Effect of air plasma treatment on wickablity of knitted fabrics

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Abstract

Textiles have undergone chemical wet processing from time immemorial. Unable to withstand the pressure generated on account of the pollution levels, eco-friendly alternative raw materials and technologies are being developed continuously besides novel technologies. Plasma technology on regenerated cellulosic fabrics not only reduce the energy, chemical, time involved during various operations, they incorporate comfort and functional properties. This paper addresses the wickablity property of air plasma treated knitted fabrics. A simple wickablity factor has been developed to characterise the wickablity of fabrics. The vertical wickablity test has been used to obtain the wicking parameter that quantifies wickablity of fabric treated with air plasma. Results show that the new wickablity parameter 'W' is higher than that of untreated control. Thus this method is a useful tool to objectively quantify wickablity. Results also show that the intensity of plasma treatment varies with different materials and wale and course ways require different treatment times for bringing out the desired results. Thus, plasma treatment also leads to anisotropic properties to fabrics.

Keywords: *Knitted fabrics, Low pressure glow discharge plasma, wickability.*

1. Introduction

Wicking plays an important role in determining the overall quality of textile product as well as the end-use applications and product costs. Vertical wicking methods have been developed to determine wickability and many have conducted studies using them[1]. A major upsurge in research on wicking took place in 2012, with the development of a tester which permits the determination of vertical, horizontal and downward wicking. The vertical wicking governs the saturation, horizontal capillary pressure and downward wicking permeability. In many methods, vertical wicking was the principal method used but the manner in which the wicking height was monitored was different.

No method has been developed to quantify wickability except the slopes '$h/t^{1/2}$' and 'h^2/t' suggested by Kamath et al[2] , Sharabaty[3]and Mazloumpour et al[4]. Hence there is a need for a simple method to quantify wickability. Treatments such as plasma treatment enhance the wickability, as suggested by Wong et al[5]. It is extremely important to quantify the changes in the wickability of plasma treated materials. Vertical wicking test has been used to obtain a refined parameter to quantify the changes in the wickablity of a series of weft-knitted fabrics made from bamboo, bamboo/cotton and cotton/modal yarns.

As has been pointed out the vertical wickability test was used to quantify the wicking properties of plasma treated fabrics. Many published papers have mentioned the wickability test Wong et al[5] . However, the characterisation of the wickability has not been attempted. Laughlin and Davies[6] suggested a modification in the formula given by Washburn[7]

$h^2=Ct$ … (1)

which is :

$h=C' t^K$ … (2)

Taking the logarithm on both sides of the above equation we get:

$In(h) =K In(t) + In C'$ …(3)

which is very similar to the equation given by De Boer[8].It was pointed out by him that a negative correlation existed between 'C' and 'k'(-0.95). Also, log't' was negatively correlated with the constant 'C' which is wicking test (-0.93). Hence, the slopes h^2/t or $h/t^{1/2}$ cannot adequately express wickability. Deviations from Washburns equation have been pointed out by much research workers. The relationship between wicking height and time can be conveniently represented by the power relationship given in the following equation:

$h=Ct^k$ … (4)

where 'h' is a wicking height, 'C' is constant, 't' is time and 'k' is the slope. Taking logarithm on both sides. The above equation becomes:

$\log h=k\log t + \log C$ …(5)

The time exponent 'k' and intercept 'C' are interdependent and hence it is not logical to make comparison among different fabrics using the time exponent 'k'. To overcome this difficulty a wickability factor W is defined that makes the wickability comparisons among different fabrics possible

$W=C/k$ (cms or mms) … (6)

The wickability factor 'W' includes both 'C' and 'k' making comparisons possible. The wickability factor 'W' has been used in the study to quantify the changes that occur in the wickability of bamboo, bamboo/cotton and cotton /modal fabrics following air plasma treatment.

