DESIGN OF YARN PROPERTIES FOR IMPROVED FABRIC PERFORMANCE

SALOPEK C., I. & SKENDERI, Z.

Abstract: *Textile fabrics cover a vast range of consumer and industrial products made from natural and. In the production process, fibers have to be spun into a carefully designed yarn structure with specified properties, in order to give the desired aesthetics and/or technical performance. This chapter covers the investigation of different yarn properties – evenness, tensile properties, hairiness and friction considering the differences in fibre type and yarn count. The values of each measured property are discussed and finally, the quality of yarns for the knitting process is evaluated.*

Key words: *yarn, textile, evenness, tensile, hairiness*

Authors´ data: Assist. Prof. Dr. Sc. **Salopek Cubric**, I[vana]; Prof. Dr. Sc. **Skenderi**, Z[enun], University of Zagreb, Faculty of Textile Technology, Prilaz baruna Filipovica 28a, 10000 Zagreb, Croatia, ivana.salopek@ttf.hr, zenun.skenderi@ttf.hr

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1. Introduction

Textile fabrics cover a vast range of consumer and industrial products made of natural and man-made fibers. In the production process, fibers have to be spun into a carefully designed yarn structure, in order to give the desired aesthetics and/or technical performance (Lawrence, 2003). In the manufacture of knitted fabrics, there are certain minimum requirements for the yarn that interacts with other parameters during production .Yarns have restricted value in themselves because their value lies in the contribution to the structure and properties of textile products. Among a number of fabric properties that are affected by yarn properties, significant influence is reported for the transfer of heat and water vapor (Salopek Cubric et al. 2013; Salopek Cubric & Skenderi, 2007 & 2010).

Recently, there was a number of studies related to the properties of ring spun yarns, but majority of the studies focused either at the yarns produced from the same raw material, or at the investigation of limited number of yarn properties. In the study carried out by Ünal et al., the effects of parameters on tenacity and elongation of yarns are investigated. As a result of the study, equations and neural network models that predict the tenacity and elongation of yarns are obtained. According to the authors, the obtained equations and models are statistically important and have high coefficient of multiple determination (Ünal et al., 2009). Fibre length is one of the key properties of cotton and has important influence on yarn production and yarn quality. The study carried by Cai et al. is focused at the investigation of fibre length and its influence on two yarn properties – strength and irregularity (Cai et al., 2013). On the basis of investigation, linear regression models are developed to predict spun yarns' properties. In another study, the intention was to predict the most important yarn quality characteristic derived from cotton fibre properties measured by means of a High Volume Instrument (HVI), (Ureyen & Kadikoglu, 2006). Linear multiple regression methods were used for the estimation of yarn quality characteristics. In the article written by Dayik (Dayik, 2009) are proposed approaches for the determination of the breaking strength of the yarn. The results obtained from the computational tests show that developed "GEP" (Gene expression programing) technique is a good technique in terms of precision and prediction of yarn properties (98.88%).

Taking into account that a number of published studies focused at only one raw material or certain yarn property, the intention of the study presented in this chapter is to get a comprehensive overview. Therefore, for the investigation are carefully designed 18 yarns that differ considering the raw material and count. In the study are observed and discussed changes in tensile properties, evenness, hairiness and friction among designed yarns.

2. Experiment

2.1 Yarn raw materials

For the purposes of this study the following raw materials are selected: 100% cotton, 50/50% cotton/modal, 100% viscose, 100% lyocel (Tencel®) and 100% polyester standard and 100% polyester with profiled cross-section. From the named raw materials, combed single yarns were produced. The yarns are made in four counts: 20, 17, 14 and 12 tex for each raw material type. The average twist coefficient of produced yarns (α_{tex}) is 3417 (Salopek Cubric, 2009). The list of produced yarns with designation and basic determinants is shown in the Tab. 1.

