

Effect of Different Interlining Types on the Mechanical and Thermophysiological Performance of Shirting Fabrics

Özlem Tektaş Çelikkanat¹, Hilal Şendur¹, Özge Ural², Emine Dilara Koçak²

¹İpekyol Giyim San. Paz. ve Tic. A.Ş. Design Center, İstanbul, Türkiye

²Department of Textile Engineering, Faculty of Technology, Marmara University, İstanbul, Türkiye

Email: ozge.ural@marmara.edu.tr, dkocak@marmara.edu.tr

How to cite this paper: Çelikkanat, Ö.T., Şendur, H., Ural, Ö. and Koçak, E.D. (2026) Effect of Different Interlining Types on the Mechanical and Thermophysiological Performance of Shirting Fabrics. *Journal of Textile Science and Technology*, 12, 55-68.

<https://doi.org/10.4236/jtst.2026.123005>

Received: May 3, 2026

Accepted: July 6, 2026

Published: July 9, 2026

Copyright © 2026 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

This study evaluates the mechanical durability and thermophysiological comfort performance of different interlining types used in the collar region of shirting fabrics. Three plain-woven shirting fabrics (S1 - S3) were combined with six different interlining types (woven, knitted, and nonwoven; sew-in and fusible applications), and the performance of the resulting composite structures was analyzed. Mechanical properties, including tensile strength in warp and weft directions, bursting strength, adhesion strength, and bending rigidity, as well as comfort-related parameters such as air permeability, thermal resistance, and relative water vapor permeability, were measured. The experimental data were statistically evaluated using two-factor ANOVA. The results indicate that interlining type is generally a more influential factor than fabric type for most performance parameters. Woven interlinings demonstrated higher performance in linear tensile strength, whereas elastic knitted interlinings provided advantages in bursting strength. Fusible interlinings, applied under higher pressing parameters, produced greater adhesion strength and thermal resistance; however, they reduced air and water vapor permeability. In contrast, the sew-in method offered a more balanced comfort performance. The findings highlight the necessity of optimizing the trade-off between mechanical stability and comfort properties in collar applications and provide scientifically grounded criteria for interlining selection in industrial shirt manufacturing.

Keywords

Interlining, Fusible Interlining, Mechanical Performance, Thermophysiological Comfort, Shirting Fabric

1. Introduction

Interlinings used in garment components that require form stability, such as collars, cuffs, and plackets in ready-to-wear products, are selected according to the fabric type, model characteristics, and intended use. These materials are positioned between the fabric and the lining or between fabric layers in order to enhance the structural strength and shape retention of the garment. Fixed either through fusing (adhesive bonding) or sewing methods, interlinings contribute to maintaining the garment's form and dimensional stability from the manufacturing stage throughout its service life. Widely used in various apparel products including suits, shirts, jackets, skirts, and trousers, interlinings play a crucial role in garment shaping, preserving structural integrity, and supporting aesthetic performance [1].

In ready-to-wear production, the selection of interlining and the joining method (particularly adhesive bonding and sewing-based applications) is considered a critical design parameter affecting bond strength, bending/rigidity behavior, dimensional stability, and handle properties of composite structures. Recent studies indicate that the temperature-pressure-time combination applied during the fusing process significantly influences bonding quality and overall performance. Therefore, optimization of process parameters through experimental design and modeling approaches has become increasingly important [2] [3]. In particular, the development of models that predict bond strength in shirt components based on measurable parameters has gained importance in terms of production quality assurance and process repeatability [2]. Similarly, studies aiming to predict the composite behavior of collar structures through drape analysis have enabled a more systematic discussion of the interlining-process-performance relationship [4]. In parallel, the literature reports a growing number of studies addressing both performance evaluation and sustainable material trends in interlining systems (e.g., fully biodegradable adhesive interlinings), reflecting an increasing tendency to optimize environmental requirements together with functional performance [1] [5].

In the literature, existing studies have generally examined either mechanical properties or comfort-related parameters separately. However, comprehensive investigations that simultaneously evaluate the mechanical durability and thermophysiological comfort performance of fabric-interlining composite structures remain limited. To address this gap, the present study analyzes the interaction between three plain-woven shirting fabrics and six different interlining types using a two-factor ANOVA approach. The aim is to provide a comprehensive assessment of their combined performance and to establish a scientific basis for optimal interlining selection in industrial shirt manufacturing.

2. Materials and Methods

2.1. Materials

In this study, three different shirting fabrics with the technical properties presented in **Table 1** were used as the base materials.

Table 1. Technical parameters of the shirting fabrics.

