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MEASURING WATER TRANSPORT THROUGH TEXTILE FABRICS BY AN ELECTRICAL CAPACITIVE TECHNIQUE

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ABSTRACT

Given its importance in major treatments including dyeing and finishing processes, the present work studied water transport through textiles and introduced a novel apparatus based on electrical capacitive technique to measure it. Fabrics made of cotton and viscose having 17 and 26 wefts/cm were examined. Also, the influence of weaving design on water transport phenomenon was discussed. The obtained results, given as function of time, were consistent with gravimetric techniques and validate the use of the developed apparatus to study water transport through fabrics.

KEYWORDS

Electrical capacitive technique, Fabrics, Balance, Water transport.

1. INTRODUCTION

The liquid flow through fibrous designs can be observed in many textiles processing such as wetting, dyeing and finishing processes. Indeed, liquids wet the surface through the inter-fibers spaces depending on capillary forces (Kissa, 1996). In attempts to examine textile properties, a number of studies on wicking properties of textiles have been carried out. In this framework, the compilation of the literature revealed that many techniques and methods were developed in order to experimentally describe the liquid penetration into textiles.

First of all, a colored liquid was used to interpret and measure the liquid rise in textile design (Kawase et al. 1986); (Kawase et al. 1986). Perwuelz etal. (Perwelz et al, 2000) developed another method based on the analysis of CCD images taken during the capillary rise of colored liquid in yarn design. The studies of Hseih et al.(Hseih et al., 1986, 56 (11)); (Hseih et al., 1986, 56 (12)) and Pezron (Pezron et al., 1995) focused on the measurement of the impregnation liquid mass variation in the solid design using a balance.

Moreover, another technique which is based on the electrical resistance principle was established and the liquid height was measured using a single probe (Nath et al., 2001). Furthermore, Ramesh et al. (Ramesh et al., 2011); (Ramesh et al., 2012) developed a technique based on electrical open and closed circuit principles to measure the vertical capillary height of the liquid in the fabric as function of time.

In addition, water transport measurement through textile fibers was also conducted using an electrical capacitance (Ito, Muraoka, 1993); (Tagaya et al., 1987). This technique consists of an apparatus

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construction with a specially designed electrical amplifier circuit and condenser electrodes. In between, sample fibers are set. In previous works, our laboratory described the capillary ascension measurement and the rising liquid mass in fabrics (Hamdaoui et al., 2006). A mathematical model was then proposed to allow the determination of the governing diffusion coefficient. Furthermore, we developed a method based on the electrical resistance measurement in attempts to determine the time-space water content evolution (Hamdaoui et al., 2008). The obtained results allowed us to deduce the fabrics capillary pressure curve and the flow velocity. Herein, our present approach aim is to develop a novel concept of a capacitive technique to study the kinetic water transport through fabrics and validate its convenience via a balance instrument. Cotton and viscose fabrics in various forms were chosen as study cases. So, the influence of three parameters, namely fibers type, weft count and weave design, on water transport phenomenon is discussed.

2. MATERIALS AND METHODS

2.1. Apparatus description

As described earlier, the instrument studied by Ito et al. (Ito, Muraoka, 1993) was restricted to the wicking measurement through fiber and yarn designs. Based on its target, we adopted a similar principle with modifications in attempts to study water transport through various fabrics designs.