Nr.	Designation	Raw material	Yarn count, tex
1	C1	Cotton	20
2	C2	Cotton	17
3	C3	Cotton	14
4	C4	Cotton	12
5	CM1	Cotton + modal	20
6	CM2	Cotton + modal	17
7	CM3	Cotton + modal	14
8	CM4	Cotton + modal	12
9	V1	Viscose	20
10	V2	Viscose	17
11	V3	Viscose	14
12	V4	Viscose	12
13	T1	Tencel®	20
14	T2	Tencel®	17
15	T3	Tencel®	14
16	T4	Tencel®	12
17	PE1	Polyester standard	20
18	PE2	Polyester profiled	20

Tab. 1. Yarn designation and basic determinants

2.2 Measurement

Within the scope of the experimental part, the following yarn properties were tested: evenness, tensile properties, hairiness and coefficient of yarn friction (against metallic surface). All tested yarns are taken from the cones.

The parameters that characterize the evenness of yarn i.e. number of faults per 1km i.e. thin places (Ntn), thick places (Ntk), neps (Ntn) mass variation expressed by coefficient of variation (CVm, cut length of 1cm) are measured using the Keisokki evenness tester, model KET-80. During the measurement, the following sensibility levels are used: -50% for thin places, +50% for thick places and +200% for neps. Tensile properties of produced yarns, i.e. breaking force (F), breaking elongation (ε_B), work to rupture (Wr) and tenacity (T) are measured on a dynamometer Statimat M produced by Textechno, as described in ISO standard (ISO 2062, 2009). The number of fibers in different lengths (2, 4, 6 and 8 mm) is determined using the hairiness meter produced by Zweigle company. The speed of yarn delivery is set to 50 $m \times min^{-1}$. Finally, the coefficient of yarn friction (μ) was determined using the F-meter G 534 produced by Zweigle, according to the ASTM standard (ASTM D 3108-07, 2007).

3. Results and discussion

The results of yarn evenness measurement are shown on Figures 1-3. Number of thin places on all investigated yarns is zero, and therefore the graphical presentation of this indicator is omitted. As seen from the Fig. 1., number of thick places for all investigated yarns is 0-60 and on average increases with the reduction of yarn count – with increasing the yarn fineness, except for viscose yarn of 20 count. The reason of that may be the mechanical damage of someone elements of production machinery (spinning machine, roving frame or drawing machine). The number of neps is 0-118 and on average is generally higher for finer yarns. For yarns that are used in the knitting process, it is of great importance to have lower number of yarn faults i.e. thick places and neps because they may cause the breakage of threads, higher wear of needles, appearance of uneven fabric surface and low color egality. As seen from the Fig. 3., coefficients of mass variation are in the range 5 to 14% and are highest for yarns in count of 12 tex.

Considering the influence of raw material to the evenness parameters, the results indicated that the highest number of thick places is present on yarns produced of natural fibers. Unlike staten, there are no regularities for the influence of raw material on the number of neps and coefficient of mass variation. The results also indicated significant differences between the two yarns produced of polyester. Namely, it was shown that polyester with profiled cross-section has higher values of all measured parameters that characterize the yarn evenness.

