Alenka Pavko Čuden
Oddelek za tekstilstvo, Naravoslovnotehniška fakulteta, Univerza v Ljubljani

Parametri zbitega levo-desnega pletiva (3. del): debelina pletiva in Knaptonova konstanta

Izvirni znanstveni članek

Poslano *junij 2010* • Sprejeto *september 2010*

Parameters of Compact Single Weft Knitted Structure (Part 3): Fabric Thickness and Knapton Constant

Original Scientific Paper

Received *June 2010* • Accepted *September 2010*

Abstract

Fabric thickness is one of the important knitted fabric parameters influencing the insulation properties, handle and material consumption. In the previous research, fabric thickness was mainly examined within the framework of studies of other knitted fabric structural parameters and properties, and only rarely as the main research topic. The research objective was to comparatively analyse fabric thickness and Knapton constants of knitted fabrics made from core-spun yarns with elastane core and those made from conventional yarns. It was established that the knitted fabrics made from yarns with elastane core are significantly thicker than the knitted fabrics made from yarns without elastane core, with equal linear density, produced on the same knitting machine under the same conditions, all influencing the performance properties of elasticized knitted fabrics. It was also established that the Knapton constant of dense and loose knitted structures from yarns with elastane core decreases while it increases for the yarns without elastane core. A new parameter, i.e. fabric thickness interlacing factor, was defined.

Vodilni avtor/corresponding author:
dr. Alenka Pavko Čuden
tel.: +386 1 200 32 16
e-mail: alenka.cuden@ntf.uni-lj.si

Izvleček

Eden pomembnih parametrov pletiva je debelina, saj vpliva na izolacijske lastnosti, otip in porabo materiala. V dosedanjih raziskavah je bila debelina pletiva večinoma obravnavana v okviru študij drugih strukturnih parametrov in lastnosti pletiva, kot glavni predmet raziskav pa le redko. Cilj raziskave je bil primerjalno analizirati debelino pletiv in Knaptonove konstante pletiv iz prej z elastanskim jedrom ter iz konvencionalnih prej. Ugotovljeno je bilo, da je pletivo iz prej z elastanskim jedrom, gosto in redko pleteno, pomembno debelejše od pletiva iz prej brez elastanskega jedra enake nazivne dolžinske mase ter pletenega na istem stroju in pod enakimi pogoji, kar vpliva na uporabne lastnosti pletiv z elastanom. Ugotovljeno je bilo tudi, da se z mokro relaksacijo Knaptonova konstanta gostih in redkih pletiv iz prej z elastanskim jedrom zmanjša, pletiv iz prej brez elastanskega jedra pa poveča. Definiran je bil nov parameter debelinski faktor vpletanja niti.

Ključne besede: pletenje, pletivo, debelina pletiva, Knaptonova konstanta, debelinski faktor vpletanja niti

1 Uvod

Pletiva so kompleksne in dimenzijsko občutljive strukture. Spremembe temeljnih parametrov, tj. širine, višine in dolžine zanke ter debeline pletiva, pomembno vplivajo na uporabne in udobnostne lastnosti pletiv ter na načrtovanje njihove proizvodnje, zato so geometrijski parametri pletenih struktur že dolgo predmet poglobljenih raziskav. En pomembnih parametrov pletiva je tudi

Keywords: knitting, knitted fabric, fabric thickness, Knapton constant, fabric thickness interlacing factor

1 Introduction

Knitted fabrics are complex and dimensionally sensitive structures. A variation of basic parameters, i.e. loop width, height and length, and fabric thickness, significantly influences the performance and comfort properties of knitted fabrics and their production planning. Consequently, geometrical parameters of knitted structures have been an extensive research topic for some time now. Fabric thickness is one of the important knitted fabric parameters influencing the insulation properties, handle and material consumption.

Until now, the optimal knitted loop and knitted fabric parameters have been defined solely for the fabrics knitted from conventional yarns. Due to the compactness of relaxed fabrics, the parameters of knitted fabrics made from highly elastic yarns with elastane core differ considerably from the parameters of knitted fabrics made under same process conditions from yarns without elastane core. The research objective was to comparatively analyse the thickness of knitted fabrics made from yarns with elastane core and from conventional yarns, respectively.

2 Knitted fabric thickness, yarn diameter and Knapton constant

The knitted fabric thickness as a geometrical parameter was mainly discussed by the scientists who treated their loop models as a space curve. In 1914, Tompkins [1] wrote that the knitted fabric thickness equals twice the yarn diameter. Although Pierce's loop model [2] mathematically describes a two-dimensional knitted loop shape, it can be seen from the loop model figures that the knitted fabric thickness is more than twice the yarn diameter. Vekassy's general loop model [3] discusses the knitted loop as a line without the parameter of yarn diameter. On the other hand, his loop models of normal and compact structures define the knitted fabric thickness being twice the yarn diame-

debelina, saj vpliva na izolacijske lastnosti, otip in porabo materiala.

Optimalni parametri zanke in pletiva so bili do zdaj opredeljeni le za pletiva iz konvencionalnih prej. Parametri pletiva iz visokoelastičnih prej z elastanskim jedrom se zaradi zbitosti relaksiranega pletiva pomembno razlikujejo od parametrov pletiva iz prej brez elastanskega jedra, pletenega pri enakih procesnih pogojih. Cilj raziskave je bil primerjalno analizirati debelino pletiv iz prej z elastanskim jedrom in iz konvencionalnih prej.

