Journal of Textile and Apparel, Technology and Management
Volume 11, Issue 2, 2020

Influence of Feed Yarn Techniques on Absorption Rate of Bi-material knitted Single Jersey Fabrics

P. Kanakaraj and R. Ramachandran
PSG College of Technology, India

ABSTRACT

Innovation in product developments reveals higher benefits in the applications of functional and aesthetic aspects. The knitted fabrics are used in development of moisture management products than other fabrics. In this study the single jersey fabrics are produced with bi-materials such as polyester/cotton, polypropylene/cotton and nylon/cotton. The cotton leed yarn feed, synthetic leed yarn feed, combined yarn feed and plated feed techniques were adopted for the production of plain jersey fabrics. The rate of water absorption (percentage area/second) of the produced fabrics has studied using Adobe Photoshop CS-2. The influence of feeding techniques on absorption rate of jersey fabrics was studied. Based on result and statistical analysis, it reveals the absorption rate of the various bi-material knitted fabrics has significant difference with respect to yarn feeds and variation of time periods. The polyester constituted knitted fabrics has higher absorption rate as compared to other combination yarn feed fabrics.

Keywords: knitting, moisture absorption, Image analysis, yarn feed

1. Introduction

The moisture vapor from the human body can pass through openings between fibers or yarns to the atmosphere. The moisture management of the textile materials plays important role to keep the wearer comfort. The primary objective of moisture management fabric in clothing is concerned, the transport of both moisture vapor and liquid away from the body. In hot conditions, trapped moisture can heat up and lead to fatigue or diminished performance. In cold conditions, trapped moisture will drop in temperature and cause chilling and hypothermia. Excess moisture may also cause the garment to become heavy, as well as cause damage to the skin from chafing. Cotton fiber is a good moisture absorber. Contrary to synthetic fibers, it does not transport water from the surface by using the capillarity, but uses the absorption method, which let water to penetrate through the fabric. Based on fiber type, construction/structure of the fabric, thickness/weight and chemical treatment of the fabric the behavior of the fabric is varied. The property of the fabric is mainly depending on its base fibrous properties [1]. The polypropylene fiber have very low moisture absorbency but excellent in moisture vapor permeability and wicking capabilities. As polypropylene does not become wet and its thermal insulation is retained during and after strenuous activity. Polyester has outstanding dimensional stability and offer excellent resistance to dirt, alkalis, decay, mold and most common organic solvents. Being durable, yet lightweight, elastic and a comfortable smooth feel, these are all important qualities to consumers for wide variety of applications. Excellent heat resistance, good moisture transport properties, low moisture absorption, easy care properties and low cost make it very useful [2]. Nylon has characteristics like lightweight, exceptional strength, good drape ability, abrasion resistant, easy to wash, resists shrinkage and wrinkling resilient, fast drying, low moisture absorbency, can be pre-colored or dyed in a wide range of colors, resistant to damage from oil and many chemicals, static and pilling can be problem, poor resistant to continuous sunlight.

The combining synthetic and natural yarn in development of moisture management knit fabric produced from many methods such as blending of synthetic with cotton yarn in yarn processing state. In knit fabric combination of stitches produced from blending of yarns in fixed striper and auto stripper techniques. By production of layered fabric, raw material variation in layer by layer either splitable or sandwich structure. The moisture management property of the plated fabric is improved by synthetic fabric. The raw materials used in the plated fabrics have the inner layer finer than those of the outer layer. Within the inner layer yarn, the fibers were relatively the coarser than within the outer layer yarn [4]. For liquid transport within fabrics, two phenomena must be accounted: wetability and wickability. The term 'wetting' is usually used to describe the change from a solid-air interface to a solid-liquid interface. Wicking is the spontaneous flow of liquid in a porous substrate, driven by capillary forces [3]. The liquid spreading area is depends on the structure and raw material used in the fabric. The special polyester is used as compared to polypropylene, polyamide and ordinary polyester. The combined knit structure produces dynamics wetting liquid spot as compared to plain weft knitted plated fabric. The arrangement of natural and manmade yarn stitches in the inner and outer surface of the knit fabric influences the wetting area of the liquid [5]. The attempt has been taken to study the influence of yarn feeding techniques on rate of water absorption in terms of pixels (%/sec.) of bi-material knitted single jersey fabric has been studied.