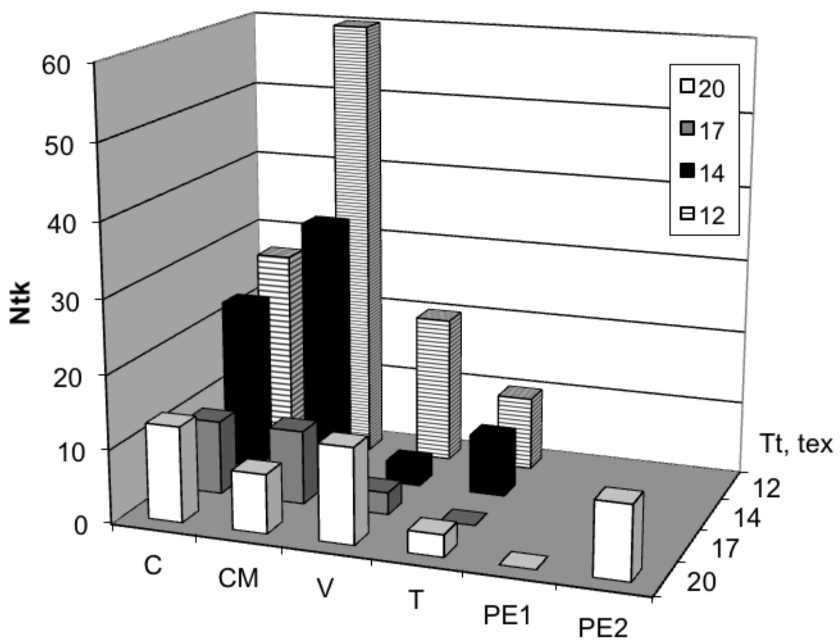

Fig. 1. Number of thick places

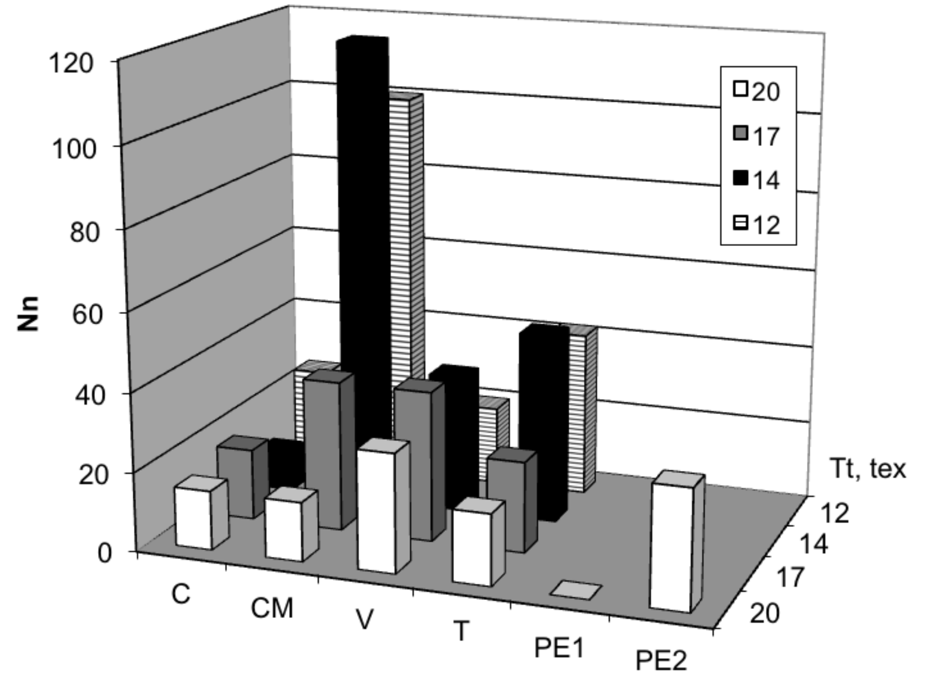

Fig. 2. Number of neps

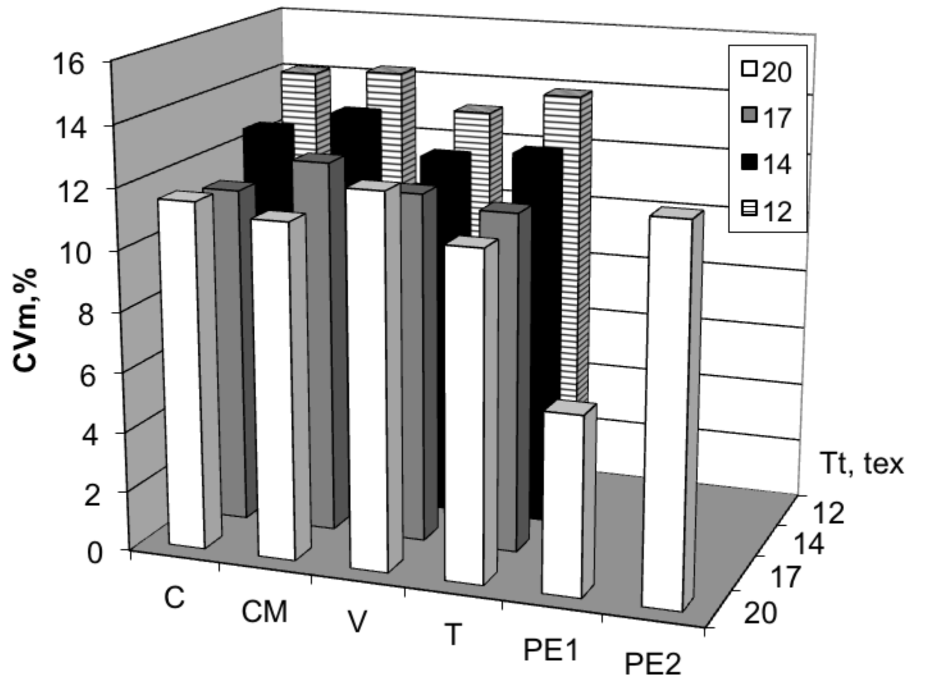

Fig. 3. Coefficient of mass variation

The test results of yarn evenness are also compared with with Uster® statistics (Uster® Statistics, 2007). Generally, Uster® Statistics is used primarily for comparison as well as classification of fibers, slivers, rovings and yarns in relation to world production. Comparison of thin places, thick places, neps and coefficients of mass variation with the results provided by Uster® is shown in the Tab. 2. From the comparison, it can be seen that for a number of cases, the values are below the line of 5%. That particularly applies to yarns made of viscose and Tencel®. With regard to the comparison of evenness parameters with recommended values from the literature, it may be concluded that the overall assessment of the quality of yarn intended for knitting is very high.

Sample	Percentage of producers that produce yarn with same or higher values of a single evenness parameter			
	Number of thin places	Number of thick places	Number of neps	Coefficient of mass variation
C1	50	5	<5	25
C2	50	<5	<5	5
C3	25	25	<5	5-25
C4	5	25	<5	75