2 Debelina pletiva, premer preje in Knaptonova konstanta

Debelino pletiva so kot geometrijski parameter v svojih modelih zanke obravnavali predvsem tisti znanstveniki, ki so zanko obravnavali prostorsko. Že Tompkins je leta 1914 [1] zapisal, da je debelina pletiva dvakratnik debeline preje. Čeprav Peirceov model zanke [2] matematično izraža ploskovno obliko zanke, je iz risb modela vidno, da je debelina pletiva več kot dvakrat večja od debeline preje. Vekassijev splošni model [3] obravnava zanko kot črto, torej brez parametra debeline preje, modela zanke normalnega in zbitega pletiva pa debelino pletiva definirata kot dvakratnik debeline preje, tj. $d_{pl} = 2d_{pr}$. Enako razmerje v svojem modelu predvideva tudi Dalidovič [4]. Suh [5] predpostavlja, da je zanka usločena; kraka zanke ležita na konkavni ravnini. Čeprav je iz slike modela mogoče sklepati, da je $d_{pl} \geq 2d_{pr}$, debelina pletiva v razmerju z drugimi parametri, ni matematično definirana. Morooka Hi., Matsumoto in Morroka Ha. [6] so v svojem modelu predpostavili dvodimenzionalno obliko zanke, ki so jo utemeljili z zanemarljivo debelino pletiva glede na dolžino zanke.

Številni raziskovalci so eksperimentalno študirali geometrijske parametre pletenih struktur iz konvencionalnih prej. Večinoma je bila preiskovana enostavna levo-desna struktura, merjene pa širina zanke (horizontalna gostota), višina zanke (vertikalna gostota) in dolžina zanke. Debelina pletiva je bila večinoma obravnavana v okviru študij drugih strukturnih parametrov, kot glavni predmet raziskav pa le redko [7, 8, 9, 10, 11]. Ugotovljeno je bilo, da je debelina popolnoma relaksiranih (konsolidiranih) pletiv iz konvencionalnih prej neodvisna od dolžine zanke ter odvisna le od premera preje. Definirana je bila Knaptonova konstanta K_5 kot razmerje med debelino pletiva in debelino preje z eksperimentalno določenimi vrednostmi $K_5 = 4{,}8–6{,}8$ [7].

Pri analizah lastnosti pletene strukture je bilo ugotovljeno, da je mogoče krivuljo *tlačna obremenitev/debelina pletiva* razdeliti v tri območja: prvemu linearnemu območju sledi nelinearno in nato spet linearno območje [8]. Pozneje je bilo ugotovljeno, da se glavni del pletene strukture začne deformirati v drugem območju krivulje *tlačna obremenitev/debelina pletiva* [9]. Ugotovljeno je bilo tudi, da je debelina pletiva odvisna od vrste vlaken in od njihovih la-

ter, i.e. $d_{pl} = 2d_{pr}$. The same relation is anticipated in Dalidovich's model [4]. Suh [5] presumed the loop being flexed, the loop limbs lying on a concave surface. Although it can be concluded from his loop model figure that $d_{pl} \geq 2d_{pr}$, the knitted fabric thickness is not defined in the relation to other parameters. In their loop model, Morooka Hi., Matsumoto and Morooka Ha. [6] presumed the loop shape being two-dimensional, which was substantiated with a negligible knitted fabric thickness compared to the loop length.

The geometrical parameters of knitted structures made of conventional yarns have been experimentally studied by several researchers. Mainly, the basic single jersey structure was discussed, and the loop width (horizontal density), loop height (vertical density) and loop length were measured. The knitted fabric thickness was mostly measured within the knitted fabric structural parameters investigation and was presented as a principal research in few papers only [7, 8, 9, 10, 11]. For the knitted fabrics in fully relaxed (consolidated) state made from conventional yarns, fabric thickness was shown to be independent of the loop length, depending only on yarn diameter. The Knapton constant, K_S, was defined as the ratio between the knitted fabric thickness and yarn thickness (diameter) with an experimentally defined value $K_S = 4.8–6.8$ [7].

With the analysis of the knitted structure properties, it was stated that the pressure loading/fabric thickness curve can be divided into three regions during the lateral compression – the first linear region followed by the non-linear region and the second linear region [8]. Further on, it was shown that the main structure of the knitted fabric begins to deform at the second region of the pressure loading/thickness curve [9]. It was also established that fabric thickness is primarily dependent on the fibre type and properties. Only basic fibres, such as silk, cotton and polyester, were investigated [10].

Yarn thickness has a direct impact on the knitted fabric thickness. It equals the yarn diameter if a round yarn cross-section is presumed. The yarn diameter is a parameter difficult to define as the yarn is not a solid body of known density. Its porosity amounts to 30–70 %. The yarn

stnosti. Preiskovani so bili le nekateri materiali: svila, bombaž in poliester [10].

Na debelino pletiva neposredno vpliva debelina preje. Enaka je premeru preje, če predpostavimo, da je prerez preje okrogel. Premer preje je težko določljiv parameter, ker preja ni trdno telo znane gostote, saj znaša njena poroznost 30–70 odstotkov; jedro preje je gosto, plašč pa sestavljajo prosti konci vlaken, ki štrlijo iz površine [12]. Posledica nizkega vitja pletilskih prej je spremenljiv dejanski premer preje v pletivu [13].

