Indian Journal of Fibre & Textile Research
Vol. 47, June 2022, pp. 177-180

Comfort properties of moisture management finished bi-layer knitted fabrics: Part I - Thermal comfort

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Received 23 April 2021; revised received and accepted 12 August 2021

Six samples of bi-layer knitted fabrics have been given the moisture management finish, with the formulation containing amino silicone polyether copolymer, along with the hydrophilic polymer and wetting agent in the ratio of 1:2 with *p*H 5.5 at 60°-70° C. It is found that the chemical combination of wetting and finishing agents, and the experimental conditions are proved to be the best possible options taken in this study. The fabrics are tested for various thermal comfort properties, such as air permeability, thermal conductivity, thermal resistance, and water vapour permeability. The bi-layer fabric structure along with the application of the optimized moisture management finish makes the fabric more suitable for sportswear, exhibiting good comfort properties, like water vapor permeability, air permeability, thermal resistance, thermal conductivity, and moisture management properties. The results of the air permeability, water vapour permeability, thermal conductivity and moisture management tests indicate that, the microdenier polyester (inner)- microdenier polyester (outer) fabric treated with suitable optimized moisture management agent shows better thermal comfort property, providing high levels of comfort. Hence, these fabrics are preferred during summer, active and sportswear.

Keywords: Bi-layer knitted fabrics, Microdenier polyester, Thermal conductivity, Thermo-physiological comfort, Thermal resistance, Thermal comfort

1 Introduction

Nowadays, sports has become a vital part of everyone's daily activity. Sports induce a person to be fit both physically and mentally. In general, all humans sweat a lot during any physical activity. Consequently, the apparels used for sports must be capable of absorbing and transmitting the sweat and offering a feel of comfort to the wearer. The general requirement of a sport textile is that it should be of good wearability, generally determined through the comfort characteristics, at an affordable price. For a sports textile to be of comfort, it should possess a fairly good moisture management property, which is generally achieved in sports textiles, by a suitable use of fibre / yarn and by modifying the yarn and fabric structures during manufacture and also by using suitable chemical finishes, etc.

Comfort is one of the key parameters to be considered in all sports wear. In general, the quality of apparel is mostly decided by the comfort feel given by the wear. Lokhande *et al*[1]. stated that the wearer felt comfortable only if the sweat released by the body is transferred/evaporated outside and if not the sweat accumulates on the inner surface of the fabric, that is in contact with the body. When the person sweats more and more, the cloth starts sticking to the body surface, which causes irritation, thus altering his level of comfort and influencing his performance. Chowdhury *et al.*[2] stated that the sportswear is said to have physiologically comfort if the heat and moisture is well transported in the garment and provide a comfort feel to the wearer. Gupta *et al.*[3] found that the use of glutaraldehyde as a crosslinking agent on alkali modified PET, created voids on the surface, improving comfort properties. The antistatic, antioxidant, and hydrophilic properties are improved and it offers smoother and softer feel to the fabric. Tyagi and Sharma[4] stated that the application of amino silicone finish reduces the inter yarn space, resulting in a low air permeability fabric. This amino silicone finish leads to 14 – 33 % water vapour diffusion reduction due to the decrease in inter-yarn space. This chemical application increases the surface

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tension, in turn, improving the wickability. Alam *et al.*[5] applied moisture management finish on the micro denier polyester fabric to study the hydrophilic property, where overall results showed improvement in hydrophilicity of the treated fabrics.

Bi-layer knitted structures have two main elements (back or inner layer), directly in contact with the skin and acts as a separation layer. The diffusive hydrophobic and conductive components of this layer help in removing and transporting sweat to the outer layer. Face or outer layer serves as the absorption layer, and it is in contact with the environment. The absorptive hydrophilic components of this layer help in covering larger areas of uptake of sweat and its evaporation to the outside environment[6,7]. Bi-layer knitted fabrics with cotton or viscose yarns as outer layer and polypropylene yarns as inner layer keep the wearer comfortable during strenuous activities[8]. The moisture transfer mechanism through clothing during transient conditions plays a major role in deciding the wearer's dynamic comfort. In the case of double-face knitted fabrics, with inner layer fabric of hydrophobic synthetic filament yarns, offers a high capillary action, while the outer layer fabric with hydrophilic yarns, offers better moisture absorption, and allows evaporation[9].

In this research, the thermal comfort properties of six moisture management finish bi-layer knitted fabrics are studied. The bi-layer knitted fabrics, are made with different combination of yarns placed in the inner and outer layers. The selected yarn combinations are: polyester staple yarn-polyester staple yarn, polyester staple yarn-cotton, cotton-cotton, polypropylene-cotton, microdenier polyester-cotton, microdenier polyester- microdenier polyester for inner and outer layers, in which 2/76 Ne polyester yarn with cut staple length of 38mm & 0.8 denier; polypropylene (PP) with 150 denier & 108 filaments; cotton (C) with 36s Ne count; and micro denier polyester filament (MDPF) with 150 denier & 108 filaments, are taken respectively.