Fabric	Fiber Content	Weave	Fabric Weight (g/m ²)	Yarn Count	Fabric Density (ends × picks/cm)
C100	100% Cotton	Plain weave	118	Ne 40/1	30 × 18
V100	%100 Vissose	Plain weave	122	Ne 40/1	28 × 17
CV60/40	Cotton/Viscose	Plain weave	120	Ne 40/1	29 × 18

In addition to the base fabrics, six different interlining types commonly used in shirt manufacturing were examined in this study. The interlinings were selected within a weight range of 25 - 35 g/m². The structural and mechanical properties of the interlinings are presented in **Table 2**.

The application area considered in the garment was the collar component, which requires high dimensional stability and structural reinforcement. All experimental tests were conducted under standard atmospheric conditions (20 ± 2 °C temperature and 65 ± 4% relative humidity) prior to testing.

Table 2. Structural and mechanical properties of the interlinings.

Interlining Type	Fiber Content	Structure	Weight (g/m ²)	Thickness (mm)	Tensile Strength (N)	Bursting Strength (kPa)
Woven (Sew-in)	PES/Cotton %65/35	Plain weave	32 ± 1	0.18 ± 0.01	Warp: 520 ± 25 Weft: 460 ± 20	-
Warp-knit Fusible (Resin Dot)	Polyamide (PA)	Warp-knit (tricot)	28 ± 1	0.20 ± 0.01	360 ± 18	920 ± 40
Thermally Bonded Nonwoven	Polyester (PES)	Random fiber structure	35 ± 2	0.30 ± 0.02	240 ± 15	-
Fusible Elastic Warp-knit Fusible	PA/Elastane (%88/12)	Elastic knit	30 ± 1	0.22 ± 0.01	310 ± 20	1020 ± 45
Resin-Coated Woven Fusible	Polyester (PES)	Plain weave + resin dot	27 ± 1	0.17 ± 0.01	Warp: 500 ± 22 Weft: 430 ± 18	-
Non-fusible Plain Weave Cotton	Cotton (%100)	Plain weave	25 ± 1	0.16 ± 0.01	Warp: 410 ± 20 Weft: 380 ± 18	-

Note: The properties presented in **Table 2** were obtained from supplier technical datasheets and verified in our laboratory prior to sample preparation using ISO 13934-1 for tensile strength and ISO 13938-1 for bursting strength.

2.2. Method

2.2.1. Specimen Preparation and Full Experimental Matrix

To evaluate the composite structure performance under standardized conditions,

tests were executed on flat bonded composite samples prepared by combining the 3 shirting fabrics with the 6 interlining types, resulting in a fully crossed experimental layout. For fusible types (K2, K3, K4, K5), fusing was applied using a flat-bed laboratory press under the parameters specified in **Table 3**. For sew-in types (K1, K6), layers were joined via perimeter lockstitching. All test specimens were cut along the specific principal directions (warp/weft or machine/cross directions) directly from these uniform flat composite sheets. Specimen configurations were assigned as follows:

Table 3. Experimental matrix and processing parameters for fabric-interlining composites.

Interlining Code	Interlining Structural Type	Joining/ Application Method	Press Parameters (Temperature/ Pressure/Time)	Executed Laboratory Tests (5 Replicates Each)
K1	Woven (sew-in)	Interlayer placement + edge stitching	--	Tensile (Warp/Weft), Bursting, Bending Air Perm., Thermal, RWVP
K2	Resin-coated Woven	Hot press (fusing)	145°C, 3 bar, 12 s	Tensile (Warp/Weft), Bursting, Bending, Peel Adhesion, Air Perm., Thermal, RWVP
K3	Warp-knit fusible	Hot press (fusing)	140°C, 2.5 bar, 12 s	Tensile (MD/CD), Bursting, Bending, Peel Adhesion, Air Perm., Thermal, RWVP
K4	Nonwoven fusible	High-temperature pressing	150°C, 3 bar, 15 s	Tensile (Warp/Weft), Bursting, Bending, Peel Adhesion Air Perm., Thermal, RWVP
K5	Elastic warp-knit fusible	Low-pressure pressing	135°C, 2 bar, 10 s	Tensile (Warp/Weft), Bursting, Bending, Peel Adhesion Air Perm., Thermal, RWVP
K6	Cotton sew-in	Interlayer placement + stitching	--	Tensile (Warp/Weft), Bursting, Bending, Air Perm., Thermal, RWVP

Tensile Strength (Strip Method): 250 mm × 50 mm samples (gauge length: 200 mm), cut in both warp and weft directions.

Bursting Strength: Circular samples with a testing area of 50 cm² (diameter: 79.8 mm).

Bending Rigidity (Cantilever Method): 150 mm × 25 mm specimens.