3 Eksperimentalni del: priprava vzorcev in metode preiskav

Prstanske preje za pripravo vzorcev pletiv so bile projektirane in izdelane z načrtovanimi parametri za raziskovalne namene iz viskoznih (CV) in poliakrilonitrilnih (PAN) vlaken. Iz vsake surovine so bile izdelane po tri različne preje z elastanskim jedrom enake nazivne dolžinske mase: muliné sukana preja (iz oplaščene preje z elastanskim jedrom in predivne preje brez elastanskega jedra, obeh izdelanih na prstanskem predilniku), obsukana preja (elastanska filamentna preja, obsukana z dvema predivnima prejama) in oplaščena preja (preja z elastanskim jedrom, oplaščenim s predivom). Za primerjavo sta bili izdelani tudi prstanski predivni preji brez elastanskega jedra enake nazivne dolžinske mase.

Vzorci pletiv so bili pod enakimi pogoji napleteni na pletilniku UNIVERSAL MC 720 delitve E8, preja je bila neparafinirana. Iz vsake preje so bili napleteni vzorci dveh gostot. Vzorci pletiv so bili suho statično relaksirani 72 ur oz. po suhi relaksaciji tudi mokro dinamično relaksirani – konsolidirani [14].

Za merjenje debeline oz. premera preje ni standardne metode. Merjenje premera preje z mikroskopskim opazovanjem in optično-projekcijskimi metodami vključuje subjektivno določanje mej preje v neobremenjenem stanju, kar je slabost teh metod. Mehanske metode merjenja premera preje vključujejo neposredno stiskanje preje, kar je posebno problematično pri voluminoznih prejah, med katere večinoma spadajo tudi predivne pletilske preje. Na Tekstilnem inštitutu v Moskvi je bila razvita brezkontaktna projekcijsko-računska metoda za ugotavljanje povprečnega premera teksturiranih prej, metoda F. Sadikova [15]. Debeline preskušanih prej d_{prS} so bile merjene po modificirani metodi Sadikova. Iz etalonov prej, pripravljenih s predobremenitvijo niti 0,003 $cN \cdot tex^{-1}$ [15], torej 0,3 cN, so bili optično čitani odseki prej dolžine 30 mm z ločljivostjo 1200 dpi. Nato so bili natiskani na papir pri 20-kratni povečavi ter izrezani. Izmerjena je bila masa izrezanih papirnih vzorcev ter masa znane površine papirja. Za vsak vzorec preje je bilo izvedenih 10 meritev. Povprečni premer preje je bil izračunan iz površine vzorca preje:

core is compact, while the cover is composed of free ends of fibres protruding from the yarn surface [12]. A low twist of knitting yarns results in a variable practical yarn diameter within the knitted fabric [13].

3 Experimental: sample preparation and research methods

Ring-spun yarns used for the knitted sample preparation were designed and made with planned parameters for the research purpose from viscose (CV) and polyacrylonitrile (PAN) fibres. From each raw material, elasticized yarn of the same linear density was made – muliné-twisted yarn (composed of elastomeric core-spun yarn and yarn without elastane, both ring-spun), core-twisted yarn (elastane filament yarn, core-twisted with two ring-spun yarns) and core-spun yarn (yarn with elastane core and staple fibre sheath covering). For a comparison, ring-spun yarns without elastane of equal linear density as elasticized yarns were produced as well.
The knitted samples were produced on an electronic flat weft knitting machine UNIVERSAL MC 720, gauge E8 under the same process con-

$$S = \frac{m_1}{m_0 \cdot P^2} \qquad (1),$$

kjer je: S – površina vzorca preje (mm^2); m_1 – masa izrezanega obrisa projekcije vzorca preje na papir (mg); m_0 – masa 1 mm^2 papirja, na katerega je bil projiciran vzorec preje (mg); P – povečava.
Povprečni premer preje $\overline{d_{prS}}$ je bil nato izračunan po enačbi:

$$\overline{d_{prS}} = \frac{S}{L} \qquad (2),$$

kjer je: $\overline{d_{prS}}$ – povprečni premer preje (mm), S – površina vzorca preje (mm^2), L – dolžina optično čitanega vzorca preje (mm).
Debelina neobremenjenega pletiva d_{plo} je bila določena z merjenjem debeline pletiva pri različnih obremenitvah in preračunom na ničelno obremenitev. Merjena je bila debelina suho ter suho in mokro relaksiranih pletiv po standardu SIST EN ISO 5084:1996 pri različnih standardnih obremenitvah merilne noge: 20 cN·cm^{-2}, 40 cN·cm^{-2}, 60 cN·cm^{-2}, 80 cN·cm^{-2} in 100 cN·cm^{-2}. Izdelana je bila dodatna merilna noga z večjo površino in obremenitvijo 8,43 cN·cm^{-2}. Za vsak vzorec pletiva je bilo izvedenih 20 meritev. Povprečne vrednosti debeline pletiva pri vsaki obremenitvi merilne noge so bile prenesene v program Excel in narisane krivulje. Na podlagi predpostavke o nelinerani odvisnosti med tlačno obremenitvijo in debelino pletiva [8, 9] je bila za vsak posamezni vzorec poiskana enačba ujemajočega se polinoma. Iz enačbe polinoma je bila za vsak vzorec izračunana debelina pletiva pri ničelni obremenitvi.

