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THE EFFECT OF LOOP LENGTH AND YARN LINEAR DENSITY ON THE THERMAL PROPERTIES OF BAMBOO KNITTED FABRIC

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Abstract:

In this work, the thermal comfort properties of bamboo knitted fabrics have been studied in relation to loop length and yarn linear density. The objective was to determine the influence of fabric factors such as loop length and the constituent yarn linear density on the fabric properties such as air permeability, thermal conductivity, thermal resistance and relative water vapour permeability. Yarns with linear densities of 20^s Ne, 25^s Ne, 30^s Ne with the same twist levels were used to construct the fabrics of single jersey structure with loop lengths of 2.7 mm, 2.7 mm and 3.1 mm. The anticipated increase in air permeability and relative water-vapour permeability with a decrease in yarn linear density and increase in loop length was observed. In general, the thermal conductivity and thermal resistance tended to increase with the constituent yarn linear density but decreased with an increase in loop length.

Key words:

Thermal comfort, yarn linear density, air-permeability, water-vapour permeability, thermal conductivity, thermal resistance.

Introduction

One of the most important aspects of clothing is comfort. Properties like thermal resistance, air permeability, water vapour permeability and liquid water permeability are critical for the thermal comfort of a clothed body. Comfort plays a vital role in the selection of apparel. It is considered as a fundamental property when a clothing product is evaluated. The comfort provided by clothing depends on several factors. One of them is thermal comfort, other factors include softness, flexibility, moisture diffusion, etc. The thermal comfort properties of textile materials have come into sharp focus in the textile research work of recent times. Properties like thermal resistance, thermal conductivity and thermal absorptivity are influenced by fabric properties like structure, density, humidity, material type and properties of fibres, type of weave, surface treatment, finish and compressibility, air permeability, surrounding temperature and the like. Thermal comfort properties of textile fabrics are actually influenced by the gamut of fibre, yarn and fabric properties. Fibre type, spinning technology, yarn linear density, yarn twist, yarn hairiness, fabric thickness, fabric cover factor, fabric porosity and finish are major factors that determine the comfort properties of fabrics [1].

The last few years have witnessed a growing interest in knitted fabrics due to their simple production techniques, low cost, high levels of clothing comfort and wide product range. Knitting is a process of fabric formation that involves the inter-looping of yarn in a series of connected loops by means of needles. Knitted fabrics are known to possess excellent comfort properties. They not only allow for stretching and ease of movement, but they also have good handling characteristics and facilitate the easy transmission of water vapour from the body. These attributes make knitted fabrics the commonly preferred choice for sportswear, casual wear and underwear. Knitted structures offer several advantages. Physically, they present properties of comfort such as high stretch and elasticity, a snugness of fit to body shape, they are soft and pleasing to touch, offer a feeling of freshness and the like. Knitted fabrics have therefore long been preferred as fabrics in many kinds of clothing. Efforts have been made to make knitted fabrics more comfortable by incorporating different fibres, altering yarn parameters, like twist, bulk, count, and finishing treatments, and knitting factors, like stitch length, CPI, WPI and fabric weight, and by adopting new or different finishes [2].

In today's context, naturally renewable resources are increasingly being sought owing to man's commitment to protect nature. Chemical processes are being devised to produce new biodegradable materials. Such materials can successfully replace or improve the existing artificial or natural materials. Bamboo fibre is a regenerated cellulose fibre, of relatively recent origin, produced from the bamboo plant. Bamboo is an important forest biomass resource [3]. Bamboo textile products have a host of incredible properties. It is breathable, cool and extremely soft; it has a pleasant lustre, it rapidly absorbs water and is antibacterial. Yarns of bamboo fibre provide the desirable properties of high absorbency, antimicrobial behaviour and result in a soft feel in textiles and made ups [4]. It is also very hygroscopic, absorbing more water than other conventional fibres such as cotton and polyester. The most prominent attribute of bamboo material is its remarkable ability to breathe and its inherent coolness. The transverse section of bamboo fibre is predominantly filled with innumerable micro-gaps and micro-holes, a characteristic that confers to the fibre enhanced moisture absorption and ventilation. Intimate clothing like sweaters and bathing suits, and household textiles such as blankets and towels are increasingly being made from bamboo material. Bamboo-fibre clothing products display good water absorption and are comfortable, they have a pleasing lustre and are bright in colour [5].

Extensive research has been carried out to investigate the thermal comfort behaviour of knitted fabrics [3-7]. Oglakcioglu and Marmarali [8] studied the thermal properties of cotton and polyester basic knitted structures and found that each knitted structure tends to show quite different thermal comfort properties. Anand and Rebenciuc [9] concluded that fabric structure and stitch density influence thermal resistance, thermal absorptivity and relative water vapour permeability properties. Ozdil et al. [10] found that while the thermal resistance values decrease the water vapour permeability values increase with respect to yarn twist and yarn count. Gun et al. [11] studied the properties of fabrics made from 50/50 bamboo/cotton yarns and compared them with fabrics made from 50/50 viscose/cotton and 50/50 modal/cotton yarns. The study compared the weight per unit area, thickness, bursting strength, air permeability and pilling of the fabrics, and it was found that fabric weight, thickness and air permeability was independent of fibre type.

