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Comparative Study on the Properties of Vortex and Ring Spun Yarn and the Properties of Woven Fabrics Containing Those Yarns in Weft

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Abstract
The purpose of the research was to examine the properties of vortex and ring spun yarns and their influence on the properties of woven fabrics when used as weft. Two different mixtures of fibres (Cotton/PET; Cotton/PA6.6) in different portions and pure cellulose viscose (CV) fibres from the same input material were used to produce vortex and ring spun yarn of 16 & 67 tex. The properties of the measured yarns evaluated showed that ring spun yarns were, depending on the blend used, superior in the breaking force up to 30% and in the elongation at break up to 20%. The same occurred with the properties of woven fabrics in the weft direction, only that the difference was significantly smaller – up to 15% breaking force and up to 5% elongation at break. At the same time the abrasion properties of woven fabrics containing vortex yarns in the weft were significantly better than those of full ring spun yarn fabrics.

Key words: *raw materials, cotton, PA6.6, ring spun yarn properties, vortex yarn properties, woven fabrics properties.*

Introduction

Owing to recent development, Vortex yarns have become comparable with ring spun yarns in terms of visual appearance, structure and consequently properties [1 - 5]. Taking into account the production speed of Vortex yarns, which is 15 to 30 times bigger than that of ring spun yarns, they have become more competitive than ever before. Besides high production speed, Vortex yarns boast many outstanding characteristics, such as less hairiness, better resistance to pilling, better moisture absorption and wash resistance [1, 3]. However, they still exhibit inferiority in tensile properties in comparison with ring spun yarns, which is one of the important mechanical characteristics of woven fabrics, and results in the slow acceptance of these yarns in fabric production. Another disadvantage of an early Vortex production process was the impossibility of producing pure cotton yarns. Recent versions of the Vortex yarn production process allow the production of 100% cotton yarns.

All differences in yarn properties can be attributed to the differences in their structure, which is the consequence of different production processes. Three types of yarn production processes, i.e. the ring, rotor and air jet spinning, are widely accepted today [3, 6]. In all cases the twist in the yarn structure is imparted by the ring/traveler system, rotor or air jet. The number of twists as well as the position and layout of individual fibres in the yarn structure determines the structure and properties of yarns.

As a result of the spinning process, the properties of yarns produced differ. Owing to their structure, Vortex yarns have the following advantages in comparison to ring spun yarns:
- less unwanted hairiness – resulting in better visual appearance and cleaner patterns (especially in printing);
- since fibres in yarns are positioned from the core to the periphery, it is difficult for them to bepulled from their position, which results in better resistance to pilling;
- due to less twist on the surface, Vortex yarns are more open for absorbing water or water vapour, but are also able to dry faster and be dyed in brighter colours;
- owing to their structure, Vortex yarns shrink less during washing, which means that they keep their dimensional stability also after washing.

However, the disadvantages of Vortex yarns are also connected with their structure, the tensile properties. Since the Vortex spinning process is appropriate for short staple fibres (up to 38 mm), fibres are positioned from the core to the periphery of yarns, Vortex yarns cannot have the same number of twists as ring spun yarns, which definitely regulates their tensile force and tensile elongation. The breaking force and elongation at break of Vortex yarns are usually about 20% weaker than those of yarns produced by the ring spinning method from the same fibres, which actually means that Vortex yarns cannot be treated during the weaving or knitting processes with the same speed, and this may be the reason for inferior tensile and other properties of fabrics made from Vortex yarns in comparison with those made from ring spun yarns. It also means that the thinnest yarn cannot be produced by the Vortex process, as the small number of fibres in the cross section of yarn with less twist cannot ensure necessary tensile properties.

Most researches carried out so far in order to prove the properties mentioned were done on knitted fabrics [7 - 9]. One of the reasons is that knitting process does not need special preparation of both yarn systems as the weaving process does. The intention of the research presented was also to avoid the preparation of Vortex warp yarns because of their irregularities, which could cause problems during warp preparation. Hence Vortex yarns were used only in the weft direction, whereas ring spun yarn was in the warp direction. It was interesting to see how woven fabrics containing mixed yarn in the structure (ring/vortex and ring/ring) as the warp and weft would function, and to check if the phenomenon called "fabric assistance" would appear. In other words, the purpose of the research was to check if the tensile and abrasion properties of fabrics containing Vortex yarns in the weft are really inferior/superior to those of fabrics made completely from ring spun yarn with the same fibre composition, and if yes, to what extent?

