Effect of Ultrasonic Laundering on Thermophysiological Properties of Knitted Fabrics

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Abstract: The paper focuses on the application of ultrasonic energy in textile laundering. In recent years, there has been an increasing interest in ultrasonic energy application in textile industry; however, the effect of ultrasonic laundering on the thermophysiological properties of knitted fabrics has not been studied yet. This study was conducted by using polylactic acid (PLA), cotton, polyethylene terephthalate (PET), and poly acrylic (PAC) fibres containing yarns and their blends. Knitted fabrics, single pique, were made from these yarns by using weft knitting machine. The fabrics were washed ten times for 15 and 60 minutes under 40 °C by using conventional and ultrasonic washing methods. The main aim was to determine the effect of washing methods on the thermophysiological properties of the fabrics. It is also aimed to analyse and evaluate the thermophysiological properties of the PLA fabrics. The incorporation of 100 % PLA and cotton/PLA yarns into single pique knitted fabrics has been attempted to produce for the first time and studied their thermal comfort properties. The results show that the washing processes have a critical importance for the tested fabrics in terms of thermal conductivity, thermal resistance, thermal absorptivity, water vapour permeability, and heat loss. It has been also demonstrated that the fabric cleaning by using ultrasonic method enhanced the properties of tested fabrics such as thermal conductivity and % recovery. It was also noted that 15 minutes ultrasonically washed fabrics had significantly lower thermal resistance as compared to conventionally washed fabrics.

Keywords: Thermophysiological properties, Ultrasonic energy, Laundering, Poly (lactic acid) (PLA), Knitted fabrics

Introduction

Throughout history there have been associations between polymers and textile fibres. This intimate relationship between the two fields is revealed when changes occurring in one ultimately, have some impact on the other. Poly (lactic acid) fibre is one of the fastest growing biodegradable fibre types in the current trends where researchers are actively trying to introduce novel application areas as an alternative source to synthetic fibres. PLA is linear aliphatic thermoplastic polyester derived from 100 % renewable sources such as corn, not like conventional synthetic polymers which rely on reserves of oil and gas. The monomer used to manufacture PLA is obtained from renewable crops and compostable. Research on textile applications of PLA polymer has recently been reported by several researchers. It has been shown that the PLA fibre has noteworthy commercial potential as textile fibre due to its superior physical and structure properties. Both filament and spun yarns from PLA fibres have been commercialised [1,2]. Although there are some emerging fibres, the apparel sector is still dominated by two fibres, cotton and polyethylene terephthalate (PET). Poly acrylic fibre (PAC) is the third important type of synthetic fibres and widely used to produce clothing [3].

The cleaning process of laundry is synergistic actions between the mechanical energy, chemical energy, thermal energy and time. Textile substrates are subjected to industrial and domestic laundering. Conventional laundering requires a large amount of water and chemical consumption. In recent years, there has been an increasing amount of literature on ultrasonic washing [4-8]. It has been demonstrated that the ultrasonic washing method has many advantages including superior cleaning properties, reduction in process time, energy and chemical and also ultrasonic agitation produces less fibre migrations as compared to the conventional washing method [4-7]. Ultrasonic energy generates millions of bubbles or cavities into the liquid with very high frequency which constantly strike at the target material surface and as a result, removes the dirt off textile fibres. One of the most important parameters in the ultrasound mechanism is the power of ultrasonic cavitations in liquids [4-8,26].

Thermophysiological comfort has been described as the ability of garment to keep the wearer dry whilst maintaining body temperature even when the wearer is subject to varying surrounding temperatures and humidity. The comfort has been defined by many; the most popular definitions are “the absence of displeasure or discomfort” and “a neutral state compared to the more active state of pleasure”. The comforts of the garment mainly depend on its thermal properties, water vapour permeability and air permeability [9,10]. The thermophysiological comfort of fabrics depend on fibre types (natural, synthetic), yarn production method (ring, open-end) and properties (count, twist), fabric structures (woven, knitted, nonwoven) and physical features (thickness, warp-welt number) and also textile finishing process (bleaching, dyeing) [11-13].
The main objective of this research is to determine the effect of washing methods, conventional and ultrasonic, on thermo physiological properties of knitted fabrics. It is also aimed to compare PLA fibre fabric with cotton, PET, PAC fibre fabrics and their blends. The fabrics were produced with 100 % PLA, 100 % cotton, 100 % PET, 100 % PAC, 50/50 % cotton/PLA and 50/50 % cotton/PET yarns. Unwashed (control), ultrasonically and conventionally washed fabrics were tested and analysed in terms of thermo physiological (Alambeta and Permetest instruments) properties including thermal conductivity, thermal resistance, thermal absorptivity, water vapour permeability, and heat loss. One-way analysis of variance (ANOVA) was used to determine if the mean value for each fabric was different from the mean value for the group as a whole, at a significance of \( p < 0.05 \).