2 Materials and Methods

1.1 Materials

The materials used were hundred percent pure bamboo, 50/50 percent bamboo/cotton and cotton/modal single jersey knitted fabrics. The details of these are given in Table 1

2.2 Experimental Procedure

2.2.1 Plasma treatment

The bamboo, bamboo/cotton and cotton/modal knitted fabrics were treated using low pressure glow discharge plasma. The glow discharge was generated using an apparatus made by an industry. The DC glow discharge was operated at 0.5 mbar. Air was admitted into the plasma chamber using needle valve to control the pressure. Cathode was located in the centre of the chamber and the chamber walls acted as anode. Samples were placed hanging at a distance of about 18 cm from the cathode. It was operated at radio frequency of 150 to 192 MHz. The process parameters that were varied during the air plasma was the duration of treatment. The fabrics were treated for 5, 10 and 20 minutes duration. The treated fabric samples were removed from the chamber and then conditioned under standard conditions (65% RH and 25^0C) for 24 hours before testing.

2.2.2 Wickability

The vertical wicking test was done following the standard test method of DIN 53924. The duration of every test was 10 minutes and the interval between wicking length readings was within 15 seconds. Each experiment was carried out five times and the variation of wicking length was within ±5%. Regression analysis was carried out using log 'h' and log't' values. The intercept and slope values were obtained from the regression analysis. The intercept represents the wickability parameter 'C' and the value of 'k' represents time exponent, Zhuang et al[9] and Nyoni[10] have commented on 'k' parameter without taking into account 'C' values which are also equally important. The 'C' and 'k' parameters are then used to obtain 'W' the value of wickability parameter. The higher the value of 'W', the higher the wickability and vice versa.

3 Results and Discussion

Table 2 shows the 'W' values which are the 'C/k' values. In respect of bamboo, course way values are lower than those of wale way while the opposite trend is noticed in bamboo /cotton and cotton/modal blends. In the case of bamboo fabrics, wale way values are affected by plasma treatment to a greater extent compared to course-way. Bamboo /cotton and cotton modal fabrics show significant changes in course way. While ten minutes of plasma treatment are adequate for bringing out an improvement in bamboo, values of 'W' in course way are unaffected. A treatment of 20 minutes seems to be optimum for bamboo cotton, while 5 minutes seem to be adequate for course way.

In respect of cotton/modal fabric, a treatment time of 20 minutes seems to be adequate in wale way, while 5 minutes of treatment are required in course way to bring out significant changes in wickability. Thus there appears to be different responses to plasma treatment by the knitted fabrics. Thus anisotropy is present in the knitted fabrics as the values are found to be direction oriented. Wicking tests will be found to be very useful for quantifying the changes in the fabric following any physical or chemical treatments.

Table 3 gives the rise rate in respect of the three fabrics. This is obtained by differentiating the equation. The degree of deviation of the exponent from 0.5 is an indication of the deviation by what may be termed as "pure" capillary action as pointed out by Laughlin and Davies [6]

$h^2= Ct$ then $dh/dt=1/2(C/t)^{1/2}$ …(7)

These values are related to the flow.

Figure 1-3 show the 'C', 'k' and 'W' values obtained for the knitted fabrics. 'C' and 'k' values are taken for calculating 'W'. It is erroneous to comment on 'k' values without taking account 'C'. The wicking tests have been found to be successful in reflecting the changes that occur in the fabrics following plasma treatments.

Table 1: Properties of fabrics used

Fabrics	Yarn Linear Density (Tex)	Twist / Cms.	Course / Cm.	Wale / Cm.	Stitch Density (Cm2)	Loop length (mm.)	Mass per unit area (g/m2)	Tightness factor Tex 0.5 Cm-1	Loop shape factor	Thickness (mm.)	Bulk Density (g/cm3)
Bamboo	20.01	8.89	22	16	352	2.5	163.00	17.89	1.37	0.56	0.31
Bamboo/Cotton	20.5	8.46	20	16	320	2.36	155.14	19.68	1.25	0.5	0.31
Cotton/Modal	20.2	8.48	21	17	357	2.36	162	19	1.23	0.52	0.31

Table: 2: Values of W for control and air plasma treated bamboo, bamboo cotton and cotton modal fabrics

