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INFLUENCE OF THE HEMP COMPONENT IN NON–HOMOGENEOUS YARNS ON THE ELASTIC BEHAVIOR OF KNITS MADE THEREFROM

One of the aims of producing non–homogeneous yarns is the improvement of their mechanical, aesthetic and comfort properties. In the case of hemp yarns, known by their predominantly technical uses, non–homogeneous yarns containing other chemical fiber yarn components besides hemp, could serve as a solution for making hemp textiles more acceptable for the production of clothing items. Different two–plied yarns, having always as one of the components 50 Tex hemp yarn, were exposed to axial stresses. Also their behavior after the relaxation of axial stress was studied in order to obtain an insight into the change of the elastic properties. Knitted fabrics of identical structure, made of these yarns, were exposed to compression and axial tests. The results obtained, correlated with the change of the relative cover of knits and to their structure (stitch density, surface mass, density, free open surface etc.) demonstrated the influence of the non–hemp components on the change of some basic properties of knits. These data could be important for the use and maintenance of hemp containing knitted clothing, as well as for their environmental acceptability.

Key words: hemp, complex yarns, comfort, knits, compressibility, resilience, free surface.

Despite former extensive application in apparel in a range of countries, especially in rural regions, hemp has almost completely disappeared from world textile market, until the latest efforts that started in the early 90s and were oriented towards its renaissance. One of several reasons for such a situation was the lack of comfort of hemp textiles, especially in articles that came into direct contact with the skin. That was the reason why hemp was mainly used for the production of technical yarns, ropes and cordage. However, after decades of the intensive use of synthetic fibers, their application is nowadays rejected by the public in some types of clothing items: even for women's lingerie, where comfort is frequently sacrificed to a point, textile surfaces made of spun blends including natural and chemical fibers enjoy extensive markets, owing to better aesthetic, visual and tactile, i.e. comfort characteristics. The proof of the possibility of hemp fibers, if adequately refined, to be blended with other staple fibers such as cotton, wool or even silk and synthetic fibers and spun on cotton and wool spinning systems, have enabled the use of hemp for the production of comfort textile surfaces and clothing items. Another incentive seemed to exist in the production of plied yarns including fine hemp yarns as one of the components, the other one being spun or filament yarn, natural or man–made. In addition to the economic and environmental advantages, characteristic for such complex or non–homogeneous yarns, it was supposed that they would have some distinctive features, such as higher elasticity, permitting them to compress or to stretch and recover. The realization of such textile materials would be an important step in the approach of hemp clothing items to the level of comfort textiles. Presuming that the staple containing fabrics are comfortable and that filament fiber fabrics are less comfortable or uncomfortable, hemp complex yarns containing two different filament yarns were transformed into knitted fabrics, and the range of their properties related in some extent to comfort were compared. The data obtained were used to ascertain the influence of such yarns by combining some comfort properties of the knits made therefrom.

MATERIAL AND METHODS

Material

Hemp singles yarns with a fineness of 50 Tex were all complex yarns combined with viscose filament yarn and textured Tactel® (Du Pont's Nylon yarn). The properties of the yarns used to produce knitted fabrics are given in Table 1.

The complex hemp–containing yarns were mainly two–plied. Also, an attempt was made to use, if possible, yarns of similar fineness. Obviously, hemp yarn was somewhat heavier than desired. Two samples of yarn differed in tactel filament content, the first one presenting hemp yarn plied with one tactel filament and the second with two tactel filaments, i.e. two ends of tactel yarn were plied with hemp yarn as one. The nominal secondary twists of all the complex yarns were the same.

Knitted fabrics were produced from these yarns, all except one, on two machines differing in settings

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Table 1. Characteristics of the yarns used for production of knits

Fiber	Fineness of the Singles Yarn (Tex)	Fineness of the Complex Yarn (Tex)	Ply	Singles Twist (T/m)	Ply Twist (T/m)
Hemp	47.8	–	1	370	–
Viscose	30.9	–	1	113	–
Tactel	16.4	–	1	–	–
Hemp/Hemp	–	95.6	2	–	297
Hemp/Viscose	–	81.6	2	–	308
Hemp/Tactel	–	62.8	2	–	305
Hemp/Tactel/Tactel	–	78.8	3	–	308

(NoE10 and NoE12), designated as (a) and (b), respectively. All–hemp fabric could not be produced on the finer machine (NoE12), so that all–hemp samples were used for comparison only in the form of variant (a).