CM1	50	<5	5	25
CM2	50	5	5-25	5-25
CM3	25	50	50	25
CM4	5	75	75	75
V1	<5	25	5	50
V2	<5	<5	5	5
V3	<5	<5	5	5
V4	<5	5	<5	50
T1	<5	<5	<5	<5
T2	<5	<5	5	5
T3	<5	<5	5	25
T4	<5	<5	5	50
PE1	<5	<5	<5	<5
PE2	<5	25	50	5

Tab. 2. Comparison of evenness parameters with Uster® Statistics

From the values of yarn breaking force that are obtained by testing samples on the dynamometer, an increase in breaking force with the increasing the yarn fineness is seen. The lowest values of breaking force are measured for yarns in count of 12 tex and amount 158-296 N. The highest value of 713 cN is recorded for the coarsest yarn (count is 20 tex). A comparison of breaking forces for the samples of different counts, but the same composition, reveals that the largest differences are between the samples made of Tencel® fibers. Within the mentioned group of samples, breaking force of coursest yarn (sample T1) is even 241% higher than the breaking force of finest yarn (sample T4). The smallest difference between breaking forces among the samples of the same raw material, but different count is measured for cotton samples. Influence of fiber cross-sectional shape is not significant for breaking force of yarn, what can be seen by comparing samples made of polyester (PE1 and PE2).

