Indian Journal of Fibre & Textile Research
Vol. 48, December 2023, pp. 450-455
DOI: 10.56042/ijftr.v48i4.7653

Effect of air plasma treatment on thermal comfort properties of cotton/polyester knitted fabrics

V Mahalakshmi[1], KM Pachiayappan[1], C Prakash[2,a] & A Jebastin Rajwin[3]

[1]Department of Costume Design and Fashion, PSG College of Arts and Science, Coimbatore 641 014, India

[2]Department of Handloom and Textile Technology, Indian Institute of Handloom Technology, Fulia Colony, Shantipur, Nadia 741 402, India

[3]Department of Fashion Technology, Sona College of Technology, Salem 636 005, India

Received 15 October 2022; revised received and accepted 4 January 2023

The effect of plasma treatment has been studied on thermal comfort properties of cotton and polyester fibres blended in the ratios of 0:100, 50:50 and 100:0 using four types of fabric structures, single jersey, cross tuck, cross miss and twill at two different loop lengths 0.29 cm and 0.32 cm. The findings reveal that the knitted fabrics made from 100% polyester show better thermal resistance characteristics. On the other hand, the fabric made with 100% cotton gives better air permeability and water vapour permeability behavior. The fabric knitted from 100% polyester with a cross-miss structure on a loop length of 0.32 shows an excellent thermal comfort characteristic as compared to all the other samples due to its appreciable behaviors suitable for thermal conduction. The plasma treatment has a great impact on the thermal properties, in such a way that it reduces the air permeability and water vapour permeability but increases the thermal resistance.

Keywords: Blended fabrics, Comfort, Cotton, Knitted fabrics, Plasma treatment, Polyester, Thermal comfort

1 Introduction

The textile and clothing play a significant role in the evaluation of the thermal comfort characteristics, considering the outer environment and the human body. The clothing behaves as a transmission medium for the liquid and thermal moisture[1]. The main characteristic of active sportswear is its thermal comfort property. Comfort is commonly known by the wearers in many different ways according to their comfort level. Comfort is the control of body temperature, which is mostly influenced by the wearer's psychological and physiological makeup. The transmission of moisture in the cloth has a major impact on thermophysiological comfort. The maintenance of thermal homeostasis between the human body and the surrounding environment is known as thermo physiological comfort. A number of variables, including thermal conduction, air permeability, and water vapour permeability, among others, might affect thermophysiological comfort[2-4]. The single jersey fabrics made from cotton is suitable for the sport textiles. However, in the high active sportswear, the players sweat a lot and this sweat gets absorbed and clings on the fabric surface. Cotton, having a less wicking properties, is not suitable for active sportswear. However, fibres, like acrylic, polyester and polypropylene, are more suitable for these strenuous activities as they have a good excellent wicking behavior, and hence these fabrics can be suitable for active sportswear garments[5].

The transmission of water vapour in the fabric has a great impact on determining the comfort level of sports textiles. This water vapour permeability is based on the wicking, which happens through the capillary action of the fibre. The fabric's porosity and the substance's surface entropy control the capillary action[6]. The wicking is initiated when the fibres are wet by the water, occupying capillary spaces between them. The continuous wetting in the system of capillary causes the wicking of the fibres. The macro and micro capillaries present in the fibres are the main factors for the initiation of wicking. Through the kinetics of macro and micro capillaries, it is proved that short-term wicking initiated by the macro capillaries and the long-term wicking initiated by the micro capillaries attain a maximum height of wicking with a slow rate of diffusion. Also, the height of wicking increases with the increase in surface tension of the fabric[7].

[a]Corresponding author.
E-mail: dearcprakash@gmail.com

The effective wicking and moisture transport occur in the micro fibres and can be achieved with a denier less than 1.0. When the fibres are closely packed together, the diameter is apparently smaller, which results in a rapid wicking due to narrow capillaries[8]. Wicking causes a liquid to flow haphazardly through a porous substance via capillary force[9]. The rate of wicking can be determined by the structure of fibre in the yarn and the fabric structure[10]. Wicking performance is also influenced by the pore size and the porous nature of the fabric[11]. The wicking characteristics can be determined by the factors, namely gravity force, capillary force, inertia and viscous drag[12,13].

