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Source: Textile Review

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By: M. Y. Gudiyawar Sultan H.

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The added advantage of Air-Jet texturising process is the facility of blending of different type of filament yarn together. Judicious blending, decided by the optimum blend proportion to get from constituents of filaments, meet the parameter of desired quality.

It has been long assumed that a fibre that absorbs moisture tend to be more comfortable than a fibre that does not absorb moisture, thus in many articles the moisture absorbencies of fibre yarn and textiles related to their comfort have been stressed. Wicking is the spontaneous flow of a liquid in a porous substrate driven by capillary force. This flow in aporous medium cause by capillary action is governed by the properties of liquid such as surface - wetting forces and geometric configuration of the pore structure such as yarn construction, no. Of fibres in cross section, the randomness of internal structure, twist, fabric structure and loop formation specially in Air-Jet textured yarn.

Wickability of Air-Jet textured yarn and their fabric can be measured by both horizontal and vertical wicking testing method. Due to tenor body activity the body can put out as much as 1 L sweat an hour there for the fabric worn next to skin will get wet, this moisture fabric reduce the body heat & makes the wearer uncomfortable, so the fabric worn next to the skin should assist for the release of moisture quickly to the atmosphere. The fabric next to skin should have two important properties, the initial and the foremost property is to absorb the perspiration from the skin surface & the second property is to transfer the moisture to the atmosphere & make the wearer feel comfortable. Diffusion & wicking are two important properties through which moisture is transferred to the atmosphere.

This article reviews the applicable concept of wicking mechanism, kinetics of wicking, wicking testing methods and moisture transportation etc. for Single Component and blended production of air-jet textured yarns & their fabrics.

Wetting and Wicking

Wetting is a pre-requisite for wicking, wetting is of paramount practical importance in textile processes. Numerous papers have been published on wetting, and various wetting tests have been devised to obtain information on wettability, absorbency, repellency, detergency, moisture transport, etc. However, the data obtained with different tests do not correlate with each other, and none of the tests has always provided all of the information needed. The multitude of methods used to measure wetting and wicking has caused some confusion. Harnett and Mehta proposed that a test should distinguish between "wickability" per se, defined as the ability to sustain capillary flow, and "wettability," defined as the initial behavior of the fabric, yarn, or fiber when brought into contact with liquid. According to this definition, the term "wettability" describes the interaction between liquid and the substrate prior to wicking taking place. Clearly, clarification of this perplexity is needed.

Wicking Mechanisms in Yarns-The Key to Fabric Wicking Performance

Right from the World War II period, it was recognized that a better understanding of the mechanism of water transmission through and within materials could be applied to advantage in the design of fabrics and clothing assemblies. Since then, researchers have continued to try and answer the question of the role of the fibre in transporting water and the relative significance of different variables inherent in fabrics.

Gegauff published an excellent analysis of yarn mechanics as long ago as 1907 and for many years since the formulation of the Lucas-Washburn equation which was subsequently applied to explain the wicking behavior of textiles, researchers have suggested a number of complementary quantitative theories to explain the interaction of moisture and textiles. However, it is evident from literature that since the development of the Washburn equation for the flow rates in capillaries, research on the wicking of yarns and how this can be correlated with fabric wicking has generally been lagged behind compared to the substantial published research work on fibre and fabric wicking. The research trend has been centred on the wicking behavior of fabrics with a cursory mention of the influence of the yarns and the influence of yarn construction features such as twist, diameter, etc. The link between human performance and clothing and textile products in a variety of situations and the development of a number of new fibres and yarn manufacturing processes have all increased the importance of the need to study the kinematics and kinetics of liquids in yarns.

The mechanical properties of textiles are probably their most important properties technically, contributing to the behavior of fibres in processing and to the properties of the final product. As a result of the theoretical studies of yarn geometry and mechanics, such as those made by Schwarz, Plat, Trealor, Kilby, Hearle and Hearle et al. and others based on idealizations of yarn structures, the forms of cylindrical twisting are well known and have been analysed. In practice, it is known that considerable deviations from the ideal structure occur leading to somewhat irregular packing and the filaments migrating so that their distance from the central axis varies with the position along the yarn. Studies by Hearle et al. have shown that the yarn specific volume decreases with increase of twist, i.e., the radii of capillaries and their continuity decrease. The intensively modelled ideas of the geometry decrease. The intensively modelled ideas of the geometry of twisted cylindrical bundles of filaments therefore give a framework for consideration of the effect of these geometrical variations of the filament interspaces along the yarn on liquid movement.