2 Materials and Methods

Four yarns, viz polyester staple yarn (PSY), polypropylene (PP), cotton (C) 36s and micro denier polyester filament (MDPF), were selected for producing bi-layer knitted fabrics. Microdenier polyester is ideal for wicking, cotton for absorption and polypropylene for wicking, thermal and moisture transfer properties. Six double face fabrics were produced in a circular knitting machine Mayer and Cie model 2016, diameter 28", 29 gauges, with a loop length of 0.30 mm and speed 20 rev/min. Six bi-layer fabric samples produced are given below:

Sample No.	Inner layer/Outer layer
1	PSY/PSY
2	PSY/C
3	C/C
4	PP/C
5	MDPF/C
6	MDPF/MDPF

After knitting, bi-layer sample fabrics were subjected to relaxation under standard atmospheric conditions of 65% RH and 27±2°C to carry out the testing of double-face knitted fabrics. The geometrical properties of the samples were tested (Table 1).

Six samples of the bi-layer knitted fabrics were given the moisture management finish using the optimized moisture management finishing combination, such as ethoxylated alcohol (wetting agent) treatment followed by the moisture management formulation containing amino silicone polyether copolymer and hydrophilic polymer in the ratio of 1:2 with *p*H 5.5 at 60°-70°C.

3 Results and Discussion

The samples are tested for their thermal comfort characteristics, such as air permeability, thermal resistance, water vapour permeability and thermal conductivity, and the results are discussed hereunder.

3.1 Air Permeability

The flow of air through inter-yarn spaces plays a major role in providing comfort in hot and humid conditions. Air permeability of textiles is majorly affected by yarn and fabric structural parameters which influence the area of channels and shape through which flow of air occurs. The air permeability of the knitted fabrics is mainly influenced by the yarn type, fabric construction, thickness, areal density and porous nature. Table 2 shows that the untreated fabric

Table 1 — Geometrical properties of bi-layer fabrics [Loop length 30mm]

Sample No.	Thickness mm	Areal density g/m^2	Courses/ inch	Wales/ inch
1	0.752	159.00	55	38
2	0.762	160.24	57	37
3	0.790	162.36	58	37
4	0.674	158.66	58	36
5	0.646	155.91	57	36
6	0.562	148.92	56	35

Table 2 — Thermal comfort properties of moisture management finished bi-layer fabrics

Sample No.	Air permeability $cm^3/cm^2/s$		Thermal conductivity $\times 10^{-3}$ $Wm^{-1} K^{-1}$		Thermal resistance $\times 10^{-3}$ m^2KW^{-1}		Water vapor permeability, $g/m^2/day$	
	Before finish	After finish	Before finish	After finish	Before finish	After finish	Before finish	After finish
1	86	71	27.20	31.56	27.60	23.82	1913	2238
2	82	67	24.10	27.72	31.60	27.48	1903	2207
3	72	58	20.50	23.37	38.53	33.8	1901	2186
4	88	74	27.70	32.69	24.33	20.61	1961	2313
5	99	84	30.10	35.82	21.46	18.03	1969	2323
6	108	92	38.50	47.74	14.59	11.77	1978	2353

shows more porous nature and permits more air to pass through the structure. The air permeability gets reduced when the fabrics are being treated with the moisture management finish. This is clearly shown from the fabric parameters. The treated fabrics have a lesser GSM and thickness, and even the increase in courses and wales of the treated fabrics causes reduction in air permeability ($p<0.05$). This is mainly due to the reason that the pores in the fabrics get minimised due to the application of the moisture management chemicals, resulting in the air permeability reduction as compared to that of the untreated fabric (p-value 7.21×10^{-8}).

3.2 Thermal Conductivity

The ability of the fabric to conduct heat is termed as the thermal conductivity. The application of treatment results in an increased value of thermal conductivity, because of the larger surface area, which leads to a greater pickup and transmission. It is clearly evident from Table 2 that the bi-layer knitted fabric made of microdenier polyester (MDPF/MDPF) yarn on both the inner and the outer surface of the fabric shows good results, because of the lessened air gaps and an increased areal density of the fabric. As the areal density of the fabric increases the interaction between the transfer of heat in between the fibres and air is stronger, thus resulting in a higher thermal conductivity. This clearly indicates that the areal density of the fabric plays a major role in the thermal conductivity (p-value 0.002612).

3.3 Thermal Resistance

Thermal resistance is an important property associated with the thermal insulation. The higher the thickness, the greater will be the thermal resistance. Thermal conductivity is the amount of heat transmitted in a given surface area through the thickness of the fabric, and hence is influenced by its thickness, density, and structure. The thermal insulation properties of porous textile structures are influenced by the fabric thickness and air volume fraction. Table 2 shows that on application of moisture management treatment, there is a high thermal resistance of cotton bi-layer knitted yarn fabrics attributes to the hairy structure of cotton yarn, which results in the formation of thick and insulating air layer. MDPF/MDPF fabrics show higher air permeability due to thickness, structural variation and lower thermal resistance. The specific heat of the cotton fibre is relatively higher than the other fibres, and in any layer it will increase the total specific heat, which requires higher energy for any temperature rise and heat transfer to the other side of the fabric. The effect of application of the finish on thermal resistance of bi-layer knitted fabrics is significant at 95% confidence level (p-value 2.92×10^{-05}).

