Moisture management and wicking properties of polyester- cotton plated knits

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Effect of yarn linear density on moisture management and wicking properties of polyester-cotton plated knit structures has been studied. Linear density of yarns used in inner and outer layer as well as the difference in the yarn linear density for the two layers have been found to affect the liquid transfer from inner to outer layer, liquid spreading in the outer layer and hence the drying ability of the designed fabrics. Wetting time increases, while decrease in absorption rate and spreading speed is observed with the increase in inner and outer layer yarn linear density. The fabrics are graded and classified based on the obtained moisture management indices. Trans planar wicking is found higher for fabrics with greater difference in linear density between inner and outer layers as a result of selection of finer yarns in inner layer.

Keywords: Knitting, Linear density, Moisture management, Plated knits, Wicking property, Polyester-cotton fabric

1 Introduction

Moisture management and wicking properties of textiles are very crucial as they control the movement of liquid moisture from skin through clothing to environment, and therefore can influence the overall wearer comfort especially in clothing intended for next to skin applications. The basic requirement of intimate wear, sportswear and active wear is rapid dissipation of moisture vapor and liquid sweat from the skin so as to provide dry feel next to skin. Plated knit structures, characterized by distinct inner (next to skin) and outer (exposed to environment) layers are fast becoming the preferred choice for next to skin applications owing to flexibility in the selection of contrastingly different fibre and yarn variables in the two layers. Yarn variables greatly determine the thermo-physiological properties and wearer comfort by the way they affect the amount of air trapped in the fabric assembly, the size of inter yarn spaces and the openness of fabric structure. Therefore, the various yarn parameters can help in controlling the extent to which a fabric transmits heat, moisture vapour and liquid moisture. Several researchers have studied the influence of yarn variables on comfort properties of different knit structures. Chidambaram et al.[1] studied the effect of yarn linear density on thermal comfort properties of bamboo knitted fabrics and observed

decrease in thermal resistance and an increase in air and water vapour permeability as the yarn gets finer. Similar observations were reported by Bivainyte and Mikucioniene[2], Bivainyte et al[3] and Ozdil et al[4]. Ozturk et al[5] studied the influence of yarn count on wicking properties of cotton- acrylic yarns and fabrics and suggested that wicking ability of yarns and fabrics is increased with the increase in linear density of yarns. Das et al.[6] studied the effect of yarn count on in-plane and vertical wicking of polyester-viscose blended fabrics and observed that wicking height and in-plane wicking of the fabrics are reduced with the increase in yarn fineness. Raja et al.[7] investigated the influence of yarn linear density on liquid spreading of knitted fabrics and observed higher spreading rates for fabrics with low yarn linear density. The review of published literature suggests that the studies are primarily focused on the effect of yarn parameters on comfort properties of woven and knitted fabrics. However, there are very limited studies reporting the comfort characteristics of plated fabrics even though the structures are commercially gaining popularity as these structures can be specifically engineered with altogether different fibre and yarn components in the two distinct yet integrated layers. None of the studies report the influence of the difference in the linear density of yarns used in the two layers on liquid transfer from the inner layer and liquid spreading in the outer layer. Moreover there is lack of systematic literature available on the moisture management

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indices of the plated knits which give direct measure of liquid transfer from inner to outer layer and spreading of liquid in the two layers. In the view of foregoing, it is necessary to explore this field further to have clear insight into the ways in which liquid transfers and spreads in the two layers of the plated knits. The present study was, therefore undertaken to study the effect of yarn linear density on moisture management and wicking properties of polyester-cotton plated knits.

2 Materials and Methods

2.1 Materials

Cotton spun yarns of 29.5 (20s Ne), 33.3 (17.9s Ne) and 59.1 (9.9s Ne) tex and polyester filament yarns of 11.1 (100D/72), 16.6 (150D/72), 26.1 (235D/72) and 38.9 (350 D/72) tex were used for knitted sample production. Seven yarns in totality were used to knit five single jersey plated fabrics. All the five samples were knitted with cotton yarns of three varying linear density in the outer and polyester yarns of four varying linear density in the inner layer. Variation in inner and outer layer yarn linear density resulted in fabrics of different resultant yarn linear densities. Fabric cover factor for all the test samples was kept same by knitting the samples at constant machine settings.

The test samples were prepared on hand operated flatbed knitting machine (Elex, China) with machine gauge of 12, needle bed of 42 inch and 504 needles on each bed. The machine had two needle beds, namely front and rear. The front bed was utilized for sample preparation. Table 1 shows the details of prepared test samples.