Experimental

Sample preparation

Three different mixtures of fibres (1st - 67% Cotton (Co) & 33% PET-carbon, 2nd - 50% Co & 50% PA 6.6 and 3rd - 100% Micromodal cellulose viscose (CV) fibres) were used to produce Vortex and ring spun yarn of 16.67 tex. Vortex yarns were produced on a Muratec - (A) air jet spinning machine, and ring spun yarns on a Zinser - (B) machine from the same input material. Unfortunately the settings of the twist of the spinning machines were not known to us. The spinning took place in different mills (Lenzing, Austria and Litija, Slovenia), with only a request to produce the best possible yarn (with optimum twist regarding the spinning system) of certain fineness. The blend of fibres was prepared in one process and sent to both yarn producers for processing. The characteristics of fibres incorporated in the specific blend are not known to us.

Six woven fabrics were produced (Tekstina d.d. Ajdovščina, Slovenia) with the same construction and settings and under the same conditions during the weaving process, with the only difference being the type of yarn in the weft. The set density of cotton warp yarns was 30 ends/cm, their linear density 12 tex, and the weave was always twill 1/3 Z. The set density of weft yarns was 30 picks/cm. Weaving was carried out on an industrial loom - Leonardo Promatech, with a weaving width of 185 cm, number of 520 r.p.m., a proper pre-winder used. All samples see ***Figure 1***.

Method used

Several physical and mechanical properties like the density of warp and weft threads, thickness, mass per unit area, and tensile and abrasion properties were investigated.

All measurements were made in accordance with the following standards:

- the density of warp and weft threads was determined in accordance with

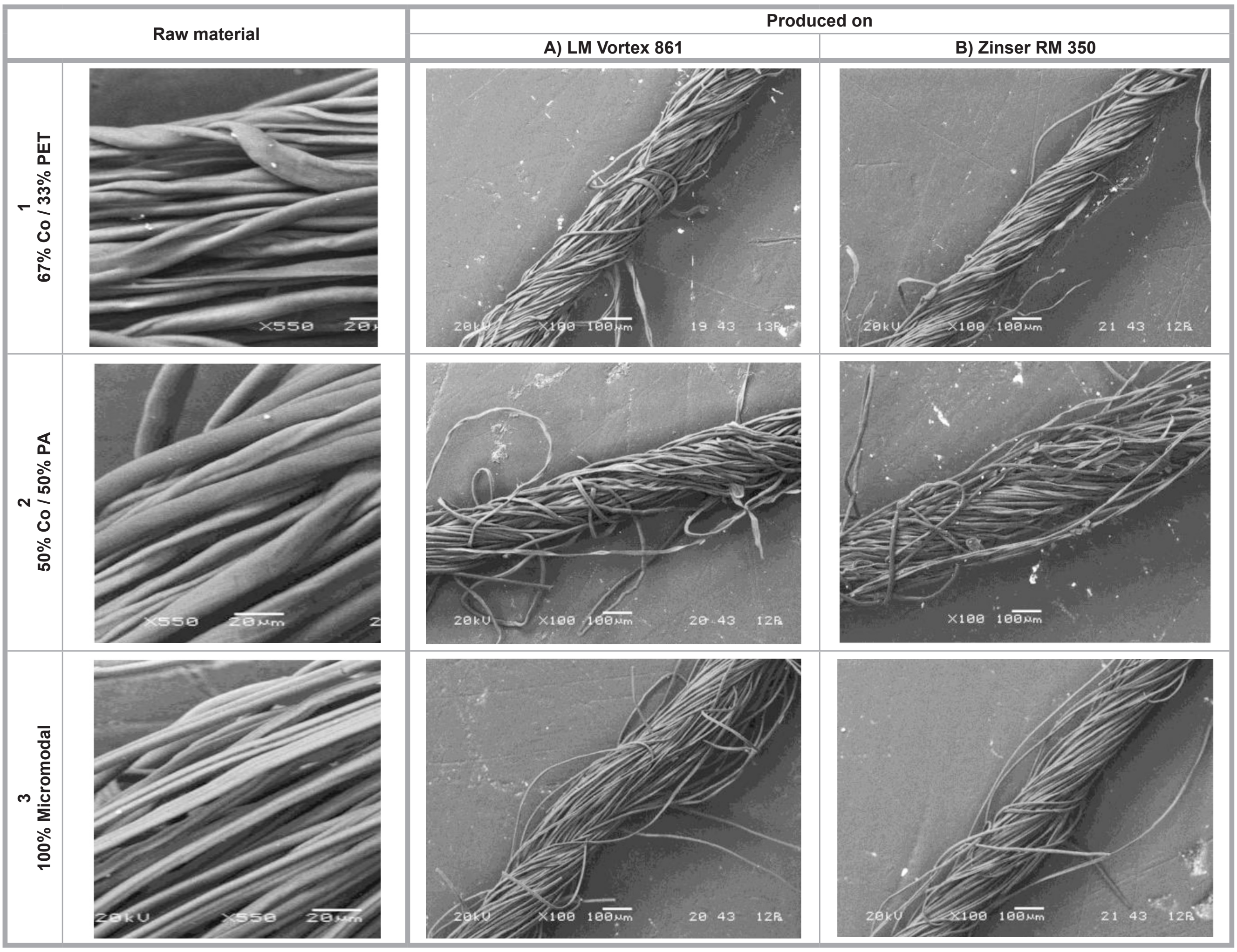

Figure 1. *Composition of yarn regarding raw materials and the production process, including SEM pictures and their marking.*

the SIST EN 1049-2:1999 (ISO 7211-2:1984 modified) standard,
- the thickness was determined in accordance with the SIST EN ISO 5084:1996 standard,
- the mass per square metre (mass per unit area) was determined in accordance with the SIST EN 12127:1999 standard,
- the Uster properties of yarns were measured on an Uster tester 3,
- to determine the yarn twist, – the direct counting method was used in accordance with Standard SIST EN ISO 2061:1996. We used Torsiometer apparatus for S & Z twist yarns, with the test length adjustable up to 500 mm and with 20 repetitions per sample.
- tensile properties – the breaking force and elongation at break were measured on an Instron 5567 dynamometer in accordance with the standard for yarns SIST ISO 2062:1993 and for woven fabrics SIST ISO 5081:1996,
- abrasion properties were determined in accordance with ISO/DIS 12945-2 (Determination of the resistance to pilling and change of appearance of fabrics –part 2: modified Martindale method). Assessment of the sample surface was conducted after 125, 500, 1000, 2000, 5000 and 7000 cycles.

Results

Tables 1, 2 and ***3*** show the characteristics and labelling of samples, values of yarn physical and tensile properties measured.

Table 4 presents physical properties of woven fabrics, whereas ***Table 5*** presents the tensile properties of woven fabrics produced in the warp and weft directions. ***Table 6*** (see page 62) presents the observations and assessment of the surface of the woven fabrics after different numbers of cycles on the Martindale tester.

Discussion

Table 2 shows that Uster values of ring spun yarns are 2% lower than those of air jet yarns, with higher hairiness (except sample 3B) and fewer thin and thick places but with more neps every 1000 m of yarn. Regarding the fibre composition, it is evident that the Co/PET blend has far more irregularities for all characteristics measured. The Co/PA blend has significantly fewer irregularities, especially as regards thin and thick places, and 100% Micromodal fibres have a very small number of irregularities, except as regards the number of neps. It is also evident that, because of the different systems used for twist delivering to the yarn, the number of twists of ring spun yarns is 2.5 to 3.5 times bigger than the number of twists of air jet spun yarns. All parameters (number of twist, Uster uniformity and number of irregularities) affect the tensile properties of yarns presented in ***Table 2***.

It is more than obvious from ***Table 3*** that the raw material as well as the spinning process play an extremely important

Table 1. *Characteristics and labelling of samples.*

Samples	Linear density, tex	Raw material	Produced on
1A	16.67	67% Co / 33% PES	LM Vortex 861
1B		67% Co / 33% PES	Zinser RM 350
2A		50% Co / 50 % PA	LM Vortex 861
2B		50% Co / 50 % PA	Zinser RM 350
3A		100% Micromodal CV	LM Vortex 861
3B		100% Micromodal CV	Zinser RM 350