2. Methods and Materials

The single jersey fabrics are produced in single jersey knitting machine. The parameters of the knitting machine are as follows, Make: Vertex Soloman Engineers, Delhi, Year: 1980, Machine diameter: 3.5 inches. Number of needles: 160. Needle type: Long-hofa 71.60 G04, Short- hofa 71.60 G03.

2.1 Bi-material Fabric Development

The synthetic yarns such as polyester, polypropylene and nylon were used as individual yarn as combined with cotton yarn in different combinations. The bi-material knitted fabric the linear density of the synthetic yarn 66^{s}Ne and the linear density of the cotton yarn is 40^{s}Ne is maintained for all fabrics production. The 12 samples were produced with synthetic and cotton yarn combinations as given in table 1 with sample codes. The yarn feeding techniques are synthetic leed feed, cotton leed feed, combined feed and plated yarn feed techniques are illustrated in figure 1. The face and back side of the single jersey fabrics are as shown in table 2. The single jersey fabric produced from synthetic leed and cotton leed yarn feeds produces random combination of synthetic and cotton yarns in face and back side of the fabrics.

Cotton Leed defined as the feed yarn, consists of two yarns in the knitting creel, which consist of core yarn as synthetic yarn and the wrap yarn as cotton yarn. Synthetic Leed defined as the feed yarn consists of two yarns in the knitting creel, which consist of core yarn as cotton yarn and the wrap yarn as synthetic yarn. The horizontal stripes produced from cotton leed and synthetic leed feed yarns are very small and vary good visual effect as shown in table 2. Whereas the jersey fabric produced from the combined yarn feed are in random combination of synthetic and cotton yarns and also there is no unique pattern in stripes. The perfect plated fabric also produced from the above synthetic and cotton yarn combinations.

Table 1: Raw material Particulars

Sample No.	Yarn feed technique	Bi-material combination	Bi-material fabric code
1	Cotton leed	Cotton-nylon	NC-CL
2		Cotton-polypropylene	PPC-CL
3		Cotton- polyester	PC-CL
4	Synthetic leed	Cotton-polypropylene	PPC-SL
5		Cotton-polyester	PC-SL
6		Cotton-nylon	NC-SL
7	Combined	Cotton-nylon	NC-CM
8		Cotton-polyester	PC-CM
9		Cotton-polypropylene	PPC-CM
10	Plating	Cotton-polypropylene	PPC-PLG
11		Cotton-polyester	PC-PLG
12		Cotton-nylon	NC-PLG