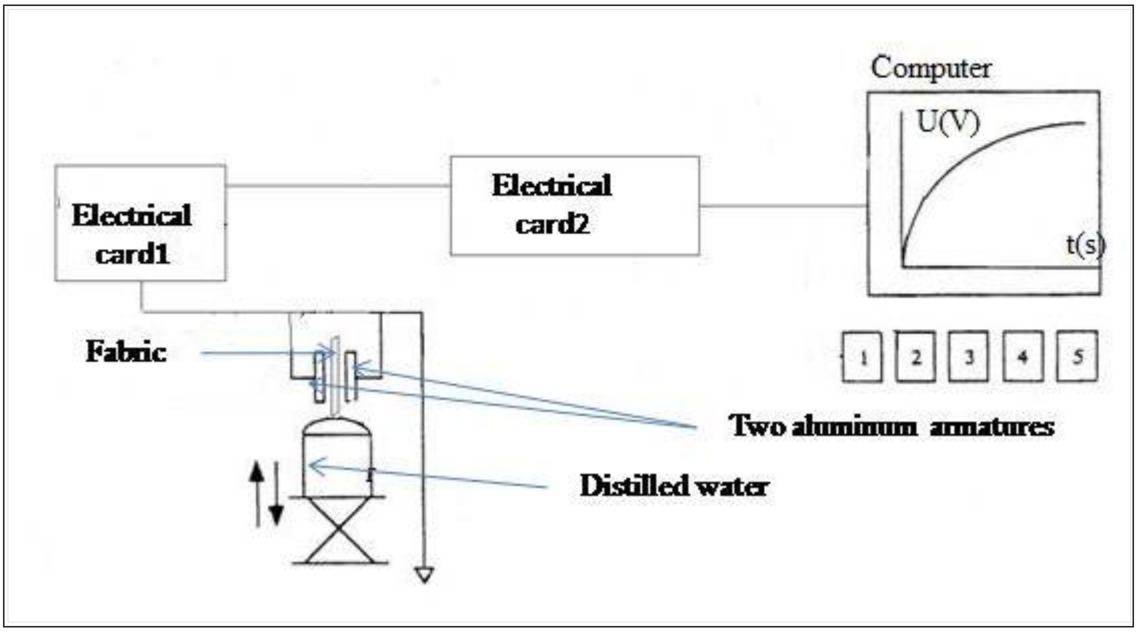

Figure 1: Experimental apparatus

As mentioned in figure 1, the cloth is held vertically through a support (with Plexiglas) and ends in water then put between two aluminum plates. All of them constitute the condenser (C) which is connected to the first electrical card whose principle is shown in figure 2.

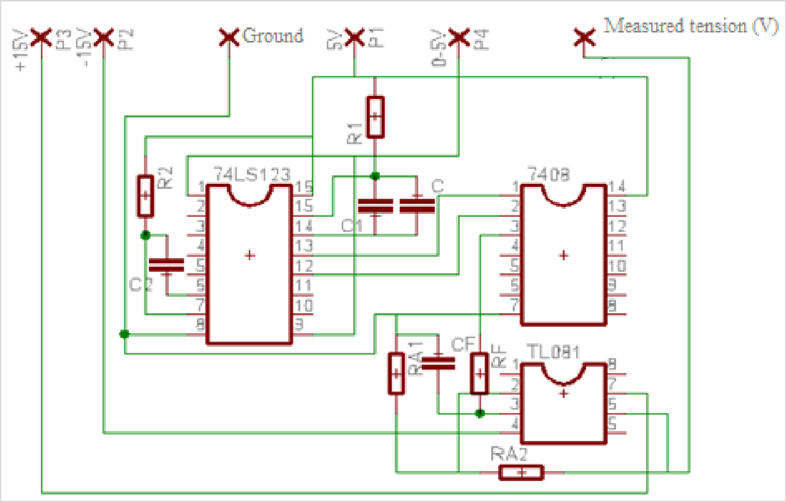

Figure2**:** The electrical diagram of Card 1

The capacitive technique could detect the electric capacity variation via the presence of two monostaples. Each one is an electric component that obtains the impulses width instead of electric current. The impulse width is a function of the external resistance and capacity. For monostaple n° 1, C_1 is connected to another capacity C. This last capacity is composed of two armatures made of aluminum (as good conductor). The dielectric is the atmosphere and the cloth whose extremity is submerged in the water container.

Thus, the pulse T_1 could be written as:

$$T_1 = R_1(C_1 + \Delta C) \qquad (1)$$

On the other hand, for monostaple 2, T_2 is given as:

$$T_2 = R_2 C_2 \qquad (2)$$

The difference between the two pulses given via the logic gate AND 7408 the formula as follows:

$$T = T_1 - T_2 = R_1(C_1 + \Delta C) - R_2 C_2 \qquad (3)$$

When: $R_2 = R_1$ and $C_1 = C_2$, the new formula becomes:

$$T = T_1 - T_2 = R_1 \Delta C \qquad (4)$$

As mentioned in the above equation, the difference between two the pulses is only a function of capacitance variation. So, it depends only on the water quantity transported to cloths.