This paper investigated the influence of different loop lengths and different yarn linear densities in 100% bamboo knitted fabric on the thermal comfort properties of the fabrics. With this aim in mind, single jersey structures were produced with yarns of three different linear densities and with three different loop lengths in the fabric, and their thermal comfort properties were evaluated and analysed.

Materials and Methods

Preparation of fabric samples

Single jersey fabric was produced from 100% bamboo yarns of count Ne 20, 25 and 30, possessing the same twist coefficient ($\alpha e = 3.6$). Table 1 lists the properties of the bamboo fibre used. The fabrics were produced in a Meyer and Cie knitting machine of the following details: Single jersey machine, model MV4, gauge 24 GG, diameter 23", speed 30 rpm, feeders 74 and number of needles 1728. The knitting-room atmosphere had a humidity of 65% and a temperature of 30 ± 2°C. Samples were produced with three different loop-length values of 2.7, 2.7 and 3.1 mm. The knitting process was achieved with constant machine settings and the samples were kept in a standard atmosphere for 24 hours to allow for relaxation and conditioning.

Table 1. Properties of the bamboo fibre.

Bamboo Fibre Properties	
Fibre length, mm	36
Fibre fineness, dtex	1.52
Tenacity, cN/tex	19.87

Evaluation of fabric properties

Structural properties like weight (mass per unit area) and thickness were evaluated. Thermal comfort properties, namely thermal conductivity, thermal resistance, water vapour permeability and air permeability, were also evaluated. The Alambeta instrument was used to measure thermal conductivity, fabric thickness and thermal resistance; water vapour permeability was measured on a Permetest instrument working on the simulated skin principle as recommended in ISO 11092; fabric air permeability was measured according to TS 391 EN ISO 9237 using Tester FX3300. All measurements were performed under standard atmospheric conditions.

Results and Discussion

The fabric properties are given in Table 2.

Air Permeability

The air permeability of the fabrics is depicted in Figure 1. It can be seen that the fabric composed of 30s Ne yarn and with 3.1 mm loop length is the most permeable fabric. The yarn fineness in combination with the large loop length results, as expected, in an open structure. The obvious decrease in fabric thickness and weight may also be clearly seen in Table 2.

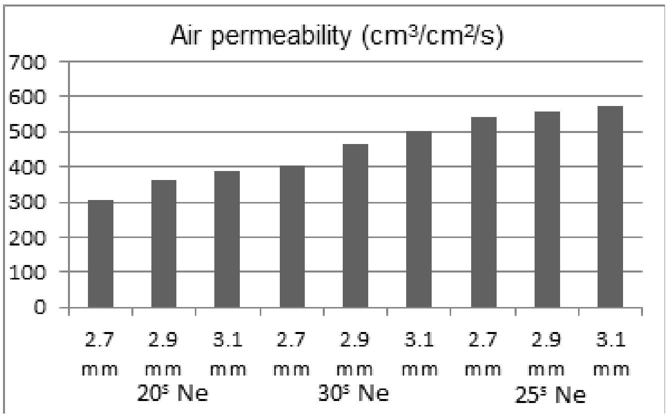

Figure 1. Influence of loop length and linear density on air permeability.

The results show that fabric thickness has a significant effect on the air permeability values of the bamboo fabric, since air permeability tended to increase as the thickness decreased, irrespective of the yarn's linear density and loop length. The lower thickness and mass per square metre also facilitated the passage of air through the fabric. The lower hairiness of

Table 2. Effect of loop length and constituent yarn count on the thermal properties of the fabrics.

Count	Loop length (mm)	Fabric thickness (mm)	Weight in unit area, (g/m^2)	Air permeability (cm^3/cm^2/s)	Relative water vapour permeability (%)	Thermal conductivity (W/mK x 10^{-3})	Thermal resistance (m^{2}K/W x 10^{-3})
20^s Ne	2.7	0.598	176	304	43.01	42.22	18.44
	2.9	0. 572	149	364	42.05	41.13	17.99
	3.1	0.563	128	389	40.44	40.77	17.03
25^s Ne	2.7	0.552	110	402	46.04	42.94	18.32
	2.9	0.542	101	467	44.97	41.87	17.74
	3.1	0.529	97	499	42.33	40.02	17.01
30^s Ne	2.7	0.540	94	542	49.28	42.1	16.78
	2.9	0.528	85	558	48.04	40.1	16.35
	3.1	0.519	80	574	46.68	38.1	16.05

the bamboo blended yarns may be another contributing factor towards the improved air permeability [3]. Fabrics made from finer yarns consistently show higher air permeability. The mass per square metre and thickness of the fabrics made from the finer yarns are lower. All these factors contribute towards the higher air permeability.

Thermal conductivity

It is observed from Figure 2 that as the linear density and loop length of the bamboo fibre increases the thermal conductivity of the knitted fabrics reduces. For the same loop length, finer yarns show lower thermal conductivity. Thermal conductivity is calculated using the following expression.

$$\lambda(\mathrm{W}m^{-1}K^{-1}) = \frac{Qh}{A\Delta Tt}$$

Where: Q is the amount of conducted heat (J); A is the area through which the heat is conducted (m^2); t is the time of conductivity (s); ΔT is the drop in temperature (K); and h is the fabric thickness (m).