4 Rezultati preiskav z razpravo

Table 1: Yarn sample descriptions

yarn label	yarn type	material composition (%)	yarn linear density (tex)	twist (m^{-1})	breaking tenacity (cNtex^{-1})	breaking extension (%)	Uster value (%)	no. of thin places	no. of thick places	no. of nobs
1	muliné-twisted yarn with elastane	97.8% CV 2.2% EL	100	500S	20.2	19.3	7.4	0	0	0
2		97.8% PAN 2.2% EL	100	500S	21.5	26.9	7.3	0	2	1
3	core-twisted yarn with elastane	97.8% CV 2.2% EL	102	500S	20.3	19.1	7.5	0	0	0
4		97.8% PAN 2.2% EL	102	500S	21.2	26.5	7.4	0	0	0
5	core-spun yarn with elastane	97.8% CV 2.2% EL	100	281Z	18.4	17.7	8.5	0	0	1
6		97.8% PAN 2.2% EL	100	278Z	19.6	23.8	9.1	0	0	0

yarn label	yarn type	material composition (%)	yarn linear density (tex)	twist (m^{-1})	breaking tenacity ($cNtex^{-1}$)	breaking extension (%)	Uster value (%)	no. of thin places	no. of thick places	no. of nobs
7	ring-spun yarn without elastane	100% CV	100	221Z	21.9	17.7	8.4	0	1	0
8		100% PAN	100	221Z	19.7	23.0	9.1	0	1	0

ditions. The yarn was not waxed. From each yarn, samples were knitted in two densities. The knitted samples were statically dry relaxed for 72 hours or additionally dynamically wet relaxed (consolidated) after a dry relaxation, respectively [14].

There is no standard method for measuring yarn thickness or yarn diameter. The yarn diameter measuring with a microscopic observation and optical projection methods involves a subjective determination of the yarn borders in an unloaded state, which is a weak point of these methods. The mechanical methods for the yarn diameter measuring incorporate a direct yarn compression, which is especially problematic with voluminous yarns, incl. ring-spun knitting yarns.

At the Moscow Textile Institute, a contactless projection-calculating method for the average diameter of textured yarns, i.e. F. Sadikov method was developed [15]. The diameter of investigated yarns, d_{prS}, was measured with the modified Sadikov method. From the yarn samples prepared with a preloading of 0.003 cNtex^{-1} [15], i.e. 0.3 cN, 30 mm yarn sections were scanned with the resolution of 1200 dpi. Afterwards, the scanned sections were printed on paper with a 20-fold magnification and cut out. The mass of the cut-out printed samples and mass of the paper sheet with a known surface area were measured. For each yarn sample, 10 measurements were performed. The average yarn diameter was calculated from the yarn sample area (Equation 1), where: S – yarn sample area (mm^2); m_1 – mass of yarn sample projection cut out of paper (mg); m_0 – mass of 1 mm^2 of paper on which yarn sample was projected (mg); P – magnification.

Table 2: Yarn and knitted fabric sample labelling

yarn label	yarn labelling		knitted fabric labelling		
	relaxation type	yarn label	relaxation type	knitted fabric density	
				dense	loose
1	dry relaxation	1S	dry relaxation	1Sg	1Sr
	consolidation	1M	consolidation	1Mg	1Mr
2	dry relaxation	2S	dry relaxation	2Sg	2Sr
	consolidation	2M	consolidation	2Mg	2Mr
3	dry relaxation	3S	dry relaxation	3Sg	3Sr
	consolidation	3M	consolidation	3Mg	3Mr
4	dry relaxation	4S	dry relaxation	4Sg	4Sr
	consolidation	4M	consolidation	4Mg	4Mr
5	dry relaxation	5S	dry relaxation	5Sg	5Sr
	consolidation	5M	consolidation	5Mg	5Mr
6	dry relaxation	6S	dry relaxation	6Sg	6Sr
	consolidation	6M	consolidation	6Mg	6Mr
7	dry relaxation	7S	dry relaxation	7Sg	7Sr
	consolidation	7M	consolidation	7Mg	7Mr
8	dry relaxation	8S	dry relaxation	8Sg	8Sr
	consolidation	8M	consolidation	8Mg	8Mr

Table 3: Knitted fabric thickness, yarn diameter and Knapton constant of dry, and dry and wet relaxed (consolidated) dense and loose structures

yarn/knitted fabric label (relaxation type)		yarn diameter	knitted fabric thickness			
			dense structure – g		loose structure – r	
		d_{prS} (mm)	d_{pl0} (mm)	K_5	d_{pl0} (mm)	K_5
1	S	0.88	1.72	1.96	2.06	2.35
	M	1.15	1.92	1.67	2.08	1.81
2	S	0.90	1.66	1.85	1.97	2.20
	M	1.25	2.26	1.81	2.62	2.10
3	S	0.72	1.61	2.23	1.92	2.66
	M	0.94	2.04	2.17	2.42	2.58
4	S	0.76	1.69	2.22	2.04	2.68
	M	1.13	2.03	1.79	2.24	1.97
5	S	0.93	1.92	2.43	2.40	3.05
	M	1.27	2.13	1.68	2.40	1.89
6	S	0.76	1.84	2.41	2.31	3.03
	M	1.40	2.47	2.00	2.79	2.26
7	S	0.65	1.10	1.71	1.01	1.57
	M	0.71	1.31	1.84	1.24	1.74
8	S	0.60	1.26	2.12	1.26	2.11
	M	0.64	1.43	2.26	1.42	2.25

The average yarn diameter was calculated with the equation 2, where: $\overline{d_{prS}}$ – average yarn diameter (mm), S – yarn sample area (mm²), L – length of scanned yarn sample (mm).