Sample	Approximate power law			
	$h = C't^k$		W = C/k (Cms.)	
	Wale	Course	Wale	Course
100% BAMBOO				
Control/Untreated	$1.35t^{0.35}$	$1.18t^{0.35}$	3.71	3.14
Air Plasma 5 Min.	$1.36t^{0.39}$	$1.36t^{0.41}$	3.48	3.31
Air Plasma 10 Min.	$1.68t^{0.23}$	$1.41t^{0.36}$	7.3	3.91
Air Plasma 20 Min.	$1.58t^{0.26}$	$1.29t^{0.41}$	6.07	3.14
BAMBOO/COTTON				
Control/Untreated	$1.32t^{0.33}$	$1.52t^{0.28}$	4	5.42
Air Plasma 5 Min.	$1.32t^{0.34}$	$1.69t^{0.27}$	3.88	5.82
Air Plasma 10 Min.	$1.35t^{0.37}$	$1.36t^{0.34}$	3.64	4
Air Plasma 20 Min.	$1.45t^{0.33}$	$1.27t^{0.37}$	4.39	3.43
COTTON /MODAL				
Control/Untreated	$0.45t^{0.33}$	$0.91t^{0.43}$	1.36	2.11
Air Plasma 5 Min.	$0.99t^{0.42}$	$1.67t^{0.29}$	2.35	5.75
Air Plasma 10 Min.	$1.53t^{0.3}$	$1.42t^{0.25}$	5.1	5.68
Air Plasma 20 Min.	$1.67t^{0.27}$	$1.48t^{0.27}$	6.18	5.48

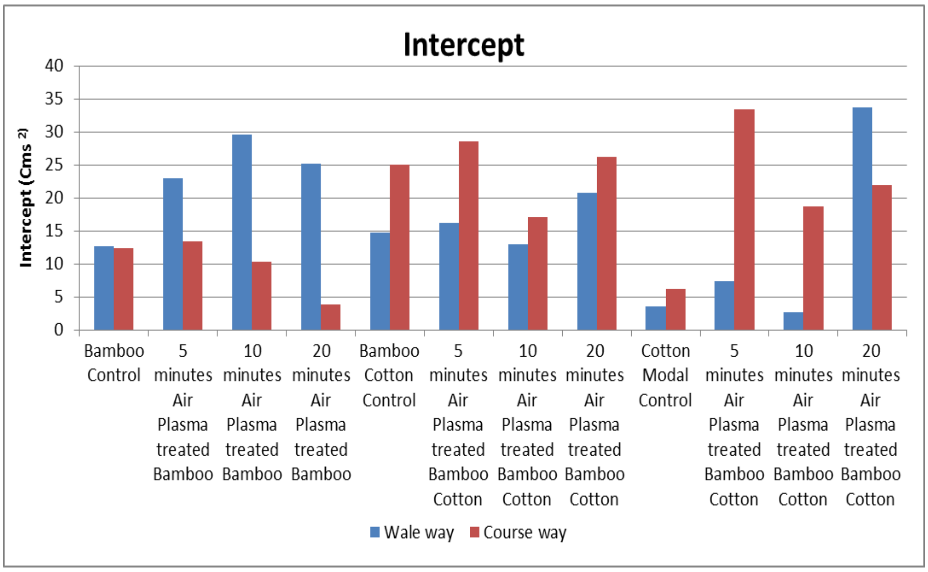

Figure 1: Values of intercepts for control, bamboo, bamboo cotton and cotton modal knitted fabric