Adhesion Peel Strength: 200 mm × 50 mm specimens, separated at one end over a length of 50 mm for clamping.

Comfort Properties (Air, Thermal, and Moisture Permeability): Circular cut specimens matching the respective clamping heads of the test devices (e.g., 20 cm²

for air permeability).

2.2.2. Testing Methods

In this study, six different interlining types were applied to the collar region of three plain-woven shirting fabric compositions: 100% cotton, 100% viscose, and 60/40 cotton/viscose. All tests were conducted under controlled environmental conditions of $20 \pm 2^\circ\text{C}$ temperature and $65 \pm 4\%$ relative humidity.

The performance of the fabric–interlining composites was evaluated in terms of mechanical properties and thermophysiological comfort parameters. The applied tests and corresponding standards are summarized below:

Mechanical (Structural) Tests

- Tensile Strength (warp and weft directions)—ISO 13934-1;
- Bursting Strength—ISO 13938-1;
- Bending Rigidity—ASTM D1388;
- Adhesion Strength (T-Peel Test)—ISO 11339;

Comfort (Thermophysiological) Tests

- Air Permeability—ISO 9237;
- Thermal Resistance (R_{ct})—ISO 11092;
- Water Vapor Permeability (Relative Water Vapor Permeability)—ISO 15496.

These tests allowed a comprehensive assessment of the mechanical durability, form stability, and comfort performance of the structures formed by different woven, knitted, and nonwoven interlining types in the collar region.

The coding of fabrics and interlinings used in this study is as follows:

- **Fabrics:** S1—100% Cotton, S2—100% Viscose, S3—60/40 Cotton/Viscose;
- **Interlinings:** K1—Woven sew-in, K2—Resin-coated woven fusible, K3—Warp-knit fusible, K4—Thermally bonded nonwoven fusible, K5—Elastic warp-knit fusible, K6—Non-fusible woven cotton.

2.2.3. Statistical Design and ANOVA Modeling

The effects of shirting fabric type (S1 - S3) and interlining type (K1 - K6) on the performance of the fabric-interlining composites were evaluated using a two-way analysis of variance (Two-Way ANOVA). The statistical model included the main effects of shirting fabric type and interlining type, as well as their interaction effect. Each experimental group consisted of five replicates ($n = 5$).

Prior to the analysis, the assumptions of normality and homogeneity of variances were evaluated using the Shapiro-Wilk and Levene tests, respectively. Statistical significance was accepted at $p < 0.05$. When significant differences were detected, pairwise comparisons were performed using Tukey's Honest Significant Difference (HSD) post hoc test. Effect sizes were expressed as partial eta squared (η_p^2). For analyses involving a reduced number of interlining types (e.g., adhesion peel strength, where sew-in interlinings K1 and K6 were not applicable), the same statistical approach was applied to the corresponding subset of experimental groups.

The effects of shirting fabric type (S1 - S3) and interlining type (K1 - K6) on the performance of the fabric-interlining composites were evaluated using a two-way analysis of variance (Two-Way ANOVA). The model included the main effects (fabric and interlining) as well as the fabric $\times$ interlining interaction.

Each experimental group was tested in five replicates ($n = 5$). Assumptions of normality and homogeneity of variances were verified using the Shapiro-Wilk and Levene tests, respectively. Statistical significance was set at $p < 0.05$. In cases where significant differences were observed, Tukey's HSD post hoc test was performed. Effect sizes were reported as partial eta squared (ηp^2).

3. Results

3.1. Tensile Strength in the Warp Direction

According to the two-way ANOVA, the fabric type had a significant effect, $F(2, 48) = 16.57$, $p < 0.001$, $\eta p^2 = 0.41$, with S1 (100% cotton) composites exhibiting higher tensile strength in the warp direction (**Figure 1**).

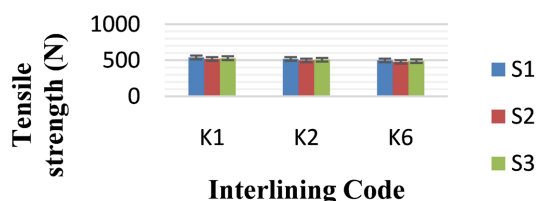


Figure 1. Tensile strength in the warp direction of different interlinings applied to shirting fabrics.

The interlining type demonstrated a very strong effect, $F(5, 48) = 192.94$, $p < 0.001$, $\eta p^2 = 0.92$.