The thickness of the unloaded knitted fabric, d_{pl0}, was defined by measuring the knitted fabric thickness at various loadings and with a subsequent calculation to zero loading. The thickness of the dry, and dry and wet relaxed knitted fabrics was measured according to the SIST EN ISO 5084:1996 standard at various standard loadings of the pressure foot: 20 cNcm⁻², 40 cNcm⁻², 60 cNcm⁻², 80 cNcm⁻² and 100 cNcm⁻². An additional pressure foot with a larger pressure surface and loading of 8.43 cNcm⁻² was designed. For each knitted fabric sample, 20 measurements were performed. The average values of the knitted fabric thickness at each pressure foot loading were trans-

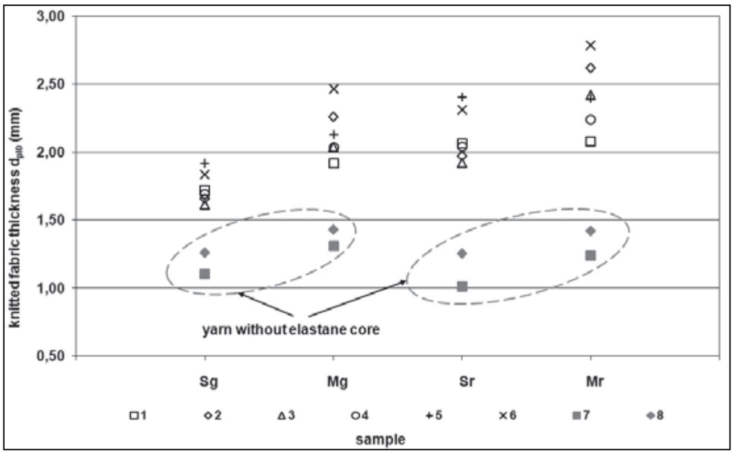

Figure 1: Comparison of fabric thickness, d_{pl0}, of dense and loose, dry, and dry and wet relaxed (consolidated) structures

ferred to Excel and the diagram curves were drawn. Based on the presumption of nonlinear pressure loading/knitted fabric thickness dependence [8, 9], an equation of a corresponding polynomial was found for each individual sample. From the polynomial equation, the knitted fabric thickness at zero loading was calculated for each sample.

4 Research results and discussion

From Table 3, it can be seen that the diameter of the wet relaxed yarns measured with the Sadikov method [15] exceeds the diameter of the dry relaxed yarns. The dry and wet relaxed yarns without elastane core exhibit the smallest diameter. The yarn diameter increase due to a wet relaxation amounts from 29.8% to 61.7% for the yarns with elastane core, and 10% or 6.2% for viscose and polyacrylonitrile yarns without elastane core, respectively. The yarn diameter increase due to a wet relaxation results in a more compact knitted structure and increased fabric thickness. This is reflected in a loop configuration change and consequently, in the knitted fabric appearance, parameters and dimensional properties.

Table 3 and Figure 1 show that the knitted fabrics made from yarns with elastane core are significantly thicker than the knitted fabrics made from yarns without elastane core, with equal linear density, produced on the same knitting machine under the same conditions. The thickness of knitted fabrics made from all yarns, with and without elastane core, increased during a wet relaxation. In most cases, the thickness of dense knitted fabrics made from yarns with elastane core increased more than the thickness of loose fabrics made from the same yarns. The loose knitted fabrics from yarns with elastane core are thicker than the equally relaxed dense knitted fabrics from yarns of the same kind, while the fabrics made of yarns without elastane core show the opposite trend – the loose knitted fabrics exhibit smaller or equal thickness than the dense knitted fabrics.

The knitted fabric thickness increase during a wet relaxation, along with an insignificant loop length change, and simultaneous loop width

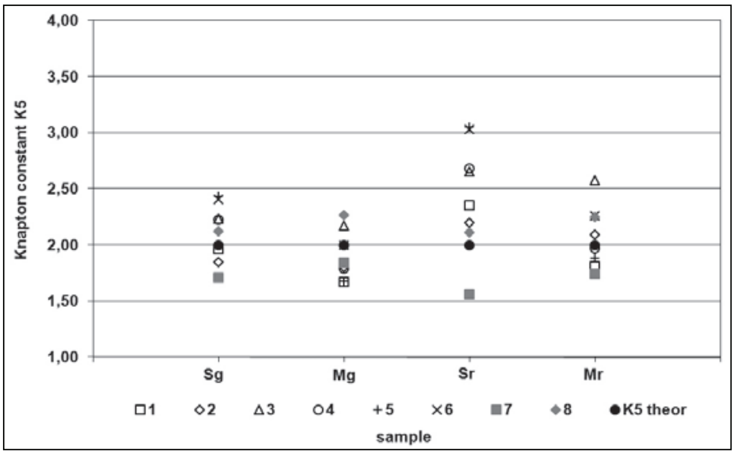

Figure 2: Comparison of Knapton constant, K_5, of dense and loose, dry, and dry and wet relaxed (consolidated) structures

Iz preglednice 3 je videti, da je premer mokro relaksiranih prej, merjen po metodi Sadikova [15], večji kot premer suho relaksiranih prej. Suho ter suho in mokro relaksirane preje brez elastanskega jedra imajo najmanjši premer. Povečanje premera preje z mokro relaksacijo je od 29,8 do 61,7 % za preje z elastanskim jedrom ter 10 % za viskozno oz. 6,2 % za poliakrilonitrilno prejo brez elastanskega jedra. Posledica povečanja premera preje pri mokri relaksaciji sta zgostitev pletene strukture in povečanje debeline pletiva, kar se kaže v spremembi konfiguracije zanke ter s tem videza, parametrov in dimenzijskih lastnosti pletiva.

