CHANGES IN PROPERTIES OF WOOL FIBRES AND YARNS THROUGH THE PHASES OF THE PROCESS OF SPINNING AND WEAVING IN DIFFERENT WEAVES

EĞİRME İŞLEMİ AŞAMALARINDA VE FARKLI KONSTRÜKSİYONLARDA DOKUMA İŞLEMİNDE YÜN LİFİ VE İPLİK ÖZELLİKLERİNDE DEĞİŞİM

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ABSTRACT

The aim of this study was to investigate the changes in properties of wool fibres through the all phases of the production processes from fibre to woven fabric. Research on fibres were carried out before spinning, after spinning and after weaving and on the yarns before weaving and after weaving. According to obtained results it can be determined that noticeable changes in the properties of the fibres and yarns through these phases have arisen. The biggest changes were recorded in the process of weaving. It was also noticed that the weave influences the changes in properties of the fibres, yarns and fabrics. Direction of the fabric that had a greater number of threads transitioning from fabric face side on the reverse side, and vice versa, have major changes in fibres and yarns strength utilization in the fabric, which means that the weave directly influences the changes in the fibres and yarns properties.

Keywords: Fibre, yarn, fabric, weave, strength utilization of fibres in the yarn, strength utilization of yarns in the fabric.

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1. INTRODUCTION

By development of new materials and processing procedures for different purposes, the continuous researches are necessary. It is particularly required for natural raw materials, which are changed by changing environmental conditions and methods of treatment of plants and animals from which the fibre originates. Wool fibres depend on such changes and require continuous monitoring, not only during the growth of wool fibre on sheep but also later through the production process, all the way to finished fabric. Therefore physical and mechanical properties of fabrics, depends not only on the constructional parameters of the fabric but also on the properties of yarns and fibres from which the fabric is made. Their properties are changed during processing and depends on the static and dynamic forces acting on them. During yarn spinning process a certain routing of fibres occurs as well as their twisting in the thread. Because of certain thread unevenness as a result of technological spinning process, variation in the yarn properties occurs, that directly affect the properties of the fabric. Yarn, particularly warp threads, during the entire process of fabric production are experiencing great physical and mechanical stresses and changes (especially unsized warp threads), which greatly affects its properties. Cyclic loading of yarns in the warp in weaving process starts from the warp beam and lasts until the cloth beam. The biggest stress of the warp threads is in the process of creating shed and pushing the weft by reed. To create a shed and to allow unhindered passage of weft through shed, the warp is pulled radially and thus cyclic strains. Besides stress, a certain abrasion between warp threads and metal parts - heddles, droppers and reed occurs, as well as in the moment of pushing weft by reed. For this reason, warp threads must have relatively high strength and elasticity to withstand the dynamic stresses that are present in the weaving process.

To obtain fabric with certain properties it is necessary to select the number of parameters of production processes, properties and raw materials, starting from the fibres that form the basis for making yarn and afterword’s fabric. The fibres properties as length, fineness and strength, and their variations, represents important parameters which directly affects the properties of yarns and fabrics. In addition, the technological process of yarn manufacturing greatly affects the final quality of the yarn. The fineness of the yarn is determined by the number of fibres in the yarn cross-section and thus the strength of the yarn. A larger number of fibres in the yarn cross-section is not the only prerequisite to its greater strength, but also uniform distribution of fibre length sufficient to create the correct twist and satisfactory strength of the fibres themselves. Such good fibre properties will be transferred not only to the yarn but also to the fabric. Dynamic forces in the yarn, during production processing especially in the weaving process, change the properties of fibres and yarns. Deformation of individual fibres are very different and depends not only on the yarn tension, frequency and speed of dynamic forces caused by the creation of shed and pushing the weft by reed, elongation properties of fibres and yarns, the type of machine and weaving conditions, but also on the fibres fineness and their position and in the yarn cross-section, as well as on the yarn fineness and number of twist [1,2]. Deformation of fibres and threads in the longitudinal direction are also formed by bending and compression and with interlaced warp and weft. These distortions largely depend on the type of material, the number of yarn twists and fineness, fabric density, weave and yarn tension in the weaving process [3-5]. Many authors have made a big contribution to the study of fibres and yarns deformations in production processes [6,7], but with the development of new materials and processing procedures, a need for broader and more fundamental research in new condition occurs and that is exactly the main goal of this research.