Kinetics of Wicking

Most textile processes are time limited, and the rate of wicking is therefore important. However, the wicking rate is not solely governed by interfacial tensions and the wettability of the fibers, but by other factors as well. The wicking rate depends on the capillary dimensions of the substrate and the viscosity of the liquid. For a theoretical treatment of capillary flow in fabrics, the fibrous assemblies are usually considered to consist of a number of parallel capillaries. The advancement of the liquid front in a capillary can be visualized as occurring in small jumps. The advancing wetting line in a single capillary stretches the meniscus of the liquid until the elasticity of the meniscus and the inertia of flow are exceeded. The meniscus contracts, pulling more liquid into the capillary to restore the equilibrium state of the meniscus. The movement of the liquid in a nonhomogeneous capillary system, such as a fibrous assembly, is discontinuous for another reason as well. The wetting front advances into the capillary system in small jumps, because the irregular capillary spaces have various dimensions.

The volume rate dV/dt of flow in a tube is given by Poiseuille's equation:

$$dV/dt = \pi r^4 P/8\eta l$$

Where r is the radius of the tube, l is the distance covered by the liquid front during time t, and P is the pressure drop across the distance l, For linear flow dl/dt,

$$dl/dt = r^2 P/8\eta l$$

Poiseulle's equation states that the flow rate in a tube is inversely related to the distance of the liquid movement. Based on Poiseulle's equation, Lucas and Washburn developed an equation for flow rates in capillaries:

$$dl/dt = rY \cos\theta_A /4\eta l$$

The limitations of the Washburn-Lucas equation are frequently overlooked. The equation incorrectly assumes a constant advancing contact angle θ_A for the moving meniscus. The Washburn-Lucas equation does not take into account the inertia of the flow, and implies that at time 0 and l = 0, the flow rate is infinite. In spite of these limitations, a variety of liquids have obeyed the Washburn-Lucas wicking kinetics.

Moisture Vapor Transfer through Textiles

Humans secrete sweat, which evaporates from skin to a microclimate and eventually to the outside environment. Clothing, as an intermediate medium between the skin and the ambient conditions, provides an impedance to the evaporation of sweat. In most cases, skin temperature is higher than the outside conditions. Thus, sweat evaporated from the skin condenses at the fabric surfaces, redistributes throughout the fabric, and then re-evaporates to the outside environment.

Figure 1 Illustrates the cross section of the skin-microclimate-fabric-environment system, showing a complete representation with the skin layer S, fabric F, and outside environment E. Between the skin and fabric is the "clothing microclimate" M. There are differences in moisture concentration C in the microclimate, at each of the inner and outer surfaces of the fabric, and eventually is the environment. These terms will be described in more detail.

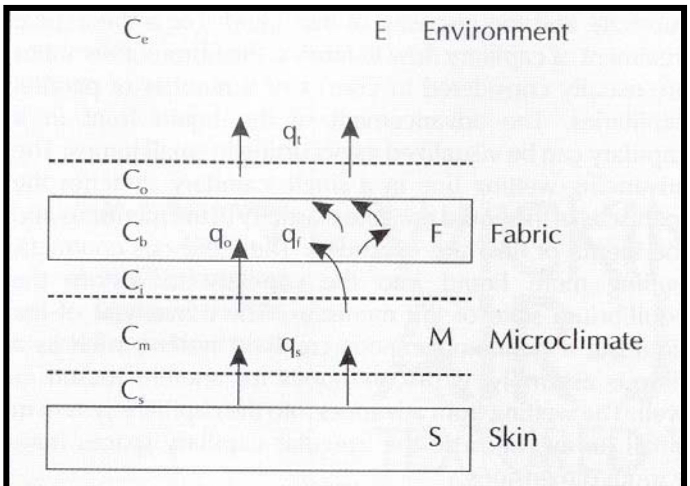

Figure 1 : Cross-section representation of the skin-microclimate-fabric-environment system

A skin surface is not smooth but three-dimensional because of papillary bridges, grooves, and hairs. C_s is the moisture concentration in air just above the skin and is assumed to be fully saturated. C_m is the moisture concentration in the microclimate between skin and fabric-surface. C_i is the moisture concentration at the inner fabric surface, which is different from C_o at the-outer surface.

