International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 12, December - 2013

Effect of Air Plasma Treatment on Comfort Properties of Bamboo Fabric

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Abstract

Plasma treatment is an emerging surface modification technique used to improve the performance of textile materials without using chemicals. The present work is concerned with the effect of air plasma treatment on the bamboo knitted fabric. The time of the treatment has been varied and the influence of these on comfort characteristics such as thermal conductivity, warm and cool feeling of fabric and air resistance has been studied. This study concluded that the air plasma treated fabrics have improved air permeability, warm feeling, good thermal resistance and thus the treatment was feasible.

Key words: Air resistance, Bamboo, Knitted fabric, Plasma treatment, Thermal resistance

1. Introduction

The fabric texture and the movement of air, moisture and heat through the fabric is extremely important for designing of garments for imparting good comfort. Several papers have been published on the methods of measurement of air permeability, thermal conductivity, *warm/cool feeling of fabrics (*$q_{max.)}$ and the results of research in the subjects (1, 2). Kan et al (3) have shown in a number of papers the advantages of plasma treatment on wool fabrics. They have reported that plasma treatment results in the reduction of air permeability and $q_{max.}$ .Plasma treatment leads to greater moisture absorption, better dye uptake and eco-friendly environment. Kan et al (4) have looked at the low stress mechanical properties of wool fabrics following plasma treatment and have provided extensive data. By plasma treatment ,the functional finishes could be imparted which include ,antimicrobial, soil repellency , stain resistance, soft handle and improved dyeing .Several surface features such as adsorption ,desorption and cross linking occur owing to plasma treatment on textile materials (5,6,7).

A plethora of literature on plasma treatment is available on textile fibres, yarns and fabrics and is well documented. Information on the effect of plasma treatment on comfort properties of knitted fabrics produced from advanced cellulosic fibres such as bamboo is scant. The aim of the work described here was to study how the plasma treatment effects the comfort properties of knitted fabrics made from pure regenerated bamboo yarns and to discover possible methods of engineering them for garments to provide better comfort. A detailed study of all the important comfort related properties namely air permeability, thermal resistivity and warm and cool feeling of fabric has been carried out.

2. Materials and Methods

2.1: Materials

A pure bamboo yarn was used for knitting the single jersey fabric. A knitting machine of 24" diameter and having a 28 gauge was used. The sample was subjected to relaxation treatment. This was found to be very effective in bringing the fabric to a stable configuration .The geometrical properties of the fabric are given in Table I.

2.2 Experimental Procedure

2.2.1 Plasma treatment

The bamboo knitted fabrics was 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 a pressure of 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 duration of air plasma treatment was 5, 10 and 20 minutes. The treated fabric samples were removed from the chamber and then conditioned under standard conditions of 25 ± 2^0C and 65± 5% rh. for 24 hours before testing.

Table I: Geometric properties of bamboo fabric

Fabric	Yarn Linear Density (Tex)	Twist / cm.	Course / cm.	Wale / cm.	Stitch Density (cm^2)	Loop length (mm)	Mass per unit area (g/m^2)	Tightness factor ($tex^{0.5}$ cm^{-1})	Loop shape factor	Thickness (mm.)	Bulk Density (g/cm^3)
Bamboo	20.01	8.89	22	16	352	2.5	175	17.89	1.37	0.41	0.439

2.2.2: Testing Procedure:
The basic geometric property of bamboo knitted fabric was tested using standard procedure. Kawabata's KES –F8-API tester was used to measure air resistance, Thermolabo II KES –F was used for testing, thermal conductivity and the warm and cool feeling - q_{max} of treated samples

2.2.2.1: Air permeability test
KES –F8-API tester was used to test the air resistance of the untreated and air plasma treated samples. In KES –F8-API tester, a constant rate of air flow is generated (i.e. $4x10^{-2}$ m/sec) and passed through the specimen. This leads to development of the pressure difference across the specimen .Since this pressure difference has linear relation with air resistance, the latter can be calculated from the former .This instrument has a digital panel meter from which air resistance of the specimen can be read directly.
The specimens were conditioned at 25 ± 2^0C and 65± 5% rh. It is then mounted onto the instrument using the clamping plates .The area of specimen is maintained at a constant rate by the piston motion of the plunger mechanism .Air is sucked through the specimen for a period of five seconds and then discharged for the next five seconds. The air resistance (Pa.sec/m) is directly read from the digital panel meter. The inverse of this value gives air permeability in units of m/Pa.sec. An average of five readings was taken.