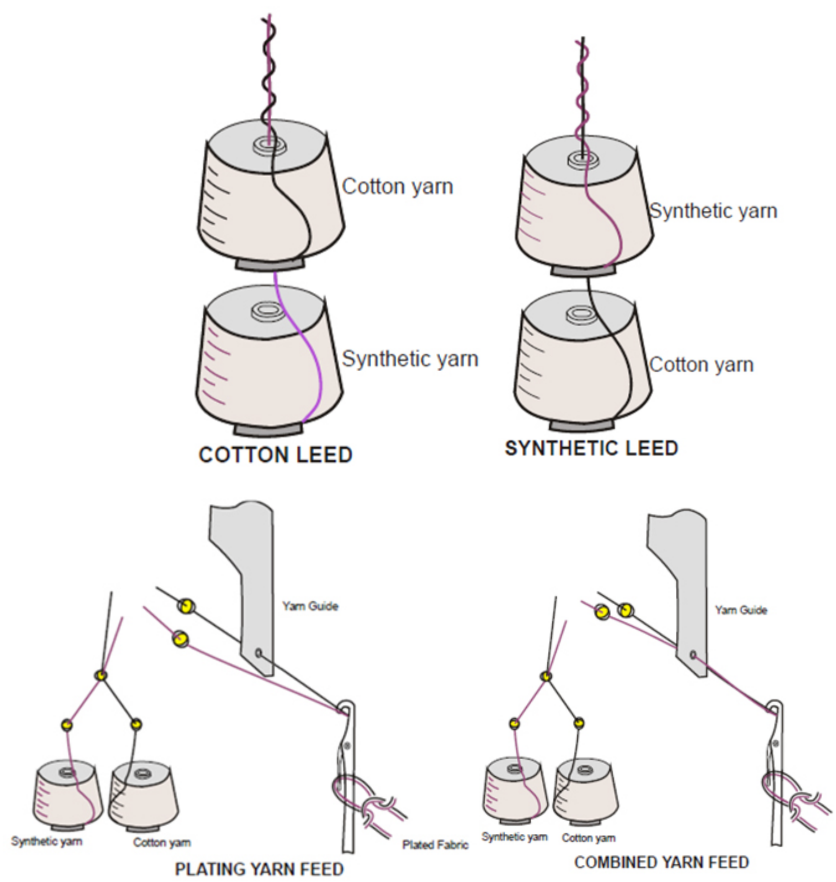


Figure 1. Yarn feed Techniques

3. Testing

The produced single jersey knit fabrics was given relaxation process and carried out the following test. The knitted fabric parameters and absorption area (pixels) are given in table 3.

3.1 Geometrical Parameters

The courses and wale density of the samples were calculated individually in the direction of the length and width of the knit fabric. The average density per square centimeter was taken for the discussion. The 20 loops in a course were unraveled and measured the length of yarn in cm (L_T) both face and back of the fabric. From the L_T value the stitch length/loop length was measured by using the following formula, the average loop length (cm) was taken and reported in table 3.

Stitch length/loop length in cm = $(L_T)/20$

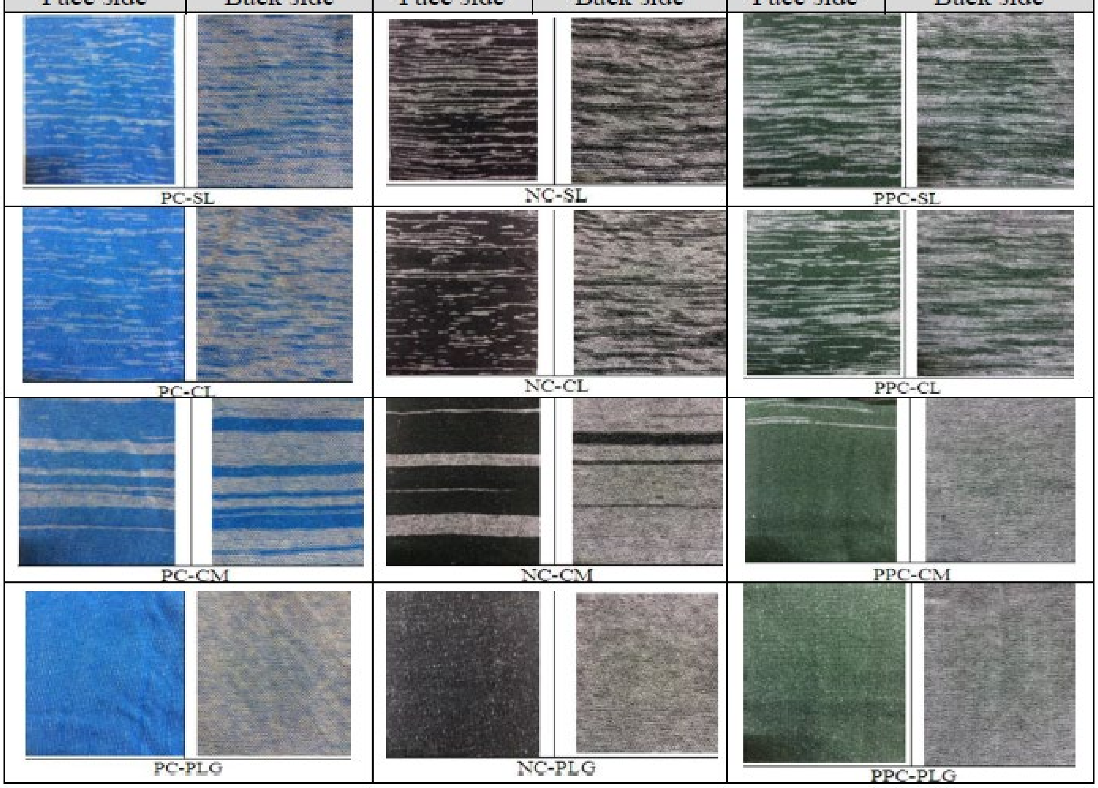
The tightness of knits was characterized by the tightness factor. It is known that, is a ratio of the area covered by the yarns in one loop to the area occupied by the loop. It is also an indication of the relative looseness or tightness of the knitted structure. For determination of TF the following formula was used

Tightness Factor (TF) = $\sqrt{T}/l$

Where T= Yarn linear density in Tex, l = loop length of fabric in cm.