Table 2. *Uster parameters of yarns and number of twists measured.*

Sample	Uster value, %	Hairiness (H)	Thin places (-50%), 10^3 m	Thick places (+50%), 10^3 m	Knops +200%	Twist, t.p.m.	Twist CV, %
1A	16.8	4.0	165	175	155	470	4.35
1B	14.7	5.0	16	157	231	1043	2.81
2A	14.8	4.7	40	85	15	338	5.56
2B	12.8	6.7	3	14	16	816	2.80
3A	12.9	4.4	0	50	25	260	3.56
3B	9.7	4.0	0	6	38	860	1.77

Table 3. *Values measured and statistical evaluation of the tenacity, breaking force and elongation at break of yarns.*

Sample	Tenacity		Breaking force		Elongation at break	
	cN/tex	CV, %	cN	CV, %	%	CV, %
1A	11.68	7.78	194.64	7.78	5.74	11.43
1B	16.35	8.77	272.64	8.77	6.83	8.70
2A	14.33	10.69	238.9	10.69	9.78	15.20
2B	17.07	11.73	284.50	11.73	8.74	22.43
3A	17.46	11.90	291.14	11.90	6.71	12.75
3B	20.29	7.10	338.20	7.10	8.93	6.25

Table 4. *Physical characteristics of woven fabric samples measured (actual values of warp/weft density, thickness and mass per unit area).*

Sample	Warp density, ends/cm	Weft density, picks/cm	Thickness, mm	Mass per unit area, g/m^2
1A	29.3	30.4	0.315	88.97
1B	29.7	30.9	0.316	88.74
2A	30.2	30.5	0.313	89.56
2B	29.6	30.9	0.323	91.06
3A	29.5	30.6	0.291	90.43
3B	29.7	30.8	0.281	90.34

Table 5. *Values measured and statistical evaluation of the breaking force and elongation at break of woven fabrics produced in the warp and weft directions*

Sample	Breaking force				Elongation at breake			
	Warp direction		Weft direction		Warp direction		Weft direction	
	N	CV, %	N	CV, %	%	CV, %	%	CV, %
1A	397.01	3.50	338.08	3.16	5.51	0.02	10.92	5.03
1B	404.46	2.95	378.87	4.01	6.11	3.66	10.42	5.27
2A	398.29	3.41	433.50	2.85	5.41	4.15	16.33	6.73
2B	411.04	2.40	439.61	2.51	6.31	4.36	15.33	4.97
3A	395.24	3.98	426.04	4.39	5.91	7.08	10.12	4.14
3B	404.75	3.99	450.27	6.15	6.21	4.43	11.82	5.69

__Table 6.__ Evaluation of the pilling effect of samples on a Martindale tester; where, mark 5 - no pilling, no changes on the surface; mark 1 - pilling over the entire surface of the sample.

Sample	Sample of cycycles					
	125	500	1000	2000	5000	7000
1A	5	5	5	5	4 - 5	4 - 5
1B	3 - 4	3	3	2 - 3	2 - 3	2 - 3
2A	5	5	5	5	4 - 5	4 - 5
2B	3 - 4	3 - 4	3	3	2 - 3	2
3A	5	5	4 - 5	4 - 5	4 - 5	4 - 5
3B	3 - 4	3	3	3	3	2 - 3

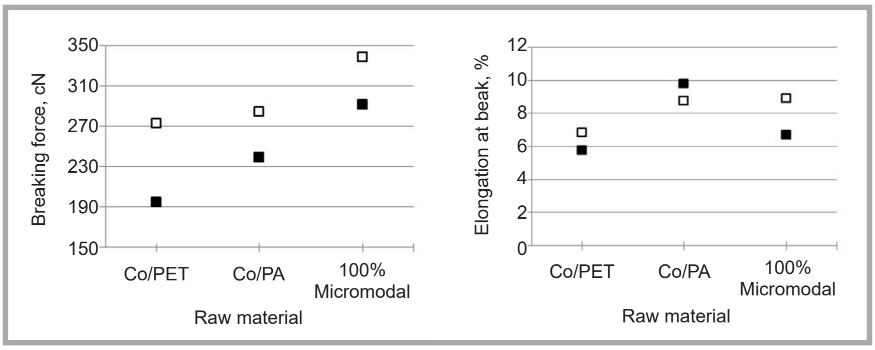

__Figure 2.__ Breaking force (left) and elongation at break (right) of yarns as a function of raw materials and type of spinning processes.

