Capillary rise in woven fabrics by electrical principle

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A technique based on electrical open and closed circuit principle has been used to measure the vertical capillary height of the liquid in the fabric as the function of time. Vertical wicking height for different types of fabrics with different yarn counts and fabric densities is observed. It is found that the yarn count and fabric density influence the wicking behavior of the fabrics.

Keywords: Comfort, Electrical principle, Wetting, Wicking

Clothing comfort is very much influenced by the liquid transport properties of textiles. The weft and warp yarns in textiles fabrics generally have an intricate structure comprising two different directions.

The liquid wets the fibre surfaces and gets transported through the inter-fibre spaces. The manner in which a liquid wicks through the pores depends on capillary forces. A variety of techniques and methods are used to study experimentally the liquid penetration into fabrics. The first technique used consists of observing and measuring the liquid rise in textile structure by using a colored liquid. Perwuelz et al. developed another method based on the analysis of CCD images taken during the capillary rise of colored liquid in yarn structure.

The results obtained by image analysis technique depend on the resolution, the quality of images and the light source. Furthermore, the kinetics of water can be more important than those of dye, and the diffusion coefficient found by this method presents the value of the diffusion coefficient of the dye, not that of the liquid. Moreover, the addition of the dye changes the surface tension of the liquid and modifies its velocity. Hsieh et al. and Pezron in their studies used a balance to measure the impregnation liquid mass variation in the solid structure. This method is unable to determine the equilibrium height and the quantity of liquid absorbed by the textile at different heights. The method consists of measuring water transport along textile fibres by an electrical capacitance. This technique includes the construction of apparatus with a specially designed electrical amplifier circuit and condenser electrodes, between which sample fibres are set. This method therefore permits only a global view of the evolution of liquid transport. The last technique is based on electrical resistance principle where the liquid height was measured by using single probe. This method is also unable to measure the liquid height at various levels. However, in the present work, a technique based on open and closed electrical circuit principle has been used to determine the capillary height of liquid at various levels without dye with respect to time. This technique helps us to do the in-depth study of the wicking behavior of the fabrics.

Circuit Description

In this circuit (Fig.1), the probe is used to measure the water level. A test probe (test lead, test prod) is a physical device used to connect electronic test equipment to the device under test. All the probe leads are pulled high through the resistors. They are placed in the different height levels. Then the probe outputs are given to 40106 hex schmitt trigger inverter.

Initially when the fabric is dry, all the probe leads are not in touch with water. So, the probe leads become high which are inverted to low through hex inverter. When the water level is increased gradually, the touched probes become low which are inverted to high by the hex inverter. Then the corresponding output signal is given to microcontroller in order to find the water level. By lab view software the successive signals from opening and closing switches in this system are captured by computer to measure the liquid height with respect to the time.

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The selected fabric, initially dry, is maintained vertically and partially immersed in a bath containing distilled water. The fabric support is composed of plexi glass plate where the screws are affixed after every 1 cm on both the sides. The metallic wires are extended halfway from the screw on both sides and touch the front and back sides of fabric at regular intervals of half centimeter. There are total of eight probes touching the front side of the fabric and another eight probes touching the back side of the fabric alternately (Fig. 2).

The fabric sample (12 cm × 5 cm) was placed in a climatic chamber maintained at 27°C and 65% RH and set in contact with the liquid. The liquid height in fabric is deduced at different instants experimentally from the signals given by the software program. The electrical circuit diagram (Fig. 3) shows an entire setup of the system.

**Preparation of Sample**

Plain woven cotton fabrics were produced by Ruti C Machine. The samples were made of varying count and construction in weft way. Weft yarns of the counts 20 s and 30 s Ne were used for the construction of 21 picks/cm, 25 picks/cm and 29 picks/cm respectively.

Warp yarn parameters were kept same in all the samples with 100% cotton of 2/60s Ne and construction of 28 ends/cm. The fabrics were undergone the commercial scouring and bleaching process. The sample (12 cm × 5 cm) were prepared in weft direction and then placed in climatic chamber at 27°C and 65% RH.

The five tests were conducted for each sample to compute the average value. The distilled water was used for the testing. All wicking measurements were performed at 28-30°C temperature (room condition) and 38 - 40% relative humidity.

Figure 4 shows the weft way wicking height (L) in mm of yarns of two different counts, keeping the density of the fabric same as a function of time (t). The results show that the capillary rise slows down as the time passes for every individual sample. The curve has sharp slopes at the beginning and becomes constant over a period of time. It is observed that the weft yarn count increases the capillary rise of the liquid in the samples. So the fabric sample produced with 20 s Ne yarn count shows highest capillary height as compared
to that with 30's Ne yarn count. Also, the influence of yarn count is pronounced at higher fabric density.

Figure 5 shows the effect of weft yarn density on capillary rise of water in weft direction. As the fabric density increases the capillary height reduces. The 21picks/cm density fabrics have a faster capillary rise as compared to the 25picks/cm and 29picks/cm density fabrics respectively. The geometrical configuration of
 porous medium is affected by the fabric density and decides the capillary rise of the liquid in the fabric. The impact of fabric density on wicking is less effective as compared to that of yarn count. The wet and dry area of the fabrics shows different electrical signals and this is used to determine the heights of liquid at different positions. The study shows that the wicking height and penetration rate reduce by increasing the weft yarn count and density of woven fabrics.

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