AUTEX 2022

21st World Textile Conference

# TECHNOLOGICAL DESIGN OF JACQUARD FABRIC AND THEIR FUNCTIONALIZATION


**Klara Kostajnšek, Špela Bajrič, Matejka Bizjak**

*University of Ljubljana, Faculty for Natural Sciences and Engineering, Department of Textiles, Graphic Arts and Design, Aškerčeva 12, SI1000, Ljubljana, Slovenia*



## ABSTRACT

Functionalization of fabrics allows us to influence the physical-mechanical properties by using special yarns that improve fabric's properties, such as elasticity, thermal regulation, protection against ultraviolet (UV) rays, 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. 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.


## MATERIALS

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 (8x2 tex; 1black :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).

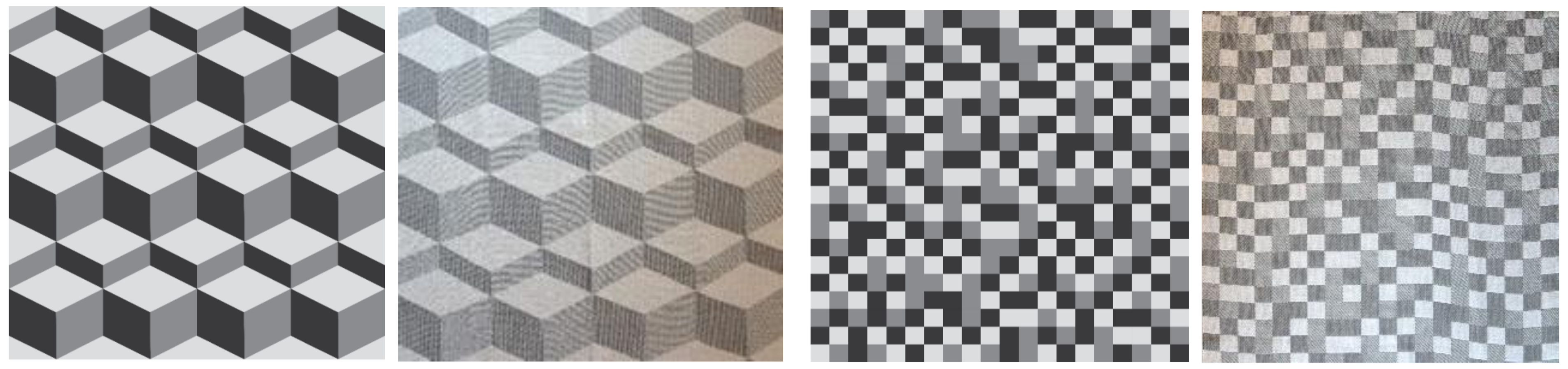

**Figure 1. Pattern and woven fabrics in two different sizes (left - larger, right - smaller)**

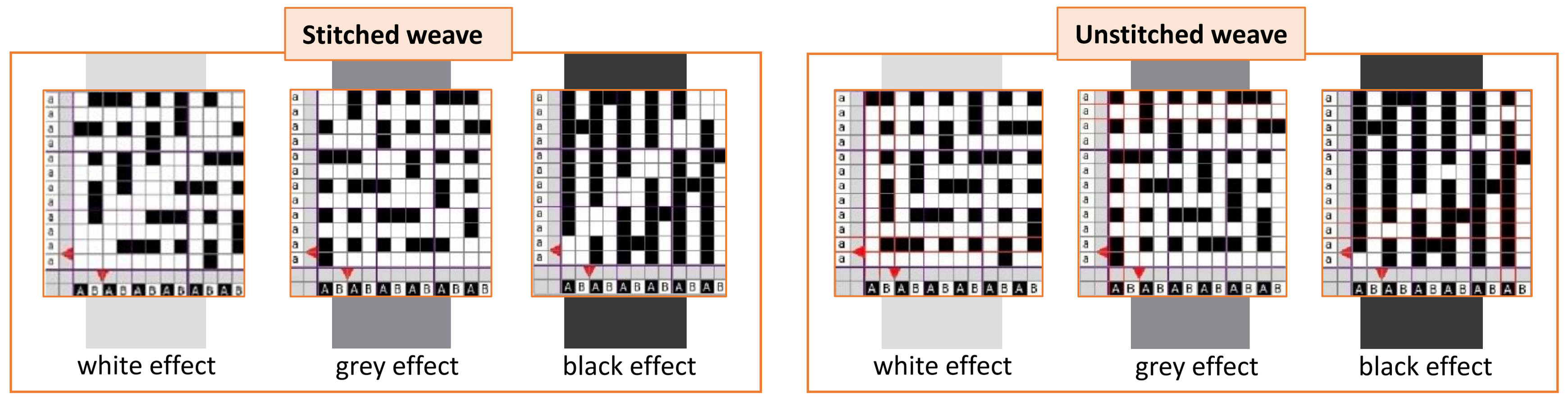


**Figure 2. Weaves for three colours in jacquard patterns**

## METHODS

- breaking strength (SIST EN ISO 2060),
- 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 DISCUSSSION

The physical properties of the woven samples are shown in Table 1, and the mechanical properties of the samples are shown in Table 2. All statistical analyses were performed using the two-way ANOVA to determine the statistically significant parameters affecting the analyzed properties. The analysis presented in Table 3 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. Physical properties of woven samples and standard deviation (SD)**

| Sample | Density [yarns/cm] warp | SD | Density [yarns/cm] weft | SD | Weight [g/m²] | SD | Thickness [mm] | SD | Air permeability [l/min] | SD | Thermal conductivity [W/mK] | SD | UZF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |

We confirm, with greater statistical confidence that the different material has a greater effect on thickness, mass, thermal conductivity and also on tensile strength in the weft direction. The interaction between factors A and B is also statistically significant as F > Fcrit and p < 0.05.

All samples with unstitched weave (sample 3 and 6) 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. The different material has a greater influence on thermal conductivity, but interactions between the material and the pattern can also be observed. 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.

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

