SSN 1392–1320 MATERIALS SCIENCE (MEDŽIAGOTYRA). Vol. XX, No. X. 2021

Effect of Self- Stitched Double Fabric's Properties on Tensile and Permeability Performances

Raziye Befru BÜYÜKBAYRAKTAR

Dokuz Eylul University Textile Engineering Department, Tinaztepe Campus, 35397, Buca- Izmir, Turkey

crossref http://dx.doi.org/10.5755/j02.ms.25238

Received 20 February 2020; accepted 29 May 2020

The double fabrics having a complex structure are used in different areas both technically and aesthetically. In this study, tensile and air permeability properties of self-stitched double fabrics were investigated. Firstly, six different self-stitched double fabrics having the same yarn type, same settings, two different weave types, and three different stitching arrangements were designed and manufactured. Then, the tensile properties of these double fabrics were tested by applying tensile test at warp and weft directions, and bias-extension test at 45° bias direction. The effect of structural properties on tensile and air permeability results was discussed statistically. The tensile properties of self-stitched double fabrics having plain weave types are mostly better than 2/2 twill ones. The differences between tensile properties of self-stitched double fabrics generally were not found statistically significant according to stitching arrangement except the double fabric having plain weave type and higher stitching points. On the other hand, the differences between air permeability properties of all self-stitched double fabrics were found statistically significant at 95 % confidence level in terms of both stitching arrangement and weave type.

Keywords: double fabric, self-stitched, tensile test, bias-extension, air permeability.

1. INTRODUCTION

Double fabrics which are also known as two-ply fabrics are a type of multi-layer fabric that can be woven by classical weaving looms. These fabrics are generally designed to increase the fabric thickness and to provide more stable and durable fabrics with a higher mass per unit area. Besides, different aesthetic designs can be done by using different raw materials, yarn structures, weave types, yarn colours, and settings on the face and back of the fabric. The usage areas of double fabrics are generally winter garments such as coats; home textiles such as blankets, upholstery fabrics and curtains; technical textiles such as conveyor belts and reinforcements for composite materials.

Two layers of double fabric are stitched to each other with different stitching methods. Double fabric constructions can be classified into three main groups according to the stitching method as self-stitched, center-stitched and interchanging double fabrics [1]. The stitching method provides to obtain fabrics having different aesthetic and performance properties. Self-stitched double fabrics have more stable and rigid structure than other methods.

The design of a double fabric is more complex than a single layer fabric. Firstly, the stitching method should be determined according to aesthetic, physical expectations and the usage area of the double fabric. The selections of raw material and yarn type are also important and effective on both performance and aesthetic properties of the double fabric. The arrangement of face and back yarns in warp and weft directions must be designed according to defined weave type and settings. If the double fabric has a colour effect on both layers, more attention is needed when arranging the colour plans of back warp and weft yarns. Finally, stitching points must be arranged to get a double fabric structure. Generally, stitching points do not appear on the double fabric's surface because they are properly placed between long floatings. It is noted that the relationship between the face and back layers is extremely complicated in the design of figured double fabric [2].

CAD-CAM systems have been developed by some researchers in order to design these complex structures easily [3-8]. Lomov et al. (1997) studied a CAD-CAM software to form 3D simulations of different designed multilayer woven fabrics and to predict some mechanical (tension, shear, bending) and structural (porosity, areal density, thickness) properties [3].Chen and Ptiyaraj (1999) described the weave plan of multilayer fabrics mathematically and generated models by using a CAD/CAM system. The weave plan of a multilayer structure was represented in the form of a 2D binary matrix, besides the cross-sectional weave and shedding and drafting plans were generated automatically [4]. Ping and Lixin (1999), proposed the application of the Kronecker Product for the construction of some different double layer weaves [5]. Koltycheva and Grishanov (2006) suggested a binary structure matrix for the generation of 3D multi-layer fabric structure [6]. Smith and Chen (2009), generated a new algorithm for 3D multilayer woven fabrics. Weave plans of each layer were defined and then weave plan of the multilayer structure was created. Besides the cross-sectional view of the structure was formed [7]. Alali and Drean (2014) modelled centre-stitched double fabrics. Layers were represented by a 2D binary matrix and then a new matrix was defined and weave plan was created for centre-stitched double fabric. All possible stitch points for the centre yarn

* Corresponding author. Tel.: +90-232-3017712; fax: +90-232-3017750.
E-mail address: *befru.buyukbayraktar@deu.edu.tr* (R.B. Büyükbayraktar)

was shown on the screen and the final weave plan was created after the selection of designer [8].