Indeed, the pulse T becomes a continuous electric voltage due to the presence of a low pass filter component made of a resistance RF mounted in series with a capacitance C_F. The electric voltage is amplified by the amplifier TL081 in order to be recorded and visualized by the computer using the second electrical card made of PIC16F876. The measured electric voltage increases until it reaches a constant value. This increase confirms the increase of water quantity through the cloth. The latter is held vertically through a support (with Plexiglas) and ends in water then put between two aluminum plates (the aluminum plates constitute the condenser electrodes).

When water climbs to cloth, conductivity increases and so the pulse T becomes longer. In fact, we have:

$$C \approx 8.85\times 10^{-12}\times\frac{\varepsilon S}{e} \tag{5}$$

- C: capacity (F)
- Ɛ: dielectric constant
- S: surface of condenser electrode (m^2)
- e: distance between the condenser electrode (m)

For textile fiber ε = 5 and for water ε = 80.

For these reasons, the capacitive technique is a sensitive. The apparatus contains two electrical cards. The first contains the monostaples and the second is based on PIC 16F876 and through it, data are transmitted to a computer.

2.2. Fabric characteristics

Herein, we examined various fabric designs in attempts to measure water wicking through textiles and to observe the effect of each fabric parameter on water transport. As mentioned in Table 1, the design, composition and weft count have been investigated. Instead, these four cloths have the same warp count, yarn size and twist per inch. For each combination listed in table 1, the sample size was N =10.

Table1: The tested fabrics characteristics

Samples	**Design**	**Composition**	**Weft count**
Sample1	Plain	Cotton	17
Sample2	Plain	Viscose	17
Sample3	Plain	Cotton	26
Sample4	Twill	Cotton	26

3. RESULTS AND DISCUSSION

3.1. Water transport measurement via capacitive technique

3.1.1. The fiber type effect

The effect of fiber type was examined by studying water transport through cotton-made cloth (sample1) and viscose-made cloth (sample2). Figure 3 presents the electric voltage (V) evolution as function of time for the two tested fabrics.

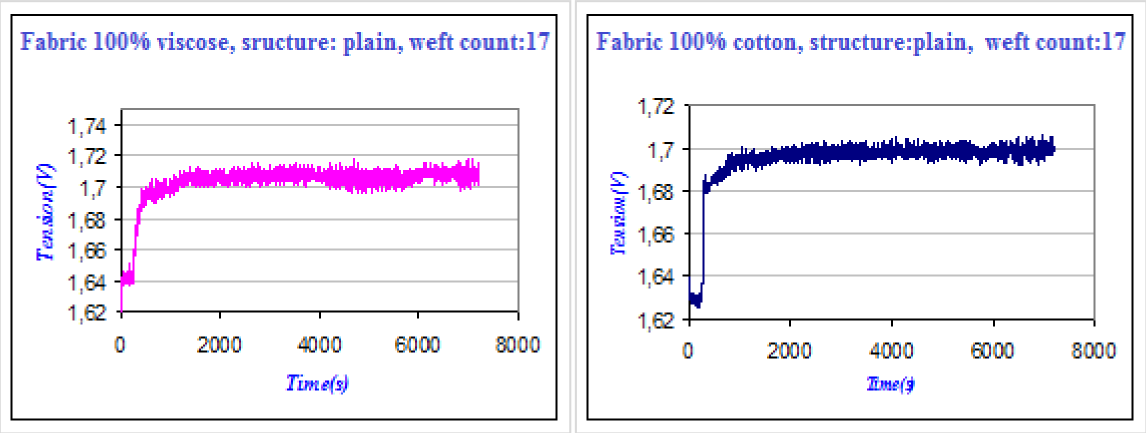

Figure3: Electric voltage Evolution (V) in fabrics as function time

The obtained results revealed that the electric voltage value for cloth 2 is more important than that found for cloth 1. This means that the rate of water transport through viscose is higher than through cotton. This was proved again by water retention values (12 for viscose and 8 for cotton). As a consequence, the fiber type affects water transport, i.e. higher water amounts in more absorbent fibers.

