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Wicking behaviour of bamboo/polyester blended yarns

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A series of weft-knitted fabrics has been produced from bamboo/polyester and bamboo/cotton blended yarns to study their wicking properties. It is found that the wickability of the blended yarn consisting of 67 % bamboo and 33 % polyester is comparatively good. Twist has a significant effect on wickability, as higher twist leads to lower wickability. Bamboo/polyester consisting of 67/33 proportion displays higher wickability, while 100 % polyester exhibit lower wickability.

Keywords: Bamboo, Blended yarn, Comfort, Fabric, Polyester, Wicking, Yarn

Moisture transmission plays a very important role in clothing, and this has been recognised for a long time. Comfort characteristics can be better understood by the wicking properties of textiles. Lucas-Washburn equation has become a defacto technique for characterizing wickability. Rajagopalan *et al.*[1] have stated that the motion of liquid in the void spaces between fibres in a yarn significantly affects wicking in fabrics. Much larger pores between yarns do not contribute much to the long range, motion of liquid based on the laws of capillarity. The yarn intersections act as new reservoirs and they are meant for feeding all branches.

Saricam and Kalaoglu[2] studied the wickability of polyester woven fabrics. Both vertical and transfer wicking as well as drying tests were conducted to study the effect of yarn type, weft density, weave structure thickness and air permeability on wickability. Drying time is found to be related to fabric porosity. An interesting observation that, 'air, textured polyester yarns show higher wickability than those of the filament yarns' has been made.

Rajagopalan *et al.*[1] have found that in their model in vertical wicking of a bundle of filaments, the non-roundness of the cross-section leads to higher wickability, a fact demonstrated by Das *et al*[3]. They have reported that polyester fibres with trilobal cross-section has higher wickability than that of circular cross-section. Zhu *et al.*[4] studied the wicking property of cotton fabric. Some of their findings are that, weft way wickability in a cotton fabric is higher than that of warp way wickability and Washburn's equation has been followed. The most interesting part of the study is the durative wicking test after removal of the wicking liquid reservoir. Square of the wicking height was found to be highly correlated with time for warp and weft directions. Another observation is that, the increment in mass absorbed per centimeter of fabric was found to be inversely proportional to the wicking height.

A plethora of literature is available on wickability of yarns. Liu *et al.*[5] have conducted studies on the wickability of filament yarns as a function of twist. Hamraovi and Nylander[6] have made an analytical approach for the Lucas-Washburn equation which is a classical one. The assumption made is that contact angle is dynamic when the liquid remains moving. Nyoni and Brook[7] have made extensive studies on wickability of filament yarns. The effect of cyclic stress on the wickability of nylon yarns has also been studied. A study of capillary flow in polyamide and polyester yarns has been conducted by Perwuelz *et al.*[8]. They have used an image analysis system and found that Washburn's equation was followed in the wicking of polyester, polyamide and glass yarns. They point out the role of heterogeneity of the yarn structure. Although the wetting properties of single fibres are homogeneous along the fibres, capillary flow rates vary in the section and along the yarn. The study of wickability of textiles is of importance for various reasons. Firstly, it provides a better understanding of the liquid/fibre contact in order to characterize any liquid flow of spin finishes dyeing, or coating of either fabrics or yarns. Secondly, it enables the characterisation of textile structures, their variability and more precisely their porosity

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resulting from the capillaries formed by the interfilament spaces in which the liquid flows. Thirdly, Sasaki and Araki[9] have related yarn structure to diffusion of dye in nylon fabric.

Generally, the capillary flow in fibrous structures follows Washburn's law which gives the variations of the liquid height has a function of time (t) in a capillary of radius (R). It may be noted that this is happening only in horizontal wicking. The relationship is given below:

$$\frac{dH}{dt} = \frac{R^2}{8\eta h}\left[\frac{2\gamma\cos\theta}{R} - \rho gh\right] \quad \ldots(1)$$

Integrating, we get

$$H^2 = \frac{R^2\gamma\cos\theta}{R.2\eta}.t \quad \ldots(2)$$

or

$$H^2 = A.t \quad \ldots(3)$$

where

$$A = \frac{R\gamma\cos\theta}{2\eta} \quad \ldots(4)$$

$$H^2 = \frac{R\gamma\cos\theta}{2\eta}.t \quad \ldots(5)$$

or

$$H = \sqrt{\frac{R\gamma\cos\theta}{2\eta}}.t^{0.5} \quad \ldots(6)$$

Determination of wickability of yarns is important to study the fibre/liquid interactions, for example surfactant absorption or finish distribution. It is fundamental to determine the kinetics of spontaneous diffusion of water in fabrics to investigate comfort in textile assemblies. Öztürk *et al.*[10] have reported the wickability of cotton-acrylic yarns and knitted fabrics. It was found that the wickability was higher in acrylic than in cotton. The coarser the count, the greater is the wicking. Also, fabric wicking was well related to yarn wicking.