The effect of structural properties on the performance properties of double fabrics was investigated in many studies [9 – 16]. Elnashar (2005) investigated some comfort properties of double fabrics having three different face weave and developed a mathematical model to calculate the porosity of these fabrics based on the cross-sectional geometry of double fabrics [9]. Elnashar and Dubrovski (2008) examined the effect of weave type and stitching arrangement on the mechanical properties of different double fabrics having six different stitching arrangements. The face layer was designed as plain weave and four different weave types were used for the back layer. It was found that the weave type was more effective than the stitching type on some mechanical properties of produced double fabrics [10]. Unal et al. (2012) designed three different self-stitched double fabrics having the same weave type but different weft stitching order and investigated thickness, air permeability and wicking properties statistically. The effect of stitching arrangement was found significant for o thickness and air permeability properties [11]. Özdemir and Yavuzkasap (2012) investigated the effect of weft density, face weave type and raw material on the seam slippage, abrasion and pilling properties of double woven upholstery fabrics and the structural parameters had been found significant on these performance properties [12]. It is common to use different raw materials on the different layers of the double fabric to improve comfort properties. Nazir et al. (2017) studied the effect of weave type and raw material on the comfort properties (air permeability, thermal resistance, water vapour resistance, and overall moisture management capacity) of double fabrics. The results also showed that micro-polyester fabrics woven with 3/1 twill weave exhibits better comfort properties [13]. Ayakta et al. (2018) investigated the effect of raw material and weft setting on some performance properties of lightweight self-stitched double fabrics having the same weave structure. It was found that the performance properties of double fabrics were different according to the raw material [14].

Akter and Chowdhury (2018) designed self-stitched double fabrics having the same weave type and different settings. Comfort and mechanical properties were investigated and denser constructions indicated higher tensile properties and less thermal conductivity [15]. Matusiak and Wilk (2018) designed three cotton double fabrics having different weave types and measured their basic structural, mechanical, and comfort properties. The mechanical properties of fabrics generally were found different according to weave design. The thermal resistance of double fabrics was much higher than single-layer woven fabrics and double fabrics are proposed as winter clothing material [16]. Alam et al. investigate some structural and mechanical properties of double-layer denim fabrics. They designed three different double layer denim fabrics and their properties were compared with a single layer denim fabric. Stiffness of single fabric was found higher than double fabrics [17].

There are also different researches in which double woven fabric structures are used as a medical textile or an absorbent material [18-19]. Chen et al. (2012) developed a vascular prosthesis with a bilayer wall. The double fabric was formed in tubular form and different materials used inside and outside layer of the vascular prosthesis. The outside layer of the structure has a crimped structure by the help of stitching points and the pressure of blood inside the double-layered tubular structure was investigated [18]. Makki and Okrariani (2019) used different fabric structures (double woven fabric, tricot knitted and nonwoven fabrics) with Kapok fiber and investigate acoustic absorptive of these structures. It is noted that the double fabric woven with Kapok and cotton fabrics have good absorption properties more than others because of the complex pore structure of double fabric [19].

Fabrics are exposed to different forces from different directions during usage. Fabric behaviour against these forces such as tensile, shearing, bending, compression and friction define its mechanical properties. It is known that the structural properties of fabrics such as raw material, yarn type, weave type, settings, etc. define the performance properties of the fabrics. The structural parameters must be combined optimally to design products having desired performance properties for a specific usage area. Double fabrics present many possibilities to produce fabric types suitable for different uses. Self-stitched double fabrics are preferred both in classical and technical textile applications. Investigating the properties of these complex structure is important to produce new and improved textile reinforcements. However, the researches conducted on mechanical properties of these fabrics are limited. In this study, the effect of weave type and stitching arrangement on the tensile behaviour of designed self-stitched double fabrics were investigated. Different from the literature, tensile properties of fabrics were tested not only at the warp, weft directions but also at 45º bias direction. Besides, the air permeability properties of designed self-stitched double fabrics were investigated to discuss the effects of structural properties on the three-dimensional structures.

2. MATERIALS AND METHODS

2.1. Materials

In this study, six different self-stitched double fabrics were designed and produced by using two different weave types and three different stitching arrangements. Fabrics were produced by using the same polyester yarn in warp and weft direction at both layers of the fabric. The linear density of the stable polyester yarn was 30 tex. Fabrics were woven on CCI sample weaving loom. The settings of all the double fabrics were designed same, i.e. 40 warp yarns/cm and 30 weft yarns/cm. Weave types were defined as plain and 2/2 twill and the same weave type was used in both layers of one fabric. Different stitching arrangements were applied to investigate the effect of stitches. Stich points were placed according to the twill stitching order. The structural properties of designed double fabrics are summarized in Table 1. The weave plans of designed self-stitched double fabrics and the meaning of marks are given in Fig. 1.