2.2 Methods

2.2.1 Physical Properties

The thickness of fabrics was measured on Essdiel thickness gauge at a pressure of $20gf/cm^2$ according to ASTM D 1777-96, 2007. Aerial density was

Table 1 — Fibre and yarn characteristics

Sample code	Fibre type		Yld, tex		Resultant Yld, tex	Outer & Inner layer Yld difference
	Outer	Inner	Outer	Inner		
PC$_1$	C	PET	29.5	11.1	40.6	18.4
PC$_2$	C	PET	29.5	16.6	46.1	12.9
PC$_3$	C	PET	29.5	26.1	55.6	3.4
PC$_4$	C	PET	59.1	26.1	85.2	33.0
PC$_5$	C	PET	33.3	38.8	72.1	5.5

C — Cotton, PET — Polyester, Yld — Yarn linear density.

determined according to ASTM D-1059. A sample size of 10cm×10cm was cut and weighed on electronic weighing balance. Aerial density was obtained by dividing the weight of test sample with the area of the sample.

2.2.2 Moisture Management Properties

Moisture management tester (MMT) (SDL Atlas, Hong Kong) (AATCC Test method 195-2009) was used for testing the liquid moisture transfer properties of the fabrics. Moisture management tester is capable of determining liquid transfer through fabrics in multiple directions such as spreading of liquid outward on the inner surface of the fabric, liquid transfer through the fabric from the inner to the outer surface and spreading of liquid outward and evaporation from outer surface of fabric[8,9,10].

The following parameters were obtained from moisture management tester (MMT):

Wetting time WTt (top/inner) and WTb (bottom/outer) — Top and bottom wetting times are defined as time period in which inner and outer surfaces of the fabric begin to wet respectively after the test starts.

Absorption rate ARt (top/inner) and ARb (bottom/outer) — Top and bottom absorption rates are the initial slopes of the water content curves from wetting point to peak values on fabric inner and outer surfaces.

Spreading speed SSt (top/inner) and SSb (bottom/outer) — Top and bottom spreading speeds are the moisture spreading speeds on the inner and outer fabric surfaces to attain maximum wetted radius.

Accumulative one way transport index – Accumulative one way transport index (AOTI) is the difference in accumulated moisture between the inner and the outer fabric surfaces in the time period of test.

2.2.3 Wicking

Trans planar wicking (liquid absorption perpendicular to fabric plane) of test samples was determined by Gravimetric Absorbency Tester (GATS).

3 Results and Discussion

3.1 Moisture Management Properties

3.1.1 Top and Bottom Wetting Time

Top (WTt) and bottom (WTb) wetting time indicate the time taken by liquid to wet the inner (next to skin) and outer layers of the fabrics as the test commences. Figure 1 shows the top and bottom

wetting time for the test samples. It is observed that top and bottom wetting time increase with the increase in yarn linear density (PC_1 – PC_3) due to corresponding increase in fabric thickness and aerial density (Table 2). Test liquid takes longer time to traverse thicker fabrics as water has to go through more number of fibres during traversing assembly of coarse yarns and hence higher wetting time for coarser yarn fabrics. On the contrary, yarns of low linear density result in fabrics of low thickness and, in turn, low water retention capacity which would further result in fast liquid spreading behavior of fine yarn fabrics compared to their coarser yarn counterparts[7].

The fabrics show marginal difference in top and bottom wetting time except for PC_4 and PC_5 fabrics. PC_4 fabric is knitted with cotton of highest yarn linear density in the outer layer and PC_5 fabric with coarse

Fig. 1 —Effect of yarn linear density on top and bottom layers wetting time

inner layer yarn and finer outer layer yarn. Top wetting time is higher than bottom wetting time for PC_5 fabric, the reason being higher linear density of inner layer yarn (polyester) compared to outer layer (cotton). Thus, the hydrophobic nature of fibre together with high yarn linear density restrict the wetting of inner layer rapidly. However, bottom wetting time is lower (2.8 s). As the inner layer of the fabric wets, the liquid transfer through capillary wicking is initiated. Hence, the wetting of inner layer is followed by liquid transfer by capillary wicking to outer layer which then immediately begins to wet and shows lower wetting time. PC_4 fabric, on the other hand shows opposite trend with bottom wetting time higher than top wetting time, and a great difference between the values of top and bottom wetting time is observed. This may be attributed to greater difference in yarn linear density of inner and outer layers (33 tex). Outer layer consists of coarse cotton yarn (59.1 tex) which takes 44.5 s to wet (Table 2) in spite of the hydrophilic nature of fibre. Grades for top wetting time ranges from medium to fast in top wetting time and slow to very fast in bottom wetting time (Table 3).

