Fibres and Textiles **30**(1), 2023, 36-41 DOI: 10.15240/tul/008/2023-1-006

COMFORTABLE AND PROTECTIVE HYBRID WEFT-KNIT PLATED FABRIC FROM GLASS AND WOOL/ACRYLIC YARNS

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ABSTRACT

In this study, hybrid weft-knit plated fabrics were produced by co-feeding glass and wool/acrylic blend yarns. While the wool/acrylic yarn in contact with skin is expected to provide comfort, the glass yarn next to the environment is to provide protection. The physical, structural, air permeability, bursting strength, and the protection against flame properties of glass plus wool/acrylic plated fabric were compared with the reference fabrics consisting completely of glass or wool/acrylic blend yarn. Two factors: the yarn composition and the cam setting of the knitting machine were considered. Two-ply of glass yarn was fed to the each face of the reference glass fabric, and a single-ply of wool/acrylic yarn was fed to the each face of the reference wool/acrylic fabric. On the other hand, while the hybrid plated fabric's back face accommodated two-ply of glass yarn, its front face involved a single-ply of wool/acrylic yarn. Two different cam settings, loose and tight, were selected. The physical and the structural properties of the fabrics were measured. Then, air permeability, bursting strength, and the protection against flame tests were performed. Test results were subjected to detailed statistical data analysis and how they were affected by the yarn composition and the cam setting was presented with visual and self-explanatory graphs.

KEYWORDS

Glass yarn; Weft knit fabric; Plated fabric; Protective fabric; Air permeability.

INTRODUCTION

While textile fabrics only provided covering when they first appeared, now this expectation evolved into functionality. By functionality, it is understood that the fabric not only covers and comforts the individual, plus protects him against dangers from the outside. This expectation has increased the need for the hybrid fabrics where the natural yarns that provide comfort and the synthetic yarns that offer protection are used together. The wool fiber stands out with its comfort and insulation feature. On the other hand – as a result of its affordable price, moderate mechanical properties, high protection against flame and chemicals – glass fiber is widely used in technical textile applications. However, due to its hard and brittle structure, the glass fiber experiences high level of breakage in the fabric formation processes [4, 7, 8, 11]. The contact of broken fiber ends with the skin causes itching and discomfort. In addition, the moisture absorption performance of glass fiber is very low, which significantly lowers its comfort feeling. On the other hand, its compatibility with human skin, moisture absorption capacity, and thermal insulation capability renders the wool fiber very valuable in comfortable clothing.

Woven fabrics require laborious weaving preparation processes such as weft yarn preparation, warping, sizing, tying and drawing-in. However, these pre-processes are not required for weft knitted fabrics. Therefore, the production cost of weft knitted fabric is considerably lower than that of woven fabric. Woven and weft knitted fabrics are also quite different from each other in terms of fabric structure and performance. The weft knitted fabric, which consists of meshed loops, easily stretches when exposed to any in-plane or out-of-plane load and easily takes the desired three-dimensional shape. This makes it possible to produce comfortable clothing from weft knitted fabric that drapes the body without any folding, and wrinkling [3, 6, 12-15].

The fabric pattern is one of the critical features that determine the performance of the fabric. The pattern of the weft-knit fabric is determined by the number and the position of different types of stitches inside the knit repeat, and the cam setting. Besides, the cam setting controls the fabric tightness through determining the size of the loops. Therefore, it is possible to produce weft knitted fabrics in numerous architectures by playing with the fabric pattern and the cam settings [1-2, 5, 9-10].

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In this study, it was planned to produce protective and comfortable weft knitted fabric with different tightness using glass and wool/acrylic yarns. Due to the disturbing effect of the glass fiber in contact with the skin, the plated weft-knit fabric structure was selected. In the plated fabric structure, the wool/acrylic yarn was used on the surface of the fabric in contact with the body, while glass yarn was used on the other side (outer) of the fabric. It was anticipated that glass yarn provides protection against dangers from outside, while wool/acrylic yarn in contact with the skin is thought to provide comfort by establishing the desired micro-climate between the body and the fabric.

EXPERIMENTAL

Materials

In this study, E-glass multifilament yarn with a single-ply yarn count of 136 tex, and individual fiber diameter of 9 microns was used. Nm 7 count, high bulk, 50/50% wool/acrylic blend yarn was used as the yarn that would provide wearability and comfort to the fabric. Plated weft-knit fabrics were produced by Brother KH-864, hand-operated, 5E gauge knitting machine. The plating yarn feeder used in the production of all fabrics and the different yarn compositions fed to the feeder are given in Figure 1.