2.2. Method

In this study, firstly, the structural properties (setting, thickness and mass per unit area) of the produced double fabrics were determined according to related standards.

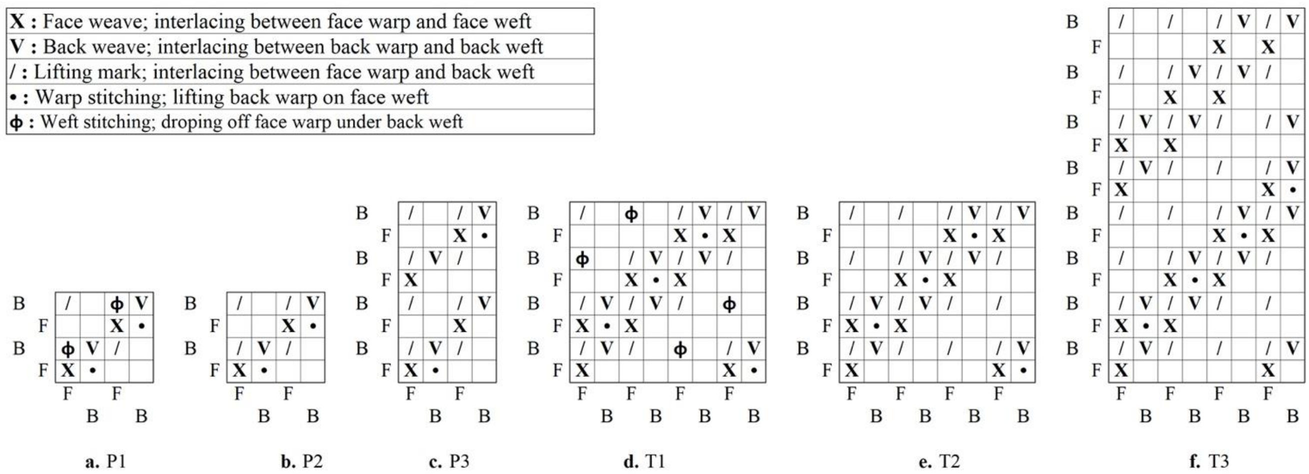

Fig. 1. Weave plans of designed self-stitched double fabrics

Table 1. Structural properties of designed fabrics

Fabric code	Weave type		Stitching arrangement	Setting of fabric warp-weft, cm^{-1}
	Face	Back		
P1	Plain	Plain	Warp and weft stitching	40 – 30
P2	Plain	Plain	Warp stitching	40 – 30
P3	Plain	Plain	Loose warp stitching	40 – 30
T1	2/2 Twill	2/2 Twill	Warp and weft stitching	40 – 30
T2	2/2 Twill	2/2 Twill	Warp stitching	40 – 30
T3	2/2 Twill	2/2 Twill	Loose warp stitching	40 – 30

The tensile test was applied according to TS EN ISO 13934-1 standard [20]. Sample dimensions are 50 mm × 350 mm and the test length is 200 mm. Samples were prepared along the warp, weft directions. Tests were done by using the Instron 4411 test instrument with a test speed as 100 mm/min. In the bias-extension test, sample dimensions and test properties are the same as the tensile test. In the bias-extension test, samples are prepared as warp and weft yarns are initially oriented at 45° angle to the loading direction. All tests were done under standard atmospheric conditions and five repeats were realized for each direction and fabric type. At the end of the tests, the maximum load (breaking load, kN) and the maximum displacement (mm) values of fabrics were recorded.

The air permeability of fabric is related to its three directional pore structure and it is known that the weave type and yarn geometry affect the air permeability [21]. The air permeability properties of self-stitched double fabrics were defined in order to discuss the three-dimensional structure of designed double fabrics. The air permeability tests were performed by using Textest Air Permeability Tester FX 3300 Labotester III according to TS 391 EN ISO 9237 standard [22]. Ten samples were tested for each fabric type. Besides, the volumetric porosity (*VP*, %) of self-stitched double fabrics were calculated by Eq. 1 [13]. Here, *w* is mass per unit area (kg/m^2), ρ_f is the density of fibres (kg/m^3) and *t* is the thickness of fabric (m). The density of polyester fibre is 1.39 g/cm^3. The results of structural, tensile and air permeability properties were discussed statistically by ANOVA analysis using Minitab 14.

$$VP\ (\%) = \left(1 - \frac{w}{\rho_f x t}\right) x100. \quad (1)$$

3. RESULTS AND DISCUSSION

3.1. Structural properties

The face and back images of the self-stitched double fabrics captured by using an optical microscope system and are given in Fig. 2.