Table 2. Single Jersey Knitted fabrics

Polyester cotton Bi-material fabrics		Nylon cotton Bi-material fabrics		Polypropylene cotton Bi-material fabrics	
Face side	Back side	Face side	Back side	Face side	Back side



3.2 Area of Absorption-Image Analysis

The produced single jersey bi-material fabrics were taken for the area of water absorption study. The distilled water is taken in the pipette, which is fixed perpendicularly 10 cm distance between the water drop and the base level. At the same time the HD video camera also fixed for capturing the area of absorption. One drop of distilled water is dropped from the pipette which is recorded till the drop of water is fully wetted and spread. After the testing process, from the capturing video the area of water absorption is calculated with respect to time. The area of water absorption for the single jersey bi-material fabrics are calculated with respect to time such as 0 Sec.,(Initial), 5 Sec., and 10 Sec.,. The each samples absorption area photographs were taken from the capturing video to analyze the number of pixels in the wetted area. The raw pictures are converted in to threshold image using Adobe Photoshop CS-2 from the edited image the area of absorption calculated in terms of number of pixels. The top absorption area in terms of number of pixels is tabulated in table 3.

3.2.1 Percentage Absorption Area

The absorption areas of the produced knit fabrics were done based on the above procedure. The percentage absorption area of the knit fabrics also recorded in table 3. The determination of the parameter is done based on the equation mentioned below

Absorption area (%) = (Area of absorption with respect to time – Area of absorption at initial state) / Area of absorption with respect to time) x 100

3.2.2 Water Absorption rate

The absorption rate of knitted fabrics produced from synthetic leed yarn feed, cotton leed yarn feed, combined yarn feed and plated yarn feed in percentage per second is determined based on the following equation. The ratio of the percentage absorption area and with the time is calculated as absorption rate per time.

Absorption Rate (%/Second) = Area of Absorption (%)/Time interval in seconds

Table 3. Jersey fabric parameters and absorption area parameters of Bi-material knitted fabrics

Bi-Materials Code	Loop length (cm)	Stitch Density (Stitches/ Cm^2)	Tightness factor ($Tex^{1/2}\ cm^{-1}$)	Absorption Area (%)		Absorption Rate (%/sec.)	
				up to 5 sec.	5 sec. - 10 sec.	up to 5 sec.	5 sec. - 10 sec.
PC-S L	0.62	81.84	9.488	75.14	26.16	15.03	5.23
PC-C L	0.8	78.43	7.353	85.42	43.08	17.08	8.62
PC-CM	0.77	75.02	7.64	78.34	40.70	15.67	8.14
PC-PLG	0.77	93	7.64	55.81	65.75	11.16	13.15
PPC-S L	0.58	100.44	10.143	64.37	16.52	12.87	3.30
PPC-C L	0.9	96.26	6.536	54.61	10.97	10.92	2.19
PPC-CM	0.46	96.88	12.78	57.23	11.33	11.45	2.27
PPC-PLG	0.52	100.44	11.31	66.12	16.74	8.65	3.35
NC-S L	0.66	89.13	9,805	44.78	34.15	8.96	6.83
NC-C L	0.73	78.43	8.058	58.38	15.58	11.68	3.12
NC-CM	0.74	89.13	7.95	43.26	29.90	13.22	5.98
NC-PLG	0.71	112.38	8.285	55.58	17.19	11.12	3.44

4. Liquid Transports through Bi-Material Knitted Fabrics

The absorption of liquid particulars transported into the fabric through wetting followed by wicking [7]. The capacity of the fabric to sustain the capillary action is called as wickability of the fabric. This process is influenced by the wetting property of the fabric, moisture concentration layers in the fabric, structural aspect of the fabric and finishing. The figure 2 shows the liquid transport through bi-material jersey fabric from step 1 to step 5. The synthetic face fabric layer of bi-material fabric has large capillary spaces between the fibers. These interactions between the fibers are bonded by fiber cohesion force. Initially the liquid particles are transported through these capillaries; the collective capillary forces are enhancing the wicking process. The capillary pressure is inversely proportional to the radius of the capillaries. Once the narrow spaces between the fibers achieve the saturated level through the capillaries, the large open air spaces in the fabric or air volume within the fabric starts to transport the liquid through the fabric [8]. On saturation of top layer in the place of core liquid touches the fabric, liquid transport through bottom layer of the fabric started. Here also follows the same phenomena, but due to lower forces acting during wetting and wicking, wicking happens lower rate as compared to top layer of the fabric.