The fabric surface, as well as the skin surface, is in reality a three-dimensional air space, due to the construction of fabrics and many surface fibers. The fabric surface includes not only surface fibers but also air entrapped between those fibers and the still air layer just above the fibers. C is the moisture concentration in the bulk fabric and C_o at the outer surface. C_e is the moisture concentration that remains constant in the environment far from the skin-clothing system.

In terms of the rate of vapor transmission, q_s is the moisture flux from the skin. There are two passages for moisture traveling through the fabric from inside to outside: one passage is the large open air space or air volume within the fabric, and the other is by some interaction with the internal structure or pores of the fiber. Two moisture transfer flux terms are used to represent these two different passages: q_a denotes the flux of moisture passing through the larger open air space in fabric, and q_f represents moisture flux along the surface of the fibers. Most of the available moisture will pass directly through the air space as vapor because of the fabric air volume.

Note that there is not one simple diffusion process or single term to describe these two different passages of moisture transfer through the fabric. One process for moisture transfer is that of straight-through diffusion, identified with the large moisture flux q_a through the open spaces in the fabric. The other process consists of a smaller moisture flux q_f along the fibers. This latter process identified with q_f is more complex, primarily one of distillation, and we believe it is a significant contributor to clothing comfort. This moisture distillation process involves condensation of water vapor from the microclimate C_m onto the fabric inner surface C_i, a liquid film transfer of moisture along the fibers q_f to the fabric outer surface C_o, followed by a re-evaporation and then diffusion of moisture toward the drier environment C_e.

Figure 2 Illustrates a generalized relationship between the variables of moisture transfer. The flux of sweat from the skin q_s is constant whenever there is enough sweat present so that the skin surface is fully wet. The experiment starts after q_s reaches equilibrium. In actual wear, q_s starts from a very low value, known as insensible perspiration. It increases continuously under heat stress and approaches equilibrium. Moisture flux through the fabric q_t rises in a curvilinear fashion, since it requires some time to saturate the microclimate M and fabric F.

If one integrates q_s and q_t over time, then the difference between these two integrals is the area between curves q_s and q_t . This area OAB indicates the sum of moisture held near the skin, in microclimate M, near both fabric surfaces, and in the bulk fabric.

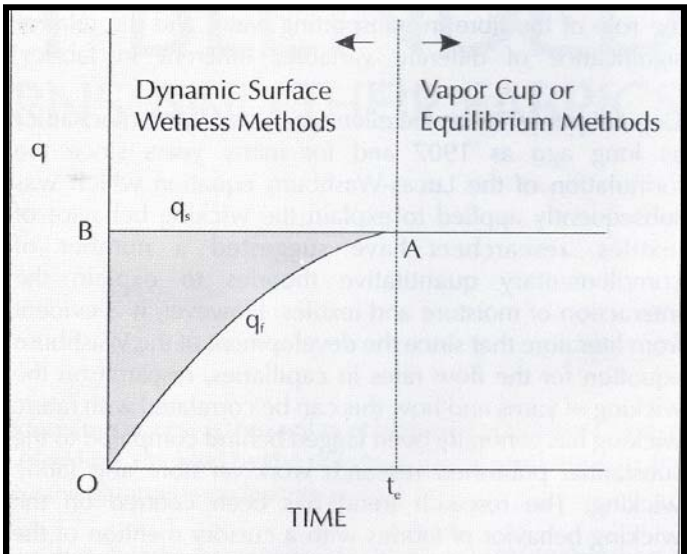

Figure 2 : Generalized determination of moisture vapor transfer variable

Generally, there are two different approaches to measuring moisture (vapor) transfer. One is the dynamic surface wetness method, and the other is the vapor cup equilibrium method. Dynamic surface wetness methods are concerned with moisture transfer prior to t_e i.e., the time to reach equilibrium. By contrast, vapor cup or equilibrium methods deal primarily with the moisture transfer after time t_e. Two questions in dynamic surface wetness measurements are whether the OAB differs depending on the intrinsic properties of fiber or finish, and how C_m, C_i, C_b and C_o are related to area OAB.