Tukey's HSD test revealed that the highest warp tensile strength values were obtained with the woven interlinings K1 and K2, which formed a distinct statistical group ($p < 0.05$) superior to all knit and nonwoven alternatives. When considering the application method, the slight decrease in tensile strength observed for K2 (hot press at 145°C, 3 bar, 12 s) compared to K1 can be attributed exponentially to localized rigidification, which potentially hinders free yarn mobility during multi-axial load distributions. The fusing process induces micro-level rigid zones within the fabric-interlining composite, altering the stress distribution. In contrast, sew-in interlinings (K1 and K6) preserve the inherent deformability of the fabric structure, as no adhesive bonding restricts fiber mobility. According to foundational literature [6] this comparative reduction in structural confinement within stitched assemblies typically allows individual yarns to align more efficiently along the stress vector, offering a plausible explanation for their higher tensile yield.

3.2. Tensile Strength in the Weft Direction

The effect of the fabric was significant ($F(2, 48) = 13.78$, $p < 0.001$), as was the

effect of the interlining ($F(3, 48) = 87.09$, $p < 0.001$), while their interaction was not significant ($p = 0.265$) (**Figure 2**).

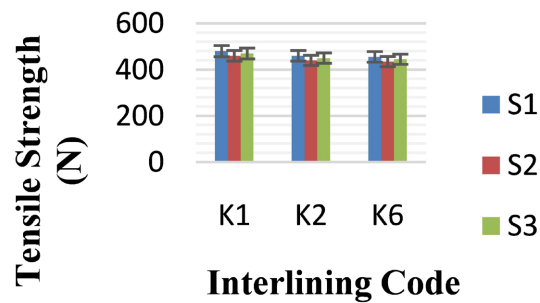


Figure 2. Tensile strength in the weft direction of different interlinings applied to shirting fabrics.

Post-hoc multiple comparisons demonstrated that the woven cotton sew-in assembly (K6) achieved significantly higher weft tensile values than the fused counterparts K3 and K5 ($p < 0.01$). An increase in interlining thickness did not lead to an improvement in tensile strength in the weft direction. Regarding application methods, interlinings applied via thermal pressing exhibited localized stiffening and compression at the fabric-interlining interface. It is interpreted that such compression might constrain the structural relaxation of the weft yarns, potentially generating premature stress concentrations. In contrast, stitched interlinings impose less restriction on interlayer movement since no adhesive bonding is present, allowing greater flexibility within the fabric structure. This may facilitate more uniform load distribution compared to fused systems [3] [6].

3.3. Tensile Strength in MD—Machine Direction (Nonwoven Subset)

The tensile strength results in the MD direction for the K4 nonwoven interlining (**Figure 3**) indicate that the fabric factor is the dominant parameter. For this specific subset ($df_{\text{fabric}} = 2$, $df_{\text{error}} = 12$), the values are ranked as S1 (420 N) > S3 (410 N) > S2 (400 N), and Tukey's HSD confirmed that the 100% cotton base (S1) performed significantly better than the 100% viscose base (S2) ($p = 0.034$). The higher strength observed in the S1 fabric can be attributed to its fiber structure and yarn organization, which enhance interfacial bonding and consequently improve load transfer. Although the structural continuity of the nonwoven interlining is limited, the compaction and bonding effects within the composite structure contribute to load-bearing capacity in the MD direction.

3.4. Tensile Strength in Machine CD—Cross Direction

Similarly, the results obtained in the CD direction demonstrate that the fabric factor is statistically significant ($p < 0.05$) (**Figure 4**). The values maintain the same ranking as S1 (405 N) > S3 (395 N) > S2 (385 N), exhibiting a trend consistent

with the MD direction.

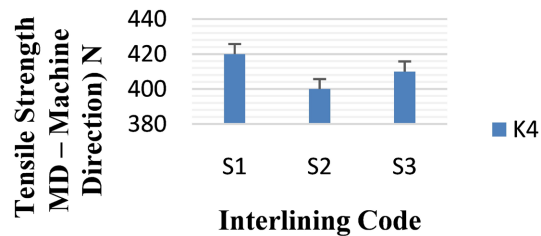


Figure 3. Machine Direction (MD) tensile strength values of nonwoven interlinings applied to shirting fabrics.

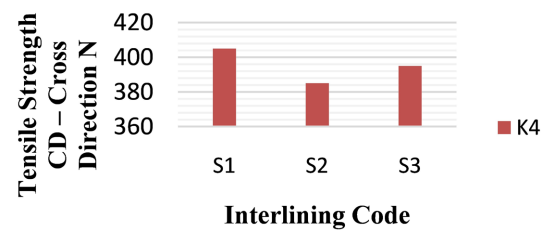


Figure 4. Cross Direction (CD) tensile strength values of nonwoven interlinings applied to shirting fabrics.

This finding suggests that the fabric structure influences composite strength irrespective of direction. However, the fact that all CD values are lower than those in the MD direction reveals the anisotropic behavior associated with the fabric's production direction. Despite the isotropic nature of the nonwoven interlining, the directional properties of the base fabric remain the governing factor in determining the mechanical performance of the composite system.

