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TECHNOLOGICAL DESIGN OF JACQUARD FABRIC AND THEIR FUNCTIONALIZATION

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ABSTRACT

Functionalization of fabrics allows us to influence the physical-mechanical properties by using special yarns that improve fabric's properties, such as elasticity [1,2], thermal regulation [3,4], protection against ultraviolet (UV) rays [5–7], etc. In addition, from a design point of view, the shape and size of the pattern, its frequency and area distribution are also important, not only as a visual effect, but also in terms of the above-mentioned properties [8–10]. The aim of the study was to determine how different weft yarns, the size of the pattern and weave affect the final properties of the jacquard fabric.

Six jacquard fabrics were woven on the same warp with two different weft yarns (cotton, Lyocell Clima) in two different patterns and two groups of double twill weaves (stiched and unstiched). The results show that fabrics made of cotton have poorer mechanical properties and lower permeability than fabrics with Lyocell Clima weft. Double unstitched fabrics generally have poorer mechanical properties and UV protection factors (UPF), but better air permeability values. A statistically significant influence of the raw material was shown for thickness, mass, thermal conductivity, tensile strength and, in the case of the size pattern and weave, for air permeability, breaking and tear strength..

KEYWORDS

Functionalization, jacquard pattern, physical-mechanical properties, cotton, Lyocell Clima.

MATERIALS AND METHODS

The influences of the basic construction parameters of woven fabrics on their properties are well known. The extent to which the shape and size of the jacquard pattern and the frequency of weaves in certain areas of the fabric influence the properties (UV protection, comfort) of fabrics that are important to the end user is somewhat less studied.

Six woven samples were produced on the same cotton warp (8×2 tex; 1 black : 1 white) and with the same loom setting (40 warps/cm; 40 wefts/cm). The fabrics were made from two different types of weft yarns (cotton, 24 tex and Lyocell Clima, 25 tex), in two different pattern sizes (Figure 1) and two groups of double twill weaves (stitched, unstitched; Figure 2).

In designing the jacquard fabrics, we created the first pattern with larger white, black and grey squares that create a 3D visual effect (Figure 1, left), while the second pattern consists of frequently changing smaller squares (Figure 1, right). Different sizes and shapes in the jacquard patterns mean different frequencies of the different weaves, which affect the frequency of thread interlacing, which in turn affects the compactness of the fabrics and thus the comfort properties or the protective properties, i.e.

UV protection.

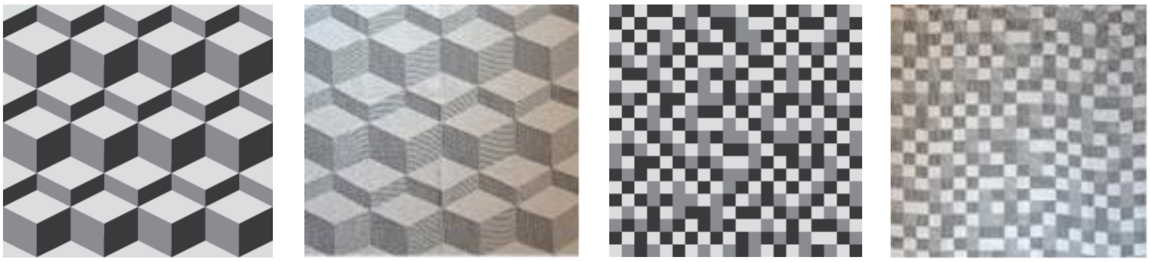

Figure 1. Pattern and woven fabrics in two different sizes (left - larger, right - smaller).

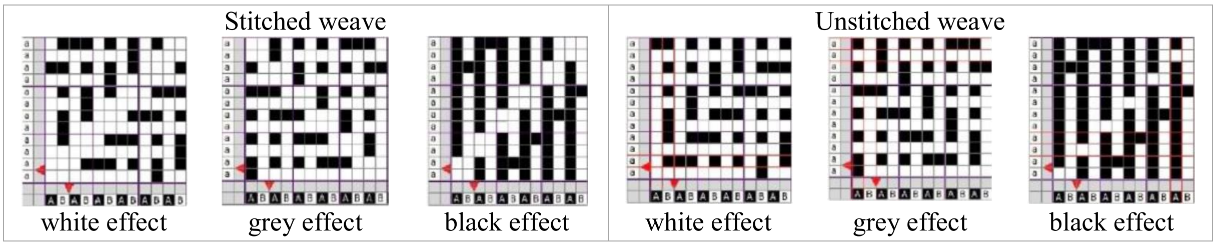

Figure 2. Weaves for three colours in jacquard patterns.