In this work, we studied in detail the contribution of Ci and C_o to the area OAB. This is in the dynamic region, which is believed to be a critical factor in explaining comfort sensations of human subjects. Also, the fabric and yarn structures were constructed to be essentially similar, so as to control for differences in fabric porosity or fiber volume. The primary interest thus lies in the effect of selected fiber types on moisture transfer q_t or moisture vapor flux through the fabric. Part II will concentrate on the influence that finishes applied to these same fibers and fabrics have on dynamic surface wetness and moisture vapor transfer.

Dynamic of Moisture Transportation with Relation with Thermal Resistance

When human skin perspires, the main objective is to lose excessive heat from the body. This excessive heat is mainly lost through evaporation of the moisture from the surface of the skin. Moisture present on the skin surface of a clothed human can often produce uncomfortable sensations such as prickle and wet-cling. Should the human body cool rapidly, excessive heat loss from the skin through conduction or evaporation may result in post-exercise chill. Thus, in order for the clothed human to remain comfortable, the moisture needs to be removed from the skin surface mechanically. This is achieved through the use of fibres and fabrics which absorb the moisture and, thus, remove it from the skin surface. In this situation the majority of the heat lost is conductive, strongly influenced by the amount of moisture present.

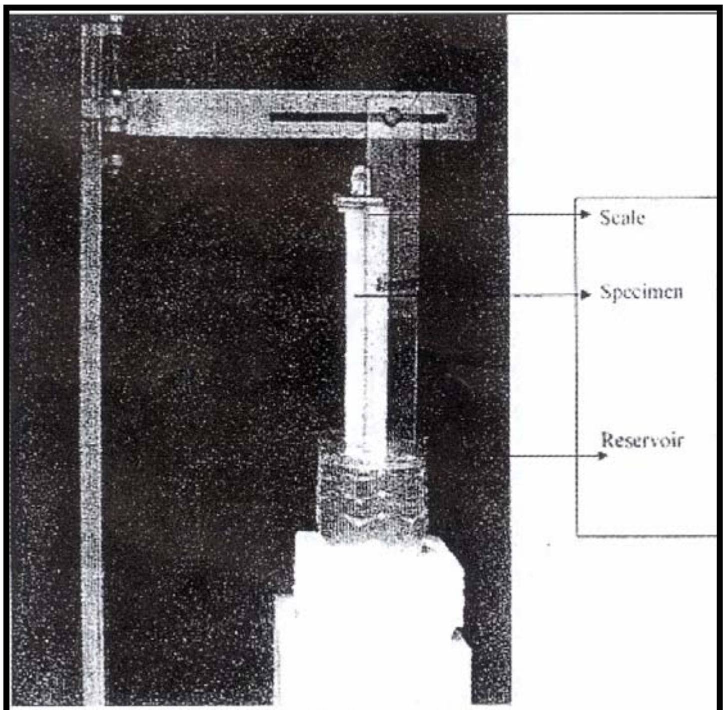

Figure 3 : Vertical wicking apparatus

Once the skin has cooled and perspiration is reduced, the heat lost from the surface of the skin must be restricted. Wet fabrics have a much lower thermal insulation than their dry counterparts and so reduction of conductive heat loss may not be achieved. Other researchers have studied this problem concluding that the moisture does not necessarily need to be removed from the skin surface but, instead, be kept warm. However, natural thermoregulation by the skin is a dynamic process and thus a more effective method for achieving thermo-physiological comfort is the use of 'dynamic' fabrics, rather than those with a high thermal resistance. A 'dynamic' fabric is one which will have a thermal insulation which is low when the skin surface is hot and wet and increasing when the surface of the skin drys and cools. Typical 'dynamic' fabrics are highly wicking layered fabrics, which not only absorb moisture from the skin surface but also transport it effectively away, leaving the skin surface and the layer of fabric closest to the skin relatively dry at all times. In this manner the fabric will appear cooler during moisture transfer but will recover a substantial level of thermal insulation once moisture transfer has been completed. In contrast a 'non-dynamic' fabric system does not respond in this manner and is one where the absorbed water remains relatively static and thermal resistance of the system is minimal at all times when the fabric is wet.

The objective of this study is to evaluate the relationship between moisture presence and thermal insulation of selected fabrics and to identify the criteria required for developing novel 'dynamic' fabrics.