3.1.2 Top and Bottom Absorption Rate

Figure 2 shows the top (ARt) and bottom (ARb) absorption rates for the test fabrics. Top and bottom absorption rates decrease with the increase in yarn linear density due to increase in thickness and aerial density of PC_1- PC_3 fabrics. It is desirable that inner layer of fabrics intended for next to skin applications should have lower absorption rate so as to ensure dry
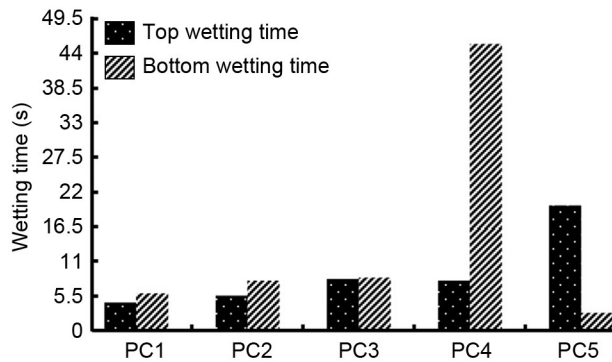
Table 2 — Physical and Moisture management properties

Sample code	Aerial density g/m²	Thickness mm	WTt s	WTb s	Art %/s	ARb %/s	SSt mm/s	SSb mm/s	AOTI
PC_1	155	0.91	4.4	5.9	63	66.6	3.10	2.6	365.0
PC_2	168	1.15	5.5	7.9	33	55.4	2.30	2.5	689.5
PC_3	174	1.31	8.2	8.4	14	49.7	0.85	2.1	490.2
PC_4	195	1.51	7.9	45.5	87.5	44.5	0.66	0.2	-15.9
PC_5	182	1.42	19.8	2.8	197.4	53.7	0.25	1.6	964.9

WTt & WTb– Top & bottom wetting time, ARt & ARb –Top & bottom absorption rate, SSt & SSb – Top & bottom spreading speed, AOTI– Accumulative one way transport index.

Table 3 — Grading of plated fabrics based on moisture management indices

Sample code	WTt s	WTb, s	Art, %/s	ARb, %/s	SSt, mm/s	SSb, mm/s	AOTI
PC_1	Fast	Medium	Fast	Fast	Fast	Medium	Very good
PC_2	Medium	Medium	Medium	Fast	Medium	Medium	Excellent
PC_3	Medium	Medium	Slow	Medium	Very slow	Medium	Excellent
PC_4	Medium	Slow	Fast	Medium	Very slow	Very slow	Poor
PC_5	Medium	Very fast	Very fast	Fast	Very slow	Very slow	Excellent

feel next to skin. PC_5 fabric shows the highest top absorption rate followed by PC_4 fabric. Both the fabrics seem unsuitable for next to skin applications based on the findings of the study as high liquid absorption in the inner layer tend to saturate the next to skin layer with liquid slowing down the liquid transfer to outer layer and may result in feeling of skin wetness and discomfort. Bottom absorption rate is higher than top absorption rate for PC_1-PC_3 fabrics, suggesting that as these fabrics absorb less liquid in inner layer, they would remain dry next to skin. Bottom absorption rate is highest for PC_1 and lowest for PC_4 fabric. It has been reported that finer the inner layer yarn and greater the difference between inner and outer layer yarn linear density, better is the liquid transfer from the inner to the fabric's outer layer. PC_4 fabric although has greater difference in inner and outer layer yarn linear density (Table 1), it consists of coarser cotton yarn in the outer layer compared to PC_1 fabric. PC_1 fabric is knitted with finest polyester yarn in the inner layer and has the lowest resultant yarn linear density, thereby ensuring rapid liquid transfer by inner layer and high absorption in the outer layer. It can, therefore, be inferred that increasing the difference between inner and outer layer yarn linear density by use of finer yarn in inner layer rather than by increasing coarseness of outer layer yarn will result in enhanced liquid transfer properties. The test fabrics show slow to very fast grades in top absorption rate and medium to very fast grades in bottom absorption rates as shown in Table 3.