2. MATERIALS AND METHODS

The mechanical properties of the fabric directly depends on the properties of yarns and fibres from which it is formed, technological methods of processing, the modernization of production and conditions. Their properties are changed during production processing, so after each phase fibres and yarns properties are poorer [8-11]. Therefore, the aim is to optimize each phase in the more economical and high-quality processing. It is important to control the most influential parameters and aspire that their values be within the limits of acceptability. Some of the properties of the fibres, yarns and fabrics, which directly affect the quality of the finished material, are not obtained by direct measurement but computationally, such as strength, tearing length, strength number, fibres and yarns strength utilization and that will be analysed in this chapter.

The breaking force is the resistance of fibres, yarns or fabrics to static force of stresses until break and it is expressed in absolute value (mN, cN or N). The strength of fibres and yarns is defined as the breaking force per Tex and the strength of the fabric is defined as breaking force per cross-sectional area of the sample that is tested.

Strength utilization of fibres in the yarn (η_f) is calculated according to the following equation:

$$\eta_f = \frac{F_y \times 10}{F_f \times N_f} \times 100 \quad (\%) \qquad (1)$$

where F_y is yarn breaking force, F_f is fibre breaking force and N_f is the average number of fibres in the yarn cross-section.

Strength utilization of yarns in the fabric (η_y) is calculated according to the following equation:

$$\eta_y = \frac{F_w \times 10}{F_y \times N_y} \times 100 \quad (\%) \qquad (2)$$

where F_w is fabric breaking force, F_y is yarn breaking force and N_y is number of threads (yarns) in the fabric at 50 mm (width of fabric in tests of breaking force).

The length of tearing fabric (L_w) is calculated with a purpose of comparing values of breaking forces of different fabrics. It represents the notional length of fabric 5 cm wide, which would be suspended and under the action of gravity interrupted. Fabric own weight and gravity elicit the occurrence of force equal to the breaking force and is calculated using the following equation:

$$L_{w_{w1,w2}} = \frac{F_{w_{w1,w2}} \times 1000}{m_w \times b} \Rightarrow \frac{F_{w_{w1,w2}} \times 1000}{m_w \times 50} \Rightarrow \frac{F_{w_{w1,w2}} \times 20}{m_w} \; (km) \qquad (3)$$

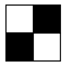
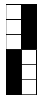
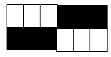
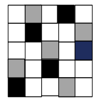
where $L_{w_{w1,w2}}$ is tearing length of fabric in the warp (w_1) or weft (w_2) (km) and m_w is fabric weight (g/m^2).

The properties of the fibres from combed sliver and the yarn before and after weaving were tested. The same yarns were used for the warp and weft threads in production of fabrics with four different weaves: plain P 1/1, transverse rips R 3/3(1+1), longitudinal rips R 1/1 (3+3) and 5-reinforced midfield satin A 1/4 (2+3). All four fabrics were woven on the same weaving machine tt. Sulzer, with weft insertion by single rigid rapier in a textile factory Varteks, Varaždin, in the length of 15m, at constant weaving conditions. The test samples were made after fabric stabilization. The fibre composition was 100% wool, fibre thickness was 22.12 microns, respectively 13.33 dtex, yarn fineness was 50 tex and the number of twist 505 twist/m. The constructional parameters of tested fabrics are shown in Table 1.