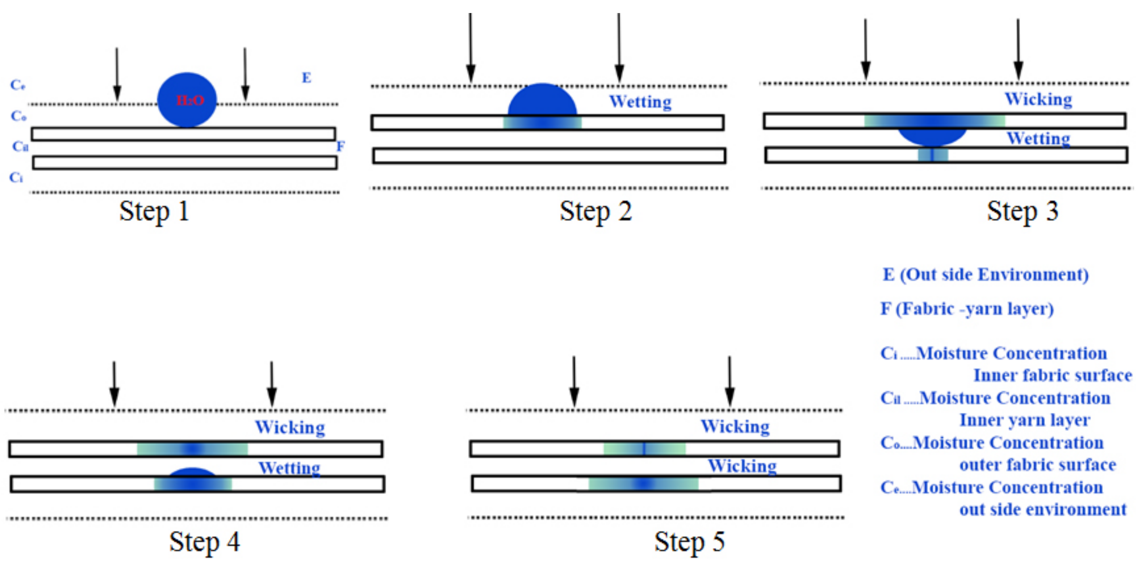


Figure 2. Liquid transport through bi-material knitted fabrics

5. Result and Discussion

The bi-material knitted fabrics produced by varying the yarn and also feeding tested for the absorption area in terms of number of pixels and absorption rate as percentage per second. Initially the absorption of fabric surfaces takes lesser time and latter increases the time for rate of absorption for all yarn feed fabrics.

5.1 Absorption Rate for PC knitted single jersey fabrics

The absorption rate (%/Sec.) of PC knitted fabrics is shown in figure 3. In PC bi-material fabrics the initial rate of absorption is higher up to 5 sec. and reduced between 5 sec. to 10 sec. except PC-plated knitted fabrics. The water particles starts enter in to smaller pores in the polyester surfaces, because of capillary action and its forces inside the yarn the wicking gets faster to fill all the places in the yarn with increasing wicking rate [6].