The effects of treating cellulose and air plasma, as well as their effects on the hydrophilicity of cotton fabric[14]. The outcome suggests that both treatments are effective in raising the hydrophilicity of cotton fabrics. The improvement in hydrophilicity will cause improvement in fabric's chemical and physical modification. The improvement of hydrophobization of cotton fabrics by optimising the types of gases and plasma treatment parameters such as distance, time, and frequency. Hexamethyldioxane gas plasma treatment on cotton fabric samples can improve the contact angle on the fibre by up to 130°, which smoothens the surface of the fibre. The hexafluoroethane plasma also increases the hydrophobization of the surface of fibres[15].

The investigation was carried out on the absorption time necessary to adsorb 0.6 L of distilled water in order to determine the wettability of subsequent treatments of corona[16]. The cotton fabric has undergone an RF air plasma treatment to increase the fabric's hydrophilicity. Process variables, such as electrode distance, treatment time, and RF power have been tuned to study how they affect the cotton fabric's ability to absorb water. Hence, this research is focused on the influence of air plasma treatment on the thermal comfort characteristics of polyester/cotton blended fabrics.

2 Materials and Methods

The polyester fibres of 150 denier and cotton fibres of 36^s Ne were blended in the ratios of 0:100, 50:50 and 100:0 in four types of fabric structures, like single jersey, cross tuck, cross miss and twill, and with two different loop lengths (0.29 cm and 0.32 cm) in a circular knitting machine, Mayer & Cie, (model 2016) with a diameter of 28 inch and 29 gauge, at 20 rev/min.

2.1 Dimensional Properties

The loop length, areal density and thickness of all the knitted fabrics were evaluated. The courses and wales per unit length were determined using the standard of ASTM D 3887. The fabric thickness was determined using the Shirley thickness gauge as per the standard of ASTM D1777-96. The ASTM D3776 standard has been used to calculate the fabric's areal density.

2.2 Plasma Treatment

An apparatus from Diener Electronic GmbH (vacuum plasma) was used to treat the knitted materials. The fabric samples were positioned between the plasma device's two electrodes. The working pressure can be changed by using the vacuum pump. After the evacuation process had been completed for ten min, the electricity was turned back on. Up until the start of the glow discharge, the plate current was gradually increased. The electrical power between the electrodes has been altered using the power control knob. All plasma treatments have been performed using a constant glow discharge plasma system powered by air gas and operating in an atmospheric environment. The plasma therapy lasted for a consistent 10 min. The fabric sample was positioned between the electrodes, 7 cm separating it from each electrode. The machine was run at a frequency of 70 KHz.

2.3 Comfort Properties

The KES-F8 AP1 standard at BS 5636 1990 has been used to evaluate the fabrics' air permeability. Using the Lee's disc equipment and the ASTM D7340 standard, the fabric's thermal conductivity was determined. The BS 7209:1990 standard was used to evaluate the fabrics' water vapour permeability.

3 Results and Discussion

The geometrical properties of the fabric samples have been examined (Table 1). It is obvious that the areal density and thickness of the fabrics have a substantial impact on the ratio of polyester to cotton fibres in the blend. With an increase in the percentage of cotton fibres, the fabric's areal density and thickness increase. The geometrical characteristics of the fabric are significantly affected by the plasma treatment. The fabric's thickness and areal density increase with the plasma treatment. This is due to etching of the fibre on the fabric surface.