3. RESULTS AND DISCUSSION

The yarn that was used for warp and weft in the process of weaving fabrics in four different weaves (15 m of each fabrics) was spun from wool fibre. Despite maintaining conditions constant during the fabrics weaving, the results of tests carried out indicate that the constructional parameters of fabrics and yarns differ by weaves (Table 1). The density of the fabric in the warp direction varies within 1.6% (from 24.8 threads/cm in the fabrics 3 to 25.2 threads/cm in the fabric 2) and in the weft direction within 5.1% (from 14.9 threads/cm in the fabric 3 to 15, 7 threads/cm in the fabric 1). Shrinkage in the warp direction varies even within 18.1% (from 3.91% in the fabric 4 to 4.77% in the fabric 3), a weft direction within 24.3% (from 8.26% in the fabric 3 to 10.75% with the fabric 1); while the fabric thickness between the fabrics of different waves varies within 25.6% (from 0.61mm in the fabric from 1 to 0.82mm in the fabric 3) and the fabric weight just within 2.6% (from 224 g/m^2 in the fabric 4 to 230 g/m^2 in the fabric 1).

Table 1. Constructional parameters of fabrics

		Fabric 1	Fabric 2	Fabric 3	Fabric 4
Weave					
D_w (threads/10cm)	Warp	251	252	248	250
	Weft	157	154	149	152
S_w (%)	Warp	4.76	4.08	4.77	3.91
	Weft	10.75	10.00	8.26	9.65
T (mm)		0.61	0.72	0.82	0.69
m_w (g/m^2)		230	226	226	224

D_w - fabric density (threads/10cm), S_w - fabric shrinkage (%), T - fabric tickness (mm), m_w - fabric mass (g/m^2)

Table 2. Tested values of fibres from combed sliver, yarns and fabrics

		Fibres from combed sliver	Fibres from yarn	Fabric 1		Fabric 2		Fabric 3		Fabric 4	
				Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
N_f (n)	$\bar{x}$	-	98	82	86	83	88	78	81	80	87
	CV (%)	-	14.5	12.6	20.4	16.5	18.6	13.1	10.8	12.4	16.7
L (mm)	$\bar{x}$	72.5	75.2	62.4	66.1	72.7	68.8	65.8	74.9	70.5	74.0
	CV (%)	28.9	38.4	42.1	45.3	32.1	37.9	43.1	35.0	40.0	42.9
F_f (mN)	$\bar{x}$	74.4	69.1	54.4	58.6	58.2	64.0	60.0	68.9	62.5	67.2
	CV (%)	18.9	15.6	17.8	14.4	16.0	15.3	17.4	16.0	16.2	18.9
ε_f (%)	$\bar{x}$	13.0	8.9	7.5	8.3	7.6	8.3	7.3	8.2	8.0	8.7
	CV (%)	9.4	11.8	9.1	9.6	11.8	15.7	8.7	10.1	16.5	10.7
σ_f (mN/dtex)	$\bar{x}$	5.6	5.2	4.1	4.4	4.8	4.4	4.5	5.1	4.7	5.0
	CV (%)	7.9	10.7	5.4	5.5	4.6	7.6	5.1	9.6	6.4	10.6

N_f - number of fibres in the yarn cross-section (n), F_f - fibre breaking force (*cN*), ε_f - fibre elongation at break (%), σ_f - fibre strength (mN/dtex)