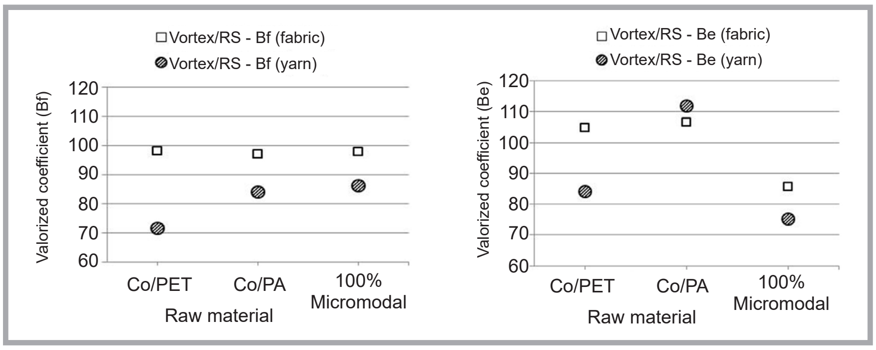

__Figure 3.__ Comparison of valorised coefficient of tensile properties of yarns and fabrics in the weft direction (left- breaking force (Bf), right - elongation at break (Be)) in dependence on raw materials.

role in the tensile properties of yarns. ***Figure 2*** presents the breaking force and elongation at break as a function of the raw material and type of spinning process. It is clear that the ring spinning process imparts a maximum breaking force to yarns regardless of the material used. It is also clear that as the percentage of cotton fibres in the blend increases, the breaking force decreases. Thus in all cases the yarns made from Co/PET: 67/33 blend exhibited a minimum breaking force, the yarns made of Co/PA: 50/50 blend - higher breaking force, and pure Micromodal yarns showed the highest breaking force.

A combination of both influential factors, i.e. raw material and type of spinning process, gave the results shown in ***Figure 2*** – left. The yarns made of the Co/PET and Co/PA blends produced on a Murata jet spinner have only 71.4% and 83.94% resp. of the breaking force of the yarns produced on a Zinser ring spinning machine. A hundred percent of Micromodal fibres have a slightly higher value of 86.05%. Generally speaking, Vortex yarns have by 15 to 30% lower breaking force or tenacity comparing to ring spun yarns with the same fibre composition.

As regards the elongation at break shown in ***Figure 2***– right, the results are not as clear as for the breaking force. Obviously the raw material plays a more important role than the spinning process in the case of the Co/PA blend, as the air jet produced yarns show a higher elongation at break than ring spun yarns. In the case of the Co/PET blend and 100% Micromodal, the air jet produced yarns have about 75 to 84% of the elongation at break of ring spun yarn.

Evaluation of the influence of different raw materials and different spinning processes of the yarns inserted in woven fabrics as the weft is also shown in ***Figure 3***, made through valorization/comparison of tensile properties of yarns and fabrics containing those yarns in relation to the type of blend and spinning process.