Methods

The physical properties of samples related to comfort included: mass of the fabric, thickness, number of wales and courses per cm, free open area, air permeability, density, compressional resilience and deformation under axial stress. Tests were performed on fabrics in the relaxed state, in a laboratory conditioned at 22°C and RH 65%.

The initial thickness of the fabrics was measured on a fabric thickness measuring device (TexTest–FX 306) under a pressure of 30 g/cm^2 according to the standard JUS F.S2.021. The open free area, defined as the projected fabric area unoccupied by fibers (yarns), was assessed using a simple computer method described in detail elsewhere [1,2]. In principle, the computer Adobe PhotoShop program, was applied in order to collect and measure the quantity of light passing through the interstices of the yarn in the knits. An example of data collected by scanning samples of knits and using quantitative information supplied by PhotoShop is illustrated in Figure 1.

The densities of the knitted fabrics were calculated by dividing their mass by thickness.

The compressional behavior of the knits was tested in order to obtain an insight into the softness of the material by assessment of its ability to deform under a compressive load. Also, its resilience i.e. its tendency to return to its original dimension after unloading, was measured, and expressed as the "permanent set", i.e. the measure of fabric inability to recover after compression. Samples were compressed and relaxed for five cycles progressively increasing the load from 30 g/cm^2 (thickness without added load), to 170 g, 420 g, 670 g and 1170 g and finally to approximately a tenfold load of 1670 g/cm^2 [3]. The difference in sample thickness without added load and under maximum load in the first cycle of "loading–unloading" determined their compression. The value of the difference between the initial thickness and the thickness after the fifth cycle determined the compressional resilience, i.e. the permanent set, according to following equation:

$$C = [(T_0 - T_{max})/T_0]100\%;$$

$$S = \{[(T_0)^{1st} - (T_0)^{5th}]/(T_0)^{1st}\}100\%$$

where: C – is the compression (%); T_0 – the thickness at 30 g/cm^2; T_{max} – the thickness at 1670 g/cm^2; S – the permanent set (%); $(T_0)^{1st}$ – the 1st cycle thickness at 30 g/cm^2; and $(T_0)^{5th}$ – the 5th cycle thickness at 30 g/cm^2.

Taking into account the fact that when fabric in air, thermal insulation, as one of the comfort factors, is governed primarily by fabric thickness, air permeability was measured according to the standard JUS F.S0.100. The measurements of air permeability were compared with the values of the open free surface of the knits, as two indicators of air accessibility to the body, with a pronounced effect on its comfort.