| Sample | Breaking strength [N] Warp (SD) | Breaking strength [N] Weft (SD) | Breaking elongation [%] Warp (SD) | Breaking elongation [%] Weft (SD) | Tearing strength [N] Warp (SD) | Tearing strength [N] Weft (SD) | Elongation [mm] Warp (SD) | Elongation [mm] Wef (SD) | Pilling degree 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 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.

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 Table 2, 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.

**Table 3. 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 | | | |

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. 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.

## 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 stiched weave.

**REFERENCES**


[1] Kostajnšek, K., Dimitrovski, K., Kadoğlu, H., Çelik, P., Başal Bayraktar, G., Bedez Üte, T., Duran, D., Ertekin, M., Demšar, A. & Bizjak, M. (2021). Functionalization of Woven Fabrics with PBT Yarns. Polymers 13(2), 260.
[2] Rijavec, T., & Bukošek V. (2009). Novel fibres for the 21st Century. Tekstilec, 47, 13-25.
[3] Iqbal, K., & Sun, D. (2015). Development of thermal stable multifilament yarn containing micro-encapsulated phase change materials. Fibers and Polymers, 16(5), 1156-1162.
[4] Ng, W. S., & Hu, H. (2018). Woven Fabrics Made of Auxetic Plied Yarns. Polymers (Basel), 10 (2),226.
[5] Kostajnšek, K., Urbas, R., & Dimitrovski, K. (2019). A New Simplified Model for Predicting the UV-Protective Properties of Monofilament PET Fabrics. Autex Research Journal, 19 (3), 263-270.
[6] Ana Kocić, A., Bizjak, M., Popović, D., Poparić, G.B., & Stanković, S. B. (2019). UV protection afforded by textile fabrics made of natural and regenerated cellulose fibres. Journal of Cleaner Production, 228, 1229-1237.
[7] Ghane, M., & Ghorbani, E. (2016), Investigation into the UV-Protection of Woven Fabrics Composed of Metallic Weft Yarns. Autex Research Journal, 16 (3), 2015-0021.
[8] Ng, M. C. F., & Zhou J. (2009). A Study on Figured Double-face Jacquard Fabric with Full-color Effect. Textile Research Journal, 79(10), 930-936.
[9] Bilisik, K., & Demir, F. (2010). Dimensional and mechanical characterization of newly developed denim fabrics based on experimentally determined property-structural pattern relations for upholstery applications. Fibers and Polymers, 11, 521–530.
[10] Bizjak Bojič, M., & Dimitrovski, K. (2000). The Role of Technological Parameters at Woven Fabrics Construction. International Journal of Polymeric Materials and Polymeric Biomaterials, 47(4), 603-612.