spacing of fabrics knitted in full-cardigan principle, i.e. those have tuck loops in every course, changed in absolute value at most. Especially this difference is typical for fabrics knitted in a basis of rib 1×1. The elongation in course direction (by deformation in course direction) of fabrics knitted in full-cardigan rib principle is the greatest.
3. Fabrics knitted in a basic structure distinguish for the greatest elongation at break (and similarly for the maximum force to rupture) in a course direction. Elongation at break in course direction of basic rib fabrics (R1×1-I, R2×2-I, R1×1×1×2-I) is 3.1÷3.6 times greater than in wale direction.
4. In case of deformation in wale direction the greater elongation at break (similarly maximum force to rupture) demonstrates fabrics knitted in tuck-rib stitch patterns. Elongation at break of tuck-rib stitch fabrics knitted in a basis of 1×1 and 1×1×1×2 rib is the same in course and wale direction. And elongation at break in course direction of tuck-rib stitch fabrics knitted in a basis of 2×2 rib is about twice greater than in wale direction.

REFERENCES

1. Mikučionienė, D., Tvarijonavičienė, B. Investigation of Influence of Stretching Knitted Fabrics on Value of its Shrinkage *Materials Science (Medžiagotyra)* 2 1997: pp. 55–59.
2. Ūnal, A., Offermann, P. Influence of Knitting Structure on Deformation of Reinforced Knitted Fabrics *Melliand Textilberichte* 4 2005: pp. 258–260 (in German).
3. Čiukas, R., Pivoras, T., Tvarijonavičienė, B. Investigation and Prediction of Structure Parameters of Double Jacquard Knitted Fabrics *Materials Science (Medžiagotyra)* 9 (2) 1998: pp. 81–83.
4. Čiukas, R. Design of Knitted Fabrics *Fibres&Textiles in Eastern Europe* 17 (2) 1997: pp. 37–39.
5. Čiukas, R. Technical Design of Weft Knitted Fabrics *Materials Science (Medžiagotyra)* 5 (2) 1997: pp. 59–62.
6. Čiukas, R. Theoretical Determination of Parameters of Weft Knitted Fabrics *Materials Science (Medžiagotyra)* 3 (2) 1996: pp. 72–73.
7. Gravas, E., Kickens, P., van Langenhove, L. Prediction Fabric Weight per Unit Area of Single- and Double-Knitted Structures using Appropriate Software *Autex Research Journal* 6 (4) 2008: pp. 13–19.
8. de Araújo, M., Fangueiro, R., Hong, H. Modelling and Simulation of the Mechanical Behaviour of Weft-Knitted Fabrics for Technical Applications, Part II *Autex Research Journal* 3 (3) 2003: pp. 117–123.
9. de Araújo, M., Fangueiro, R., Hong, H. Modelling and Simulation of the Mechanical Behaviour of Weft-Knitted Fabrics for Technical Applications, Part III *Autex Research Journal* 4 (1) 2004: pp. 107–112.
10. Stolyarov, O. Structure and Mechanical Properties of the Weft-Knitted Aramid Fabrics for Composite Reinforcement *Internation Textile Conference in Dresden, December 04–05* 2008: p. 9.
11. Bekampienė, P., Domskienė, J. Analysis of Fabric Specimen Aspect Ratio and Deformation Mechanism during Bias Tension *Materials Science (Medžiagotyra)* 15 (2) 2009: pp. 167–172.