3.5. Bursting Strength

The effect of the interlining on bursting strength was highly pronounced (**Figure 5**) $F(1, 24) = 180.96$, $p < 0.001$, $\eta^2 = 0.88$, while the effect of the fabric was weak but significant ($p = 0.041$). The interaction between fabric and interlining was not significant ($p = 0.104$).

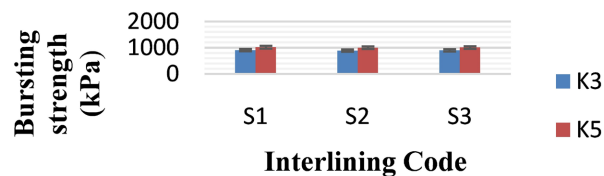


Figure 5. Bursting strength values of shirting fabrics treated with different interlinings.

Tukey's HSD test established that the elastic warp-knit interlining (K5) reached the absolute highest bursting strength across all base fabrics, outperforming the nonwoven alternative K4 by a statistically significant margin ($p < 0.001$). For bursting strength, structural characteristics and elasticity of the interlining were

more critical than thickness. Despite being thinner, K5 demonstrated the highest performance, suggesting that the application method can have a more significant impact than thickness alone. The elastic warp-knit interlining was applied at a relatively low pressing temperature and pressure (135°C, 2 bar), which preserved the structural integrity of the elastic fibers and enhanced the fabric's multiaxial deformation capacity. Based on theoretical accounts of polymer joining [7] [8], it is hypothesized that higher pressing temperatures could potentially limit the long-chain compliance and phase homogeneity of elastomer networks. Thus, the lower thermal exposure during the K5 application is proposed as a key factor in avoiding structural embrittlement, thereby preserving its multiaxial displacement benefits.

3.6. Adhesion Strength

The interlining factor was dominant in determining adhesion strength (Figure 6) ($F(5, 72) = 2389.77$, $p < 0.001$), while the fabric factor was also significant ($F(2, 72) = 20.18$, $p < 0.001$). The interaction between fabric and interlining was significant ($p = 0.001$).

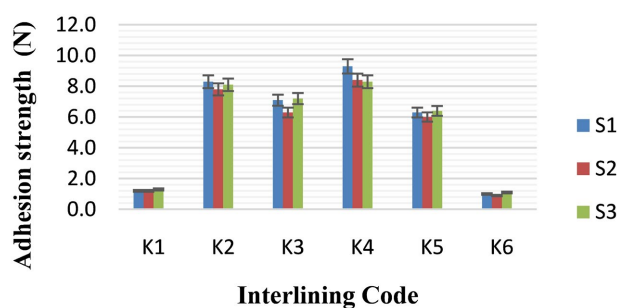


Figure 6. Adhesion strength values of different interlinings applied to shirt fabrics.

Both interlining thickness and fusing (application) parameters significantly influence the adhesion performance and peel strength of fused fabric composites, as these factors directly affect resin penetration, bond formation, and interfacial cohesion between fabric layers [3] [9]. The high thickness of K4 combined with elevated pressing parameters (150°C, 15 s) allowed for deeper penetration of the polymer adhesive, thereby increasing the interfacial bonding area.

Pairwise comparisons via Tukey's HSD showed that the nonwoven fusible interlining (K4) generated significantly higher peel resistance than all other fusible categories ($p < 0.001$). This superior performance can be attributed to the combined effects of interlining thickness and fusing (application) parameters, which significantly influence the adhesion performance and peel strength of fused fabric composites by directly affecting resin penetration, bond formation, and interfacial cohesion between fabric layers [3] [9]. Specifically, the high thickness of K4 combined with elevated pressing parameters (140°C or 150°C, 15 s) allowed for deeper penetration of the polymer adhesive, thereby increasing the interfacial bonding area. From a macro-structural perspective, as pressing temperature and duration

increase, the viscosity of the polymer adhesive decreases, facilitating more effective infiltration and mechanical anchoring into the yarn intersections. In contrast, interlinings applied by stitching, which do not involve adhesive and thermal processing, show no such improvement in bonding performance regardless of increased thickness [5].

3.7. Bending Rigidity

Two-way ANOVA results (Figure 7) indicated that the interlining factor exerted a dominant and highly significant effect on bending rigidity ($p < 0.001$).