3.1.3 Top and Bottom Spreading Speed

Spreading speed of textiles is essential in determining the drying ability of textiles, as the fabric structures that can spread liquid over large areas, also facilitate liquid evaporation to the environment. Top (SSt) and bottom (SSb) spreading speeds are observed to decrease for PC_1 – PC_3 fabrics with the increase in
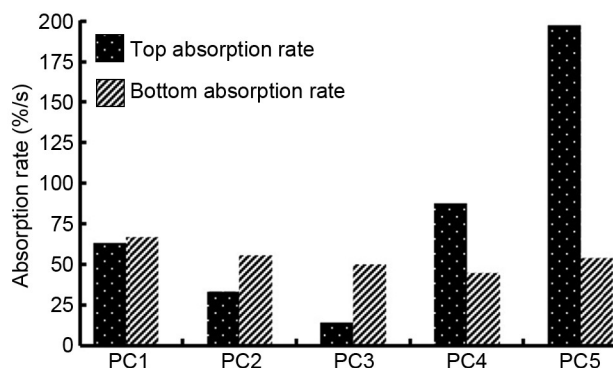
yarn linear density, as fabrics become thicker and heavier (Fig. 3). PC_1 fabric shows the highest value of top and bottom spreading speed, suggesting that the fabric provides large spreading area for liquid evaporation and hence would dry quickly. High spreading speed of PC_1 fabric may be attributed to low resultant yarn linear density and, in turn, low thickness and low wetting time, while low values of top and bottom spreading speed for PC_4 and PC_5 fabric may be attributed to high wetting time (Table 2). More time the fabric takes to wet, lesser would be its spreading speed and hence such fabric would take longer to dry. In the light of above argument, it can be said that both PC_4 and PC_5 fabrics would be slow drying fabrics.

3.1.4 Accumulative One Way Transport Index

Accumulative one way transport index (AOTI) gives a direct indication of fabric liquid transfer capability from inner to the outer layer. All the fabrics are graded very good to excellent in accumulative one way transport index except PC_4 fabric with poor grade and negative value of accumulative one way transport index, as shown in Fig. 4.

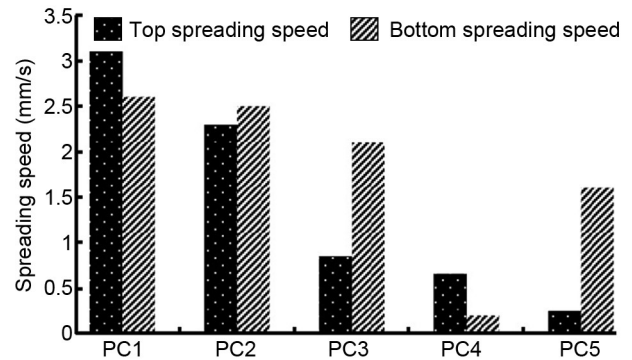Based on the values and grades of moisture

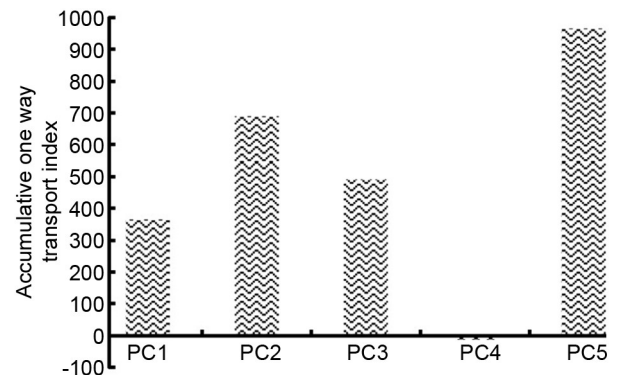Fig. 3 — Effect of yarn linear density on top and bottom layers spreading speed