We focused on two factors. The first one is the yarn composition, and the other is the cam setting of the knitting machine. While the yarn composition had three sublevels (completely glass yarn, completely wool/acrylic blend yarn, and the combination of glass and wool/acrylic blend yarn), the cam setting had only two sublevels (loose and tight cam settings). In the production of completely glass yarn fabric, 2-ply of glass yarn was fed into both the front and rear eyes of the plating yarn feeder (Figure 1). In glass plus wool/acrylic yarn (hybrid) fabric; while a single-ply of wool/acrylic yarn was fed to the rear eye of the feeder, 2-ply of glass yarn was fed to the front eye. Finally, in the fabric consisting completely of wool/acrylic yarn, a single-ply of wool/acrylic yarn was fed to both the front and rear eyes of the feeder. The yarn composition was coded as given below:

WA: single-ply wool/acrylic yarn, G: single-ply glass yarn;

GG/GG: 4-ply of glass yarn fabric (2-ply of glass yarn on both the front and back faces of the fabric).

WA/GG: The front face is a single-ply of wool/acrylic yarn, while the back face is 2-ply of glass yarn fabric.

WA/WA: 2-ply of wool/acrylic yarn fabric (a single-ply of wool/acrylic yarn on both the front and back faces of the fabric).

Two fabric tightness levels, 4 (tight fabric) and 8 (loose fabric) were selected as the cam setting. Thus, a total of 6 (3x2) different weft-knit plated fabrics were produced. The images of the fabrics are given in Figure 2.

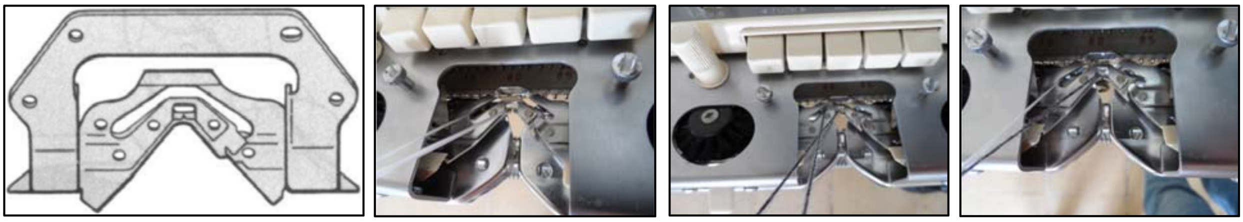
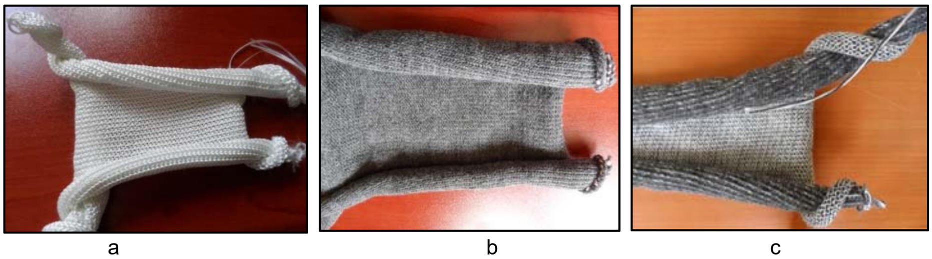


Figure 1. The plating yarn feeder and different yarn compositions fed to the feeder.



a b c

Figure 2. The completely glass yarn GG/GG fabric (a), the completely wool/acrylic yarn WA/WA (b), the hybrid WA/GG fabric (c).

Methods

A digital thickness gauge device with a presser foot diameter of 21.15 mm and a compression pressure of 2 kPa was used to measure the fabric thickness. BS 5441 standard was followed for length measurement. ASTM D737 was followed and the SDL ATLAS M021A test device was used in the air permeability tests. The circular fabric test area was taken as 20 cm^2 and the pressure drop was chosen as 200 Pa. Bursting strength test was performed on the knitted fabrics according to BS EN ISO 13938-1. A dome with an internal diameter of 30.5 mm and a corresponding internal area of 7.3 cm^2 was selected. The "Surface Ignition" test procedure was performed on the knitted fabrics via following the BS EN ISO 15025 standard. A specified flame with an application time of 10-second was performed on the back (purl loop) face of the all fabrics, thus the glass yarn surface of the wool/acrylic plus glass yarn (hybrid WA/GG) fabric sample was exposed to the flame.