2.2.2.2: Thermal conductivity test
Thermolabo II KES –F was used to measure thermal conductivity of fabrics. The electrical energy required o maintain at 10^0C difference in temperature between BT box and water box is noted from the instrument. The constant thermal conductivity is calculated by the following formula:
K= WD/A Δ T Watts /cm/^{0}C,
Where W= power consumption in watts reported by the instrument
D= thickness of sample in cm
A= area of copper plate of BT box in cm^2
ΔT=difference in temperature (^{0}C) between BT box and water plate. An average of five readings was taken for each fabric sample.

2.2.2.3: Measurement of warm/cool feeling: (q_{max}):
The q_{max} is the highest heat flux observed when a hot body (T Box) comes in contact with a fabric maintained at a constant temperature. The hot body (i.e. T Box) is kept at 10^0C above the ambient temperature. Fabric of size 25x25 cm is then kept above the water box to keep, opposite sides of the fabric at constant temperature, q_{max} is measured as J/cm^2/sec or W/m^2.An average of five readings is taken .The heat loss per unit area under of 10 ^{0}C temperature difference was measured by the warm/cool feeling (q_{max}) in W/cm^2.It reflects the instantaneous warm/cool feeling sensed when there is an initial contact of the fabric. A lower value implies better warmth retention properties.

3. Results and Discussion

The thickness and mass of air plasma treated bamboo fabrics are given in Table 2:

Table 2: Thickness and mass of air plasma treated bamboo fabrics

Samples	Thickness(mm)	Mass (g/ m^2)
Control	0.3819	175.2
5 minutes air plasma treated bamboo	0.4206	170.6
10 minutes air plasma treated bamboo	0.4503	169
20 minutes air plasma treated bamboo	0.4603	164.2

The thickness of the untreated bamboo fabric was 0.382mm while the thickness of 20 minute air plasma treated sample was 0.46 mm.The thickness of 5 and 10 minutes air plasma treatment bamboo fabrics was 0.42 and 0.45 respectively.

Figure 1-4 illustrate the trends obtained by air plasma treated bamboo samples.

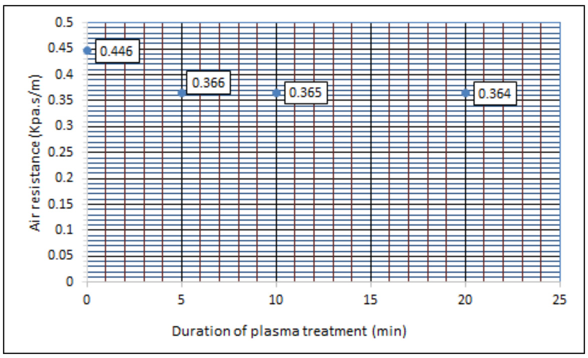

Figure: 1: Air Resistance (R) of untreated and air plasma treated bamboo fabrics.

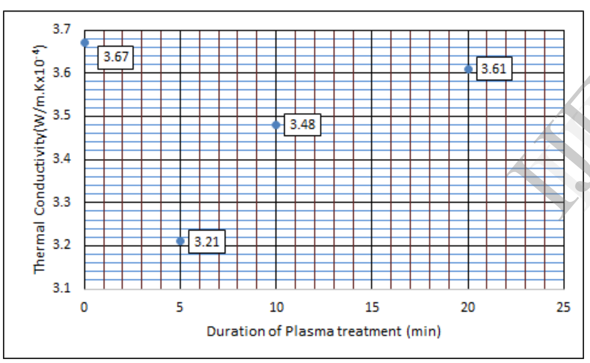

Figure 2: Thermal conductivity (K) of untreated and air plasma treated bamboo fabrics

The air resistance of untreated pure bamboo knitted fabric was found to be 0.446 KPa.s/m and the lowest air resistance of 0.364 KPa.s/m was in case of 20 minutes air plasma treated sample. The air resistance of 5 and 10 minutes air plasma treated samples was 0.366 KPa.s/m and 0.365 KPa.s/m respectively.

