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An Investigation Of The Wicking Behaviour Of Bamboo/Polyester Blended Yarns

A.Viswanathan

SNS College of Technology, Coimbatore - 641035, Tamil Nadu, India.
Email.ID: viswa_mathematics@ yahoo.com

S.N. Subbramanian

SNS College of Technology, Coimbatore - 641035, Tamil Nadu, India.
Email.ID: snsamrita@yahoo.com

R. Sowmya

Vogue Institute of Fashion Technology, Bengaluru - 560025, Karnataka, India

Abstract

An investigation of the wickability of a series of bamboo/cotton blended yarns differing in twist and blend composition is reported. The blend consisting of 67% bamboo and 33% polyester shows higher wickability while 100% polyester yarn shows lower wickability. Wickability reduces with higher twist levels. It was found that Washburn's equation was not obeyed by the yarns.

Keywords: Yarn wicking, bamboo/polyester blends, twist.

Introduction

That moisture transmission plays a very important role in clothing 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 characterising wickability. Rajagopalan et al. [13] in their excellent paper have stated that the motion of liquid in the void spaces between fibres in a yarn significantly affect 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. That yarn intersections act as new reservoirs and they are meant for feeding all branches have been recognised. In a very recent paper, Saricam and Kalaoglu [14] report on the wickability of polyester woven fabrics. Both vertical and transfer wicking and 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 [13] have found that in their model in vertical wicking of a bundle of filaments, the nonroundness of the cross section leads to higher wickability a fact demonstrated by Das et al.[2, 3]. They have reported that polyester fibres with trilobal cross section has higher wickability than that of circular cross section.

Zhu et al [18] have conducted a study on 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 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 centimetre 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 [8] have conducted studies on the wickability of filament yarns as a function of twist. Hamraovi and Nylander [5] 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 front is in movement. Nyoni et al [10] have made extensive studies on wickability of filament yarns. The effect of cyclic stress on the wickability of nylon yarns has been studied. A study of capillary flow in polyamide and polyester yarns has been conducted by Perwuelz et al [12]. 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. First, 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. Second it enables the characterisation of textile structures, their variability and more piecisily their porosity resulting from the capillaries formed by the interfilament spaces in which the liquid flows. Third, Sasaki et al [15] have related yarn structure to diffusion of dye in nylon fabric. Bayramli and Powell [1] have studied the dynamics of polymer impregnation in the field of technical textiles.

Generally speaking, the capillary flow in fibrous structures follows Washburn 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.

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

Integrating we get

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

or

$$H^2 = A.t$$

where

$$A = \frac{R\gamma\cos\theta}{2\eta}$$

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

or

$$H = \sqrt{\frac{R\gamma\cos\theta}{2\eta}}.t^{0.5}$$

Determination of wickability of yarns is important to study of 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.

Ozturk et al. [11] have reported on the wickability of cotton-acrylic yarns and knitted fabrics. It was found that the wickability was higher in acrylic than in cotton and the coarser the count, the greater the wicking. Also, fabric wicking was well related to yarn wicking. There are a number of papers on yarn wickability by Subbramanian et al [16], Nyoni [10], Wang et al [17] and Das et al [2, 3]. Hamdaoui et al [4] have found that viscose yarns had higher diffusion coefficient than cotton yarns and thus show higher wickability. Cross sectional area of fibre was found to affect wickability by Wang et al [17] and Das et al [2, 3].

Mazloumpour et al [9] have calculated $\frac{L^2}{t}$ which they call as equivalent geometric factor neglecting the earth's gravitational field. They demonstrate 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 has been upsurged. Predictions of wickability in filament yarns has been successfully carried out by many workers. Wicking studies of yarns have been a forerunner for understanding fabric wicking. Very thorough studies on yarn wickability have been conducted by Nyoni [10] and Kamath et al [6] 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 research workers. 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. Parameters in yarn wicking Kamath et al [6] 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. Consequently, the study discussed in this paper was conducted in an attempt to investigate the wicking properties of bamboo/polyester blends differing in twist and blend composition.

Experimental

Materials

Polyester and bamboo fibres were used and yarns of 30 Ne were made with two twist multipliers 3.4 and 4.0. The blend compositions used were 100% bamboo, 100% polyester, 80% bamboo/20% cotton 67/33, 50/50, 33/67, 20/80.

Before the tests were done, the samples were conditioned under the standard atmospheric conditions of 20 ± 2°C 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.

Table 1. Particulars of yarns

Yarn type	**100% B**	**80B 20P**	**67B 33P**	**50B 50P**	**33B 67P**	**20B 80P**	**100% P**
Yarn count (Ne)	30	30	30	30	30	30	30
Yarn count (CV%)	0.5	1.2	1.5	0.7	0.8	0.6	0.5
Twist	3.4	3.4	3.4	3.4	3.4	3.4	3.4
	4	4	4	4	4	4	4

Methods

Wicking of yarns was studied using the method followed by Liu et al.[8]. 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.