RESULTS AND DISCUSSION

Yarn composition changed the fabric thickness at a statistically significant level (Figure 3 and Table 1). While the bulky structure of the wool/acrylic yarn increased the fabric thickness, the thin and regular structure of the glass yarn decreased the fabric thickness. The addition of wool/acrylic yarn to the fabric structure also increased the fabric thickness variation (standard deviation).

The addition of glass yarn to the weft knitted fabric decreased the loop length (Figure 4 and Table 2). This is attributed to the thin and low-volume nature of the glass yarn. In other words; the addition of wool/acrylic blend yarn, which has a voluminous structure, to the fabric increased the loop length.

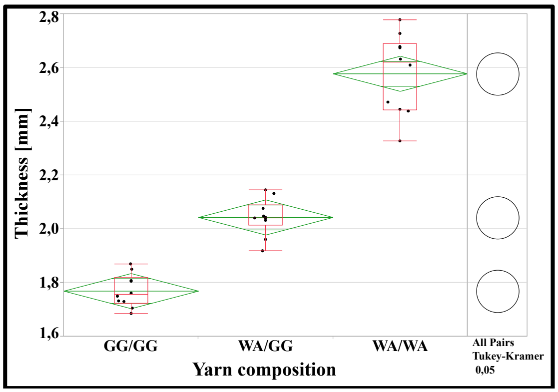


Figure 3. The effect of yarn composition on thickness.

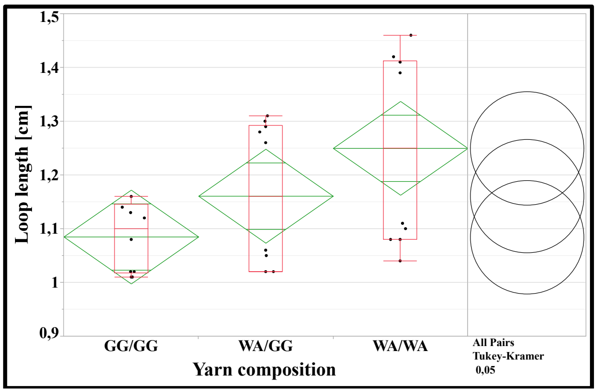


Figure 4. The effect of yarn composition on loop length.

Note: The horizontal green line dividing the green diamond corresponds to the mean, while the distance between the lower and upper corners of the green diamond shows the confidence interval based on the 95% confidence level. One comparison circle for the mean calculated at each sublevel level is given in the right-hand column. The circles representing means that differ significantly from each other (α = 0.05) either do not intersect or intersect slightly.

Table 1. The effect of yarn composition on thickness.

Property	Yarn composition				n	mean	sd	LL	UL	p-value
Thickness [mm]	WA/WA	A			10	2.58	0.15	2.51	2.64	<0.0001
	WA/GG		B		10	2.04	0.07	1.98	2.11	
	GG/GG			C	10	1.77	0.06	1.70	1.83	

Note: Levels that are not combined with the same alphabetic capital letter differ significantly from each other (α = 0.05). **n**: number of measurements, **sd**: standard deviation, **LL**: lower limit, **UL**: upper limit. The limits were established according to the 95% confidence level. A p-value less than 0.05 is an indication that the difference between at least two levels is statistically significant and is colored red.

Table 2. The effect of yarn composition on loop length.

Property	Yarn composition			n	mean	sd	LL	UL	p-value
Loop length [mm]	WA/WA	A		10	1.25	0.18	1.16	1.34	0.0362
	WA/GG	A	B	10	1.16	0.14	1.07	1.25	
	GG/GG		B	10	1.08	0.06	1.00	1.17	

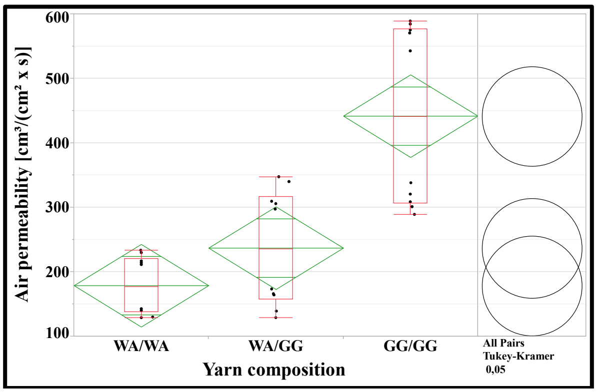


Figure 5. The effect of yarn composition on air permeability.