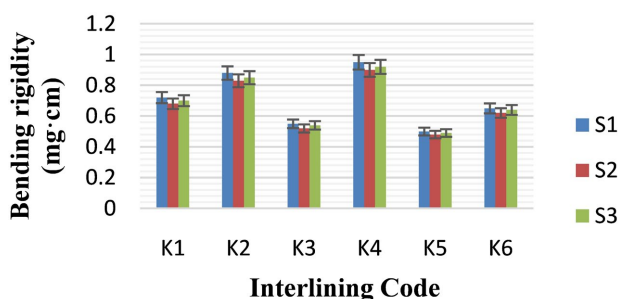


Figure 7. Bending rigidity values of different interlinings applied to shirt fabrics.

Tukey's post-hoc analysis paired the thickest nonwoven interlining (K4) with a unique, significantly elevated stiffness group ($p < 0.001$) compared to all other configurations. Although the fabric factor was significant, its effect size was smaller, and the interaction was not significant. This suggests that the ranking of interlinings in terms of rigidity is maintained independently of fabric type. Increased thickness leads to a higher second moment of area of the fabric cross-section, which in turn significantly enhances bending rigidity due to the strong dependence of flexural stiffness on geometrical inertia [10] [11]. The application method also plays a decisive role in determining bending behavior. Thermally bonded interlinings, especially under high temperature and pressure, create strong adhesive interfaces that restrict interlayer movement and increase composite stiffness. In contrast, mechanically joined structures, such as stitched assemblies, allow relative movement between layers, resulting in lower bending rigidity [3] [10].

3.8. Air Permeability

ANOVA results (Figure 8) showed that the interlining factor significantly affected air permeability ($F(6, 84) = 391.36$, $p < 0.001$), and the fabric factor was also significant ($F(2, 84) = 36.79$, $p < 0.001$). The interaction between fabric and interlining was not significant ($p = 0.274$).

The stitched cotton interlining assembly (K6) yielded the highest mean air permeability, separating itself significantly from all fused interlining configurations ($p < 0.001$). Air permeability was inversely related to interlining thickness. The

high thickness of the K4, combined with dense thermal pressing conditions, likely caused partial pore closure within the fabric structure, thereby reducing airflow. This behavior can be attributed to compression-induced changes in pore geometry and internal structure, as reported in the literature [12]. Regarding the application method, thermal pressing compresses the fabric and interlining layers, decreasing the effective pore volume, whereas stitched interlinings preserve microgaps between layers, causing less reduction in airflow. Additionally, studies on coating-based fusible interlinings have shown that increasing adhesive coating area (or dot density) can significantly reduce air permeability by blocking macropores and restricting airflow through the fabric structure [13].

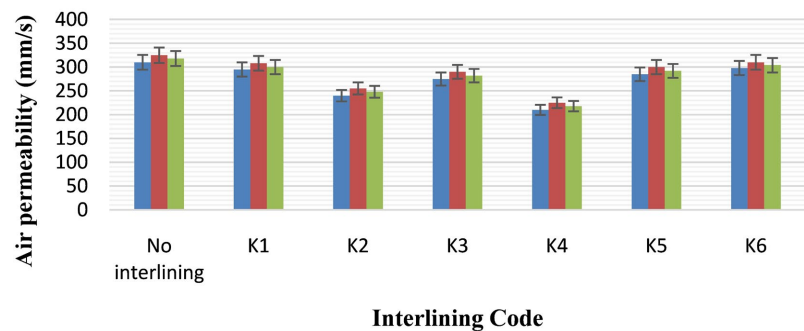


Figure 8. Air permeability values of different interlinings applied to shirt fabrics.

3.9. Thermal Resistance

ANOVA results (Figure 9) indicated that the interlining factor had a significant effect on thermal resistance ($F(3, 48) = 251.78$, $p < 0.001$), while the fabric factor was not significant ($p = 0.084$), and the interaction was also non-significant ($p = 0.448$).

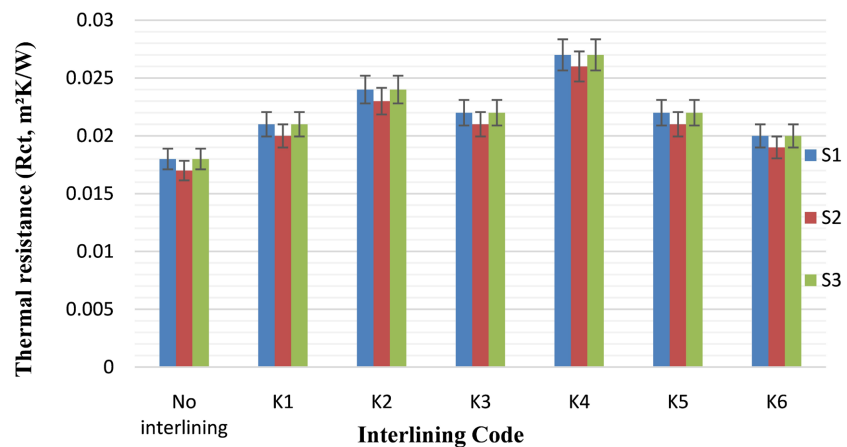


Figure 9. Thermal resistance values of different interlinings applied to shirt fabrics.

