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Effect of Fabric Structure and Yarn on Capillary Liquid Flow within Fabrics

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Abstract

The purpose of this study was to investigate the relationship between wicking coefficients of fabrics and yarns. A range of plain fabrics were woven by varying the weave density, yarn count and fibre content. From experiments on the in-plane capillary water flow within these fabrics and the yarns obtained from the corresponding fabric, the wicking coefficients of fabrics and yarns were determined. The wicking coefficient was higher for lower weave density because of the effective capillary radius. The results for four kinds of yarns showed that the 100% cotton yarn and cotton fabric had the highest wicking rate. Based on scanning electron microscope observation of cross section and longitudinal section of yarns, we discussed the effects of inter-fibre space and yarn twist on the wicking influence factor and found that the wicking rate is higher for larger inter-fibre space and yarns with fewer twists.

Keywords: Wicking; Capillary Liquid Flow; Fabric; Yarn

1 Introduction

Capillary rise in fibrous structures is frequently observed in many fields, such as wetting and wicking in textiles, paper and porous media [1-5]. Wetting is the displacement of a solid-air interface with a solid-liquid interface. In a broader sense, the term “wetting” is used to describe the replacement of a solid-liquid or liquid-air interface with a liquid-liquid interface, and a solid-air interface with a solid-solid interface. The transport of a liquid into a fibrous assembly, such as yarn or fabric, may be caused by external forces or by capillary forces only. Spontaneous transport of liquid driven into a porous system by capillary forces is termed “wicking”. Because capillary forces are caused by wetting, wicking is a result of spontaneous wetting in a capillary system [6].

There are many researches on the wetting and wicking on fabrics. Three major techniques have been used to analyze liquid flow through yarns and fabrics quantitatively. The first is measuring

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the capillary flow of a colored liquid and recording its height versus time [7-13]. The conventional Byreck method is based on this technique. The CCD camera and image analysis techniques are also used to record the height with respect to time. The second technology consists of measuring weight variation with a balance during capillary wicking [14-15]. The last is to set liquid-sensitive sensors regularly along the fabrics or yarns [16-20]. The liquid-sensitive sensors are usually for measuring humidity, electrical capacitance, temperature and so on. In essence, liquid flow within textile structures is typically studied in one of the two ways, either by measuring the liquid front height or by measuring the weight of liquid absorbed as a function of time.

Wicking plays an important role in textile application, especially in the design and use of sports wears and industrial uniforms, as well as in various processes such as dyeing, finishing and filtration. Many researches of wicking phenomenon have been investigated on the use of these techniques. Russell et al. [21] investigated in-plane anisotropic liquid absorption in nonwoven fabrics, using variations in electrical capacitance to monitor changes in the liquid absorbed by a fabric as a function of time. Benltoufa et al. [22] studied the capillary rise in macro and micro pores of a jersey knitting structure. Merve et al. [23] studied the wicking properties of cotton-acrylic yarns and knitted fabrics, and found that the wicking abilities of yarns and fabrics increased with the increase in their acrylic content and with the use of coarse yarns. Perwuelz et al. studied the capillary flow in polyester and polyamide yarns and glass fibres using a technique based on analyzing CCD images taken during the capillary rise of colored liquid in yarns. They found that the kinetics of capillary rise always follow the Washburn equation, but attribute the great dispersion of the experimental results along the yarns to the yarn heterogeneity of the inter-filament space [12]. Yanilmaz et al. investigated the relationship between different knitted structures and some thermophysiological comfort parameters by measuring the wicking height, wicking weight, and transfer wicking ratio [24]. Hsieh [7] discussed wetting and capillary theories and applications of pore structures to the analysis of liquid wetting and transport in capillaries and fibrous materials. He found that for a fibrous material to effectively transport a liquid, the fibres must be easily and thoroughly wetted by the liquid. Moreover, the significance of fibre properties had been demonstrated. Mhetre et al. [25] carried out wicking experiments on a range of cotton and polyester fabrics, which had different yarn sizes, thread spacing, and yarn types. The results showed that the wicking in fabrics was determined by the wicking behavior of the yarn, the thread spacing and the yarn migration rate, which was the ability of liquid to migrate from longitudinal to transverse threads and from transverse back to longitudinal threads.

However, there is little research on predicting the liquid transport property of a fabric from the specifications of the fabric. In this paper, we studied wicking length versus time of different woven fabrics using the thermocouple array technology [19]. We also investigated the influence of fabric structural parameters on wicking behavior, including fibre content, yarn count and weave density.

2 Basic Theory

The kinetics of wicking in textiles is critical in many applications and is often investigated by fitting the experimental data to the well-known Washburn equation [25]. For short time spans, when the effects of gravity are neglected and the extent of liquid flow is significantly less than the maximum equilibrium length, the Washburn equation [4, 26] stated that the capillary water flow rate depended on the rheological properties of the liquid and the geometry of the capillary