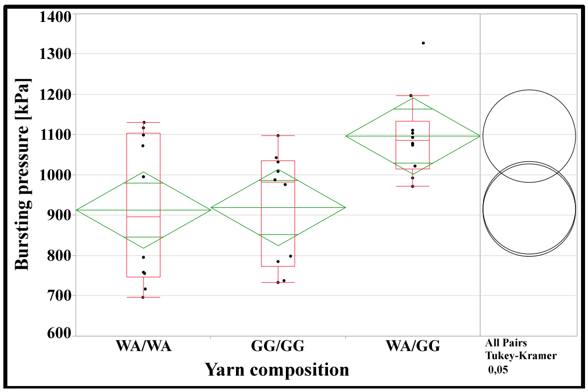


Figure 6. The effect of yarn composition on the bursting pressure.

Table 3. The effect of yarn composition on air permeability.

Property	Yarn composition			n	mean	sd	LL	UL	p-value
Air permeability [cm^3/(cm^{2}xs)]	GG/GG	A		10	441,70	138,64	377,61	505,79	<0,0001
	WA/GG		B	10	237,00	89,44	172,91	301,09	
	WA/WA		B	10	178,70	45,28	114,61	242,79	

Table 4. The effect of yarn composition on bursting pressure.

Property	Yarn composition			n	mean	sd	LL	UL	p-value
Bursting pressure [kPa]	WA/GG	A		10	1097.28	103.40	1002.50	1192.00	0.0133
	GG/GG		B	10	919.97	139.85	825.20	1014.70	
	WA/WA		B	10	913.74	183.58	819.00	1008.50	

The addition of wool/acrylic yarn, which is more voluminous and thicker than glass yarn, to the fabric structure closed the pores of the fabric and reduced air permeability (Figure 5 and Table 3). However, no statistically significant difference was observed between the air permeability of the purely wool/acrylic yarn (YA/YA) fabric and the wool/acrylic yarn plus glass yarn (YA/CC) fabric. Moreover, the addition of glass yarn to the fabric structure increased the air permeability variation of the fabric.

Figure 6 and Table 4 show the effect of yarn composition on fabric bursting strength (pressure). Hybrid plated (WA/GG) fabric with 2-ply of glass yarn on the back face and a single-ply of wool/acrylic yarn on the front face showed the highest bursting pressure. The hybrid plated fabric also exhibited the lowest bursting pressure variation, demonstrating a stable bursting performance. On the other hand, completely glass yarn (GG/GG) fabric and completely wool/acrylic yarn (WA/WA) fabric exhibited the lowest bursting pressure. The interaction of the glass yarn with the knitting elements while the yarn was being forced to take the loop form had resulted in fiber breakage, which showed itself as a decrease in bursting strength of the fabric. It is promising that the hybrid plated (WA/GG) fabric, consisting of a single-ply of wool/acrylic plus two-ply of glass yarn, exhibited the highest (statistically significant level higher than the other fabrics) and the most stable (lowest variation) bursting pressure.

The yarn composition affected the afterflame time at a statistically significant level (Figure 7 and Table 5). Completely wool/acrylic yarn (WA/WA) fabrics exhibited an average afterflame time of 123 seconds, while completely glass yarn (GG/GG) fabrics exhibited an average of zero afterflame time, that is, GG/GG fabrics did not ignite. While WA/WA fabrics burned completely, GG/GG fabrics preserved their integrity. The promising result here is that the hybrid (WA/GG) fabric and the completely glass yarn (GG/GG) fabric exhibited statistically the same average afterflame time. This is because that tightly knitted hybrid (WA/GG) fabric at the 4 cam setting did exhibit lack of flaming after the flame removal (i.e. afterflame time of zero second). Therefore, the tightly knitted (at 4 cam setting level) hybrid plated (WA/GG) fabric behaved similar with the completely glass yarn (GG/GG) fabric and did not exhibit flaming (i.e. not ignited) after the flame was removed at the end of 10 seconds.

Figure 8 shows the burned images of completely glass yarn GG/GG fabrics knitted at 4 cam settings. Glass fibers that turned into black at the flame application point but kept their integrity exhibited a decreasing yellowing with distance from the flame point.