3.4 Water Vapour Permeability

Water vapour permeability is one of the most important properties of thermal comfort that determines the capability of perspiration transportation through a textile material. Perspiration is formed and the body evaporates the heat when human bodies get over heated. The fabric with low moisture vapour permeability is unable to pass perspiration sufficiently, leading to accumulation of sweat in the clothing, and hence results in discomfort. In contradiction with the air permeability, the treated fabrics show good water vapour permeability as compared to the untreated fabrics, Table 2 shows that there is an increment in the water vapour permeability, As per the specifications of the fabric, the courses per inch and wales per inch, it is observed that this increment in the fabrics is resulted due to the treatment received, where the fabric pores get clogged, thus resulting in a opacity of the fabric, which, in turn, reduces the water vapour permeability. However, in contradiction, the increase in the water vapour permeability is due to the finishing treatment. The amino silicone finishing incorporates water absorption effect on the finer surface, which increases the fibre absorption capacity and thus an increase in the water vapour permeability (p-value 2.36×10^{-6}).

Table 3 — Two-way ANOVA analysis

Property	Factor	SS	Degrees of freedom	MS	F	p-value	F-critical
Air permeability	Bi-layer fabric	660.0833	1	660.0833	2329.706	7.21×10^{-08}	6.607891
	Type of treatment	1544.75	5	308.95	1090.412	1.38×10^{-07}	5.050329
	Error	1.416667	5	0.283333			
	Total	2206.25	11				
Water vapour permeability	Bi-layer fabric	331668.8	1	331668.8	574.4674	2.36×10^{-06}	6.607891
	Type of treatment	27016.75	5	5403.35	9.358881	0.014134	5.050329
	Error	2886.75	5	577.35			
	Total	361572.3	11				
Thermal resistance	Bi-layer fabric	42.15001	1	42.15001	207.1576	2.92×10^{-05}	6.607891
	Type of treatment	635.3713	5	127.0743	624.5408	5.54×10^{-07}	5.050329
	Error	1.017342	5	0.203468			
	Total	678.5387	11				
Thermal conductivity	Bi-layer fabric	78.69441	1	78.69441	30.78656	0.002612	6.607891
	Type of treatment	523.311	5	104.6622	40.94559	0.000465	5.050329
	Error	12.78064	5	2.556128			
	Total	614.786	11				

3.5 ANOVA Results

ANOVA testing has been conducted to analyse the statistical importance of the bi- layer knitted fabrics treated with the moisture management finish. ANOVA is carried out using the SAS System (version 8 for Windows) to evaluate any changes in moisture management properties of the fabrics. The variables are considered as significant if the probability (p) value is less than 0.05. The results of two-way ANOVA are given in Table 3 for the moisture management properties of the bi-layer knitted fabrics.

From Table 3, it is observed that the p-value for thermal comfort properties is < 0.05 on the application of the moisture management finish. This clearly shows that there is a significant influence due to the application of the moisture management finish on the thermal comfort properties of the bi-layer knitted fabrics at a 95% confidence level.

4 Conclusion

The thermal comfort properties of the developed bi-layer knitted fabrics are being influenced by the types of yarns used in the fabrics manufacture. The results obtained from this study serves as a guide for the industrial development of bi-layer fabrics with the suitable yarn selection, for the face and back layers. From the results, it can be concluded that the microdenier polyester made with the inner and outer layer fabrics, treated with suitable optimized moisture management agent, shows better thermal comfort property and higher levels of comfort. These are, hence preferred fabrics for summer, active and sportswear. The results are discussed together with two - way ANOVA test results at a 0.05 significance level.

References

1 Lokhande NB, Patil LG & Awasare AU, *Int J Eng Res Technol*, 3(2014)429.
2 Chowdhury P, Samanta KK & Basak S, *Int J Eng Res Technol*, 3(2014)1905.
3 Gupta D, Srivastava A & Kale S, *Indian J Fibre Text Res*, 38(2013)387.
4 Tyagi GK & Sharma D, *Indian J Fibre Text Res*, 30(2005)363.
5 Alam MM, Chowdhury MA, Sabnam EJ & Islam MS, *Int J Eng Tech Manag App Sci*, 5(2017)70.
6 Geraldes MJ, Lubos H, Araújo M, Belino NJR & Nunes MF, *Autex Res J*, 8(2008)30.
7 Bivainytė A, Mikučionienė D & Kerpauskas P, *Mater Sci*, 18(2012)167.
8 Suganthi T & Senthilkumar P, *J Ind Text*, 47(2018)1447.
9 Varshney RK, Kothari VK & Dhamija S, *J Text Inst*, 101(2010)495.