There are a number of paper reported studies on yarn wickability[3,5,11-12]. Hamdaoui *et al.*[13] found that viscose yarns show higher diffusion coefficient than cotton yarns, showing higher wickability. Cross-sectional area of fibre was found to affect wickability[3]. Mazloumpour *et al.*[14] have calculated L^2/t, which is the equivalent geometric factor neglecting the earth's gravitational field. They demonstrated that this value decreases as the pick density of the fabric increases.

The subject of wickability in yarns has attracted the attention of many scientists, and the need for many sophisticated techniques was upsurged. Predictions of wickability in filament yarns has been successfully studied by many workers. Yuvarani[15] and Kamath *et al.*[16] did pioneering research on yarn wickability, taking into account many factors. Moisture transmission is one of the important factors which affect physiological comfort. Fabrics that transport moisture rapidly from the human body make weavers feel more comfortable by keeping them dry. The comfort provided by fabrics can be better understood by studying their wickability. Capillary flow in yarns has been well studied by a number of researchers. This capillary action is determined by the interaction of the liquid and the fabric material by liquid properties, such as viscosity, surface tension and pore sizes. Thus, a study of wicking in yarns should provide a way to understand the role of geometric and material properties parameters in yarn wicking. Kamath *et al.*[16] have carried out a very interesting study of spin finishes in synthetic yarns by wickability.

Although a considerable amount of work has been done on the tenacity of bamboo/polyester blends, work on their wickability is scanty. Therefore, an attempt has been made to investigate the wicking properties of bamboo/polyester blends differing in twist and blend composition.

Experimental

Polyester and bamboo fibres were used to prepare yarns of 30 Ne with two twist multipliers [32.47 tpcm $(tex)^{05}$ and 38.21 tpcm $(tex)^{05}$]. The blend compositions used were 100% bamboo, 100% polyester, and 80/20, 67/33, 50/50, 33/67 & 20/80 bamboo/cotton. Before the testing, the samples were conditioned under the standard atmospheric conditions of 20 ± 2°C temperature and 65 ± 2% relative humidity for two weeks. The important particulars of the yarns together with their particulars of twist are given in Table 1.

Wicking of yarns was studied using the method followed by Liu *et al*[17]. Both ends of the yarns were clamped, with one end dipped about 3 mm into distilled water. The wicking height was monitored as a function of time. For each yarn, ten replicates were performed. Statistical evaluation of data was performed with SPSS 16 software package.

Table 1 — Particulars of yarns

Yarn characteristics	Bamboo/ Polyester yarn						
	Bamboo	80/20	67/33	50/50	33/67	20/80	Polyester
Yarn count, tex				19.68			
Yarn count (CV%)	0.5	1.2	1.5	0.7	0.8	0.6	0.5
Twist	32.47	32.47	32.47	32.47	32.47	32.47	32.47
tpcm(tex)$^{0.5}$	38.21	38.21	38.21	38.21	38.21	38.21	38.21

Table 2 — Wicking height of yarn

Blend ratio (Bamboo/polyester)	Twist factor	Wicking height, mm									
		1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
100% B	32.47	39	49	63	73	76	84	95	102	111	120
	38.21	39	43	54	58	62	64	67	73	77	80 [1]
67/33	32.47	31	56	63	70	77	86	95	108	124	131
	38.21	23	43	53	58	65	72	78	84	93	105
80/20	32.47	35	52	59	68	77	85	92	103	108	119
	38.21	31	39	44	54	57	62	.65		79	82
50/50	32.47	35	42	46	52	62	72	77	88	96	110
	38.21	34	44	49	52	54	56	59	66	73	81
33/67	32.47	36	46	55	59	64	75	80	83	85	87
	38.21	36	43	46	53	59	63	66	68	70	72
20/80	32.47	42	48	62	71	74	77	81	79	83	85
	38.21	29	41	46	49	52	54	57	61	66	69
100% P	32.47	32	38	43	52	55	58	61	62	63	64
	38.21	25	30	36	42	46	51	54	57	59	62

Results and Discussion

Table 2 shows yarn wicking results for 10 min. The statistical analysis of the results shows that at a 95 % confidence interval, blend composition is the only single factor which affects yarn wicking. Three types of analysis of data, as shown in below (Tables 3-5), have been performed:

(i) Relating In *H vs* In *t*

(ii) Relating *H vs* t^{05}

(iii) Relating H^2 *vs t*

where *H* is the height; and *t*, the time

Slopes obtained by linear regression analysis are given in Table 5. The better wicking ability of bamboo yarns might be due to their hygroscopic nature. The poor wicking of polyester yarn is due to its hydrophobic nature. Water diffuses into the bamboo fibre and the fibre swells immediately. On the basis of the slopes obtained, 67/33 bamboo/polyester blend shows the highest wickability.