By observing the average number of fibres in the yarn, it can be determined that compared to the number of fibres in the yarn before weaving (98 fibres), the number of fibres in the yarn after the weaving process greatly reduces (Table 2). This phenomenon is more present in the warp threads of all fabrics, which is understandable due to higher abrasion and stress in the warp direction; and the values range from 78 fibres in the warp threads in the fabric 3 up to 88 fibres in the weft threads in the fabric 2. The CV is relatively high and amounts from 10.8% for weft threads in the fabrics 3 to 20.4% for also weft threads in the fabric 1. Fibres length in the yarn differs within the samples and their average deviation is not great, while the CV is extremely large, as expected for the wool fibres. The average breaking force of fibres from the yarn decreased during stretching and twisting in spinning process (for 7.1%) and further in the weaving process in all samples. It is worth noting that breaking forces of fibres in the warp threads are mostly lower. The largest decrease of breaking forces of fibres in the yarn after weaving process, compared with fibres in the yarn before weaving process, is evident in the fabric 1 woven in plain weave (21.3% for the warp and 15.2% for the weft threads) and the lowest in the fabric 4 woven in satin weave (9.6% for the warp and 2.8% for the weft threads). The reason for this is the largest (fabric 1), i.e. the smallest (fabric 4) number of interweaving threads in the pattern (threads transfers from face side to reverse side or vice versa), which causes greater (fabric 1), i.e. less (fabric 4) deformation of the fibres within the yarns, especially in the warp directions. Elongation at break of fibres also decreased during the spinning (for 31.5%) and weaving process (maximum reduction of 17.9% for the warp in the fabric 3 and a minimum reduction of 2.3% for the weft in the fabric 4). Fibres tensile strength followed the course of the results of breaking forces and by the spinning process dropped for 7.1%, and additionally after the weaving process in terms of a maximum of 21.2% for the warp threads in the fabric 1 to the minimum of 1.9% for weft threads in the fabric 3.

By observing the properties of yarns (tab. 3) before and after weaving, the reduction of breaking force of yarn resulting from the weaving process is evident and the differences between the weaves are obvious. Greater reduction of breaking forces of yarns is usually in the warp direction compared to weft direction and it is most pronounced for the warp of the fabric 1 (7.8%), while the least reduction is recorded in weft threads of the fabric 4 (3.1%). Elongation at break followed the course of breaking forces and ranges from the largest elongation of yarn before weaving 12.47% to the lowest elongation of 8.18% for the warp threads of the fabric 3.

Table 3. Breaking forces of yarns before and after weaving and breaking forces of fabric samples

		Yarn before weaving	Fabric 1		Fabric 2		Fabric 3		Fabric 4	
			Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
Yarn	F_y (cN)	347.41	320.22	331.62	332.59	334.83	322.71	342.47	332.64	336.68
	CV (%)	10.21	5.86	8.42	10.29	8.41	8.67	10.34	8.33	10.54
	ε_y (%)	12.47	9.26	10.08	8.82	9.33	8.83	8.18	8.39	9.90
	CV (%)	14.33	24.42	23.86	29.38	19.43	26.6	29.99	22.68	30.21
	σ_y(cN/tex)	6.95	6.40	6.63	6.65	6.70	6.45	6.45	6.65	6.73
	CV (%)	6.49	5.86	8.40	10.29	8.41	8.67	10.34	8.33	10.54
Fabric	F_w (N)	-	537.27	362.43	547.05	346.68	538.89	380.28	535.12	372.29
	CV (%)		2.61	3.57	2.65	3.22	4.84	2.57	4.05	3.24
	ε_w (%)		26.20	15.64	20.40	10.73	23.37	23.37	26.51	15.24
	CV (%)		3.97	5.94	5.36	4.47	6.93	5.60	4.55	5.77
	σ_w(N/mm^2)		17.62	11.88	15.24	9.66	13.10	9.24	15.58	10.84
	CV (%)		1.61	2.57	1.65	2.20	3.84	1.57	3.05	2.24

The properties of the fabric also changed by different weaves. The results of the breaking force of fabric in the warp direction ranged from 535.12 N (fabric 4) to 547.05 N (fabric 2), while in the weft direction from 346.68 N (fabric 2) to 380.28 N (fabric 3). Elongation at break of fabrics changed by changing the weaves and values of conducted tests ranged for warp direction from 20.40% (fabric 2) to 26.51% (4 fabric), while in the weft direction ranges from 10.73% (fabric 2) to 23.37% (fabric 3). Tensile strength followed the course of the value of breaking forces and recorded the lowest value in the warp direction in fabric 3 (13.10 N/mm^2) and the maximum value in fabric 1 (17.62 N/mm^2); while in weft direction minimum breaking strength show fabric 3 (9.24 N/mm^2) and highest fabric 1 (11.88 N/mm^2).