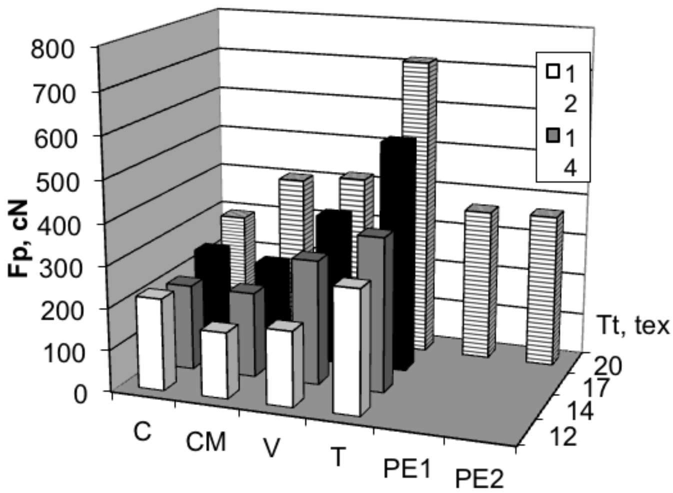

Fig. 4. Breaking force of investigated yarns

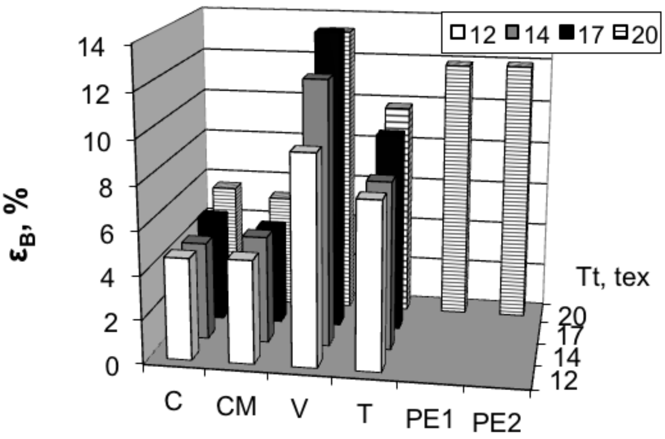

Fig. 5. Breaking elongation of investigated yarns

Breaking elongation of tested samples ranges from 4 to 13%, with coefficients of variation from 5 to 12%. Due to the nature of the process, yarn for knitting must be sufficiently flexible and stretchable. According to the literature data, the optimal elongation of yarns for knitting is up to 8% for cotton yarns and 9-17% for viscose yarns (Iyer et al., 1992). As the elongation of investigated cotton yarns is from 4 to

5% and 9 to 13% for viscose yarns, it is to conclude that the values are within the specified range. Yarns made of regenerated cellulose fibers (samples V1-V4 and T1-T4) and a synthetic polymer (samples PE1 and PE2) have higher elongation than yarns made of other observed fibers. It is also observed that, on average, elongation decreases with increase of yarn fineness. It is obtained that work done to rupture is from 180 to 2000 cN×cm. The highest values obtained to yarns spun from Tencel, viscose and PET fibers (Fig. 6). The yarns spun from cottton fibers as well as blend cotton/Modal have relatively lowest work.

