Horizontal liquid spreading behaviour of hybrid yarn woven fabric using embedded image analysis principle

D Raja1,a, C V Kouhik1, G Ramakrishnan2, V Ramesh Babu2 & V Subramaniam3
1Department of Fashion Technology, Sona College of Technology, Salem 636 005, India
2Kumaraguru College of Technology, Coimbatore 641 049, India
3Jaya Engineering College, Chennai 602 024, India

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A new technique based on the principle of embedded image processing has been used to measure the horizontal water spread in textile fabric as a function of time. Horizontal water spread areas of different fabrics with different yarn counts are observed for doubled yarn produced from ring, compact and ring/compact combinations. It is found that the doubled yarn count and doubling combinations influence the liquid spread behaviour in the fabric.

Keywords: Comfort, Image processing, In plane wicking, Horizontal wicking, Wetting

Among the most significant factors that affect garment design, especially sportswear, the most important one is the rate at which a garment wicks a liquid. Transverse wicking is a unique phenomenon with respect to the water transfer behaviour of fabrics, since it has no directional effect. However, the precise experimental measurement or the prediction of the liquid spread upon wicking poses challenges. A variety of techniques and methods are used to study experimentally liquid penetration into fabrics. Gillespie1 was among the foremost researchers to make an in-depth study of the spread of liquid drops on filter paper. Unlike filter paper, textile fabrics are not isotropic, so the area formed by a liquid spreading on a textile fabric is seldom a perfect circle. It is therefore more meaningful to measure the area covered by the spreading liquid. Another difficulty with measuring the spreading of the liquids on porous substrates is the speed with which the liquid front moves.

Kissa2 measured the area of spread of a drop of liquid on textile fabric as a function of time. The area of liquid spread was photographed at uniform time intervals with an instant-picture camera. The area depicting the spreading liquid was cut out from the dried photograph and weighed. Lee et al.3 studied horizontal wicking in fabrics by means of a spectrophotometer, to avoid using balances. They determined the liquid weight wicked into the fabric by measuring the difference in colour depth between the wet and dry fabric. Fichet et al.4 developed a method based on the change in electrical resistance of the fabric with its water content. The results obtained by this method depend on spacing of the concentric rings and the accuracy of electrical resistance value. Another instrument, developed by IIT Delhi to measure in-plane wicking of fabrics, works on the siphon principle; water uptake by the fabric is recorded manually with time. Adams et al.6 developed a similar instrument to measure the in-plane flow of fluids in a fibrous network. They used an image analysis technique to obtain the shape and position of a radially advancing fluid front to throw light on the directional permeability in the plane. Morent et al.7 and Perwuelz et al.8 used image analysis instead of an analytical balance to determine the extent of horizontal wicking. The progression of the liquid front during wicking was recorded with a digital camera and an algorithm was used to calculate the area of the fabric wetted by the fluid. In the present work, a technique based on embedded image analysis using a 32-bit digital signal processor has been used to determine the area of water spread in textile fabric with respect to time. This technique has enabled an in-depth study of the water spreading behaviour.

A 24-bit true colour digital camera of 13.1 megapixels with a high-resolution 5-glass optical lens that ensured a sharp and bright image quality was used to study the dynamics of liquid movement on the fabric surface. The camera was also fitted with a facility for automatic brightness adjustment and colour compensation. It was mounted on a stand, equipped with a C-mount and LED light, and connected to a personal computer via its USB port (Fig. 1). It is also compatible with Image-Analysis software capable of recording and processing images of the water spread on fabric.
All the experiments are carried out in a conditioned room at 27°C and 65% relative humidity. The test procedure includes mounting of test specimen on an embroidery frame, such that it is fixed firmly in the frame and at the same time stretch-free. The camera is positioned to focus the fabric where the water-spread behaviour is to be studied. A drop of distilled water, from a nozzle positioned such that its tip is six mm above the surface of the fabric, is allowed to fall on the fabric, care being taken to avoid any undue movement of the nozzle or fabric. About a second before the water is dropped on to the fabric, the camera and the software system are activated to capture a video of the fabric.