Fig. 4 — Effect of yarn linear density on accumulative one way transport index

Fig. 2 — Effect of yarn linear density on top and bottom layers absorption rate
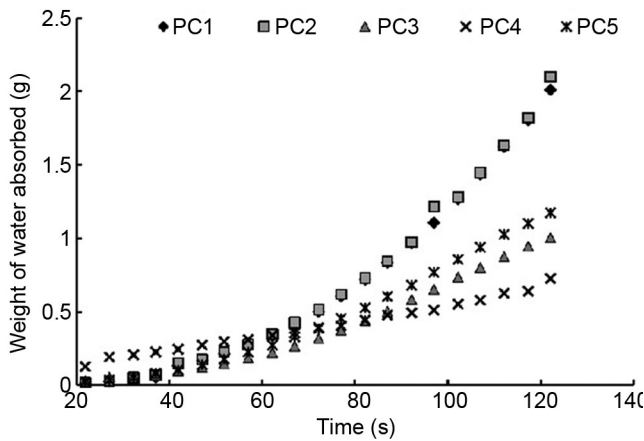
Fig. 5 — Effect of yarn linear density on trans planar wicking

management indices (Tables 2 and 3), the fabrics are classified into different categories. PC_1-PC_3 fabrics are classified as moisture management fabrics owing to high bottom spreading speed and excellent accumulative one way transport index. PC_4 fabric is classified as fast absorbing and slow drying fabric due to fast absorption in inner and outer layers, slow spreading and poor accumulative one way transport index. PC_5 fabric is classified as water penetration fabric due to small spreading area and excellent one way transport index.

3.2 Trans Planar Wicking

Figure 5 shows the trans planar wicking of the plated knits. Trans planar wicking is expected to increase with increase in yarn linear density. However, some exceptions from the trend are observed. PC_2 fabric shows the highest value of trans planar wicking which may be attributed to finer yarn in inner layer and coarser yarn in outer layer. This results in horizontal spread of liquid moisture in outer layer so that moisture is evenly distributed along this layer. Coarser yarns of outer layer increases liquid holding capacity and sinking effect, which, in turn, facilitates rapid transfer of liquid moisture from wearer's skin through inner layer to the fabric's outer layer. PC_4 fabric with greatest difference in inner and outer layer yarn linear density shows the lowest value of trans planar wicking because of coarsest cotton yarn in the outer layer; horizontal spread of liquid along the outer layer would be slow owing to more time taken to wet as suggested by high value of bottom wetting time (Table 2) even though the inner layer can pick up and transfer the moisture to outer layer. Thus, it can be inferred that there is an optimum yarn linear density and, in turn, capillary size which promote the liquid moisture transfer through wicking. Further

increase in yarn linear density may result in reduced capillary effect and hence the lower trans planar wicking.

4 Conclusion

4.1 Plated fabrics for next to skin applications can be designed with different yarn linear density in inner and outer layers. It can be inferred from the present study that fabrics knitted in plating relationship with combination of finer yarn in inner and coarser yarn in outer layer can effectively transfer liquid moisture towards outer layer owing to good moisture management and wicking properties.

4.2 Increase in inner and outer yarn linear density of plated fabrics results in increase in wetting time and decrease in absorption rate and spreading speed. Trans planar wicking increases with the increase in yarn linear density for fabrics within same range of resultant yarn linear density, although the fabrics with greater difference of linear density between inner and outer layers as a result of selection of finer yarns in inner layer show high value of trans planar wicking.

4.3 The fabrics are classified based on moisture management indices. PC_1-PC_3 fabrics are moisture management fabrics with good one way liquid transport, high absorption rate and spreading speed. The three fabrics are found suitable choice for next to skin applications owing to their ability to keep next to skin layer drier. PC_4 fabric is classified as fast absorbing and slow drying fabric while PC_5 fabric as water penetration fabric and hence both fabrics seem unsuitable in meeting the basic requirement of dry feel for next to skin clothing layer.

4.4 It is further observed that greater the difference in yarn linear density of inner and outer layer, the better is the liquid transfer from inner to outer layer by wicking, and better is the horizontal spread of transferred liquid in the outer layer. However, increasing the difference in yarn linear density by making the inner layer yarn finer rather than use of coarse yarn in outer layer results in better moisture management and wicking properties of plated fabrics.

4.5 Correct selection of inner and outer layer yarn linear density is therefore crucial for effective liquid transfer from inner to outer layers in plated fabrics intended for next to skin applications. The study therefore proposes designing of plated fabrics with fine hydrophobic yarn (polyester) preferably in the range of 11-26 tex and coarse hydrophilic yarn (cotton) preferably in the range of 29-33 tex, as such a

combination ensures dry feel next to skin by wicking of liquid moisture to outer layer without absorption in the inner (next to skin) layer. Likewise, the outer layer can absorb the transferred liquid and spread over larger area for quick evaporation to environment. It is also proposed that moisture management properties can be further improved by increasing the difference in yarn linear density of inner and outer layers preferably by increasing the fineness of inner layer yarn rather than increasing the coarseness of outer layer yarn.

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