Experimental

Materials

The study was conducted on PLA, cotton, PET, PAC fibre yarns and also cotton/PLA and cotton/PET fibre blended yarns. The unbleached short-staple ring-spin yarns were procured from the UK market and the yarns counts were determined in accordance with TS 244 EN ISO 2060: 1999. The counts of the yarns were found to be Ne 30/2 ±2. A standard powder type commercial detergent was employed with a 1 g/l ratio. The brand name of detergent used in this study is DAZ (manufactured by Procter Gamble Ltd) and the ingredients of the detergent are;

- 5-15 % anionic surfactants which oxygen-based bleaching agents;
- <5 % non-ionic surfactants, phosphonates, polycarboxylates, zeolites;
- Optical brighteners, enzymes, perfumes, butylphenyl methylpropional, hexyl cinnamal, geraniol.

Manufacturing of Knitted Fabrics

Prior to the knitting process, the yarns were conditioned for 48 hours in 65±2 % relative humidity and 20±2°C temperature. The fabrics were produced by using a laboratory-type of weft circular knitting machine. Single pique (commercially known as Lacoste®) structures were knitted. The single pique structure is shown in Figure 1 and the technical details of the pique fabrics is explained elsewhere [14]. Pique fabric is most commonly used for the designing and fabrication of summer clothes such as t-shirts.

Washing Processes

The knitted fabric specimens were ultrasonically and conventionally washed at 40°C degree washing temperature with two different washing times, 15 and 60 minutes. For the ultrasonic washing method, the ultrasonic bath (Branson 2200, 220 volt and 205 watt) was employed using 20 kHz frequency. The conventional washing was performed using Roaches model-MB lab type HT dyeing machine. The specimen sizes were prepared 30×30 cm. A 1 g of detergent and 1 l of deionised water was pre-prepared as a mixture and poured into the ultrasonic bath for each specimen. The specimens were washed using both ultrasonic and conventional methods and each fabric washing was repeated 10 times and after the washing process, the specimens were rinsed three times in deionised water. Finally, the specimens were left to dry at room temperature for 24 hours [8].

Thermophysiological Comfort

All the fabrics were preconditioned before testing for 24 hours in 65±2 % relative humidity and 20±2°C temperature. Fabric weight (gm²) and thickness (mm) were determined in accordance with BS EN 12127:1998 and ASTM D1777 – 96(2011)e1, respectively. The thermophysiological properties of the knitted fabrics were determined by using the Alambeta and Permetest instruments (Sensora Instruments, Czech Republic). The Alambeta instrument provides values for thermal conductivity, thermal resistance (insulation), thermal absorptivity (warmth-to-touch), fabric thickness and thermal diffusivity. The test instrument was used to analyse the transient and steady state thermophysical properties of the fabrics. The specimens of 20×20 cm were prepared and placed in between two plates. With the two plates the heat flow through the fabric due to the different temperature of the bottom measuring plate (at ambient temperature) and the top measuring plate which is heated to 40°C. The thermal absorptivity of the textile structure is a measure of the amount of heat conducted away from structure’s surface per unit time [15-17]. The test was performed on the dry and wet states of the nonwoven fabrics which were wetted with 0.2 m/ of distilled water in the centre of the fabrics and allowed 4 minutes before retesting, in order to allow for the thermal recovery of the fabric. All tests were carried out on both faces of each specimen and the mean values calculated.

There are three fundamental ways by which heat energy can be transferred through the porous materials such as knitted fabrics conduction, convection, and radiation. Depending on the fibre’s specific thermal conductivities, the size and configuration of the space between the fibres in the woven specimen, heat transfer mechanisms - conductive, radiative, and convective - will provide very different contributions to the overall heat transfer throughout the specimens. Very complex interactions and contributions of various heat transfer mechanisms in the overall thermal properties of woven fabrics makes the direct instrumental measurement of

![Figure 1. Single pique knit structure [14].](image-url)