The software, equipped with a facility to change the interval time (seconds) between successive image captures, was used to record a specific number of frames per second. As the recording is started approximately a second before the fall of drop on the fabric, the initial water-free image serves as a reference frame for computing the area of water spread in the fabrics. The images (Fig. 2) depict the stages of the spread of water in the fabric.

Calculation of the Area of Water Spread in Fabric

Figure 3 shows a schematic of the image analysing system. The captured videos are transferred and stored in the computer. The videos are converted into individual frames using MATLAB coding and transferred to an embedded kit, Blackfin ADSP-BF532 DSP, via an RS-232 cable. Using a background subtraction algorithm shown in Fig. 4, the processor subtracts the reference frame from the subsequent frames, the resulting output image being the difference in image which is a binary image obtained by thresholding. The area of water spread in the fabric is computed from the number of white pixels in each successive frame.

As the thresholding process could vary depending on the lighting conditions, constant lighting is maintained around the test-specimen. The final calculated areas of water-spread are sent back to the computer for the graph plot by means of the MATLAB software.

Preparation of Sample

Two sets of 40s Ne, 60s Ne and 80s Ne yarns were spun each on conventional ring and Suessen-Elite compact spinning machines. Yarns of same count were doubled in different combinations like ring-yarn/ring-yarn, compact-yarn/ring-yarn and compact-yarn/compact-yarn, on a Jeetex (DRT) doubling machine. Plain woven cotton fabrics were produced on a Sulzer Ruti C Machine. Three sets of fabric were produced from the 2/40s Ne yarn using the three types of doubled yarns, namely ring-yarn/ring-yarn, compact-yarn/compact-yarn, ring-yarn/compact-yarn, maintaining the same ends/cm and picks/cm. Similar sets of fabrics were produced with the 2/60s and 2/80s Ne doubled yarns.
All the fabrics were subjected to typical commercial scouring and bleaching processes under identical conditions. Test specimens (10 cm diameter) of each type of fabric were prepared and allowed to condition in a climatic chamber maintained at 27°C and 65% RH.

Distilled water was used as the wetting liquid to determine the liquid-spread characteristics for each fabric; 10 test specimens were used per fabric type and the average values of the water-spread parameters were recorded for each of them.

**Effect of Doubled Yarn Count on Water Spread in Fabrics**

Figure 5 shows the water-spread areas in the fabrics as a function of time. It is natural to expect the area of water spread in the fabric to increase with time and this is clear from the graphs for all the fabrics. Another observation is that the rate of water absorption is initially high due to a relatively larger amount of water available for absorption. This is obvious from the shape of the curves, which are initially steep up to about 5s of wetting and later on distinctly less steep; there is much less water available for absorption during the later stages of wetting. The radial spread of water in these fabrics is also clearly dependent on the count of the constituent yarns, the fabric composed of the 2/80s Ne yarn showing the maximum area of water spread and that composed of 2/40s Ne the least, at any time during the water spread. This is due to less thickness of finer count...
fabric and less number of air space between the fibres for finer count as compared to the coarser count. Hence, the accumulation of liquid in between the air space is reduced and enhances the spreading of finer count fabrics.

Effect of Doubled Yarn Type on Water Spread in Fabrics

Figure 6 shows respectively the effect of doubled yarn composition in the fabrics on the areas of water spread. It may be observed that for all the three counts of yarn used, the fabrics composed of doubled yarns produced from ring-yarn/ring-yarn combination show the maximum areas of water spread. Fabrics composed of doubled yarn of compact-yarn/compact-yarn combination show the lowest areas of water spread, while those of doubled yarn of ring-yarn/compact-yarn combination show intermediate values. This finding is expected as it is well established that ring-spun yarns have lower packing density and more air space within the yarn structure as compared to compact yarns. The impact of different combinations of yarn on spreading is less as compared to the count of yarn.

The wet area of the fabric is detected by embedded device Blackfin ADSP-BF532 digital signal processor image processing technique. This study shows that the spreading rate increases with increase in count of the yarn and the ring, and ring doubled yarn shows maximum spreading area as compared to other two combinations.

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References