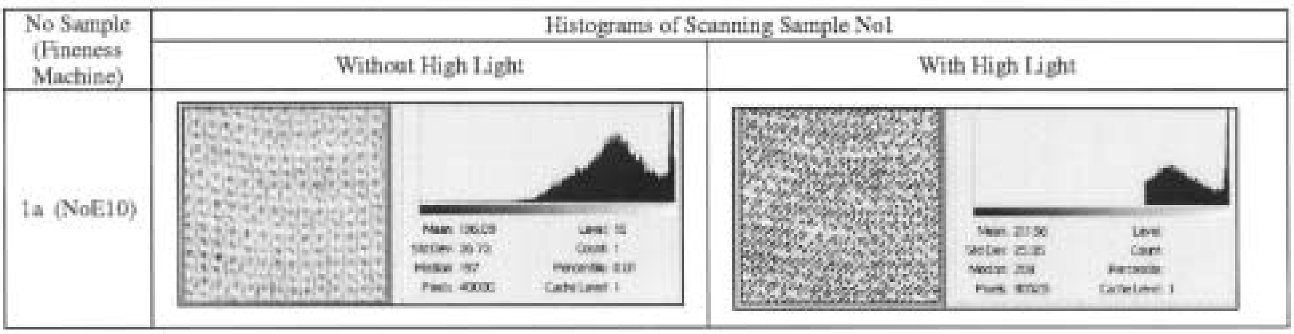

Figure 1. Scanning of knits

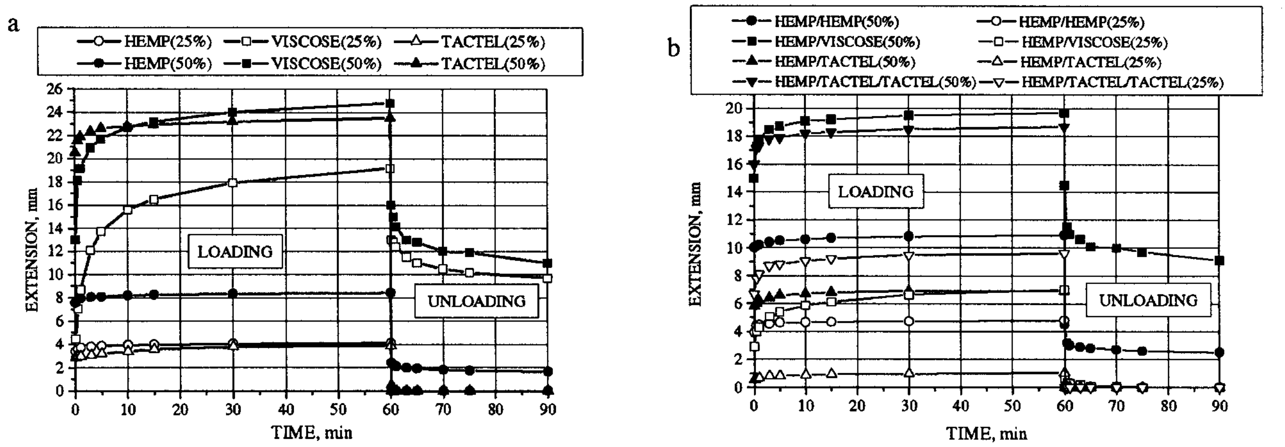

Figure 2. Elastic properties of complex hemp–based yarns: a) singles yarns, b) plied yarns

Also, the distortability of fabrics, influencing the aesthetic characteristics of knits, as well as their ability to open up and to change their permeability was measured using a Fryma Fabric Extensiometer, a simple apparatus for testing the stretch and recovery of textile fabrics [4].

RESULTS AND DISCUSSION

An illustrative, first insight into the influence of yarn components in complex yarns was obtained by testing their deformation under axial stress valued at 25% and 50% of the hemp component breaking strength. As presented in Figure 2, the inclusion of viscose and tactel components in complex hemp–based yarns significantly changed the deformation behavior in relation to all–hemp plied yarn, showing sensitivity to both the type of the component and the structure of the yarn. It may be seen that the deformation of singles hemp yarn under axial stress was similar to tactel and significantly lower in comparison with viscose filament under lower stress, while the behavior of viscose and tactel was similar under higher stress and appreciably different from hemp. However, the picture is changed if complex yarns are considered: hemp/tactel combinations gave the most extensible (hemp/tactel/tactel yarns) and the least extensible yarns (hemp/tactel yarns) under both levels of stress applied. Under higher stress both tactel containing complex yarn had the highest elastic component of deformation, while under lower stress hemp/tactel yarn showed the lowest elastic recovery and hemp/tactel/tactel yarns again the highest. Obviously, combinations of components drastically differing in respect to their behavior under stress, indicated that a range of different properties of knits, related to comfort, could be expected.

An analysis of some physical properties of knitted fabrics, presented in Table 2, illustrates the diversity of fabric properties attained by combining hemp yarn with other components. It was interesting to notice that, although all the fabrics were knitted on the same machines, in the same weaves, their relaxation prior to laboratory analysis, specific in each case, did not differ in the number of stitches except in the case of hemp/tactel/tactel yarn produced on the finer machine (sample No4b).

As to the thickness of the fabrics, the hemp/hemp combination normally enabled obtaining of the thickest knits, having high mass per surface unit and densities similar to other fabrics produced on the coarser machine. However, if produced on the finer machine the hemp/tactel/tactel yarn made knit was the heaviest, having also the highest density and opacity, as illustrated by Figure 3, which presentis the surface

Table 2. Some physical properties of the experimental samples

Sample No	Yarn Composition	Fineness of the Machine	Properties of the knits						
			Density (g/cm^3)	Stitch Density (cm^{-1})		Surface Density (cm^{-2})	Length of Loop (mm)	Thickness (mm)	Mass (g/m^2)
				D_h	D_v	D_n D_v			
1_a	Hemp/Hemp	NoE10	0.026871	11	12	132	6.75	1.6486	443.0
2_a	Hemp/Viscose	NoE10	0.025170	11	12	132	6.9	1.4302	360.1
2_b		NoE12	0.030588	12	16	192	5.5	1.5228	465.8
3_a	Hemp/Tactel	NoE10	0.025139	11	12	132	6.6	1.2180	306.2
3b		NoE12	0.024738	12	16	192	5.25	1.3966	345.5
4_a	Hemp/Tactel/Tactel	NoE10	0.024754	10	13.2	132	6.75	1.5306	378.9
4b		NoE12	0.031602	12	18	216	5.5	1.5040	475.3

