International Journal of Thermal Sciences 85 (2014) 40–46

Contents lists available at ScienceDirect

International Journal of Thermal Sciences

journal homepage: www.elsevier.com/locate/ijts

Statistical models for predicting the thermal resistance of polyester/cotton blended interlock knitted fabrics

Ali Afzal [a,*], Tanveer Hussain [b], Muhammad Mohsin [c], Abher Rasheed [d], Sheraz Ahmad [a]

[a] Department of Materials and Testing, National Textile University, Sheikhupura Road, Faisalabad 37610, Pakistan
[b] Department of Textile Processing, National Textile University, Faisalabad, Pakistan
[c] Department of Textile Engineering, University of Engineering and Technology, Faisalabad, Pakistan
[d] Department of Garment Manufacturing, National Textile University, Faisalabad, Pakistan

ARTICLE INFO

Article history:
Received 14 January 2014
Received in revised form
12 June 2014
Accepted 12 June 2014
Available online 11 July 2014

Keywords:
Statistical model
Knitted fabric
Polyester
Cotton
Thermal resistance
Comfort

ABSTRACT

Thermal resistance is one of the key aspects of thermo-physiological comfort of knitted clothes. The aim of this study was to develop statistical models for predicting the thermal resistance of polyester/cotton blended interlock knitted fabrics. Fabric samples were knitted at three different tightness levels, with yarns of three different linear densities each with three different polyester/cotton blend ratios. Based on thermal resistance results of the knitted samples, three different statistical models were developed comprising different input variables as predictors. The validation results showed that the thermal resistance of polyester/cotton interlock fabrics could be predicted using the developed statistical models with an average percentage error of 4–8%. It could be concluded from the sensitivity analysis that the most influential factor affecting the thermal resistance was fabric stitch length, followed by yarn specific heat and fabric areal density.

1. Introduction

The primary needs of human being include textiles as a major commodity. It comprises all the items used to protect the body from external environment. Textiles are used to cover as well as protect the body. When the external climatic conditions outmatch the body requirements, some specific fabrics are used to provide the optimum body demands for better comfort feelings. Comfort can be defined as "a pleasant state of psychological, physiological and physical harmony between a human being and the environment" [1]. Clothing plays a vital role in thermoregulatory process as it alters heat loss from the skin and also changes the moisture loss from skin [2].

Different researchers investigated the effect of fibre, yarn and fabric properties on the thermal comfort performance of different fabrics [3–8]. Cimilli et al. [3] investigated the effect of material type used for thermal comfort properties of plain jersey socks by modal, micro modal, bamboo, soybean, chitosan, viscose and cotton fibres. The results obtained suggested that there was statistical significant difference between the fibre type and the thermal resistance of fabrics. Schneider et al. [4] investigated the thermal conductivity of different fibres under moist conditions. Wan et al. [5], Schacher et al. [6] and Ramakrishnan et al. [7] explained the effect of fibre fineness on thermal resistance of fabrics. According to them, the micro-denier fibre gives low thermal conductivity and higher thermal resistance. Oglakcioglu et al. [9] studied the thermal comfort properties of 1 × 1 rib knit fabrics with different fibre blend ratios of cotton and angora fibre.

Pac et al. [10] studied the effect of fibre morphology, yarn and fabric structure on thermal comfort properties of fabric. Ozdil et al. [11] investigated the effect of different yarn parameters on thermal comfort of 1 × 1 rib knitted fabric. They explained that by decreasing count and yarn twist, the thermal resistance increases while moisture vapour permeability decreases. Majumdar et al. [12] found that by the use of finer yarn for knitted fabric formation of plain, rib and interlock structures by blend of bamboo and cotton fibres, the thermal conductivity of fabric reduces.

Khoddami et al. [13] explained that by the use of hollow fibre, the fabric thickness increases which increases the thermal resistance of the fabric. Greyson [14], Havenith [15] and [16] presented their findings that heat resistance increases by increasing the air entrapped in the fabric as well as fabric thickness. Ucar and Yilmaz [17] have worked on thermal insulation properties of different rib structures made from cotton. Oglakcioglu and Marmarali [18] have

* Corresponding author. Tel.: +92 322 407 5177; fax: +92 41 923 0098.
E-mail address: aliafzalch89@gmail.com (A. Afzal).

http://dx.doi.org/10.1016/j.ijthermalsci.2014.06.016
1290-0729/

Nomenclature

Tt	Yarn linear density, tex
C	Specific heat of yarn, J g^{-1} K^{-1}
l	Stitch length, mm
t	Fabric thickness, mm
m	Fabric areal density, g m^{-2}
R_{ct}	Fabric thermal resistance, m^2 K mW^{-1} (m^2 K W^{-1} $\times 10^3$)

studied the thermal comfort properties of different knitting structures. The structures under considerations were single jersey, interlock and 1 × 1 rib constructions with polyester and cotton fibres. They explained that interlock structure in both fibre types provide the higher thermal resistance due to more thickness of fabric.

It is observed that no study has been carried out on the influence of fibre, yarn and fabric properties on thermal resistance of the interlock knitted fabrics. The objective of this study is to determine the effect of fibre type, composition, yarn and fabric properties on thermal resistance of the interlock knitted fabrics and statistically model them for prediction purposes in future.