Preglednica 3 in slika 1 kažeta, da je pletivo iz prej z elastanskim jedrom pomembno debelejše od pletiva iz prej brez elastanskega jedra enake nazivne dolžinske mase ter pletenega na istem stroju in pod enakimi pogoji. Debelina pletiv, pletenih tako iz prej z elastanskim jedrom kot tudi iz prej brez elastanskega jedra, se je z mokro relaksacijo povečala. Debelina gosto pletenih pletiv iz prej z elastanskim jedrom se je v večini primerov bolj povečala kot debelina redkih pletiv iz istih prej. Redka pletiva iz prej z elastanskim jedrom so debelejša od enako relaksiranih gostih pletiv iz istovrstnih prej, medtem ko je pri pletivih iz prej brez elastanskega jedra ravno narobe: redka pletiva imajo manjšo ali enako debelino kot gosta.

Povečanje debeline pletiva z mokro relaksacijo ob le malo spremenjeni dolžini zanke ter zmanjšani širini in višini zanke kaže na to, da se z mokro relaksacijo spremeni oblika zanke, ne pa pomembno tudi njena dolžina.

Knaptonova konstanta K_5 [7] podaja razmerje med debelino pletiva d_{pl0} in premerom preje d_{prS}. Če je pletivo po debelini normalne strukture, je debelina pletiva dvakratnik premera preje (K5 teor na sliki 2). Iz preglednice 3 je videti, da se z mokro relaksacijo Knaptonova konstanta gostih in redkih pletiv iz prej z elastanskim jedrom zmanjša, pletiv iz prej brez elastanskega jedra pa poveča. Pri pletivih iz prej z elastanskim jedrom je Knaptonova konstanta red-

and loop height decrease indicates that the loop shape changes due to a wet relaxation, while the loop length change is not important.

The Knapton constant, K_5, [7] assigns the relation between the knitted fabric thickness, d_{pl0}, and the yarn diameter, d_{prS}. If the knitted fabric exhibits a normal structure with regard to thickness, the knitted fabric thickness is twice the yarn diameter (K5 theor in Figure 2). From Table 3, it can be seen that the Knapton constant of dense and loose knitted structures made from yarns with elastane core decreases, while it increases for the knitted fabrics made from yarns without elastane core. For the knitted fabrics made from yarns with elastane core, the Knapton constant of loose structures is higher than the Knapton constant of dense structures. In contrast, the Knapton constant of loose knitted structures is lower than the Knapton constant of dense knitted structures for the fabrics made from conventional yarns.

On the grounds of the preliminary analysis of the results of basic knitted loop parameter measurements (i.e. loop width, loop height, loop length, yarn diameter and knitted fabric thickness) with the principal component analysis (16), the fabric thickness interlacing factor, v_{deb}, can be defined, i.e. the ratio between the loop length and the knitted fabric thickness: Equation 3, where: v_{deb} – fabric thickness interlacing factor, ℓ – loop length (mm), d_{pl0} – fabric thickness (mm).

From Table 4 and Figure 3, it can be seen that the fabric thickness interlacing factor, v_{deb}, of knitted fabrics made from yarns without elastane core (Samples 7 and 8) exhibits significantly higher values than the fabric thickness interlacing factor, v_{deb}, of knitted fabrics made from yarns with elastane core (Samples 1–6). For the knitted fabrics made from yarns with elastane core, it holds the values v_{deb} = 3.6–6.0, while for the knitted fabrics made from yarns without elastane core, it holds the values v_{deb} = 5.9–11.4. The loose and wet relaxed structures exhibit higher values of the fabric thickness interlacing factor. The fabric thickness interlacing factor decreases with a wet relaxation and with the increase in density.

kih pletiv večja od Knaptonove konstante gostih pletiv. Pri pletivih iz konvencionalnih prej pa je, nasprotno, Knaptonova konstanta redkih pletiv manjša od Knaptonove konstante gostih pletiv.

Na podlagi predhodne analize rezultatov meritev temeljnih parametrov zanke (širina, višina in dolžina zanke ter premer preje in debelina pletiva) z metodo glavnih komponent [16] je mogoče definirati debelinski faktor vpletanja niti v_{deb}, tj. razmerje med dolžino zanke in debelino pletiva:

$$v_{deb} = \frac{\ell}{d_{pl}} \quad (3),$$

kjer je: v_{deb} – debelinski faktor vpletanja niti, ℓ – dolžina zanke (mm), d_{pl0} – debelina pletiva (mm).