We investigated the physical-mechanical properties of the yarns and fabrics according to standard methods: breaking strength (SIST EN ISO 2060) and diameter of yarns, warp and weft density (SIST EN 1049-2), weight (SIST EN 12127), thickness (SIST EN ISO 5084), air permeability (SIST EN ISO 9237), thermal conductivity (DIN 52 612), ultraviolet protection factor (UPF) (AS/NZS 4399), breaking strength and elongation (SIST EN ISO 13934-1), further tear force (ISO 13937), and pilling resistance (ISO 12945-1).

RESULTS AND DISCUSSION

The sample labelling and construction parameters of the yarns and the fabrics are shown in Table 1, the physical properties of the woven samples are shown in Table 2, and the mechanical properties of the samples are shown in Table 3. All statistical analyses were performed using the two-way ANOVA to determine the statistically significant parameters affecting the analysed properties. The analysis presented in Table 4 explains the relationship between the different materials (yarns) and the different sizes of pattern and weave with other physical-mechanical properties of the samples.

Table 1. Data on numbering and construction parameters of the reference patterns and standard deviation (SD).

Sample	Pattern	Material and fineness [tex]		Density [yarns/cm]		Breaking tenecity [cN/dtex]				Yarn diameter [mm]			
		warp	weft	warp	weft	warp	SD	weft	SD	warp	SD	weft	SD
1	larger	white CO 8 × 2 tex	CO 24 tex	40	40	white 200.0	16.4	184.4	40.8	0.1947	0.02	0.221	0.03
2	smaller												
3	smaller/ unstitched												
4	larger	black CO 8 × 2 tex	Lyocell Clima 25 tex			black 167.1	19.2	221.9	30.5	0.2053	0.03	0.199	0.02
5	smaller												
6	smaller/ unstitched												

The warp density of the woven samples (Table 2) is quite similar to the on-loom warp density

(40 ends/cm). An increase in densities is observed in the weft, with woven samples with thinner wefts reaching the highest density in the weft and vice versa.

The samples with cotton weft are the thickest (0.927 mm), the samples with Lyocell Clima are 10% thinner. The different yarns affect the thickness and mass, which is expected and confirmed by the two-way analysis ANOVA. The magnitude of the F-statistic is obviously higher for factor A (different material) than for factor B (different pattern) - so we can say with greater statistical confidence that the different material has a greater effect on thickness, mass, and also on tensile strength in the weft direction and thermal conductivity (Table 4). The interaction between factors A and B is also statistically significant as $F > F_{crit}$ and $p < 0.05$. All samples with unstitched weave (sample 3 and 9) have the highest air permeability, where the looseness of the weave is crucial for the permeability of air between the threads. In addition, a smaller diameter of the Lyocell Clima thread results in the highest air permeability. Therefore, the size of the pattern has a statistically significant influence on air permeability (Table 4). Different materials and consequently pattern size influencing also thermal conductivity. Thermal conductivity is higher for fabrics with larger geometric squares, which represent more weft threads on the surface, than for fabrics with smaller geometric patterns. The different material has a greater influence on thermal conductivity, but interactions between the material and the pattern can also be observed.

Table 2. Physical properties of woven samples and standard deviation (SD).

Sample	Density [yarns/cm]				Weight [g/m²]	SD	Thickness [mm]	SD	Air permeability [l/min]	SD	Thermal conductivity [W/mK]	SD	UZF
	warp	SD	weft	SD									
1	39.2	0.8	43.0	1.4	188.6	1.1	0.904	0.03	96.31	12.5	0.11	0.001	15.82
2	39.4	1.1	43.0	1.4	190.2	0.8	0.899	0.03	86.71	13.2	0.11	0.009	16.05
3	39.2	1.3	42.2	0.8	190.6	0.5	0.979	0.02	136.94	4.0	0.08	0.008	9.25
4	39.2	1.3	42.6	1.7	180.4	0.5	0.826	0.03	104.11	14	0.09	0.003	6.75
5	39.0	0.7	41.8	1.9	176.8	0.8	0.800	0.02	99.750	9.3	0.09	0.002	7.58
6	40.4	1.1	43.4	1.1	175.0	1.0	0.844	0.04	146.70	3.0	0.08	0.003	5.14

Table 3. Mechanical properties of woven samples and standard deviation (SD).