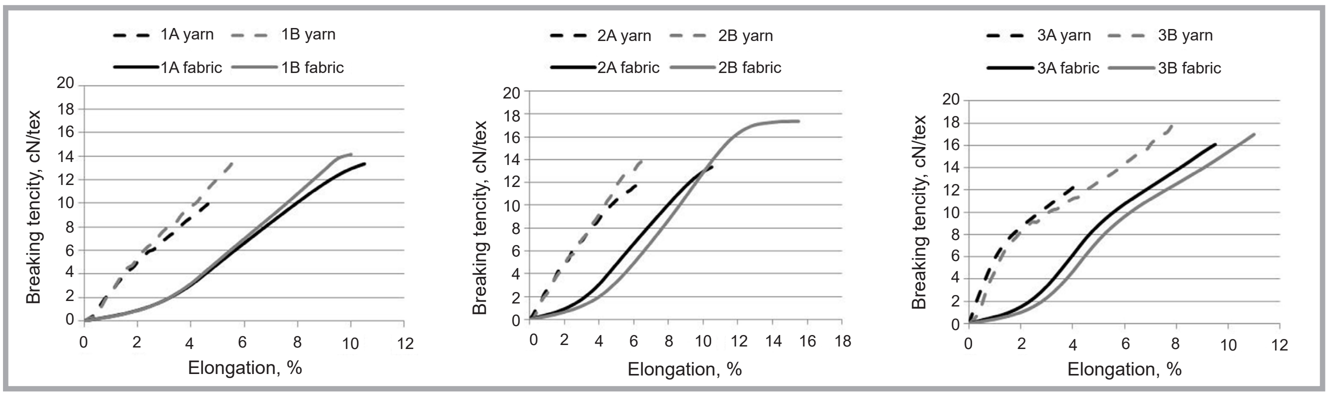

__Figure 4.__ Stress-strain curves of a particular yarn composition produced by the air jet and ring spinning methods (1, 2 & 3 broken lines) compared with the stress-strain curves of woven fabrics in the weft direction reduced to single yarn (1, 2, 3 full lines).

The most important part of the research is shown **Figure 3**. It is clear that, in general, the coefficient of breaking forces of the fabrics in the weft direction between the Vortex and ring spun yarns increases by about 15% with regard to the same coefficient of breaking forces of the yarns. It means that the Vortex yarns used as the weft participated almost equally in the breaking force of the fabrics in the weft direction as ring spun yarns in spite of their by 15 to 30% smaller breaking forces.

To create stress-strain curves of the fabrics in the weft direction, which would be comparable with the stress-strain of the yarns, we used the calculation of measured values – the fabric breaking force in the weft direction divided by the number of yarns and the fineness of yarn. It is evident in **Figure 4** that the values of single yarns calculated from measurements of the breaking force and the elongation at break of woven fabrics in the weft direction are higher than the values of individual yarns before weaving. The explanation for this phenomenon probably lies in so-called "fabric assistance",where the interlacing points of fabrics give additional strength to inferior yarns, probably due to the effect of friction and the shorter distance between interlacing points in comparison with the standard measured distance for yarns. In this case, the possibility that yarn irregularities would cause yarn distortion and breakage is therefore small. In other words, the breaking force of fabrics calculated as a sum of individual yarns is lower in some cases than the values measured in the same direction. It is also evident from **Figures 4.a** and **4.b** that in dependence on the blend composition of fibres the stress-strain curves for yarns almost have a linear shape, which can be explained with smaller adhesion between different kinds of fibres and easier/faster slipping, unlike in the case of one fibre composition yarn (**Figure 4.c**). On the other hand, there is no significant difference in the shape of the stress - strain curve of fabrics in the weft direction regardless of the yarn composition or production process.

Another evaluation of the results achieved was made through the correlation between the tensile properties of weft yarns and the those of woven fabrics in the warp and weft directions. The results are shown in **Table 7** for samples produced, allowing us to make a few conclusions.

Table 7. *Tensile properties of samples in the warp and weft directions in correlation with the tensile properties of yarn introduced in the weft.*

Yarn breaking properties	Fabric breaking force		Fabric elongation at break	
	Warp direction, N	Weft direction, N	Warp direction, %	Weft direction, %
Breaking force, cN	0.126	0.764	-0.599	-0.094
Elongation at break, %	0.238	0.819	-0.593	0.823

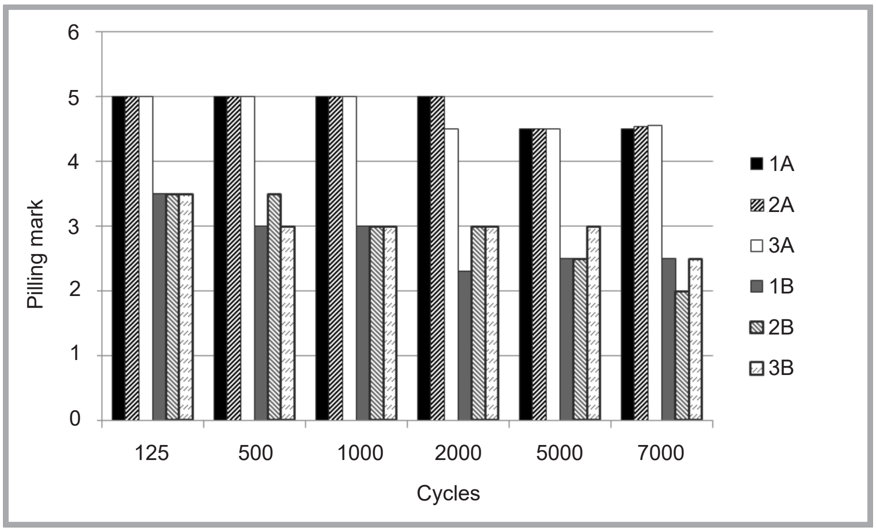

Figure 5. *Graphic presentation of the resistance to pilling on the face side of samples containing Vortex and ring spun yarns in the weft.*