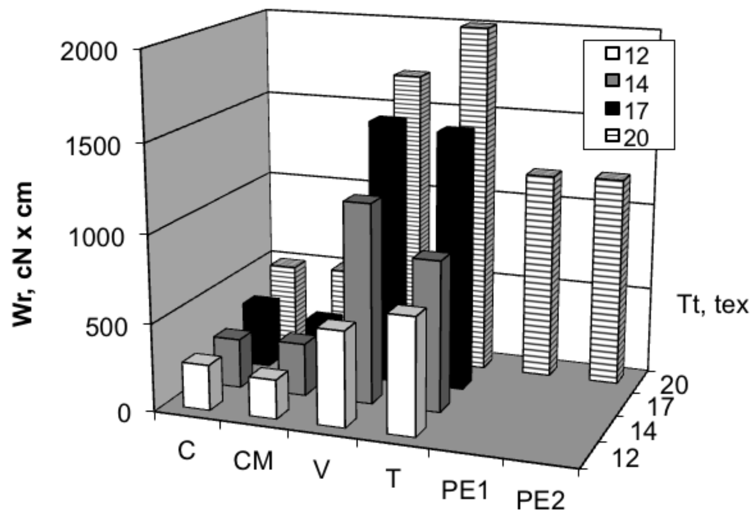

Fig. 6. Work to rupture of investigated yarns

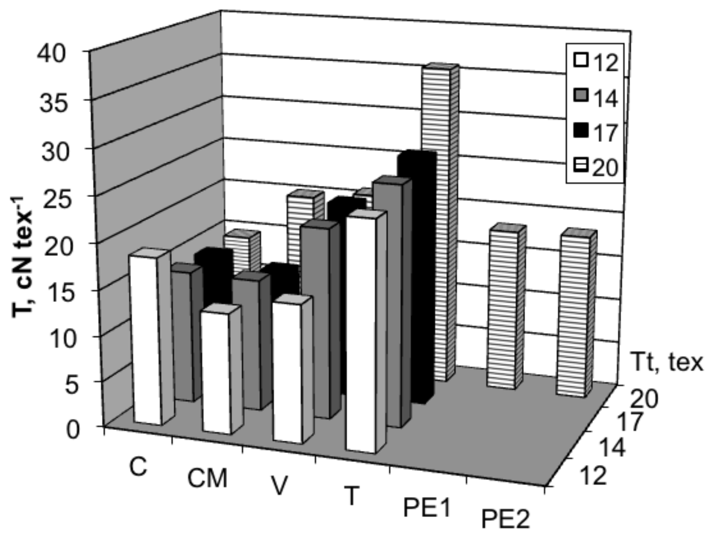

Fig. 7. Tenacity of investigated yarns

Tenacity of knitting yarns is, unlike the tenacity of weaving yarns, of minor importance because the load of yarn during the knitting process is lower than a load during weaving. However, the tenacity of yarns for knitting must be sufficient to handle loads on knitting machine and to contribute the required stability of fabric. Requirements for the minimal tenacity of yarn is not clearly defined in the literature. According to some authors, the optimal tenacity of cotton combed yarn for knitting is 10-22 cN×tex^{-1} (Iyer et al., 1992). From the comparison of values obtained for investigated cotton yarns with values from the literature, it is concluded that the strength of the yarn produced is optimal for knitting (values are in the range 14 to 18 cN×tex^{-1}).

Comparison of tensile properties with Uster® statistics is shown in Tab. 3. From the comparison, the wider range of values can be seen.

Sample	Percentage of producers that produce yarn with same or higher values			
	Breaking force	Breaking elongation	Work to rupture	Tenacity
C1	95	75	50	<95
C2	95	75	50-95	<95
C3	95	95	95	<95
C4	75	75	95	75
CM1	5	50	50	5
CM2	<95	95	95	<95
CM3	95	50	50-95	<95
CM4	<95	75	<95	<95
V1	50	50	5-50	5
V2	50	5-50	5	5
V3	50	50	50	5
V4	95	<95	<95	50-95
T1	5	<95	5	5
T2	5	<95	5-50	5
T3	5	<95	50-95	5
T4	5	<95	95	5
PE1	<95	50	<95	<95
PE2	<95	50	<95	<95

Tab. 3. Comparison of tensile parameters with Uster® Statistics

The results of yarn hairiness measurement are graphically expressed through the number of protruding fibers in the lengths 2 and 4 mm per 1 meter (Fig. 8 and 9). As seen from the figures, investigated yarns have 26-60 protruding fibers in the length of 2 mm and 3-22 fibers in the length of 4 mm. The number of increases with the reduction of yarn fineness. Significant differences in the number of protruding fibers are observed between samples made of polyester fibers.