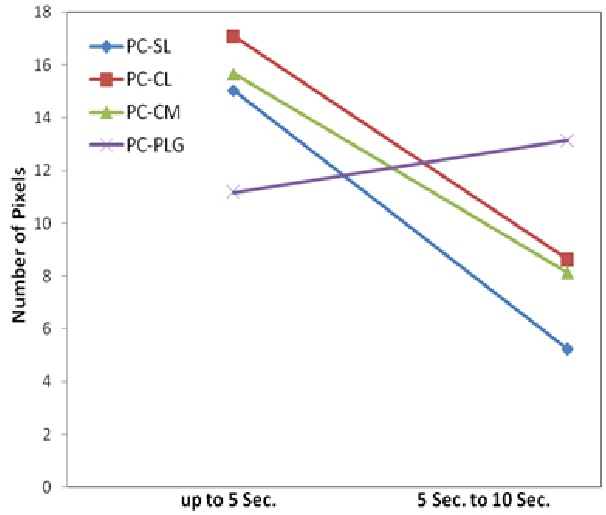


Figure 3. Absorption rate of PC single jersey knitted fabrics

During the initial absorption the PC-CL feed fabric provides higher absorption rate followed by PC-CM, PC-SL and PC-PLG fabrics. As discussed in 2.1, in cotton leed yarn feed the presence of higher contribution of polyester yarn in the face surface of the fabric improves the rate of absorption. The water droplet falls on the fabric surface, because of wicking property of the polyester suddenly transmit the water particles in to the yarn in the fabric surface. At the same time the presence of cotton yarn in the fabric absorbs the water from the synthetic yarn. Due to this action the rate of absorption of water increases in this fabric. When time increases from 5 sec. to 10 sec. the rate of absorption reduces, may be the cotton yarn in the fabric absorbs maximum water particles the rate of absorption reduces on the fabric surfaces. In PC-CM jersey fabrics the random design pattern generated during production consists of wide horizontal stripes of hydrophilic and hydrophobic yarns in face surface of fabric. The combined yarn feed fabric have the similar characteristics of fabric produced from plated yarn feed based on face surface yarn in the fabric. But this is not a standard pattern as shown in table 2.

Whereas, in synthetic leed yarn feeding the jersey fabric face surface contains more cotton yarn and less synthetic yarn. So the wicking of the fabric by absorption is affected by the presence of more hydrophilic surface. After 5 sec. to 10 sec. the absorption rate is increased due to wicking by the hydrophobic yarn (polyester) next to cotton yarn. This wicking property is affected by discontinuous contact pattern in between hydrophilic and hydrophobic yarns in PC-SL knitted jersey fabrics. The initial absorption area of PC-PLG fabric is lower than other fabrics with varying yarn feed. In plated yarn feed fabric the liquid particles touches the fabric surfaces spontaneous wicking happens by the presences of polyester yarn in face of fabric. But in other hand absorption by the cotton fiber reduces the wicking, results lower area of wetting in face of the fabric reveals lower absorption rate. By the achievement of saturation level over a period of time by the hydrophilic yarn, the wicking improves and achieve higher absorption rate at face of the fabric.

The statistical analysis for the PC knitted fabric is shown in table 4. The results shows there is significant difference between the A: yarn feed of PC bi-material knitted fabrics (P-value= 3.24E-70< 0.05) and also the absorption rate (%/sec.) between B: up to 5 second and 5second to 10 second (P-value= 7.57E-87< 0.05). The interaction between A and B also highly significant for absorption rate (%/sec.) of PC bi-material knitted fabrics (P-value= 6.53E-82< 0.05).

4.3 Absorption Rate of PPC knitted single jersey fabrics

The absorption of the fabric is closely related to the type of material and moisture regain capacity of the yarn [9]. The PPC knitted jersey fabrics gives the absorption rate in the order of PPC-PLG, PPC-SL, PPC-CM and PPC-CL. The face surface of the bi-material fabric is hydrophobic yarn which gives constant face surface in plated yarn feed fabric(PPC-PLG), because of lower absorption capacity of the polypropylene, the liquid particles are wicked rapidly by the face yarn and interact with other yarn in a feed. The polypropylene provides highest liquid particles to the bottom layer. These results are in accordance with [10] who have reported that the trans planar wicking i.e., through the thickness of fabric is high for PPC plated fabric. Whereas PPC-SL knitted fabric, the face and back surface yarns randomly varied as cotton and polypropylene. The presence of hydrophilic yarn on face surface of the PPC-SL fabrics reduces the wicking property. So the absorption rate is reduced from PPC-PLG fabrics. But the same trend was absorbed between 5 sec. to 10 sec. period of time. This is because of absorption capacity of the cotton yarn in the fabrics.