2. Experimental

2.1. Yarn preparation

Carded ring spun yarns of varying cotton/polyester blend ratios in range from 60/40 to 35/65 were used with linear densities 36.9 tex (Ne 16/1), 29.5 tex (Ne 20/1) and 24.6 tex (Ne 24/1) for knitting interlock knitted fabric samples. The twist multipliers for each yarn linear density of different blend ratios were kept the same, i.e., 3.43, 3.45 and 3.47 for 36.9 tex, 29.5 tex and 24.6 tex respectively. The properties of the yarns used in this study are given in Table 1.

The raw materials and spinning machine settings were kept the same during the production of all the yarns. No extra treatment was applied to these yarns before knitting them into fabric samples.

2.2. Fabric preparation

The as-spun yarns were used to knit the fabric samples in double jersey interlock knit fabric structure with varying tightness levels to achieve different fabric areal densities. The three tightness levels were selected (slack, medium and tight) constituting stitch lengths of 3.2 ± 0.1 mm, 3.5 ± 0.1 mm and 4.1 ± 0.1 mm. The change in fabric structures with different tightness factors is evident from Fig. 1. The samples were fabricated on an 18 gauge Jacquard circular interlock machine with positive yarn feeding system, 1728 total needle count and 30 inches diameter. The tight fabric samples for 36.9 tex yarn could not be knitted on the selected machine due to knitting machine limits and therefore excluded from the current study. A total number of 24 different fabric samples were made for this study. The fabric constructions are given in Table 2.

2.3. Fabric processing

The knitted fabric samples were semi bleached at 110 °C using hydrogen peroxide 50% (0.5759 g/L), stabilizing agents (Terminox ultra 50-L, 0.0384 g/L), caustic soda (5 g/L) and wetting agent (Viscavin FTC, 0.1920 g/L) for 10 min, followed by rinsing.

The dyeing of polyester fibre content was followed through disperse dye, Navy blue Eco 300% (by Techron) (0.0762 g/L), Terasil yellow W-6GS (by Terasil) (0.0549 g/L) and Yellow Brown XF (by Dianix) (0.1755 g/L), at 130 °C for 35 min in the presence of levelling agent (Levenol V-505N, 0.2688 g/L). The fabric samples were reduction cleared followed by polyester dyeing at 95 °C for 25 min, in the presence of a wetting agent, sodium hydrosulphite and caustic soda. The cotton fibre content was dyed with reactive dyes Synozol Navy blue KBF (0.3017 g/L), Drimagen E3R (0.384 g/L), Synozol Red K 3BS (0.0987 g/L) and Everzol Yellow 3RS H/C (0.5485 g/L) at 60 °C for 30 min in the presence of soda ash (7.679 g/L)), anti-crease (Rucoline Jes, 0.192 g/L) and sequestrant (Alkaquest AM-700, 0.1536 g/L), followed by washing-off at 95 °C for 10 min with detergent (Cotoblanc STG-L, 0.384 g/L), followed by rinsing and neutralization at 50 °C for 10 min with acetic acid (0.95 g/L). After dyeing, the knitted fabric samples were dried and stabilized in a compactor at speed of 22 m/min and 110 °C temperature.

2.4. Fabric testing

The knitted fabric samples were pre-conditioned at a temperature of 47 °C and relative humidity of 20% for four hours in hot-air oven followed by conditioning in standard atmosphere according to ASTM D 1776 [19] at temperature of 20 ± 2 °C and relative humidity of 65 ± 2%. The stitch length of the fabric was calculated from loop length of 150 stitches. The thermal resistance testing was performed on an SDL Atlas M259B sweating guarded hotplate [20] according to ISO 11092:1993 [21]. This instrument is also known as skin model used to simulate the mass and heat transfer processes which occur next to the skin surface. The samples were placed on the thermal plate enclosed in a controlled environment. The samples were tested in standard conditions for the thermal resistance which were 20 ± 0.1 °C air temperature, 65 ± 3% R.H, 35 ± 0.1 °C

Table 1
Properties of the yarns used in this study.

Parameters	Mean values								
	36.9 tex			29.5 tex			24.6 tex		
PES:CO (%)	40:60	52:48	65:35	40:60	52:48	65:35	40:60	52:48	65:35
Tt_a (tex)	36.45	36.41	36.57	29.23	29.19	29.25	24.40	24.42	24.39
U %	9.53	9.11	8.74	10.18	9.65	9.39	10.87	10.24	9.88
N_{tn} (−50%)	0	0	0	0	0	0	0	0	0
N_{tk} (+50%)	35	34	20	65	47	42	108	92	88
N_n (+200%)	57	45	38	92	76	72	181	161	147
H	8.10	7.76	7.65	7.81	7.26	7.02	7.19	7.01	6.78
Ta (cN tex^{-1})	18.72	21.49	26.34	18.04	20.60	25.71	17.27	20.35	25.68
ε_b (%)	7.28	8.94	10.09	6.42	7.57	8.94	5.81	7.41	8.66
Tm	544	544	543	611	611	610	672	672	672

PES – polyester, CO – cotton, Tt_a – actual yarn count, U – evenness, N_{tn} – number of thin places on 1000 m, N_{tk} – number of thick places on 1000 m, N_n – number of neps on 1000 m, H – hairiness, Ta – tenacity, ε_b – breaking elongation, Tm – number of twists per 1 m.