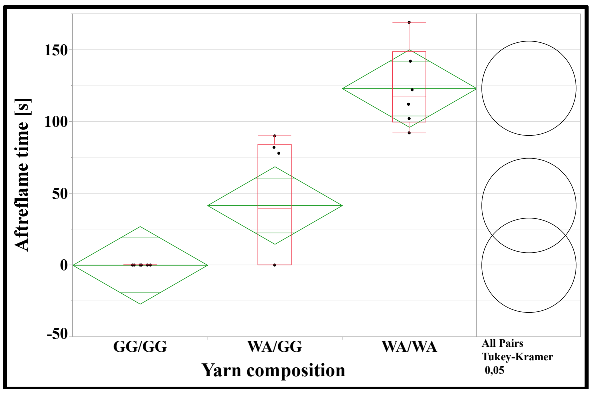


Figure 7. The effect of yarn composition on afterflame time.

Table 5. The effect of yarn composition on afterflame time.

Property	Yarn composition			n	mean	sd	LL	UL	p-value
Afterflame time [s]	WA/WA	A		10	123.17	28.29	96.12	150.21	<0.0001
	WA/GG		B	10	41.67	45.81	14.62	68.71	
	GG/GG		B	10	0.00	0.00	-27.05	27.05	

Figure 8. Pictures taken after the burning test of completely glass yarn GG/GG fabric knitted at 4 cam settings.

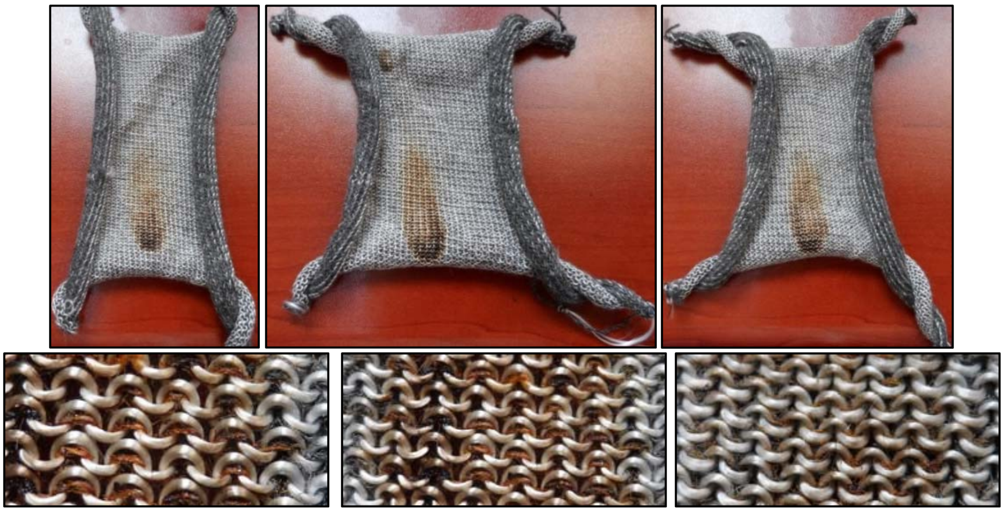


Figure 9. The photos of the burned WA/GG hybrid fabric knitted at 4 cam setting.

Figure 9 shows the photos of the burned WA/GG fabric knitted at 4 cam setting. Flame propagation in WA/GG hybrid fabric remained within a limited area. The tight fabric structure and the presence of 2-ply of glass yarn on the surface where the flame is applied stopped the flame propagation. While the wool/acrylic yarn became charred at the flame application point, this charring decreased as moved away from the application point.

CONCLUSIONS

In this study, weft-knit plated hybrid fabrics with different tightness were produced from glass and wool/acrylic yarns. In the hybrid plated fabric, while front face of the fabric formed from single-ply of wool/acrylic yarn, the back face formed from 2-ply of glass yarn. The physical, structural, air permeability, bursting strength, and protection against flame properties of the hybrid fabric were compared with the reference fabrics those consisted of only 4-ply of glass or only 2-ply of wool/acrylic yarn. The hybrid fabric exhibited comparable air permeability performance with the fabric from completely wool/acrylic yarn, while it demonstrated statistically significantly better bursting pressure than the reference fabrics from completely glass or wool/acrylic yarns. The hybrid fabric with tight cam setting also showed the similar flame resistance with the fabric from completely glass yarns.

***Acknowledgements**: We would like to thank Scientific Research Projects Management Unit (BAPYB) of Gaziantep University for their financial support to this study under the project number of MF.ÖKAP.21.11. This study was supported in the category of research project with undergraduate student participation. The second and third authors are the current undergraduate students of Textile Engineering Department of Gaziantep University.*

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