3.1.2. The weft count effect

The results, shown in Figure 4, indicated that the amount of water transported through sample 3 is more important than through sample 1. Based on electric voltage values measured for the two fabrics, we observed that the rate of water transport through cloth increases with weft count (weft count = 17 for cloth 1 and it is equal to 26 for cloth 2). This can be due to increased tortuosity with higher weft count, i.e. tighter fabric design (Hamdaoui et al., 2006).

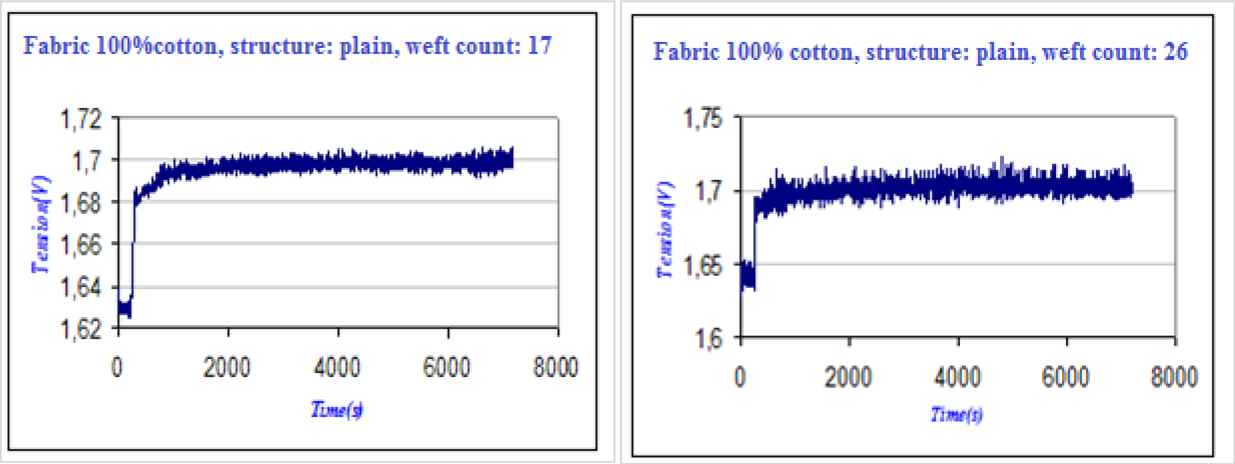

Figure4: Electric voltage Evolution (V) in fabrics as function of time

3.1.3. The weave design effect

Water transport behavior through twill and plain designs is shown in figure 5. As observed, the rate of water transport through sample 4 is lower than that through sample3. Indeed, the plain design is tighter than twill and consequently leads to larger tortuosity. This phenomenon can be explained as water in these conditions could hardly diffuse.