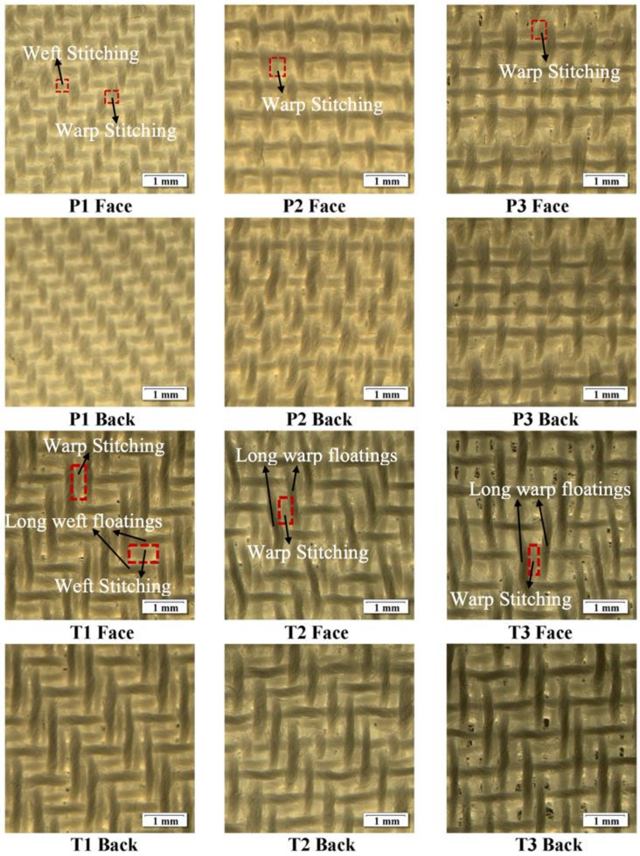

Fig. 2. Face and back layer images of self-stitched double fabrics

The magnification of the images is 40x. In twill fabrics, the stitching points do not appear exactly on the surface of the fabric structure because stitches were properly placed between long yarn floatings, and thus they are covered by longer floatings of 2/2 twill weave as seen on Fig. 2. However, in plain structure, stitches cannot be covered in such a way, therefore the stitches will interfere with the fabric structure. Especially, P1 double fabric having both weft and warp stitching points show a twill effect on the surface of the fabric.

The analysed structural parameters of self-stitched double fabrics are given in Table 2.

Table 2. Measured structural parameters of double fabrics

Fabric code	Warp-weft setting, cm^{-1}		Fabric thickness, mm	Mass per unit area, g/m^2
	Face layer	Back layer		
P1	20 – 15	20 – 15	0.63	208.66
P2	20 – 15	20 – 15	0.66	206.22
P3	20 – 15	20 – 15	0.80	207.78
T1	20 – 15	20 – 15	0.77	208.68
T2	20 – 15	20 – 15	0.89	210.64
T3	20 – 15	20 – 15	1.02	209.38

The differences between mass per unit area of different double fabrics, having same yarn counts, same settings but different weave designs, were not found significant at 95% confidence level. Similar to the single-layer fabrics, the thickness of double fabrics having 2/2 twill weave was higher than double fabrics having plain weave. Because long floatings cause the yarn to be freer. On the other hand, the differences between the thickness of fabrics having different stitching arrangements were found significant at 95% confidence level for each weave type. The decrease of the stitching points has increased fabric thickness. The increased stitching points make the fabric more compact.

3.2. Tensile test results

In Fig. 3, load-displacement curves of tensile and bias-extension test results are shown for samples of T1 double fabric. It can be observed that samples have higher maximum (breaking) load at warp direction. On the other hand, samples have maximum displacements at bias direction. At the beginning of the bias-extension test, warp and wefts yarns begin to shear. Therefore, the increase in load is slow at the beginning. These results are valid for other double fabrics, too.

In Fig. 4, the load-displacement curves of bias-extension test for different plain double fabrics (P1, P2, P3) having different stitching arrangements are given as an example. P1 double fabric having more stitching point have a higher breaking load. The differences between fabric were investigated statistically.

In Fig. 5, maximum load and maximum displacement results of tensile and bias-extension tests are summarized. The load at warp direction were higher than the load at the weft and 45° bias directions for all fabric types and the differences between maximum load at warp direction and the other directions were found statistically significant at 95 % confidence level. This is especially as a result of the higher setting in the warp direction. In Fig. 5 a, interval plot of maximum loads at 95 % confidence level are also given according to test direction and fabric type.