Tukey's HSD test grouped the nonwoven fusible interlining (K4) as the top insulation layer, showing a statistically significant expansion in R_{ct} over the thin woven alternatives K2 and K6 ($p < 0.001$). Thermal resistance is directly related to

interlining thickness and the amount of trapped air. Increased thickness enhances insulation by entrapping still air, which has low thermal conductivity. Furthermore, the presence of adhesive layers in fusible interlinings may alter heat transfer pathways within the composite structure, potentially contributing to increased thermal resistance.

3.10. Relative Water Vapor Permeability (RWVP)

Two-way ANOVA (Fabric $\times$ Interlining) results (Figure 10) indicated that the interlining factor had a dominant and highly significant effect on RWVP ($p < 0.001$).

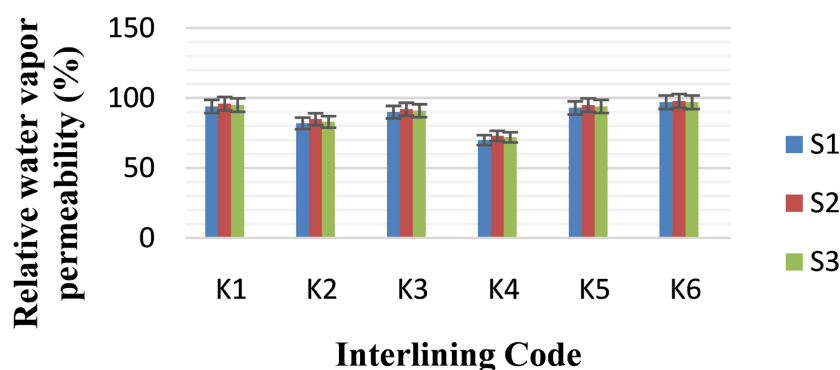


Figure 10. Relative water vapor permeability values of different interlinings applied to shirt fabrics.

Two-way ANOVA (Fabric $\times$ Interlining) results (Figure 10) indicated that the interlining factor had a dominant and highly significant effect on RWVP ($F(5, 72) = 512.44$, $p < 0.001$). The fabric factor was also statistically significant but with a smaller effect size, and the interaction was not significant. This suggests that the influence of interlinings on moisture transfer exhibits similar trends regardless of fabric type.

Statistical testing validated that the stitched combinations (K1 and K6) maintained an identically superior water vapor permeability pool (94% - 98%), establishing a statistically significant gap ($p < 0.001$) over the nonwoven fusible group K4 (70% - 73%). The highest RWVP values were observed for K6 and K1 (stitched interlinings), ranging from 94% to 98%, whereas the lowest values were recorded for K4 (nonwoven fusible interlining, 70% - 73%). This ranking is directly related to both the application method and thickness. The thickest interlining ($K4 \approx 0.25$ mm) extended the diffusion path, increasing vapor transfer resistance. As thickness increases, pore continuity decreases, leading to reduced relative water vapor permeability. In fusible interlinings applied via thermal pressing (particularly K2 and K4), the adhesive layer partially blocks micro-pores, further limiting vapor diffusion. High pressing temperature and pressure create a dense film effect at the fabric-interlining interface. In contrast, stitched interlinings (K1 and K6) preserve the pore structure, maintaining higher moisture transfer. The elastic warp-knit

interlining (K5), despite being fusible, exhibited high RWVP due to its open loop structure.

The dominant effect of interlinings on water vapor resistance (RWVP) can be explained by the extension of the diffusion path due to increased thickness and the presence of adhesive layers. In multilayer textile systems, water vapor transmission decreases as the number of layers increases, since additional interfaces introduce higher resistance to moisture diffusion. Furthermore, adhesive coatings may partially obstruct pore structures, thereby restricting moisture transfer through the fabric assembly.

4. Conclusions

The findings of this study indicate that the primary factors governing the performance of shirting fabric-interlining composites are the type of interlining and the application method. In tensile and bending tests, woven interlinings maintained more effective linear load transfer, whereas nonwoven fusible structures exhibited lower strength due to limited fiber continuity. For bursting strength, elasticity rather than thickness was the determining factor, with the elastic warp-knit interlining demonstrating superior performance owing to its multiaxial deformation capacity. Thermal pressing enhanced adhesion strength; however, in some cases, it induced localized stiffening that restricted yarn mobility.