3.1 Air Permeability

The air permeability behaviour of polyester/cotton blended knitted fabrics is shown Fig. 1. It is observed that the air permeability of the fabric increases with the content of polyester fibre. This is due to the fact that the thickness of the fabric is reduced with the increase in the content of polyester fibre and it becomes lighter weight, which allows more

Table 1 — Physical properties of knitted fabrics

Sample No.	Sample	Loop length cm	Fabric	GSM, g/m^2		Thickness, mm		CPI	WPI
				Before plasma	After plasma	Before plasma	After plasma		
1	Single jersey	0.29	Cotton	173.33	174.25	0.683	0.6822	30	40
2			Cotton: polyester (50:50)	155.56	156.21	0.599	0.591	26	38
3			Polyester	143.37	143.33	0.555	0.561	24	35
4	Single jersey	0.32	Cotton	155.23	157.68	0.593	0.601	26	36
5			Cotton: polyester (50:50)	137.4	139.21	0.537	0.53	24	33
6			Polyester	133.37	135.68	0.491	0.4912	22	31
7	Cross tuck	0.29	Cotton	215.66	218.1	0.855	0.855	34	46
8			Cotton: polyester (50:50)	195.66	197.11	0.782	0.781	33	44
9			Polyester	175.66	176.34	0.687	0.689	30	40
10	Cross tuck	0.32	Cotton	190.35	194.18	0.742	0.744	32	42
11			Cotton: polyester (50:50)	167.23	169.45	0.632	0.637	28	39
12			Polyester	150.4	152.53	0.573	0.571	26	36
13	Cross miss	0.29	Cotton	156.37	157.21	0.601	0.621	28	38
14			Cotton: polyester (50:50)	145.23	146.19	0.555	0.556	24	35
15			Polyester	120.3	121.18	0.437	0.43	21	30
16	Cross miss	0.32	Cotton	145.23	148.21	0.56	0.563	25	35
17			Cotton: polyester (50:50)	110.23	111.55	0.401	0.412	20	30
18			Polyester	100.1	101.1	0.387	0.382	20	27
19	Twill	0.29	Cotton	188.23	190.65	0.736	0.73	30	41
20			Cotton: polyester (50:50)	185.23	186.32	0.691	0.694	30	41
21			Polyester	157.23	159.41	0.605	0.615	28	38
22	Twill	0.32	Cotton	170.35	172.21	0.663	0.671	28	40
23			Cotton: polyester (50:50)	150.35	153.35	0.571	0.572	26	35
24			Polyester	135.56	137.56	0.533	0.53	23	33