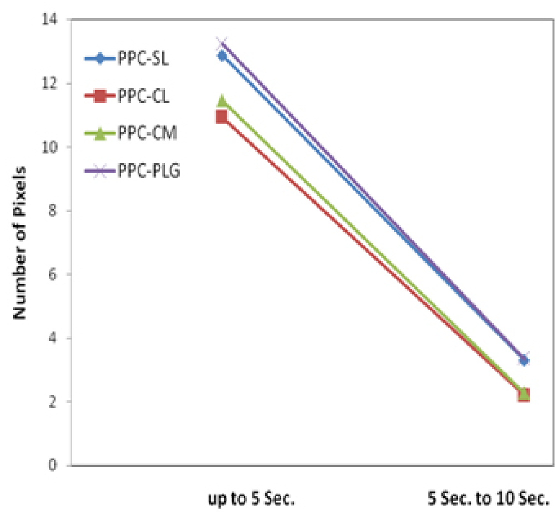


Figure 4. Absorption rate of PPC single jersey knitted fabrics

The PPC-CM and PPC-CL yarn feed fabrics are lower absorption rate at initially up to 5 sec. and between 5 se. to 10 sec. as compared to other fabrics. The random pattern of big strips in PPC-CM yarn feed fabrics reduces the absorption. In PPC-CL fabric, the polypropylene surfaces cover random area in face of fabric. So there is discontinuous liquid movement along the capillaries in between the yarns which reduces absorption rate of the fabric.

The result of statistical analysis for the polypropylene constituted knitted fabric is shown in table 4. There is significant difference between the A: yarn feeds of PPC bi-material knitted fabrics (P-value= 9.15E-59< 0.05) and also the absorption rate (%/sec.) between B: up to 5 second and 5second to 10 second (P-value= 1.12E-85< 0.05). The interaction between A and B also highly significant for absorption rate (%/sec.) of PPC bi-material knitted fabrics (*F*-value= 4089.566> *F-Crit*=2.90112).

4.4 Absorption Rate of NC knitted single jersey fabrics

The NC bi-material knitted fabrics produced with SL, CL, CM and PLG yarn feed techniques have the water absorption rate is higher at initial 5 seconds in the order of CL, PLG, SL and CM yarn feed fabrics and lower between followed 5 seconds & 10 seconds in the order of SL, CM, PLG and CL yarn feed fabrics. The result shows for rapid absorption rate NC-CL fabric is suitable than other NC bi-material knitted plain jersey fabrics. In NC-CL fabrics the face surface has higher constitution of hydrophobic yarn which induces the wicking of liquid particles to other yarn in a layer of fabric. Once the bottom layer achieves the moisture regain limit further absorption is affected, for long period of time the area of absorption rate is reduced. Same trend has absorbed by the researchers as N/C combination plated fabric is not suitable for rapid transfer because of high absorption and not effective wicking [10].

When time period increases, among NC yarn feed fabrics, synthetic leed feed fabric provides higher area of absorption rate (%/sec.). This may be the face surface of fabric has more constitution of cotton yarn, which transport the absorbed liquid particle to other yarn in a layer because of good liquid transport property in longitudinal fabric axis. The hydrophobic yarn has good wicking capacity compared to face yarn. So this fabric is most preferred where rate of absorption property is required for long period of time.

Anova results shows significant difference at 95% level in between water absorption rate (%/Sec.) of NC bi-material knitted fabrics. The result shows there is a significant influence of the variables A: yarn feeds (P-value= 8.73E-40< 0.05), B: Between timings (up to 5 sec. and 5 to 10 sec.) P-value is 4E-74< 0.05 and interaction between A and B (P-value= 2.99E-64< 0.05) shown in Table 5.

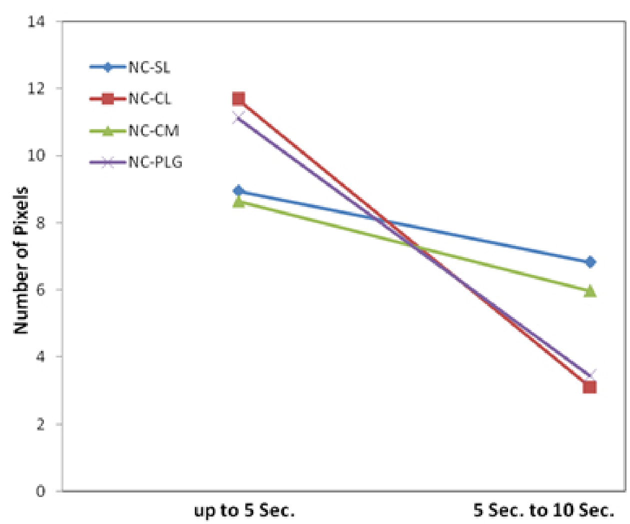


Figure 5. Absorption rate of NC single jersey knitted fabrics

Table 4. Two-way ANOVA with Replication Results

Absorption Rate (%/Sec) of PC knitted fabrics

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
A: Between Yarn feeds	40.23908	3	13.41303	258586.8	3.24E-70	2.90112
B: Between timings (up to 5 sec. and 5 to 10 sec.)	354.1964	1	354.1964	6828474	7.57E-87	4.149097
Interaction between A and B	216.6094	3	72.20313	1391988	6.53E-82	2.90112