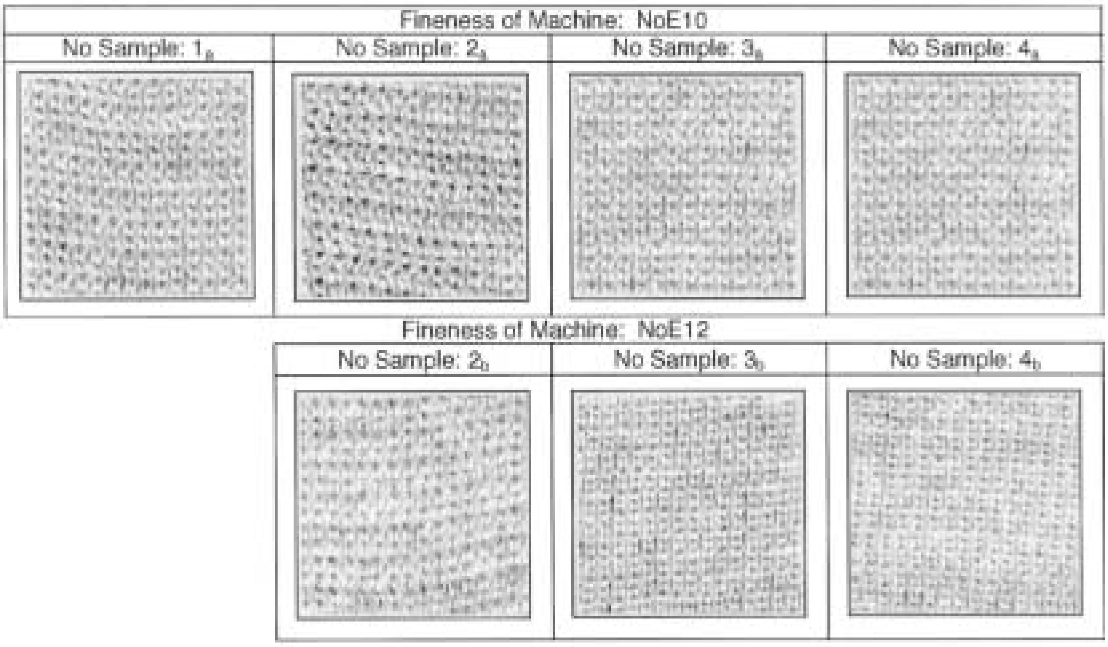

Figure 3. Scanned samples of knits

characteristics of the knits. It may be seen that scanned prints of the knits show significant differences in their appearance. Despite the rather high content of hemp in most of them, the character of viscose or tactel filament inclusion is clearly manifested: the specific character of the surfaces, introduced by the intrinsic properties of component yarns, surface hairiness, the number of points of contact and different preferred orientations may also be seen.

Even more, the obvious differences in surface roughness of the fabrics could be related to a different feel of warmth, in the sense the rougher the surface, the warmer the feel of fabric. Here also the setting of the machine could have an important role, as illustrated, for example, in the case of knits produced from complex, hemp/viscose yarns.

A quantitative insight into these differences may be obtained from the values of the open free surfaces (Table 3). Knits produced on the coarser machine have the most open surface in the case viscose and hemp were used, while in the case of the knits produced on the finer machine the open free surfaces were similar, the variant produced from hemp and one tactel yarn having more open surface than hemp–viscose and hemp–two tactel yarns. The results of air permeability were not in accordance with the open free surface in all the variants tested. Though the sample N^{o}2a, with the greatest open free surface, also demonstrated the greatest air permeability, the introduction of one tactel filament in the complex yarn, with the same open free surface as the variant folded with two tactel yarns, resulted in great differences in air permeability. Also, the influence of machine settings was different in the case of multifilament yarn combinations (viscose) in comparison with complex yarns containing textured filament, both regarding the open free surface and air permeability. However, introduction of a textured filament component in the complex yarn caused a more unified change of the open free surface in relation to the change of air permeability in the cases of both machine settings. Probably the air motion disturbed the fibers in the components of the complex yarns in different ways, thus