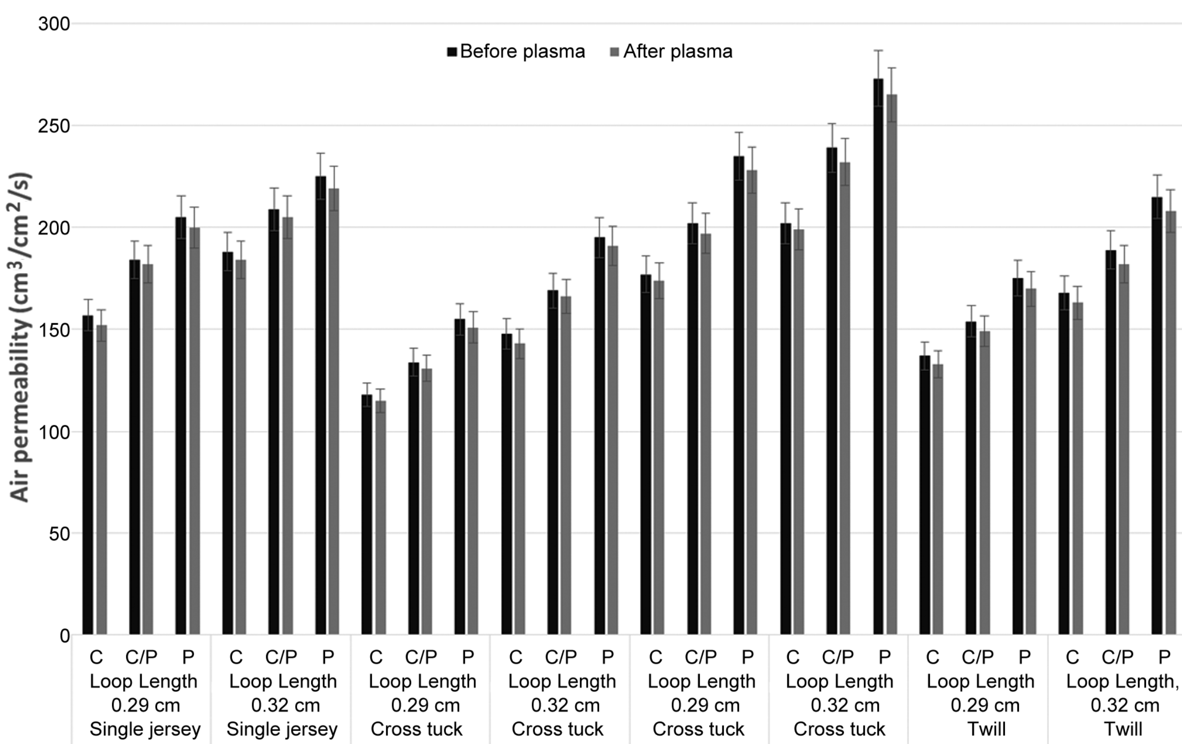

Fig. 1 — Air permeability of cotton/polyester blended fabrics [C– cotton, C/P– cotton/ polyester (50:50), and P– polyester]