The amount of fibre per unit area increases and the amount of air layer decreases as the weight increases. As well-known, thermal conductivity values of fibres are higher than the thermal conductivity of entrapped air. The lower thermal conductivity of fabrics made from the finer counts could be ascribed to the higher porosity value of the fabrics made from finer yarns [3].

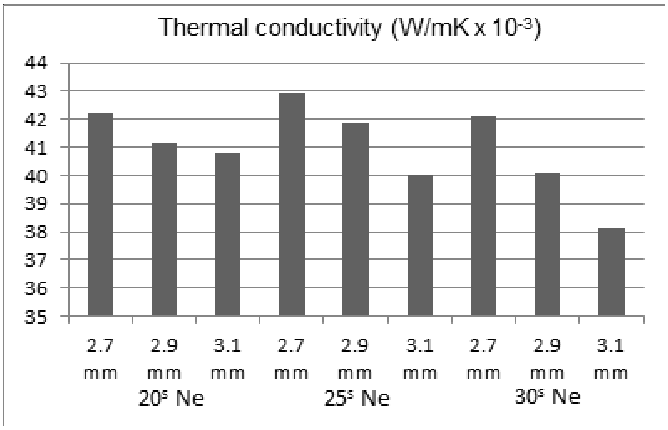

Figure 2. Influence of loop length and linear density on thermal conductivity.

Thermal resistance

As can be seen from Table 2, as the fabric thickness decreases the thermal resistance values decrease. This situation might be explained by the fabric thickness. The fabric thickness value is significantly lower in the 3.1 loop length with 30sNec linear density (Figure 3). Therefore with the decrease in fabric thickness, the thermal resistance will decrease as is given in the following equation:

$$\mathrm{R}(m^2kW^{-1}) = \frac{h(m)}{\lambda(\mathrm{W}m^{-1}K^{-1})}$$

where: h - thickness (m), λ - thermal conductivity (W/mK).

Relative water vapour permeability

Figure 4 illustrates the values of water vapour permeability with respect to loop length and different linear density. According

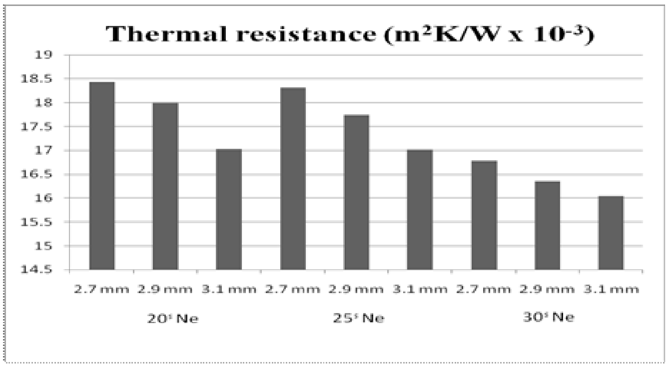

Figure 3. Influence of loop length and linear density on thermal resistance.

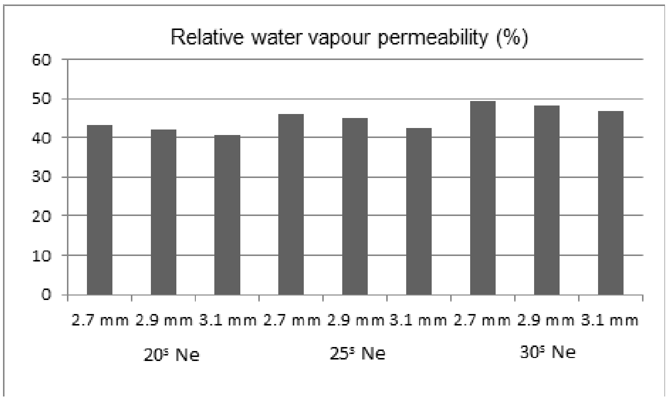

Figure 4. Influence of loop length and linear density on relative water vapour permeability.

to the results, there is no significant difference between the relative water vapour permeability values of bamboo fabrics. The water vapour permeability is highly dependent on the macro-porous structure of the constituent fibres. According to the results, as the linear density of bamboo fibre increases, the water vapour permeability increases. The water vapour permeability is higher for fabrics made from finer yarns. The higher water vapour permeability of bamboo fabrics can be attributed to the lower values of mass per square metre and thickness, which facilitate the easy passage of water vapour through the fabrics.

Conclusion

In this study, the thermal properties of single jersey fabrics knitted with 20 Ne, 25 Ne and 30 Ne 100% bamboo yarns with different loop lengths were investigated. The increase in linear density and loop length in the fabric affected the thermal comfort properties. The thermal resistance and thermal conductivity values of these fabrics were compared and it was found that as the yarn gets finer the thermal resistance and thermal conductivity decrease. The water vapour permeability and air permeability shows concomitant increases as the linear density and loop length increases.

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