The number of fibres in the yarn cross section influenced the breaking force (Figure 1). Warp and weft threads have lost a part of the fibres during weaving process, which depended on the weave and stress, particularly warp threads in the fabric 1 and 3. Fibber breaking forces influenced on the yarn breaking forces in all tested fabrics, i.e. weaves (Figure 2). Less stress suffered the weft threads and thus the fibres that are spun in the weft thread. The minimum breaking force of yarn is in the fabric 1 (plain weave) in the warp direction and highest in the fabric 3 (longitudinal rips weave) in the weft direction.

been calculated (Table 4). According to the results it can be determine that the strength utilization of fibres in the yarn before weaving is minor (54.25%) compared to the utilization of fibres in the yarns (warp and weft) after weaving (from 56.48% to 69.01%). Utilization of fibres in warp threads is substantially higher in the fabric 2, 3 and 4, while in the fabric 1 the utilization of fibres is higher in weft threads. In weaving process, the warp and weft threads are tensioned and partly irreversibly stretched which results levelling fibres in yarns, greater contact between them and therefore their higher utilization. The utilization of fibre in warp threads is highest in the fabric 3 (68.96%), i.e. the fabric 1 (68.95%), while the lowest is in the fabric 2 (64.94%). The utilization of fibre in weft threads deviates in average more, compared to the warp threads and it is lowest in the fabric 3 - 56.48% (in which the utilization of fibre in the warp threads was the highest), while the highest utilization of 69.01% is in the fabric 1 (where the utilization of fibres in warp threads was among the highest). It means that the utilization of fibre is higher in those weaves i.e. threads that have the greatest number of transitioning of the warp threads from the face side on the reverse side of fabric and vice versa (plain weave - fabric 1 and longitudinal rips - fabric 3).

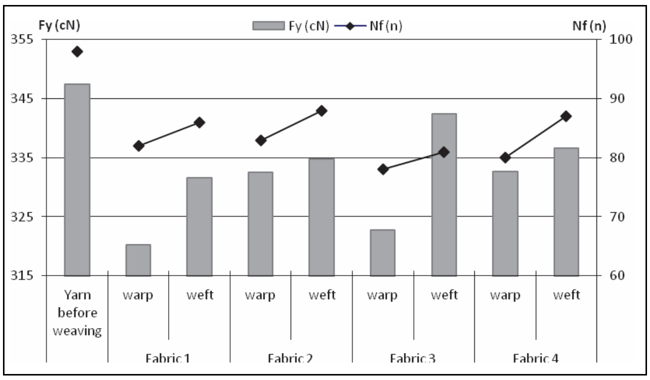


Figure 1. Yarn breaking forces (Fy) and number of fibres in the yarn (N_f)

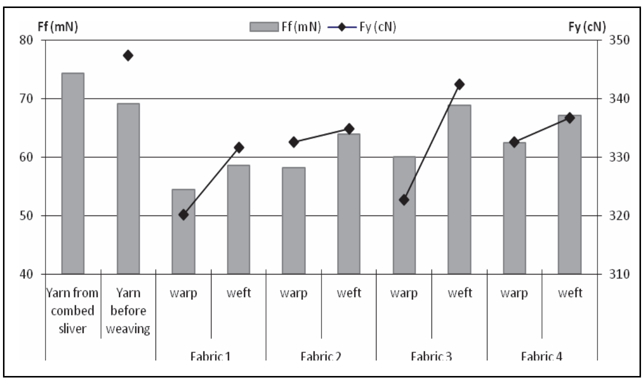


Figure 2. Fibres breaking forces (Ff) and yarn breaking forces (Fy)