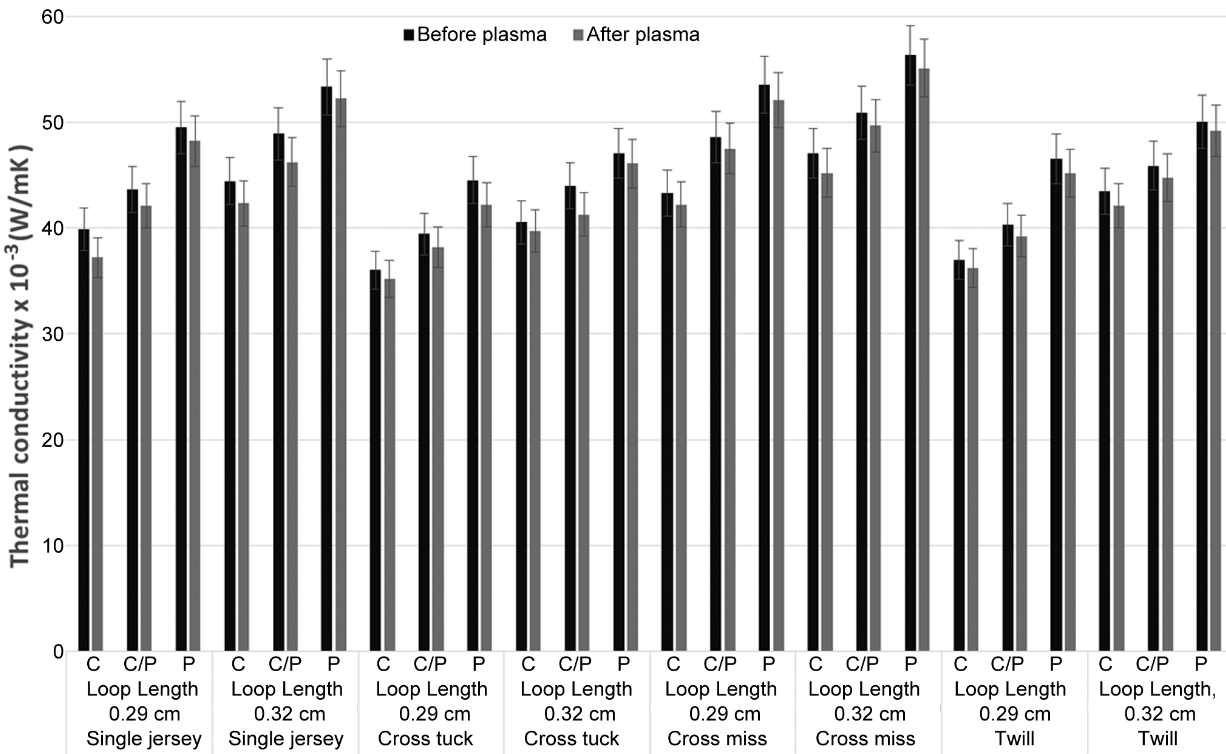

Fig. 2 — Thermal conductivity of cotton/polyester blended fabrics

air with lower resistance. On the other hand, the cotton fibre will have more protruding ends and hairiness, which act as a great barrier to air flow. It is noted that the maximum air permeability is achieved by the 100% polyester cross-miss fabrics having a loop length of 0.32 cm. The air permeability increases with the increase in loop length, as the fabric surface becomes looser and porous in nature, resulting in increased air permeability. The air permeability decreases after the plasma treatment because of the etching effect due to plasma treatment. The etching effect increases the thickness of the fabric and resists the more air flow.

3.2 Thermal Conductivity

The thermal conductivity of cotton/polyester fibre is shown in Fig. 2. It is found that the thermal conductivity of the fabric increases with the increase in polyester fibre. This is due to the fact that polyester fabrics are thinner and fibre is a good conductor of heat[17]. The thermal conductivity increases with the increase in loop length; highest for the loop length 0.32 cm. This is because of the fact that higher loop length fabrics have more space to conduct the thermal heat. Also, the thermal conductivity decreases after the plasma treatment, as the plasma treatment creates more roughness to the fabric, which will develop more entrapped air and provides thermal insulation property.

3.3 Thermal Resistance

The thermal resistance of cotton/polyester fibre is shown in Fig. 3. The fabric structure has a great impact on the thickness of the fabric and the air fraction volume. The thermal resistance of the fabric increases with the increase in thickness of the fabrics. The thermal resistance of the fabric is directly proportional to the fabric thickness[17]. As the content of the cotton fibre increases, the thermal resistance of the fabric also increases. The thermal resistance of the fabric decreases with the increase in the loop length. This is due to the fact that with shorter loop length, the fabric gets tighter and has reduced space for the heat flow. The cross tuck and twill structures show a higher thermal resistance behaviour as compared to the single jersey and cross miss structures. The thermal resistance of the fabric increases with the plasma treatment. As the plasma treatment causes etching on the fabric surface and creates more entrapped air, it acts as the insulation medium.

3.4 Water Vapour Permeability

The water vapour permeability of the polyester/cotton blended fabrics is shown in Fig 4. The water vapour permeability increases with the increase in polyester fibres. The fabrics made out of polyester possess a good