Table 4: Knitted fabric thickness, d_{pl0}, loop length, ℓ, and fabric thickness interlacing factor, v_{deb}, of dense and loose, dry, and dry and wet relaxed (consolidated) structures

knitted fabric label (relaxation type)		dense knitted fabric – g			loose knitted fabric – r		
		d_{pl0}	ℓ	v_{deb}	d_{pl0}	ℓ	v_{deb}
1	S	1.7183	8.68	5.0	2.0628	11.99	5.8
	M	1.9167	8.67	4.5	2.0805	11.39	5.5
2	S	1.6577	8.86	5.3	1.9716	11.75	6.0
	M	2.2606	8.62	3.8	2.6218	11.49	4.4
3	S	1.6131	8.93	5.5	1.9206	11.57	6.0
	M	2.0367	8.71	4.3	2.4200	11.46	4.7
4	S	1.6905	8.97	5.3	2.0385	11.85	5.8
	M	2.0339	8.72	4.3	2.2377	11.70	5.2
5	S	1.9160	8.67	4.5	2.4027	11.64	4.8
	M	2.1287	8.25	3.9	2.3956	11.33	4.7
6	S	1.8353	8.86	4.8	2.3096	11.76	5.1
	M	2.4659	8.75	3.6	2.7865	11.40	4.1
7	S	1.1029	8.72	7.8	1.0108	11.50	11.4
	M	1.3084	8.47	6.5	1.238	11.29	9.1
8	S	1.2615	8.69	6.9	1.2552	11.48	9.2
	M	1.4305	8.64	5.9	1.4199	11.32	8.0

** loop length, ℓ_{IN}, was measured with a new method (14)*

Iz preglednice 4 in slike 3 je videti, da je debelinski faktor vpletanja niti v_{deb} za pletiva iz prstanskih prej brez elastanskega jedra (vzorci 7 in 8) pomembno višji od debelinskega faktorja vpletanja niti v_{deb} za pletiva iz prej z elastanskim jedrom (vzorci 1–6). Za presku-

5 Conclusions

Knitted fabrics made from yarns with elastane core are significantly thicker than the knitted fabrics made from yarns without elastane core, with equal linear density, produced on the same knitting machine under the same conditions. The thickness of knitted fabrics made from all yarns, with and without elastane core, increases during a wet relaxation. The loose knitted structures from yarns with elastane core are thicker than the equally relaxed dense knitted structures from yarns of the same kind, while the fabrics made of yarns without elastane core show the opposite trend – the loose knitted structures exhibit lower or equal thickness than the dense knitted structures.

The Knapton constant of knitted fabrics made from yarns with elastane core decreases during a wet relaxation, while it increases for the knitted fabrics made from yarns without elastane core. For the knitted fabrics made from yarns with elastane core, the Knapton constant of loose structures is higher than the Knapton constant of dense structures. In contrast, the Knapton constant of loose knitted structures is lower than the Knapton constant of dense knitted structures for the fabrics made from conventional yarns.

On the grounds of preliminary statistical analyses, the thickness interlacing factor, v_{deb}*, was defined, i.e. the ratio between the loop length and the knitted fabric thickness,* $v_{deb} = \ell/d_{pl}$*. For the knitted fabrics made from yarns with elastane core, it holds the values 3.6–6.0, while for the knitted fabrics made from yarns without elastane core, it holds the values 5.9–11.4.*

The fabric thickness interlacing factor, $v_{deb,}$ *of knitted fabrics made from yarns without elastane core is significantly higher than the fabric thickness interlacing factor of knitted fabrics made from yarns with elastane core. The fabric thickness interlacing factor decreases with a wet relaxation and with the increase in density.*

Acknowledgements

The yarn samples were designed and produced by Predilnica Litija, Slovenia. The knitted samples were produced by Pletilstvo Vene, Ivančna

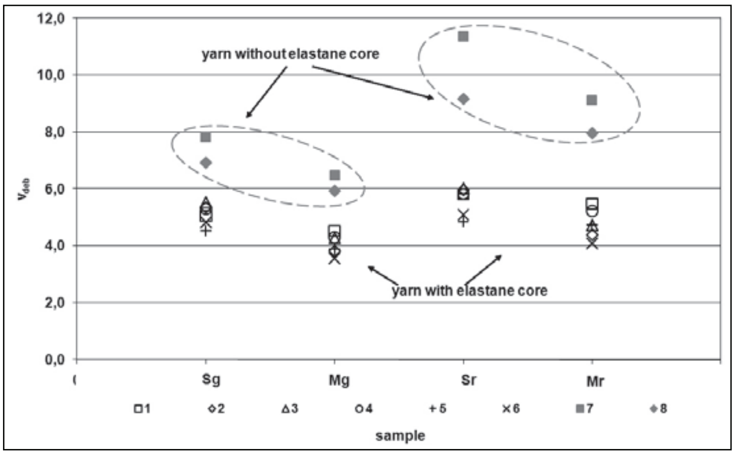

Figure 3: Fabric thickness interlacing factor, v_{deb}*, of dense and loose, dry, and dry and wet relaxed (consolidated) structures made from yarns without elastane core and yarns with elastane core*

šana pletiva iz prej z elastanskim jedrom ima vrednosti v_{deb} = 3,6–6,0, za preskušana pletiva iz prstanskih prej brez elastanskega jedra pa 5,9–11,4, pri čemer dosega višje vrednosti za redka in suho relaksirana pletiva. Debelinski faktor vpletanja niti se z mokro relaksacijo in povečanjem gostote pletiva zmanjša.