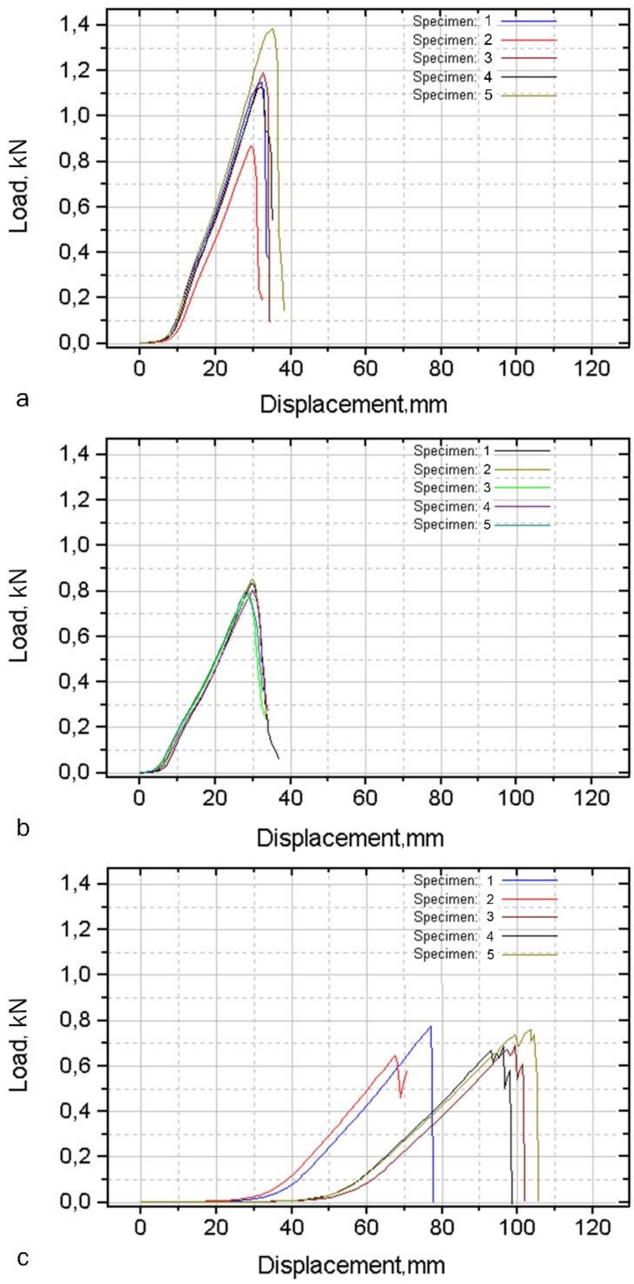

Fig. 3. Load-displacement curves for T1 samples at different directions: a – warp; b – weft; c – bias (45°)

In the study, different stitching arrangements were applied in order to investigate the relationship between the stitching arrangement and tensile results. Stitching arrangement was found statistically significant on maximum load values in 45° bias direction according to weave types. At 45° bias direction, the maximum load of P1 double fabric having maximum stitching point was higher, and the differences between the maximum load of other plain double fabrics (P2, P3) and P1 were found significant at 95 % confidence level. However, the differences between the maximum load of fabrics having warp and loose warp stitching arrangements were not found significant. At 45° bias direction, the maximum load of T3 double fabric having lower stitching point was lower and the differences between T3 and the other double twill fabrics (T1, T2) were found significant at 95 % confidence level.