The highest thermal conductivity of 3.67 W/cm ^{0}Kx10^{-4} was in case of untreated bamboo and the lowest of 3.21 W/cm ^{0}Kx10^{-4}, in case of 5 minutes air plasma treated pure bamboo fabric. The thermal conductivity of 10 and 20 minutes air plasma treated sample was 3.48 W/cm ^{0}Kx10^{-4}and 3.61 W/cm ^{0}Kx10^{-4} respectively

The thermal resistance of untreated bamboo sample was 10.41 (m^2 K/W)10^{-3} while, the highest thermal resistance of 13.10 (m^2 K/W)10^{-3} was in case of 5 minutes air plasma treated fabric. The thermal resistance of 10 and 20 minutes air plasma treated sample was 12.94(m^2 K/W)10^{-3} and 12.75 (m^2 K/W)10^{-3} respectively.

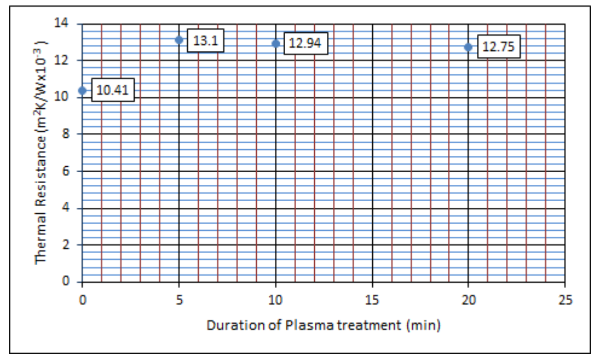

Figure 3: Thermal resistance of untreated and air plasma treated bamboo fabrics

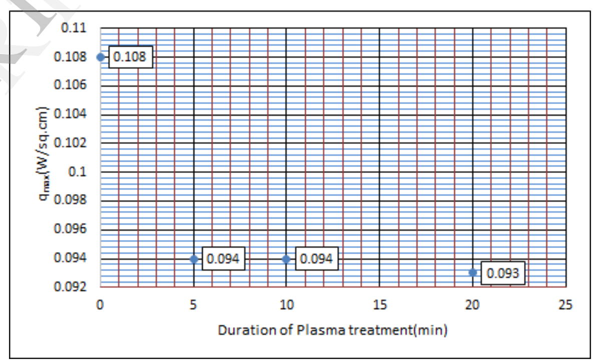

Figure 4: q_{max} of untreated and air plasma treated bamboo fabrics.

Similarly, the highest and lowest q_{max} of 0.108 W/sq.cm and 0.093 W/sq.cm was in case of untreated control and 5 minutes air plasma treated bamboo fabric respectively. While the q_{max} of 10 and 20 minute air plasma treated sample was 0.094 W/sq.cm.

From the above results it is observed that as the intensity of treatment increases, the air resistance decreases. Thermal conductivity and q_{max} follow the same trend. The thermal resistance of air plasma treated samples is greater than the untreated bamboo knitted fabric. A lower value of air resistance indicates good air permeability and good comfort .The value of q_{max} indicates the heat lost per unit area under the condition of 10^0C difference. A low value indicates better warmth retention properties .A drop of 13% in q_{max} is apparent in the air plasma treated fabrics. Also, a drop of 12.5 % is indicated in thermal conductivity following the air plasma treatment. Lower thermal conductivity is due to the bulky nature of the fabric which is an insulating medium .It means that the fabric entrapped air in the loose fibrous spaces and did not allow heat of the inner layer to be transmitted to the outer layer. Similar findings were observed for cotton –acrylic bulked yarn fabrics. (8)

Thermal resistance values of air plasma treated bamboo fabrics are higher than that of the control indicating that the resistance to heat has increased. Thus, the thermal resistance of pure bamboo knitted fabric is improved by air plasma treatment .While a larger value of air resistance indicates poorer air permeability, it indicates a good performance for thermal resistance. This is consistent with the findings of Kan and Karahan (9, 10)

4. Conclusion

Plasma treatment is feasible and its treatment in respect of bamboo knitted fabric has led to improved thermal resistance, air permeability and warmth. Modern consumers demand functional qualities like air permeability and thermal resistance from textile products they purchase. Fabrics can be styled in a wide range to possess comfort properties to meet consumer needs. Ecological concern and emphasis on biodiversity has led to this research on air plasma treatment for bamboo knitted fabrics. This treatment to bamboo can be exploited to produce functional textiles.

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