The breaking force and elongation at break of weft yarns practically do not affect the breaking force of the fabric in the warp direction. The correlation coefficients between the breaking forces in the warp direction and tensile properties of the weft yarns are very small and similar – **Table 7**. In all cases the samples that have ring yarns in the weft exhibit up to 10 N higher breaking forces – **Table 5**.

The breaking force and elongation at break of weft yarns definitely have a major influence on the breaking force of fabrics in the weft direction. This is confirmed by a high correlation coefficient between the breaking force of fabrics in the weft direction and the tensile properties of weft yarns for the fabrics produced. In all cases, the samples containing ring spun yarn in the weft show higher breaking forces. There is no proven explanation for that exception as after repeating the experiment, the results remained similar.

The tensile properties of weft yarns have an important influence on the elongation at break of fabrics in the warp direction. The correlation coefficient is negative and has a value of about -0.6. The breaking force of weft yarns does not affect the elongation at break of fabrics in the weft direction. The correlation coefficient is negative and about -0.1. The elongation at break of weft yarns mostly influences the elongation at break of fabrics in the weft direction, which is seen from the highest correlation coefficient. The difference between samples containing Vortex and ring spun weft is not significant. All statistic data just confirm the expectation that the tensile properties of fabrics depend primarily on the properties of yarns introduced in the same direction and additionally on the properties of yarns in the perpendicular yarn system together with their interactions.

Determination of the fabric surface propensity to pilling was evaluated through the Matindale method. The results are shown in **Table 6** and in **Figures 5** & **6**. It is according to expectation that Vortex yarn dominating on the face of the woven fabric examined, show from one to two grades better pilling resistance than ring spun yarns in fabrics with same composition. It is clear that samples with ring spun yarns in the weft that dominate on the fabric surface after only 125 cycles of abrasion, do not have the best mark for pilling resistance – marks 3 to 4. After 500 cycles almost all samples containing ring spun yarns get mark 3 and after