Results and Discussion

Table 2 shows yarn wicking results for 10 minutes. The statistical analysis of the results showed that at a 95% confidence interval blend composition was the only single factor which affected yarn wicking. Three types of analysis of data shown in Table 3, 4 and 5 were performed

(1) Relating ln H vs ln t
(2) Relating H vs $t^{0.5}$
(3) Relating H^2 vs t

Slopes obtained by linear regression analysis are given in Tables 3, 4 and 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 this 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 and 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 Liu et al.[8]. It is also interesting to note that as the percentage of polyester increases, there is a progressive decrease in wickability.

Table 2. Wicking height of the yarn (mm)

Time (m) Yarn type	TF	1	2	3	4	5	6	7	8	9	10
100% B	3.4	39	49	63	73	76	84	95	102	111	120
	4.0	39	43	54	58	62	64	67	73	77	80
80B/ 20P	3.4	35	52	59	68	77	85	92	103	108	119
	4.0	31	39	44	54	57	62	65	68	79	82
67B/ 33P	3.4	31	56	63	70	77	86	95	108	124	131
	4.0	23	43	53	58	65	72	78	84	93	105
50B/ 50P	3.4	35	42	46	52	62	72	77	88	96	110
	4.0	34	44	49	52	54	56	59	66	73	81
33B/67P	3.4	36	46	55	59	64	75	80	83	85	87
	4.0	36	43	46	53	59	63	66	68	70	72
20B/80P	3.4	42	48	62	71	74	77	81	79	83	85
	4.0	29	41	46	49	52	54	57	61	66	69
100% P	3.4	32	38	43	52	55	58	61	62	63	64
	4.0	25	30	36	42	46	51	54	57	59	62

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

Time (m) Yarn type	TF	k	c	R^2
100% B	3.4	0.486	1.305	0.984
	4.0	0.317	1.316	0.976
80B/ 20P	3.4	0.51	1.247	0.992
	4.0	0.429	1.065	0.982
6.7B/ 33P	3.4	0.577	1.183	0.972
	4.0	0.592	0.938	0.981
50B/ 50P	3.4	0.498	1.102	0.924
	4.0	0.332	1.208	0.944
33B/67P	3.4	0.397	1.265	0.988
	4.0	0.318	1.242	0.985
20B/80P	3.4	0.328	1.427	0.965
	4.0	0.343	1.111	0.983
100% P	3.4	0.331	1.141	0.984
	4.0	0.391	0.91	0.991

Table 4. Wicking height vs square root of time

Time (m) Yarn type	H Vs $t^{0.5}$	R^2 value
100% B	3.656	0.98632
	2.328	0.97359
80B/ 20P	3.642	0.98713
	2.465	0.98093
6.7B/ 33P	4.034	0.95586
	3.195	0.97257
50B/ 50P	3.218	0.94174
	2.21	0.94673
33B/67P	2.729	0.97900
	2.153	0.96070
20B/80P	2.59	0.90829
	2.002	0.96943
100% P	1.978	0.93772
	0.922	0.99308

Table 5. Slope of the Wicking Curves

Time (m) Yarn type	H^2 Vs t	R^2 value
100% B	13.76	0.99207
	5.822	0.96367
80B/ 20P	13.525	0.99351
	6.358	0.98881
6.7B/ 33P	16.51	0.97409
	10.117	0.98602
50B/ 50P	10.996	0.95968
	5.404	0.95620
33B/67P	7.685	0.98550
	4.891	0.96168
20B/80P	6.849	0.94125
	4.248	0.96641
100% P	4.041	0.95585
	3.794	0.99298

In order to check whether Washburn's equation is obeyed by the data, wicking height was related to $t^{0.5}$ and the slopes were computed. Kamath et al [6] call this as "Wicking coefficient" which has units of $cm/S^{½}$. The higher this value, the greater the wickability and vice versa. Table gives value of W_c for the various yarns cases it is noticed that time exponents K were less than Washburn's predicted time exponent of 0.5 which was 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 shown below.

$$H = ct^{1/2}$$

where h is the distance travelled by a liquid in time and C is proportional to the set of factors

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

where γ = surface tension of liquid, η = viscosity of the wicking liquid θc contact angle of the liquid against the fibre substance and r = capillary radius. This equation has been modified by Laughlin and Davies [7] into a general form

$$H = ct^{k} \ \ln(H) = k \ln(t) + \ln c$$

Taking logarithms of both sides of this equation gives

$$\ln(H) = k \ln(t) + \ln c$$

This equation has the form of a straight line. K values for the blended yarns which are given in Table 3, which ranged from 0.317 to 0.592.

Conclusion

The study was focused to find out the wickability of a series of bamboo/ polyester blended yarns differing in turns and blend composition Wickability was conducted to assess the effect of twist and blend composition. Twist has a significant effect on wickability in that higher twist had led to lower wickability. Bamboo/ polyester consisting of 67/33 proportion displays higher wickability while 100% polyester exhibit lower wickability.

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