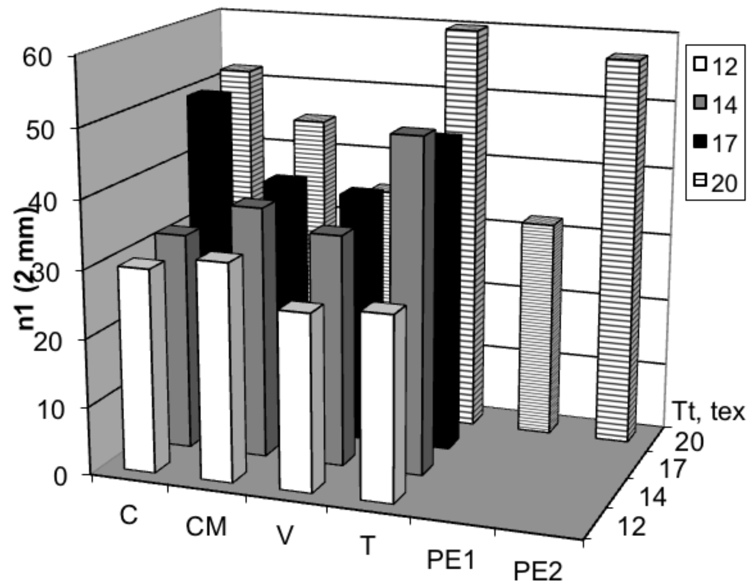

Fig. 8 Hairs in the length of 2 mm

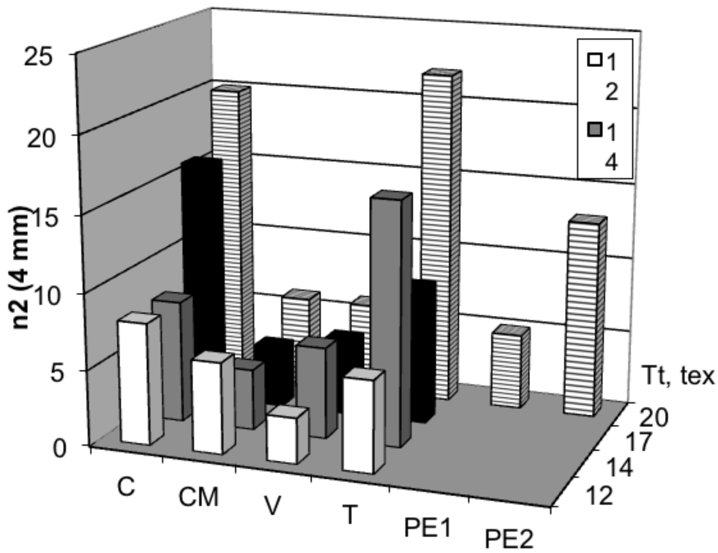

Fig. 9. Hairs in the length of 4 mm

The results of yarn friction coefficient measurements are given on the Fig. 10.
The surface friction of yarn during knitting process needs to be at the lowest possible level to allow uniform running of yarn through machine elements. The reduction of

friction directly affects the quality of produced goods. For further reduction of the friction coefficient, yarns need to be waxed during the production process.

The mean values of friction coefficient of all tested yarns are relatively low and range from 0.08 to 0.20. By increasing the yarn fineness the yarn count, the friction coefficient increases for the majority of investigated yarns. Although the change is not so significant it may be concluded that the friction coefficient depends on the yarn fineness and type of fibers. It is well seen that the values are lower for yarns made of natural polymers (i.e. viscose and Tencel®).

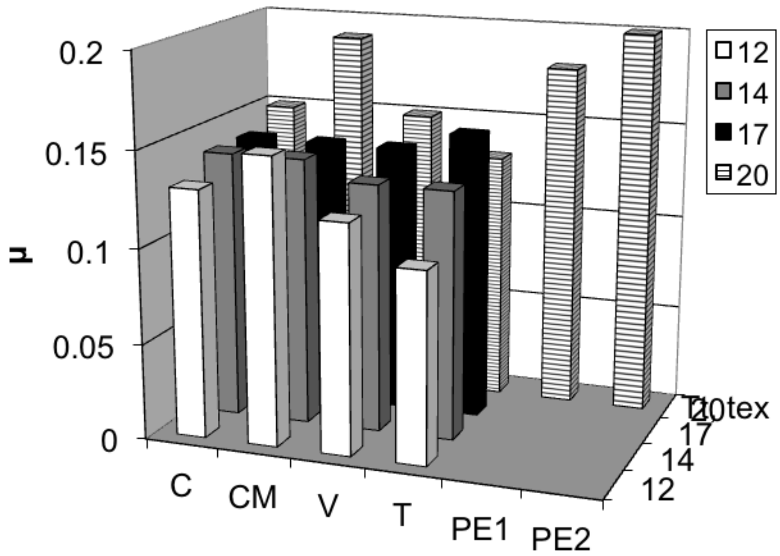

Fig. 10. Friction coefficient of investigated yarns

4. Concluding remarks

The study presented in this chapter is focused at the investigation of a comprehensive list of yarn properties that are influenced by different raw material or determined yarn count. Additional comparisons with the recommended values from the literature and the parameters of the yarn manufacturers have also indicated that the yarn parameters are within satisfactory limits.

Optimal performance of textile materials can only be achieved if all parameters of yarn design and production have been chosen meticulously in accordance with the requirements determined by the application of the product. The main remarks, outlined in this study, represent a meaningful contribution for designers and producers and should be used to design optimal yarn properties that will improve the performance of fabrics, as a final product.

5. Aknowledgement

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