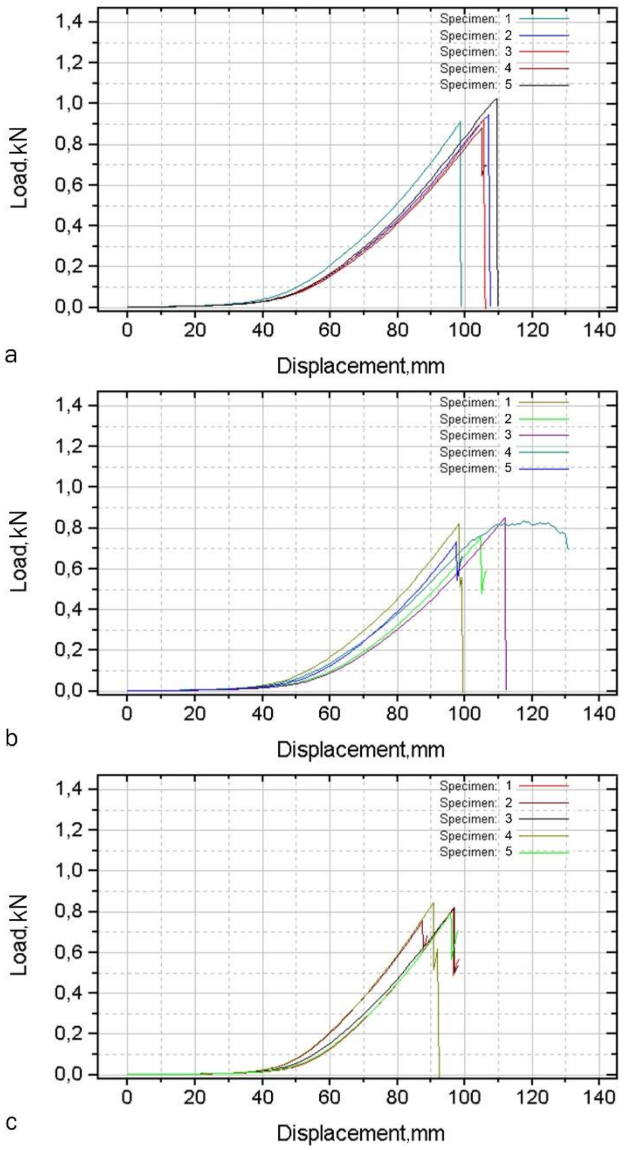

Fig. 4. Load-displacement curves of bias extension test for plain double fabrics: a – P1; b – P2; c – P3

However, at warp and weft directions, the differences between the maximum load of plain double fabrics (P1, P2, and P2) were not found significant according to stitching arrangement. This result was also valid for 2/2 twill double fabrics. The relationship between the tensile test results of double fabrics having different weave types was also investigated. Maximum loads of plain double fabrics at warp direction is higher than twill ones, and except T2 double fabric, the differences between the maximum load of plain and twill structures were found statistically significant. At weft direction, the differences between the maximum load of plain and twill double fabrics were not found statistically significant. At 45° bias direction, the maximum load of plain double fabrics are higher than twill ones and the differences between the maximum load of plain and twill double fabric structures were generally found statistically significant at 95 % confidence level. In Fig. 5 b, the maximum displacement results are shown by using an interval plot at 95 % confidence level.

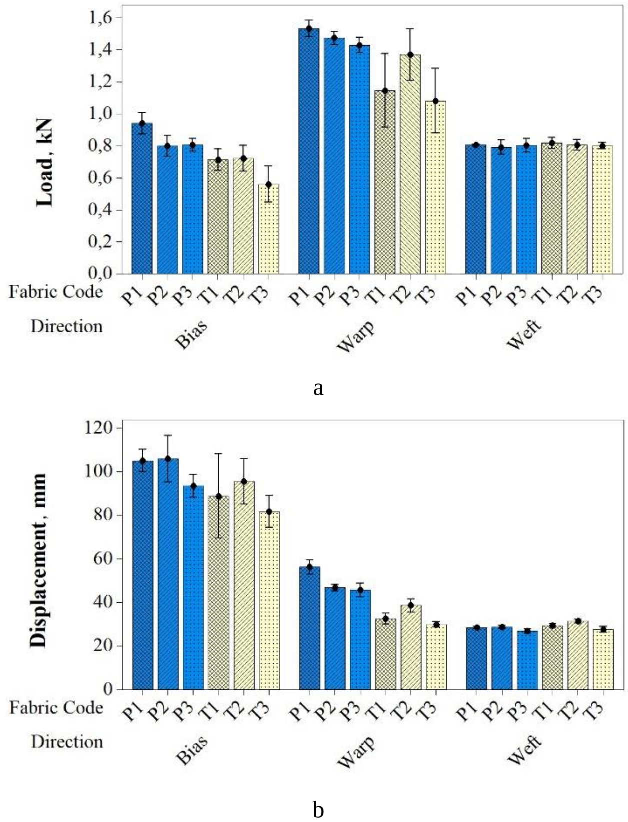

Fig. 5. Tensile and bias-extension test results of self-stitched double fabrics: a – max load; b – max displacement

The maximum displacement results of fabrics at 45° bias direction were higher and the differences between displacement results at 45° bias, warp and weft directions were found significant at 95 % confidence level for both weave type. At warp direction, the differences between plain and 2/2 twill weave types were found significant. On the other hand, the differences between maximum displacement results of plain and 2/2 twill double fabrics were not found significant at weft direction. At 45° bias direction, the differences between the displacement of T3 double fabric having lower stitching point and plain double fabrics were found significant at 95 % confidence level. According to stitching arrangement, the differences between the maximum displacement results of fabrics having the same weave type were found statistically significant in three directions except for 2/2 twill weave at 45° bias direction. For plain double fabrics, P3 having few stitching points had a lower displacement at 45° bias and weft directions and the differences between P3 and the other plain double fabrics (P1, P2) were found significant. On the other hand, at warp direction, the maximum displacement result of P1 was higher than P2 and P3 double fabrics and the differences between P1 and the others were found significant.