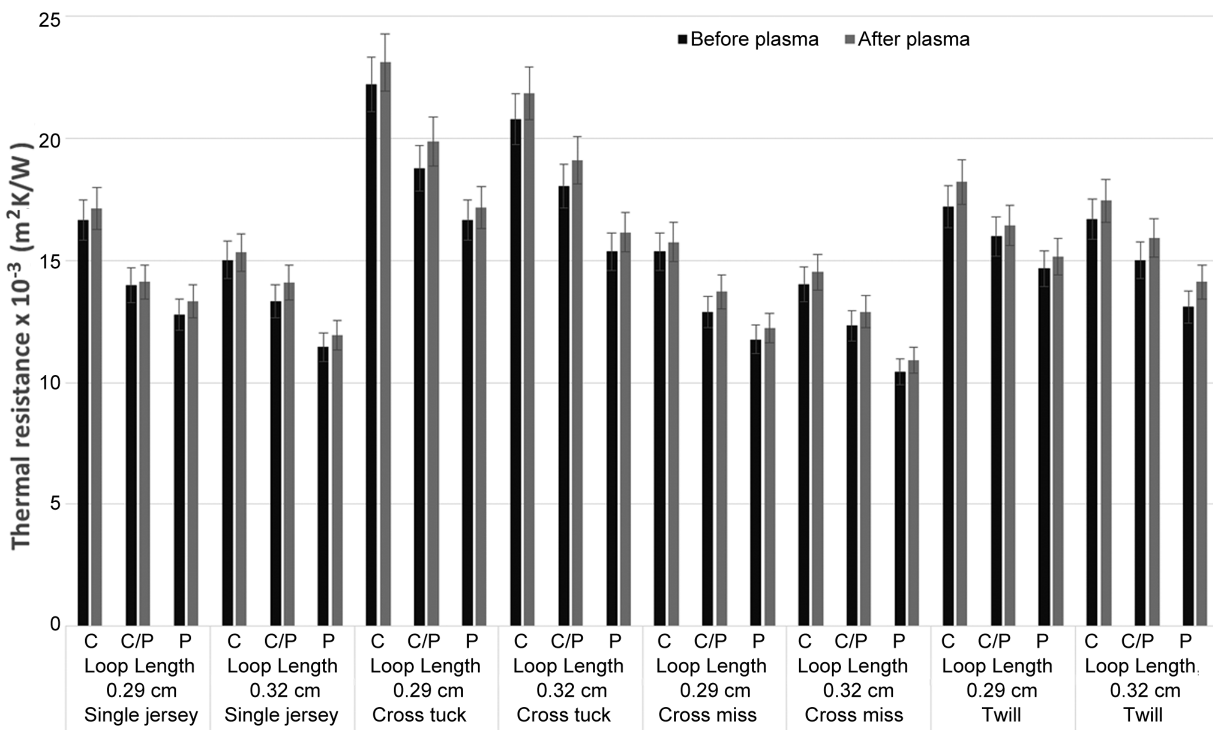

Fig. 3 — Thermal resistance polyester/cotton blended fabrics

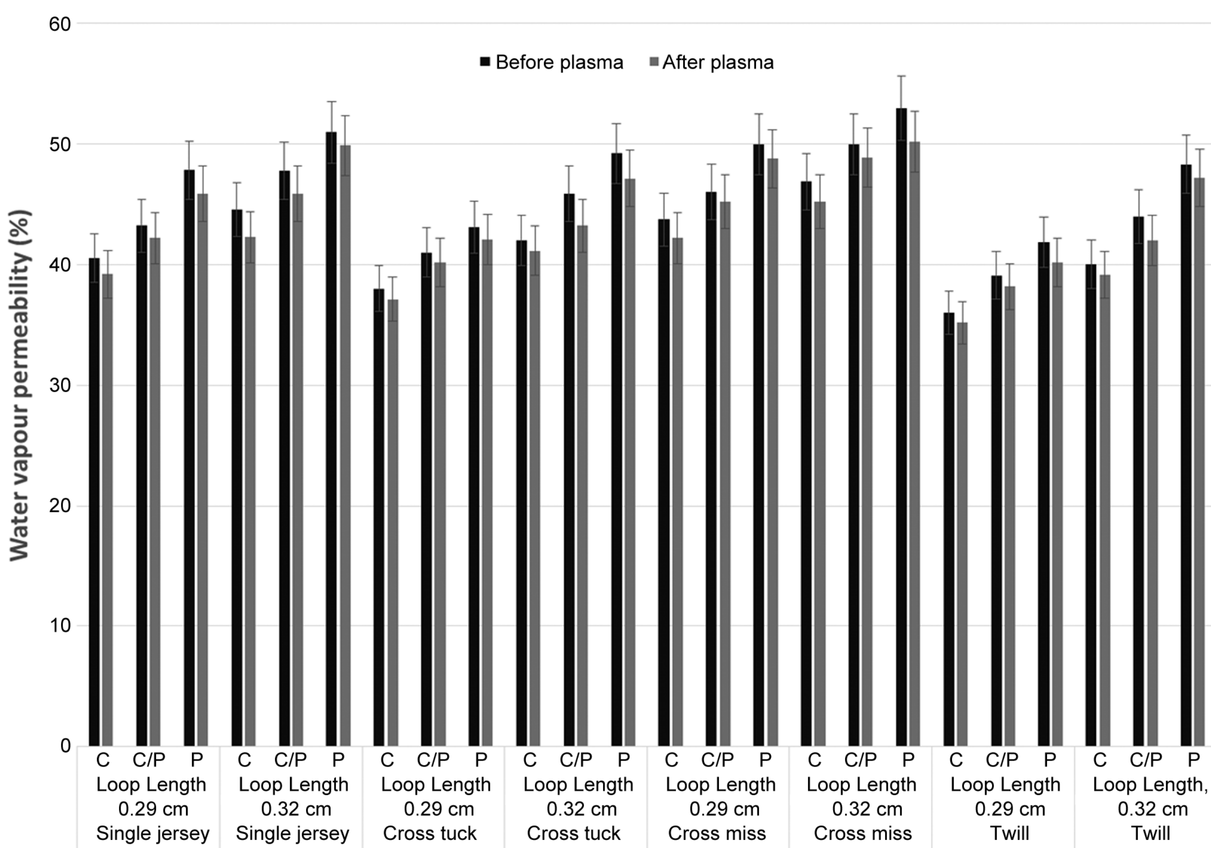

Fig. 4 — Water vapour permeability polyester/cotton blended fabrics

air permeability nature and lowest moisture regain nature, thus showing excellent water vapour permeability. As the content of cotton, increases the moisture regain of the fabric also increases and the permeable nature gets reduced due to the presence of convolutions and protruding fibres, resulting in the decrease in water vapour permeability. The water vapour permeability increases with the increase in loop length as it has more spaces to transmit the water vapour permeability. After plasma treatment, the water vapour permeability decreases as the plasma treatment causes etching on the fabric surface. This etching effect resists the passage of water vapour.

4 Conclusion

It has been investigated how air plasma treatment affects the knitted polyester/cotton materials' thermal comfort properties. It is observed that the blend ratio, kind of fabric structure, and loop length significantly influence the thermal comfort characteristics. With an increase in polyester fibre content, air permeability, water vapour permeability and thermal conductivity increase. Air permeability, water vapour permeability and thermal conductivity also increase with loop length. Additionally, the knit structure has a significant influence on the fabric's thermal comfort properties. With