Table 3. Comfort parameters of the knits

Sample No	Yarn Composition	Fineness of the Machine	Comfort parameters of the kints		
			Cover Factor ($tex^{1/2}\,cm^{-1}$)	Air Permeability ($m^3/min/m^2$)	Free Open Surface (%)
1_a	Hemp/Hemp	NoE10	14.5	89.17	23.69
2_a 2_b	Hemp/Viscose	NoE10 NoE12	13.1 16.4	122.78 87.78	28.84 15.63
3_a 3_b	Hemp/Tactel	NoE10 NoE12	12.0 15.2	102.22 91.11	15.10 19.24
4_a 4_b	Hemp/Tactel/Tactel	NoE10 NoE12	13.1 16.1	74.44 61.11	15.09 14.98

Table 4. Compression and resilience knitted fabrics

Sample No	Yarn Composition	Fineness of the Machine	Properties of the knits				
			Compressibility		Permanent Set		Hysteresis of Compression (mm^2)
			Absolute (mm)	Relative (%)	Absolute (mm)	Relative (%)	
1_a	Hemp/Hemp	NoE10	0.69	42.1	0.52	31.3	396.74
2_a 2_b	Hemp/Viscose	NoE10 NoE12	0.64 0.60	44.67 39.40	0.49 0.41	34.3 27.3	318.55 342.24
3_a 3_b	Hemp/Tactel	NoE10 NoE12	0.59 0.65	48.80 46.70	0.48 0.47	39.2 33.9	251.23 329.50
4_a 4_b	Hemp/Tactel/Tactel	NoE10 NoE12	0.74 0.58	48.20 38.70	0.58 0.42	37.9 27.8	352.17 321.38

permitting a larger amount of air to pass than the free area measurements would indicate. The influence of two tactel filaments, introduced as a simply doubled component, obviously decreased the openness of the knits. As is well known, depending the weather, lower permeability would be advantageous in cold weather, while higher permeability would serve better for hot and humid weather. By combining with yarns of different characters, the intermediate position of all–hemp knits could be adapted to both of these extremes.

Similarly, the values of the cover factor, the known geometric characteristics of knitted fabric openness (calculated on the basis of the length of the yarn absorbed in the loops), are in accordance with two other parameters of relative cover in the case of viscose/hemp yarn knits, but this regularity is not always present. Obviously, the machine settings and character of the component yarns differently influenced the data obtained by different methods.

The compressional characteristics, presented in Table 4 demonstrate slight differences between all the hemp yarns knits and the knits produced from non–homogeneous hemp–containing samples. The absolute compression under a load increase from 30 g/cm^2 to 1670 g/cm^2 was the greatest for sample N°4a, being made of hemp yarn plied with two tactel filaments. However, its compressibility, proportional to softness, was the closest to the all–hemp made knit compressibility. In fact, all the samples have rather similar compressibility or softness, due to the dominant hemp content in these yarns.

On the basis of the measurement of the permanent set, as the inability of compressed fabric to attain its original dimensions i.e. to recover, one of the hemp–viscose variants (N°2b) and one hemp/tactel variant (N°4b) both produced under the finer settings had the best behavior. However, the differences in resilience between the experimental material were not high, demonstrating again the dominant influence of the hemp component in all the samples. The influence of machine settings on the compressional behavior of knits is rather puzzling, especially in the case of viscose–containing variants. It must be taken into account that

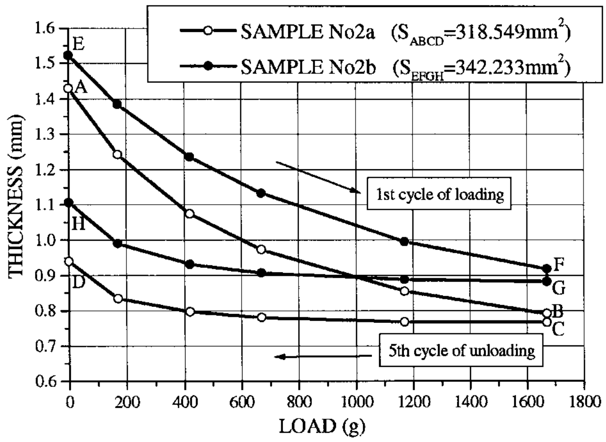

Figure 4. Hysteresis of compressin of knits (samples N°2a and N°2b)