Increase in twist has led to a decrease in wickability in all the cases. Upon insertion of twist, fibres move inward and rearrange their positions; the fibres become more compact. This, in turn, will lead to lower wickability. Also the introduction of twist leads to fibre migration which will affect wicking of yarns. When a high twist is introduced into the yarn, fibres near the yarn centre may buckle due to twist retraction. This can harm the pore structures between fibres and affect wicking behaviour of liquid[17]. It is also interesting to note that as the percentage of polyester increases, there is a progressive decrease in wickability.

Table 3 — Values of time exponents from model $H = ct^k$

Blend ratio (Bamboo/polyester)	TF	k	C	R^2
100% B	32.47	0.486	1.305	0.984
	38.21	0.317	1.316	0.976
80/20	32.47	0.51	1.247	0.992
	38.21	0.429	1.065	0.982
67/ 33	32.47	0.577	1.183	0.972
	38.21	0.592	0.938	0.981
50/ 50	32.47	0.498	1.102	0.924
	38.21	0.332	1.208	0.944
33/67	32.47	0.397	1.265	0.988
	38.21	0.318	1.242	0.985
20/80	32.47	0.328	1.427	0.965
	38.21	0.343	1.111	0.983
100% P	32.47	0.331	1.141	0.984
	38.21	0.391	0.91	0.991

TF -Twist factor, k-constant, C-constant and R^2-proportion of variance.

In order to check whether Washburn's equation is obeyed by the data, wicking height is related to $t^{0.5}$ and the slopes are computed. Kamath *et al.*[16] named this as “wicking coefficient (W_c)” which has unit cm/$S^{1/2}$. The higher the wicking coefficient, the greater is the wickability and vice versa. Table 5 gives

Table 4 — Wicking height *vs* square root of time

Blend ratio (Bamboo/polyester)	H *vs* $t^{0.5}$	R^2 value
100% B	3.656	0.98632
	2.328	0.97359
80/20	3.642	0.98713
	2.465	0.98093
67/33	4.034	0.95586
	3.195	0.97257
50/50	3.218	0.94174
	2.21	0.94673
33/67	2.729	0.97900
	2.153	0.96070
20/80	2.59	0.90829
	2.002	0.96943
100% P	1.978	0.93772
	0.922	0.99308

Table 5 — Slope of wicking curves

Blend ratio (Bamboo/polyester)	H^2 *vs* t	R^2 value
100% B	13.76	0.99207
	5.822	0.96367
80/20	13.525	0.99351
	6.358	0.98881
67/ 33	16.51	0.97409
	10.117	0.98602
50/50	10.996	0.95968
	5.404	0.95620
33/67	7.685	0.98550
	4.891	0.96168
20/80	6.849	0.94125
	4.248	0.96641
100% P	4.041	0.95585
	3.794	0.99298

value of W_c for the various yarns cases. It is noticed that time exponents k is less than Washburn's predicted time exponent of 0.5, which is attributed to the non-uniformity of the yarn arrangement and the simultaneously occurrence of wetting wicking, liquid dispersion and evaporation. Liquid transport in textile structures is studied by Washburn's well-known equation, as shown below:

$$H = ct^{1/2} \quad \ldots(7)$$

where *H* is the distance travelled by a liquid in time; and *ct* is proportional to the set of factors, as shown below:

$$\left(\frac{\gamma r \cos\theta}{2\eta}\right)^{1/2} \quad \ldots(8)$$

where γ is the surface tension of liquid; η, the viscosity of the wicking liquid; θ, the contact angle of liquid against fibre substance; and r, the capillary radius. This equation has been modified by Laughlin and Davies[18] into a general form, as shown below:

$$H = ct^k \ \ln(H) = k\ln(t) + \ln c \quad \ldots(9)$$

Taking logarithms of both sides of this equation, following relationship is obtained:

$$\ln(H) = k\ln(t) + \ln c \quad \ldots(10)$$

This equation has the form of a straight line. K values for the blended yarns (Table 3) range from 0.317 to 0.592. The interaction coefficient values for twist factors 32.47 ($spcm.tex^{0.5}$) and 38.21 ($tpcm.tex^{0.5}$) are found to be 11.51 and 7.53 respectively.

This study has been focused to find out the wickability of a series of bamboo/polyester blended yarns differing in twist and blend composition Wickability is studied to assess the effect of twist and blend composition. Twist has a significant effect on wickability, the higher twist leads to lower wickability. Bamboo/polyester (67/33) displays higher wickabilitv, while 100% polyester exhibits lower wickability. The interaction is found to be higher in respect of lower twist factor and lower for higher twist factor.

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