3.3. Air permeability test results

The air permeability and calculated volumetric porosity results of self-stitched double fabrics are given in Table 3. Discussing the effect of weave type, the air permeability of self-stitched double fabrics having 2/2 twill weave were higher than plain double fabrics. The longer yarn floatings and higher thickness of 2/2 twill weave fabrics can be a result of this situation. In terms of stitching arrangement, the increase of stitching points decreased the air permeability value for each fabric type. Because the increased stitching points creates a compact fabric structure. The differences between the air permeability results of all double fabric types were found statistically significant at 95 % confidence level.

Table 3. Air permeability and volumetric porosity results of self-stitched double fabrics

Fabric code	Air permeability, mm/s	Volumetric porosity, %
P1	155	76
P2	263	78
P3	838	81
T1	733	81
T2	989	83
T3	1873	85

Increase in stitching points increase fabric rigidity and decrease the thickness of the fabric. It can be noted that when the thickness of the fabric woven with the same yarn type and setting is higher, then its volumetric porosity is also higher. As a result of this, the air permeability of T3 double fabric having higher thickness was found higher. T3 double fabric has both 2/2 twill weave structure and loose stitching points. Therefore, it has an open three-dimensional structure than others. Conversely, P1 has the lowest thickness because of weave type and more stitching points. Consequently, it has less volumetric porosity and air permeability values. The correlation coefficient between the thickness and air permeability was found 0.98 and the correlation coefficient between volumetric porosity and air permeability was found 0.95 at 95 % confidence level. In summary, the increase of yarn floating length and the decrease of stitching points in the weave unit create thicker, bulky, porous, and permeable double fabrics.

4. CONCLUSIONS

In this paper, the effect of weave type and stitching arrangement on the tensile behaviour and air permeability property of self-stitched double fabrics was investigated. The tensile test was applied at warp and weft directions and bias-extension test was applied at 45° bias direction to investigate the tensile performance. Besides, the air permeability of double fabrics was determined.

The maximum load at warp and 45° bias directions were found higher in the double fabrics having plain weave structure. At warp and weft directions, the differences between the maximum load of plain fabrics having different stitching arrangement were not found significant at 95 % confidence level. The maximum load and displacement value at warp and 45° bias direction were found higher for P1 self-stitched plain double fabric having more stitching points. On the other hand, T3 double fabric having 2/2 twill weave type and loose warp stitching arrangement has lower maximum load and displacement values at warp and 45° bias directions. The use of more stitching points (both weft and warp stitching) increased maximum load at warp and 45° bias directions for plain weave structure. However, results showed that weave type has more effect on tensile properties of fabrics than the stitching arrangement. The weave plan and settings of a double fabric should be designed according to desired tensile properties. Investigated structural properties of double fabrics, it was observed that the decrease of stitching points increased the thickness of the structure and result in a more open three-dimensional structure. Besides, the air permeability of the self-stitched double fabrics having longer floating and less stitching points was found higher because of having a higher thickness and volumetric porosity. Consequently, the design of weave type and stitching arrangement of self-stitched double fabrics are important for a specific usage area. Plain weave type and dense stitching points can be used as compact fabrics in industrial applications. On the other hand, weave designs having longer yarn floatings and less stitching points are proper to get thicker, bulky, porous, and permeable structures.