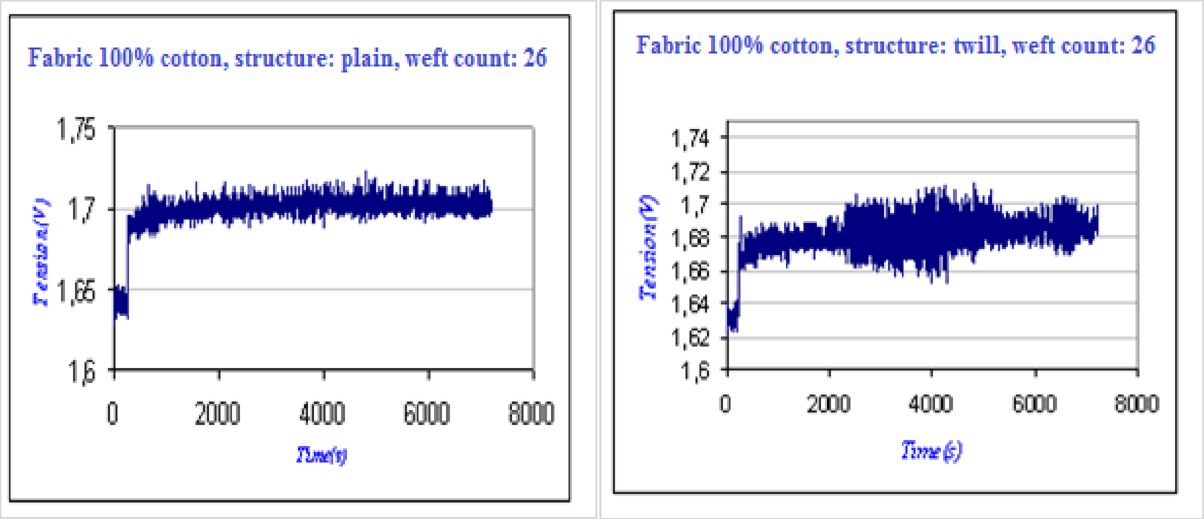

Figure5: Evolution of electric voltage (V) in fabrics with time

3.2. Results validation via weight method

To validate the results depicted from the capacitive method, the transported water weight measurement through the studied fabrics was conducted. An electronic balance having 10^{-2} as precision, is connected to a computer having the program “RS.com”. The weight variation is then measured and the influence of the earlier studied parameters was discussed and compared.

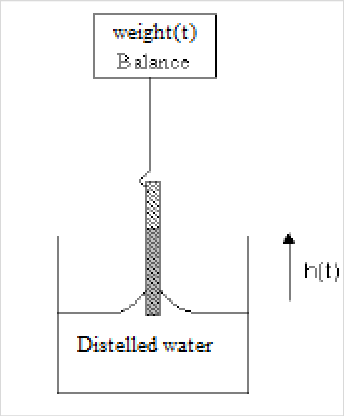

Figure 6: Water transport measurement using gravimetric method

3.2.1. Fibers type effect on absorbed water weight

As shown in Figure 7, the quantity of water absorbed by sample 2 is lower than that in sample 1. Results are in agreement with those found using electrical capacitance method. That is to say that viscose fibers are more absorbent than cotton fibers.

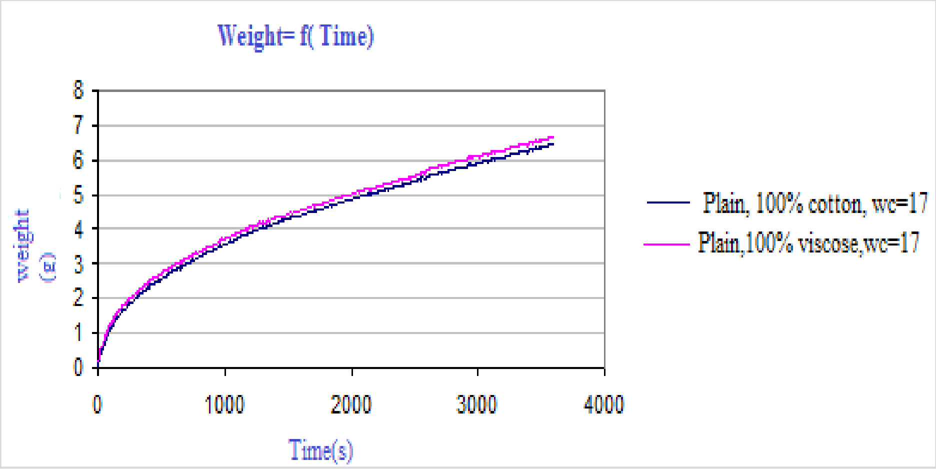

Figure 7: Effect of Fiber type on the absorbed water weight

3.2.2. The weft count effect on absorbed water weight

The quantity of water absorbed by sample 3 is less than that in sample 1. Indeed, the mass of water absorbed in fabrics increases with the weft count due to the specific area augmentation in textile. This difference in weight values was also in agreement with the electric voltage variation values observed for the same fabrics.