Based on the obtained results of tested fibres, yarns and fabrics, strength utilization of fibres in the yarn, utilization of yarns in the fabric and length of tearing of the fabric has

The utilization of the warp and the weft threads in fabrics is higher than 100%. It means that a higher breaking force of fabric (sample dimensions: 20 cm in length and 5 cm in width) with respect to the sum of the threads breaking forces, which matches the number of threads in the fabric in the direction of the test (the bundle of threads with the length of 20 cm). To be able to compare the breaking forces of yarn and fabric, the tests were conducted under the same conditions on a dynamometer. The breaking force of the fabric is higher than the sum of threads breaking forces. This results in contact of the longitudinal (warp) and transverse (weft) threads at picks, where the stretching force acting on the longitudinal threads, also acts on the transverse threads and thus impacts on higher breaking forces. Stretching the warp threads on the picks leads to their straightening and also shrinkage of weft threads, and the resultant force on the crossing point is not in the direction of the stretching force. Higher utilization of yarn in the fabric are shown in weft threads in relation to the warp threads, in all four tested fabrics. The highest utilization of the warp threads is evident in the fabric 3 (134.67%), while the lowest is in the fabric 4 (128.70%). Weft threads records the highest utilization also in the fabric 3 (148.95%) and the lowest in the fabric 2 (134.47%).

Length of tearing of the fabric, i.e. the length at which breakage of its own weight happens by the action of gravity, on the sample width of 5 cm, is higher in warp threads in all tested fabrics. Maximum tearing length of the fabric in the warp direction records fabric 2 (48.41 km) and minimum fabric 4 (39.06 km), while in the weft direction, maximum tearing length records fabric 3 (33.65 km) and minimum fabrics 2 (30.68 km).

4. CONCLUSION

Fibres properties directly affects the qualitative characteristics of yarn and fabric. Dynamic forces which cyclically occurs in the weaving process, results in fibre deformation and thus the yarn deformation, which manifests by changing their physical-mechanical properties. These changes are more expressive in the warp direction compared to weft direction in all tested fabrics, except in fabric woven in transverse rips, where weft interweaves in plain weave and warp is floating over three weft threads. The weft threads are intertwined three in a row in the same shed (except at the fabric edges), which leads to their compression by beating of reed three times in succession while they are free in the shed, causing their damage. Warp threads are for the time stationary, which contributes to their minor stretching and deformation compared to weft threads. In case of longitudinal rips, warp threads are intertwined in plain weave by three in the group and their deformations are more significant than weft threads, which are floating over three warp threads. Thus they remain on the face side or reverse side three times in succession after which they intertwined with warp threads, by transitioning from the face side on the reverse side and vice versa. According to those statements it can be concluded that the qualitative properties of the fabric directly depend, not only on the properties of fibres and yarns, but also on weaves, i.e. the way of intertwining of warp and weft threads. This is reflected in strength utilization of fibres on the strength of the fabric, where the plain and transverse rips weaves have higher utilization in the warp direction, compared to the other two weaves. Picks where the threads transfers from face side to reverse side or vice versa, causes their greater deformation, especially in the warp threads. Weft threads experience greater deformations by beating the reed when several weft threads are woven into the same shed and warp threads for the time being are stationary in the upper or lower shed.

Table 4. Calculated values according to equations from theoretical part

		Fabric 1	Fabric 2	Fabric 3	Fabric 4	Yarn before weaving
η_f (%)	Warp	68.95	64.94	68.96	66.53	54.25
	Weft	69.01	63.03	56.48	57.59	
η_y (%)	Warp	134.23	130.54	134.67	128.70	
	Weft	139.22	134.47	148.95	145.50	
$L_{W_{w1,w2}}$ (km)	Warp	46.72	48.41	47.69	39.06	
	Weft	31.52	30.68	33.65	33.24	

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