REFERENCES

1. **Baser, G.** The Technology and Art of Weaving. Part I: Basic Weaving Technique and Structures, Punto Publishing, Izmir, 2004.
2. **Ng, M.C.F., Zhou, J.** A Study on Figured Double-face Jacquard Fabric with Full-color Effect *Textile Research Journal* 79 (10) 2019: pp. 930 – 936. https://doi.org/10.1177/0040517508095603
3. **Lomov, S.V., Primachenko, B.M., Truevtzev, N.N.** Two-component Multilayered Woven Fabrics: Weaves, Properties and Computer Simulation *International Journal of Clothing Science and Technology* 9 (2) 1997: pp. 98 – 112. https://doi.org/10.1108/09556229710168243
4. **Chen, X., Potiyaraj, P.** CAD/CAM for Complex Woven Fabrics. Part II: Multi-layer Fabrics *Journal of the Textile Institute* 90 (1) 1999: pp. 73 – 90. https://doi.org/10.1080/00405009908658692
5. **Ping, G., Lixin, D.** Algorithms for Computer-aided Construction of Double Weaves: Application of the Kronecker Product *Journal of the Textile Institute* 90 (2) 1999: pp. 158 – 176. https://doi.org/10.1080/00405009908690620
6. **Koltycheva, N.G., Grishanov, S.A.** A Systematic Approach Towards the Design of a Multi-layered Woven Fabric: Modelling the Structure of a Multi-layered Woven Fabric *Journal of the Textile Institute* 97 (1) 2006: pp. 57 – 69. https://doi.org/10.1533/joti.2005.0213
7. **Smith, M.A., Chen, X.** CAD/CAM Algorithms for 3D Woven Multilayer Textile Structures *International Journal of Materials and Textile Engineering* 3 (9) 2009: pp. 538 – 549.
8. **Alali, M., Drean, J.Y.** CAD/CAM for Double Woven Fabric: Center Warp Stitching *SAGE Open* 2014: pp. 1 – 15. https://doi.org/10.1177/2158244013518922
9. **Elnashar, E.A.** Volume Porosity and Permeability in Double-Layer Woven Fabrics *AUTEX Research Journal* 5 (4) 2005: pp. 207 – 218.
10. **Elnashar, E.A., Dubrovski, P.D.** The Influence of the Weave and the Method of Stitching on Selected Mechanical Properties of Woven Double Fabrics *Autex Research Journal* 8 (2) 2008: pp. 41 – 43.
11. **Unal, P.K., Kayseri, G.O., Kanat, Z.E.** The Effect of Different Connections in Double Layered Woven Fabrics on

Comfort Properties *Fibers and Polymers* 13 (2) 2012: pp. 258 – 263. https://doi.org/10.1007/s12221-012-0258-x

12. **Özdemir, H., Yavuzkasap, D.** The Effects of Yarn and Fabric Structural Parameters on the Seam Slippage, Abrasion and Pilling Properties of Double Woven Upholstery Fabrics *Industria Textila* 63 (6) 2012: pp. 307 – 314.
13. **Nazir, M.U., Shaker, K., Nawab, Y., Fazal, M.Z., Khan, M.I., Umair, M.** Investigating the Effect of Material and Weave Design on Comfort Properties of Bilayer-Woven *Journal of the Textile Institute* 108 (8) 2017: pp. 1319 – 1326. https://doi.org/10.1080/00405000.2016.1247616
14. **Ayakta, D.Y., Sülar, V., Öner, E.** Performance of the Double Face Lightweight Woven Fabrics from Sustainable Yarns 7th International Technical Textiles Congress Proceeding Book, Meta Basım Press, Izmir, 2018: pp. 103 – 111.
15. **Akter, S., Chowdhury, S.** The Construction Principle of Double Cloth and Its Properties *Trends in Textile Engineering & Fashion Technology* 4 (4) 2018: pp. 1 – 10. https://doi.org/10.31031/TTEFT.2018.04.000595
16. **Matusiak, M., Wilk, E.** Investigation of Mechanical and Utility Properties of Two-Layer Cotton Woven Fabrics *AUTEX Research Journal* 18 (2) 2018: pp. 192 – 201. https://doi.org/10.1515/aut-2017-0032
17. **Alam, R., Islam, T., Haider, A., Haque, N., Islam, J., Zakaria, M.** Development of Double Cloth Structure to Facilitate Versatile Application of Denim Fabric *Journal of Textile Science and Technology* 5 2019: pp. 19 – 26. https://doi.org/10.4236/jtst.2019.51002
18. **Chen, Y., Ding, X., Li, Y. King, M.W., Gao, J., Zhau, X.** A bilayer Prototype Woven Vascular Prosthesis with Improved Radial Compliance *Journal of the Textile Institute* 103 (1) 2012: pp. 106 – 111. https://doi.org/10.1080/00405000.2011.552956
19. **Makki, A.I., Oktariani, E.** Acoustic Absorptive Properties of Kapok Fiber, Kapok Fiber Layered Tricot Fabric and Kapok Fiber Layered Double Weave Fabric *Journal of Physics: Conference Series* 1381 (012065) 2019: pp. 1 – 5. https://doi.org/10.1088/1742-6596/1381/1/012065
20. EN ISO 13934-1. Textiles – Tensile properties of fabrics – Part 1: Determination of maximum force and elongation at maximum force using the strip method, European Standards, 2013.
21. **Turan, R.B., Okur, A.** Investigation of pore parameters of woven fabrics by theoretical and image analysis methods *Journal of the Textile Institute* 103 (8) 2012: pp. 875 – 884. https://doi.org/10.1080/00405000.2011.617057
22. ISO 9237:1995. Textiles – Determination of the permeability of fabrics to air.