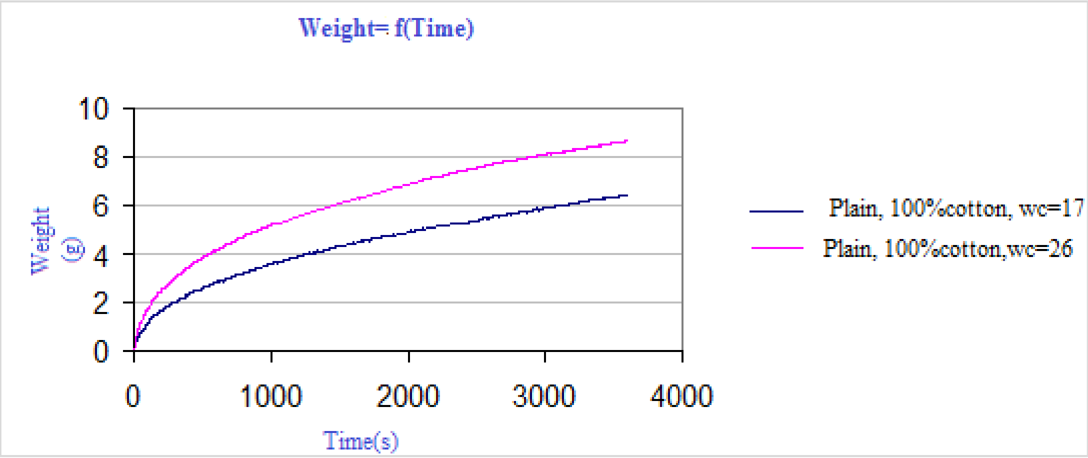

Figure 8: The weft count effect on the absorbed water weight

3.2.3. The weave design effect on the absorbed water weight

Figure 8 shows that water weight depends on the fabric design. It is more important when cloth is plain. This can be explained by the small quantity of fibers in the twill design. Results are also consistent with those found by capacitance instrument.

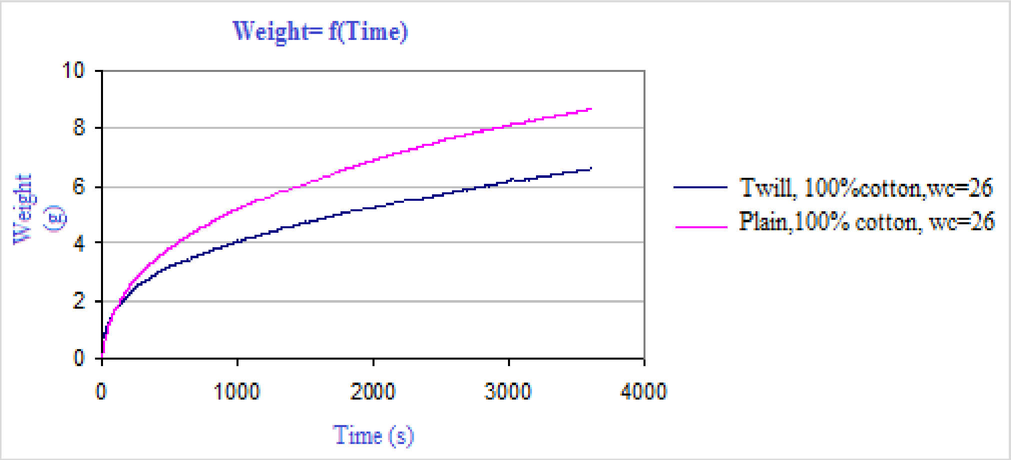

Figure 9**:** The weave design effect on the absorbed water weight

4. CONCLUSIONS

To sum up, a novel concept of an electrical capacitive technique was developed and the principle was described in details. Water transport through textile cloths was plotted against time. Results showed that such phenomenon was fiber type, weft count and weave design dependent. Experimental data were also confirmed by measuring the weight of absorbed water in fabrics. As observed, water quantity transported is greater when fibers were more absorbent. Again, the rate of water transport through fabrics increased with weft count and it became more important when fabric design is tighter. This confirms that the quantity of transported water increases with tortuosity. Through this study, we demonstrated that the developed apparatus could provide a potential evaluation of wicking phenomenon through textile fabrics. Despite the sensitivity of capacitive technique, there are fluctuations in graphs which can be explained by the vaporization phenomenon and the complexity of fabrics designs because of the presence of pores of different shapes and sizes. Thus, the experimental device could be ameliorated and developed to enhance the results. Also, further studies will be carried out to determine the relation between the measured electric voltage and the absorbed quantity of water.

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