the cross-miss construction, the permeability to air and water vapour has also increased. With the air plasma treatment, the fabric's thermal resistance enhances. Thermal conductivity, water vapour permeability, and air permeability are lowered as a result of the plasma treatment.

References

1 Stanković S B, Popović D & Poparić G B, *Polym Test,* 27 (2008) 41.
2 Karthikeyan G, Nalankilli G, Shanmugasundram O L & Prakash C, *Int J Cloth Sci Technol,* 28 (2016) 420.
3 Ramakrishnan G, Umapathy P & Prakash C, *J Text Inst,* 106 (2015) 1371.
4 Majumdar A, Mukhopadhyay S & Yadav R, *Int J Therm Sci,* 49 (2010) 2042.
5 Rajalakshmi M, Koushik C V & Prakash C, *Int J Curr Res,* 2 (2012) 1.
6 Chowdhury P, Samanta K K & Basak S, *Int J Eng Res Technol,* 3 (2014) 1905.
7 Chatterjee A & Singh P, *J Text Inst,* 2014 (2014) 1.
8 Mukhopadhyay S, *Indian J Fibre Text Res,* 27 (2002) 307.
9 Parveen Banu K & Lakshmi Manokari S, *Int J Sci Res,* 3 (2012) 1147.
10 Kissa E, *Text Res J,* 66 (1996) 660.
11 Saricam C & Fatina K, *Fibre Text East Eur,* 3 (2014) 73.
12 Liu T, Choi K & Li Y, *J Colloid Interf Sci,* 318 (2008) 134.
13 Hamraoui A & Nylande T, *J Colloid Interf Sci,* 250 (2002) 415.
14 Nithya E, Radhai R, Rajendran R, Shalini S, Rajendran V & Jayakumar S, *Carbohyd Polym,* 83 (2011) 652.
15 Chi-Wai K, Kwong C & Chun-Wah M Y, *Autex Res J,* 4 (2004) 37.
16 Ryu J, Wakida T & Takagishi T, *Text Res J,* 61 (1991) 595.
17 Frydrych I, Dziworska G & Bilska J, *Fibre Text East Eur,* 10 (2002) 40.