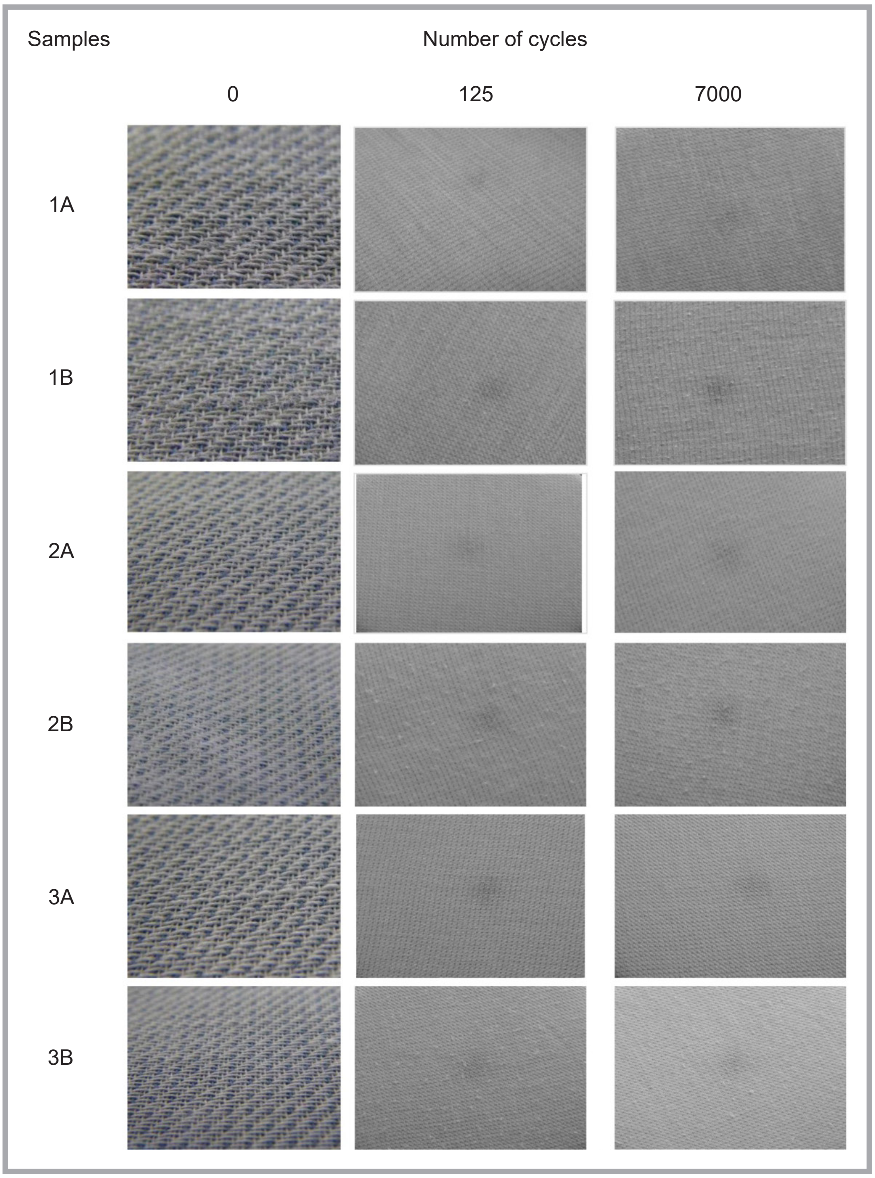

***Figure 6.** Pictures of sufaces of samples after 0, 125 and 7000 abrasion cycles.*

5000 only mark 2. Contrarily fabrics with dominating Vortex yarns on the surface examined have maximal resistance to pilling up to 500 to 1000 cycles and get mark 3 after 5000 and 7000 cycles.

Figure 6 shows visual differences in the surface appearence after 0, 125 and 7000 cycles, simply confirming the previous statments.

Conclusions

The conclusions can be divided into two parts: The first gives a more general insight into the tensile properties of woven fabrics, whereas the second part deals with specific differences between Vortex and ring spun yarns introduced in woven fabrics as the weft.

The constructions of woven samples were very convenient to make some general statements. The breaking force of any yarn system does not influence that of fabrics in the direction of the second yarn system. Differently structured yarns and those produced with different tensile properties introduced as the weft minimally influence the breaking force of woven fabrics in the warp direction. Furthermore the same tensile properties of warp yarns do not participate in the breaking force of fabrics in the weft direction. Once again it has been confirmed that the breaking force of fabrics in a certain direction primarily depends on the tensile properties of yarns laid in that direction as there was a considerable influence of the breaking force of yarn on the breaking force of fabrics in the weft direction.

However, the elongation at break of one yarn system quite significantly affects the breaking force of fabrics in the direction of the second yarn system, and does not affect the breaking force in the positioned direction (r = -0.59 and -0.094). And finally, the elongation at break of one yarn system has the highest influence on that of woven fabrics in the positioned direction (r = 0.823).

As regards the comparison of Vortex and ring spun yarns, it can be said that the results of the research were mostly expected, confirming the findings of previous researches, i.e worse tensile properties and better abrasion properties of Vortex yarns. It wasadditionally found out that Vortex yarns have, in dependence on the fibre blend, 15 to 30% lower breaking force and 15 to 20% lower elongation at break than ring spun yarns produced from the same blend.

Since the point of our research was to evaluate to what extent the difference mentioned would affect the tensile properties of fabrics, we found out that after introducing Vortex and ring spun yarn into a woven structure produced under the same condition, the difference in the tensile properties of the fabric in the weft direction became almost negligible. In general, the valorised coefficient of breaking forces of the woven fabrics in the weft direction between the samples made from Vortex and ring spun yarns increased by about 15% in relation to the valorized coefficient between the yarns themselves (***Figure 3***). In all cases it reached between 96 and 98%. In the case of the breaking elongation of fabrics in the weft direction, the quotient exceeded 100%, with the exception of the sample containing Micromodal 100%. At the same time, the fabric properties in the warp direction did not change significantly, leading to the conclusion that the use of Vortex yarn as the weft in the fabric structure does not significantly decrease the tensile properties of woven fabrics. All samples obtain (at least on their face) better abrasion properties – resistance to pilling, which could be of great importance in cases where such properties are needed.

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