Absorption Rate (%/Sec) of PPC knitted fabrics

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
A: Between Yarn feeds	22.55972	3	7.519907	49757.81	9.15E-59	2.90112
B: Between timings (up to 5 sec. and 5 to 10 sec.)	872.1412	1	872.1412	5770794	1.12E-85	4.149097
Interaction between A and B	1.85417	3	0.618057	4089.566	2.03E-41	2.90112

Absorption Rate (%/Sec) of NC knitted fabrics

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
A: Between Yarn feeds	2.449149	3	0.816383	3230.408	8.73E-40	2.90112
B: Between timings (up to 5 sec. and 5 to 10 sec.)	276.5654	1	276.5654	1094362	4E-74	4.149097
Interaction between A and B	83.09405	3	27.69802	109600.4	2.99E-64	2.90112

5. Conclusions

The combination of aesthetic appearance and functional requirements in a single jersey bi-material knitted fabric has produced with varying yarn feed techniques. The area of absorption rate in terms of percentage per second is increases for PC bi-material knitted fabrics for both rapid action and the long period of time compared to PPC and NC knitted fabrics.

The presence of higher constitution of synthetic yarn along with cotton yarn on face side of fabric improves absorption rate. The PC-CL feed bi-material fabrics shows rapid water absorption rate with respect to the area. This could be suitable for high activity level fabric applications whereas PC-PLG fabric is suitable for long activity level fabric applications.

The PPC combinations fabrics produced with various yarn feeds provides linear trend of area of absorption rate between initial and long periods of time irrespective of yarn feeds. This could be the suitable for active wear applications as compared to NC bi-material yarn feed fabrics because of lower initial absorption rate and not effective wicking character the application suited for long period of time.

References

1. D'Silva, A.P., and Anand, S.C., "Responsive garments for sportswear, their production and market strategies, Ed.: S. Gupta, NIFT, New Delhi, India 2000, pp 32-49.
2. Adanur, B.S.S and W. Sears,. Handbook of Industrial Textiles. Technomic publications, lnc., USA, 1995.
3. Jakub Wiener, Petra Dejlová, "Wicking and wetting in textiles", AUTEX Research Journal, Vol. 3, No2, June 2003
4. Qing Chen, Jintu Fan, Manas Sarkar & Gaoming Jiang, 'Biomimetics of Plant Structure in Knitted Fabrics to Improve the Liquid Water Transport Properties', Textile Research Journal, vol. 80,no. 6, 2010, pp. 568-576.

6. Bivainyte, A & Mikucioniene, D, 'Investigation on the Dynamic Water Absorption of Double-Layered Weft Knitted Fabrics', Fibres & Textiles in Eastern Europe, vol. 19, no. 6 (89), 2011, pp. 64-70.
7. Canan Saricam, Fatma Kalaoglu, "Investigation of the Wicking and Drying Behaviour of Polyester Woven Fabrics", FIBRES & TEXTILES in Eastern Europe 2014; 22, 3(105): 73-78.
8. Musaddaq Azeem, Amal Boughattas, Jakub Wiener and Antonin Havelka, "Mechanism of Liquid Water Transport in Fabrics: A Review", Fibres and Textiles (4) 2017, pp. 58-65.
9. K. Hong, n. R. S, hollies an d s. M. Spivak, "Dynamic moisture vapor transfer through textiles part i: clothing hygrometry and the influence of fiber type" Textile Research Journal, December 1988, pp. 697-706
10. Yamini Jhanji, Deepti Gupta & V K Kothari, "Moisture management and wicking properties of polyester- cotton plated knits", Indian Journal of Fibre & Textile Research, Vol. 42, June 2017, pp. 183-188
11. Yamini Jhanji, Deepti Gupta & V K Kothari, "Liquid transfer properties and drying behavior of plated knitted fabrics with varying fiber types ", Indian Journal of Fibre & Textile Research, Vol. 40, June 2015, pp. 162-169