Sample	Breaking strength [N]		Breaking elongation [%]		Tearing strength [N]		Elongation [mm]		Pilling degree
	Warp (SD)	Weft (SD)	Warp (SD)	Weft (SD)	Warp (SD)	Weft (SD)	Warp (SD)	Weft (SD)	7000 cycles
1	567.44 (19.2)	940.25 (26.4)	10.13 (0.3)	11.77 (0.3)	128.61 (6.6)	123.64 (7.3)	46.45 (5.1)	66.20 (26.3)	2.5
2	622.24 (10.8)	997.83 (25.4)	11.22 (0.2)	11.67 (0.3)	129.99 (3.8)	108.34 (8.0)	43.66 (1.5)	67.08) (31.8)	2.0
3	606.81 (2.3)	921.63 (8.6)	9.93 (0.2)	10.64 (0.2)	128.94 (4.1)	119.19 (20.9)	58.65 (9.1)	71.64 (4.6)	2.0
4	579.38 (24.1)	1147.88 (28.4)	10.29 (0.3)	11.23 (0.2)	117.76 (11.1)	108.33 (0.9)	39.93 (1.8)	77.15 (21.3)	3.5
5	590.48 (19.7)	1171.92 (2.9)	10.41 (0.1)	11.67 (0.1)	121.34 (4.2)	111.71 (6.8)	44.97 (5.5)	57.35 (8.8)	3.5
6	593.37 (6.9)	1097.20 (30.3)	8.35 (0.2)	10.33 (0.1)	138.85 (7.3	128.62 (1.5)	54.56 (6.4)	70.76 (3.2)	3.5

The highest UV protection factor (UPF) has a sample 2 with cotton weft and smaller squares pattern and stitch weave and also a sample 1 with cotton weft and larger square pattern, only these two meet the classification of good protection (UPF=16). It is obvious that the size of the pattern has no influence on the UPF, unlike the material it is made of. The breaking force in the warp direction is almost the same for all samples, but in the weft direction they all have a higher breaking force, which is due to the properties of the weft yarn used. The impact of square size and weave in the pattern are also evident, as fabrics with smaller squares and stitched weave have the highest breaking strength (Table 4). Sample 6 with Lyocell Clima and with unstitched weave has higher tearing strength than the others, showing the influence of weave on them. The degree of pilling is indicated on a scale from 5 (no pilling) to 1 (very severe pilling), as shown in Table3, which indicates that the fabrics are not particularly resistant to pilling. We obtained the best results with samples of jacquard fabrics with Lyocell Clima yarn in the weft direction, regardless of the size of the pattern and the weave.

The magnitude of the F-statistics is higher for factor B (different pattern) than for factor A (different material) - for breaking force in warp direction, breaking elongation in weft direction, tear strength and air permeability. Thus, we can confirm with greater statistical confidence that the different pattern and weave has a greater effect on the above parameters. (Table 4). The interaction between factors A and B is also statistically significant ($F > Fcrit$ and $p < 0.05$), except for elongation at break in the weft direction and air permeability. This means that the different materials have no influence on the above results.

Table 4. Some results of the two-way ANOVA.

	Thickness [mm]			**Mass [g/m²]**			**Thermal conductivity [W/mK]**		
Source of Variation	*F*	*P-value*	*F crit*	*F*	*P-value*	*F crit*	*F*	*P-value*	*F crit*
Material	176.32	1.21E-18	4.019	1609.12	1.65E-23	4.260	128225.5	1.51E-25	4.747
Pattern	22.638	7.24E-08	3.168	10.186	0.000627	3.403	7118.62	3.57E-19	3.885
Interaction	4.474	0.015925	3.168	50.372	2.57E-09	3.403	407.35	9.35E-12	3.885
	Breaking stre. in weft dir. [N]			**Breaking stre. in warp dir.[N]**			**Air permeability [l/min]**		
Source of Variation	*F*	*P-value*	*F crit*	*F*	*P-value*	*F crit*	*F*	*P-value*	*F crit*
Material	128225.5	1.51E-25	4.747	138.75	5.95E-08	4.747225	14.71088	0.00033	4.019541
Pattern	7118.62	3.57E-19	3.885	347.5393	2.39E-11	3.885294	130.1193	2.23E-21	3.168246
Interaction	407.35	9.35E-12	3.885	140.7845	4.66E-09	3.885294	0.330377	0.720095	3.168246
	Tearing strenght (weft) [N]			**Tearing strenght (warp) [N]**					
Source of Variation	*F*	*P-value*	*F crit*	*F*	*P-value*	*F crit*			
Material	5.172135	0.042115	4.747225	33.53723	8.59E-05	4.747225			
Pattern	438.066	6.08E-12	3.885294	84.50854	8.49E-08	3.885294			
Interaction	367.8999	1.71E-11	3.885294	96.93585	3.92E-08	3.885294			

CONCLUSION

We have found that the utility properties of the fabric are influenced not only by the basic design parameters, but also by the size and shape of the jacquard pattern. The colour areas and shapes of the pattern influence the frequency of thread interlacing, the frequency of thread transition from the back to the front side and vice versa, and the frequency of floatation of individual threads. For a fabric with good mechanical properties and satisfactory air permeability, we definitely recommend using yarns with special functional properties and smaller patterns with stitched weave.

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