the samples differed in thickness, and that the relative permanent set presents a more objective indicator of the fabric ability to recover. Also, hysteresis of compression between the first and the fifth cycles of loading–unloading, expressed as the surface proportional to the work of compression (Figure 4), presents supplementary information on the energetic behavior of the samples tested. It may be seen (Table 4) that all–hemp made knitted fabrics and one of the fabrics with two tactel yarns dominate in respect to the work of compression. The lowest work of compression under the conditions applied was obtained for the fabric made of a hemp/tactel yarn combination. Probably, the voluminosity of the yarns influenced the behavior of knits

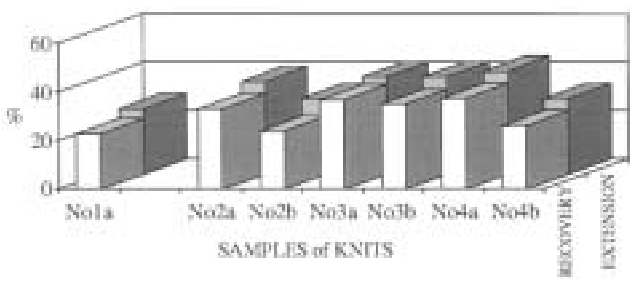

Figure 5. Elastic behavior of knits under axial stress

made therefrom during compressional stress and recovery under increasing load. The stretch and recovery data (Figure 5) of the knitted fabrics under axial stress, as assessed by the Fryma extensiometer, demonstrated the least extension of all–hemp knits, the highest ones being characteristic mostly for tactel–containing samples. Also, the recoveries were the lowest by all–hemp samples, and the highest ones by tactel containing samples. In these relations the settings of the machines again played an important role. However, these results could not be put in direct relation to the stretch and recovery data of the yarns used for the production of knits, this fact indicating the importance of the state of yarn aggregation in the fabrics for their properties related to comfort.

CONCLUSION

Knitted fabrics made of hemp yarns combined with other yarn types in complex, plied yarns, although similar to all–hemp yarn made knits, differ in some properties related to comfort, such as permeability to air, open free surface, compressibility and surface character. The means of yarn combining (plying, folding) as well as the intrinsic characteristics of individual components (textured, filament) seem to the have potential to influence the comfort of knits in the desired direction. That means that the state of yarn aggregation in the fabrics may seriously influence the comfort of knits and that experiments with a large number of different yarn combinations in complex yarns, using this simple methodology, could result in an approach to the subject of hemp fabrics comfort improvement.

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IZVOD

UTICAJ KOMPONENTE NA BAZI KONOPLJE U NEHOMOGENIM PREĐAMA NA ELASTIČNO PONAŠANJE PLETENINA

(Naučni rad)

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Pređe od konoplje, poznate prevashodno po svojoj upotrebi za tehničke svrhe, kombinovane su sa pređama na bazi hemijskih vlakana u cilju ispitivanja mogućnosti njihove primene za odevne svrhe. Stručene dvokomponentne pređe, koje su uvek sadržale pređu od konoplje finoće 50 tex, predstavljale su nehomogene (kompleksne) strukture, kakve se primenjuju u cilju poboljšanja mehaničkih, estetskih i komfornih svojstava pojedinačnih komponenata. Pređe su podvrgnute ispitivanju promene elastičnih svojstava pri aksijalnom naprezanju, čime je omogućena ocena uticaja dodatnih komponenata na promenu mehaničkog ponašanja pređa značajnog kako za dalju transformaciju u tekstilne površine tako i za njihovu upotrebnu vrednost. Pletenine identične strukture proizvedene od ovih pređa su izložene kompresionim i aksijalnim testovima. Dobijeni rezultati, stavljeni u odnos sa relativnom pokrivnom sposobnošću pletenina i njihovom strukturom (gustina petlji, površinska masa, gustina, slobodna otvorena površina) prikazali su uticaj dodatih komponenata pređa na promenu nekih osnovnih svojstava pletenina. Ovi rezultati mogu biti od interesa za upotrebu i održavanje odevnih predmeta na bazi konoplje, kao i za njihovu ekološku prihvatljivost.

Ključne reči: konoplja, kompleksne pređe, komfor, pletenine, kompresibilnost, elastičnost, slobodna otvorena površina.