Regarding comfort-related parameters (air permeability, water vapor permeability, and thermal resistance), thickness and pressing intensity were identified as the key determinants. Thicker and highly pressed fusible interlinings provided greater adhesion and thermal resistance but reduced air and moisture transfer by decreasing pore volume. In contrast, the sewing method preserved interlayer micro-mobility and pore continuity, resulting in a more balanced comfort performance. In conclusion, collar applications require a design-oriented optimization that carefully balances mechanical stability with thermophysiological comfort.

Limitations of the Study

While this study provides comprehensive insights into the multi-axial performance of collar structural composites, certain boundary conditions must be noted. The experimental evaluations are strictly limited to three distinct variants of plain-woven shirting fabrics within a narrow weight scope and a specific interlining mass range (25 - 35 g/m²). Additionally, the application procedures were limited to a single set of predefined industrial fusing and conditioning parameters. Future investigations incorporating a wider variety of fabric weaves (such as twill or satin), varied interlining densities, and industrial washing/aging cycles are necessary to fully assess the long-term durability and operational wear behavior of these composite systems.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Vilumsone-Nemes, I. (2018) Fusing of Cut Textile Components. In: Vilumsone-Nemes, I., Ed., *Industrial Cutting of Textile Materials*, 2nd Edition, Elsevier, 189-205. <https://doi.org/10.1016/b978-0-08-102122-4.00012-3>
- [2] Girija, R. and Rajagopal, S. (2022) Prediction of Bond Strength in the Fused Shirt Composites. *Research Journal of Textile and Apparel*, **26**, 419-438. <https://doi.org/10.1108/rjta-01-2021-0009>
- [3] Sudhakar, R. and Renjini, G. (2022) Evaluation and Prediction of Fused Fabric Composites Properties—A Review. *Journal of Industrial Textiles*, **51**, 3536S-3574S. <https://doi.org/10.1177/1528083720919859>
- [4] Girija, R. and Rajagopal, S. (2022) Predicting Drape of Fused Collar Using Design of Experiment. *Tekstilec*, **65**, 113-124. <https://doi.org/10.14502/tekstilec.65.2021046>
- [5] Seyidzade, L., Gurarda, A., Kanik, M. and Manasoglu, G. (2023) Development of Fully Biodegradable Fusible Interlinings for Eco-Friendly Garments and Investigation of Their Performance on a Shirt. *Journal of Applied Polymer Science*, **140**, e53888. <https://doi.org/10.1002/app.53888>
- [6] Fan, J. and Hunter, L. (2009) *Engineering Apparel Fabrics and Garments*. Elsevier.
- [7] Ge, T., Pierce, F., Perahia, D., Grest, G.S. and Robbins, M.O. (2012) Polymer Welding: Strength through Entanglements. <https://doi.org/10.48550/arXiv.1211.6796>
- [8] Takano, M., Takamatsu, K. and Saito, H. (2022) High-Strength Heat-Elongated Thermoplastic Polyurethane Elastomer Consisting of a Stacked Domain Structure. *Polymers*, **14**, Article No. 1470. <https://doi.org/10.3390/polym14071470>
- [9] Ayca, G., Mehmet, K. and Caliskan, N. (2019) Peel Resistance and Stiffness of Woven Fabric with Fusible Interlinings. *Industria Textila*, **70**, 139-146. <https://doi.org/10.35530/it.070.02.1571>
- [10] Kim, K., Inui, S. and Takatera, M. (2012) Prediction of Bending Rigidity for Laminated Fabric with Adhesive Interlining by a Laminate Model Considering Tensile and In-Plane Compressive Moduli. *Textile Research Journal*, **82**, 385-399. <https://doi.org/10.1177/0040517511420764>
- [11] Yu, Z., Zhong, Y., Gong, R.H. and Xie, H. (2022) Predicting the Bending Rigidity and Shearing Stiffness of Fabric Based on Three-Dimensional Drape Model. *The Journal of The Textile Institute*, **113**, 1767-1774. <https://doi.org/10.1080/00405000.2021.1947638>
- [12] Xiao, X., Hu, J., Hua, T., Zeng, X. and Long, A. (2015) Through-Thickness Air Permeability of Woven Fabric under Low Pressure Compression. *Textile Research Journal*, **85**, 1732-1742. <https://doi.org/10.1177/0040517515569526>
- [13] Kornilova, N., Bikbulatova, A., Koksharov, S., Aleeva, S., Radchenko, O. and Nikiforova, E. (2021) Multifunctional Polymer Coatings of Fusible Interlinings for Sewing Products. *Coatings*, **11**, Article No. 616. <https://doi.org/10.3390/coatings11060616>