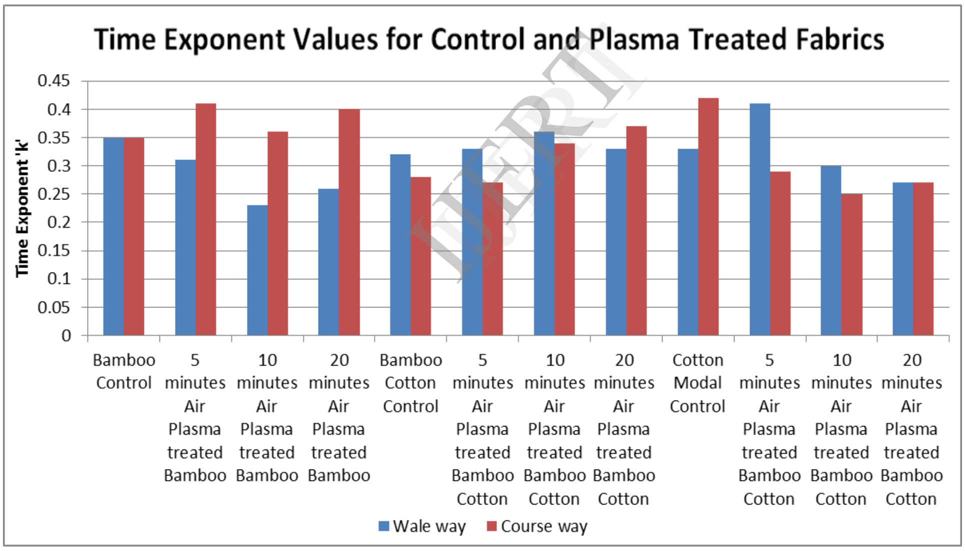

Figure 2: Values of time exponent for control and air plasma treated bamboo, bamboo cotton and cotton knitted fabrics

4. Conclusion

The new wickability factor 'W' is capable of differentiating and quantifying subtle changes in the wickability of fabrics. The simple wickability factor will prove to be an invaluable tool for fabric process and product control activities in the textile mills.

Table: 3 Rise rate of control and air plasma treated bamboo, bamboo cotton and cotton modal fabrics

Sample	Rise Rate cm/min.	
	Wale way	Course way
100% BAMBOO		
Control/Untreated	$0.47t^{-0.65}$	$0.41t^{-0.65}$
Air Plasma 5 Min.	$0.53t^{-0.61}$	$0.55t^{-0.59}$
Air Plasma 10 Min.	$0.38t^{-0.77}$	$0.51t^{-0.64}$
Air Plasma 20 Min.	$0.41t^{-0.77}$	$0.53t^{-0.59}$
BAMBOO/COTTON		
Control/Untreated	$0.431t^{-0.67}$	$0.42t^{-0.72}$
Air Plasma 5 Min.	$0.440t^{-0.66}$	$0.45t^{-0.73}$
Air Plasma 10 Min.	$0.490t^{-0.63}$	$0.46t^{-0.66}$
Air Plasma 20 Min.	$0.470t^{-0.67}$	$0.46t^{-0.63}$
COTTON/MODAL		
Control/Untreated	$0.47t^{-0.67}$	$0.39t^{-0.57}$
Air Plasma 5 Min.	$0.41t^{-0.7}$	$0.48t^{-0.71}$
Air Plasma 10 Min.	$0.46t^{-0.7}$	$0.35t^{-0.75}$
Air Plasma 20 Min.	$0.45t^{-0.73}$	$0.39t^{-0.73}$

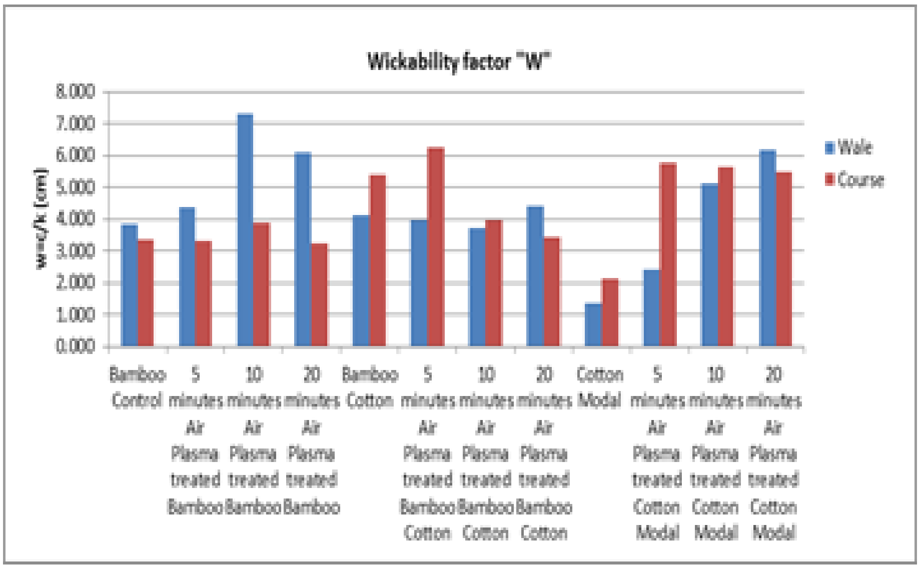

Figure 3: Value of 'w' for control, bamboo, bamboo cotton and cotton modal knitted fabrics

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