5 Sklepi

Pletivo iz prej z elastanskim jedrom je pomembno debelejše od pletiva iz prej brez elastanskega jedra enake nazivne dolžinske mase ter pletenega na istem stroju in pod enakimi pogoji. Debelina pletiv, pletenih iz prej z elastanskim jedrom, kot tudi iz prej brez elastanskega jedra, se z mokro relaksacijo poveča. Redka pletiva iz prej z elastanskim jedrom so debelejša od enako relaksiranih gostih pletiv iz istovrstnih prej, medtem ko je pri pletivih iz prej brez elastanskega jedra ravno narobe: redka pletiva imajo manjšo ali enako debelino kot gosta.

Z mokro relaksacijo se Knaptonova konstanta pletiv iz prej z elastanskim jedrom zmanjša, pletiv iz prej brez elastanskega jedra pa poveča. Pri pletivih iz prej z elastanskim jedrom je Knaptonova konstanta redkih pletiv večja od Knaptonove konstante gostih pletiv. Pri pletivih iz konvencionalnih prej pa je, nasprotno, Knaptonova konstanta redkih pletiv manjša od Knaptonove konstante gostih pletiv.

Na podlagi predhodnih statističnih analiz je bil definiran debelinski faktor vpletanja niti, tj. razmerje med dolžino zanke in debelino pletiva: $v_{deb} = \ell/d_{pl}$, ki ima za preiskovana pletiva iz prej z elastanskim jedrom vrednosti v_{deb} = 3,6–6,0, za pletiva iz prej brez elastanskega jedra pa 5,9–11,4.

Debelinski faktor vpletanja niti v_{deb} pletiva iz prej brez elastanskega jedra je pomembno višji od debelinskega faktorja vpletanja

gorica, Slovenia. We very much appreciate their assistance and co-operation.

niti pletiv iz prej z elastanskim jedrom. Debelinski faktor vpletanja niti se z mokro relaksacijo in povečanjem gostote pletiva zmanjša.

6 Viri

1. TOMPKINS, E. *Science of knitting*. New York : Wiley, 1914.
2. PEIRCE, F. T. Geometrical principles applicable to the design of functional fabrics. *Textile Research Journal*, 1947, vol. 17, p. 123–147.
3. VÉKÁSSY, A. Examination of the cover-factor and specific weight of weft-knitted or looped basis texture based on the exact value of the loop length. *Acta Technica,* 1960, vol. 31, p. 69–102.
4 DALIDOVIČ, A. S. *Osnovi teorii vjazanija*. Moskva : Legakaja industrija, 1970.
5. SUH, M. W. A study of the shrinkage of plain knitted cotton fabric, based on the structural changes of the loop geometry due to yarn swelling and deswelling. *Textile Research Journal*, 1967, vol. 37, p. 417–431.
6. MOROOKA, Hi., MATSUMOTO, Y., in MOROOKA, Ha. A geometric analysis of the stitch form of a circular plain knit fabric inserted over a cylinder. *Textile Research Journal*, 1998, vol. 68, p. 930–936.
7. *KNAPTON, J. J. F., AHRENS, F. J., INGENTHON, W. W., FONG, W.* The dimensional properties of knitted wool fabrics. Part I, The plain knitted structure. *Textile Research Journal*, 1968, vol. 38, p. 999–1012.
8. MATSUDAIRA, M., QIN, H. Features and mechanical parameters of fabric's compressional property. *Journal of the Textile Institute*, 1995, vol. 83, p. 476–486.
9. ALIMAA, D., MATSUO, T., NAKAJIMA, M., TAKAHASHI, M., YAMADA, E. Y. Pressure-thickness relation and compression mechanism of plain and rib knitted fabrics. *Journal of Textile Machinery and Society Japan, English Edition,* 2000, vol. 46, (1), p. 7–10.
10. NAKAJIMA, M., QUAYNOR L., TAKAHASHI, M., YAMADA, E. Effect of relaxation processes on the thickness of plain-knitted fabrics. *Bulletin of the Faculty of Textile Science*, *Kyoto Institute of Technology*, 2001, vol. 25, p. 7–12.
11. KOPITAR, D., VRLJICAK, Z., SKENDERI, Z. Influence of yarn count on knitted fabrics thickness and mass per unit area. *Annals of DAAAM & Proceedings, Annual, 2007.*
12. GROSBERG, P. Shape and structure in textiles. *Journal of the Textile Institute*, 1966, vol. 57, p. T383–T394.
13. GROSBERG, P. The geometry of knitted fabrics. V J. W. S. Hearle, P. Grosberg, S. Backer, *Structural mechanics of fibers. Del 1, Yarns and fabrics.* New York, London, Sidney, Toronto : John Wiley & Sons, 1969, p. 411–450.

14. *PAVKO-ČUDEN, A. Študij zanke votkovnega pletiva. Study of weft knitted loop : Doktorska disertacija. Ljubljana : Univerza v Ljubljani, Naravoslovnotehniška fakulteta, 2005.*
15. *Laboratory Practice in the Study of Textile Materials*. Edited by A. Kobljakov. Moskva : Mir, 1989.
16. PAVKO-ČUDEN, A., SRDJAK, M. Significance of elasticized knitted fabric parameters compared to conventional knitted fabric parameters. *Proceedings of 5th World Textile Conference AUTEX, Portorož, Slovenia, 2005,* p. 652–657.

Zahvala

Vzorci prej so bili izdelani v Predilnici Litija. Vzorci pletiv so bili izdelani v Pletilstvu Vene, Ivančna Gorica. Zahvaljujemo se za podporo in sodelovanje.