Wickability Testing

Following test were carried out for all types of yarns & fabrics samples. All tests were carried out in standard atmosphere, that is, 65% RH & 27 ± 2°C DBT.

Wicking is the most widely used test method for describing the ability of moisture absorption in all types of yarns & fabrics. The samples were prepared with 10 cm length & 2 cm width for fabric and 10 cm length for yarn. One end was suspended vertically on the projection behind the scale with help of clip. The load was attached to the other end of the specimen. A 5 gm. Hanging weight is loaded on the fabric to keep it under tension. Higher than this weight can close some of capillaries and inhibit fluid flow through fabric. The reservoir filled to 300 mL with liquid. Use 2 to 3 drop ink in liquid for yarn wicking. So that the height of liquid through yarn is visible. The scale along with the sample was immersed in a reservoir of liquid up to 2.5 cm mark from the bottom edge of the sample. Observation of water column were made for every 5 min. for total 25 min. in each test. 4 to 5 tests were conducted for each sample, the average of which can be calculated.

Water Absorption

In case of fabrics for measuring the area covered by the spreading liquid, cut weighing technique is used, that is, the mass of liquid absorbed as a percentage of the dry weight of an area of fabric equal to the area of the wetted region by DeBoer's approach. The samples were conditioned under standard atmospheric condition for a period of 4h. the specimen mounted on a 15cm wooden ring to have a wrinkle - free & tight surface, & placed in horizontal plane. The micropipette filled with water & fixed with vertical stand. The height of the micropipette adjusted such that the surface of the sample just 10 + 0.1 mm below the tip of the micropipette. A measured amount (0.05 & 0.1 mL) of liquid was introduce in to sample surface by micropipette. The liquid was allowed to spread. The area covered by liquid was marked with the help of marker. Allow to dry in air under standard atmospheric conditions. After reaching equilibrium, the specimen weight & irregular shape area cut out. The cut sample weighed : the weight of a sample is equal to area of a spreading. The irregular fabric weight was cross-multiplied with known square area weight of specimen to obtain area of spreading in mm2. The average of no. of test readings was taken in account. The above mentioned procedure used for all samples.

Horizontal Wicking Testing

When water droplets are put on yarns both wetting & wicking occur. This complex process can be divided into two stages.

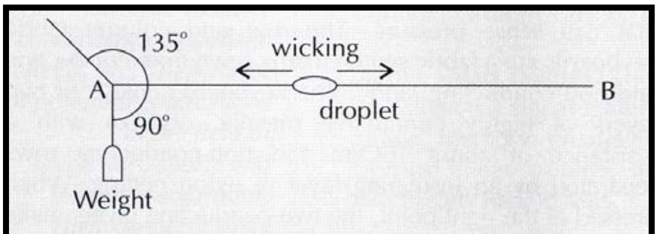

Figure 4 : Horizontal wicking apparatus

During the first stage, the droplet will expand in longitudinal direction of the yarn to form a droplet with clamshell shape (wetting), at the same time, it wicks into the inner part of the yarn. During the second stage, liquid wicks in two opposite direction independently along the yarns. The time for the first stage is typically less than 1 second. The time for the liquid to disappear ranges from 10 seconds to 300 seconds. Thus, the time it takes for water droplet to disappear is mostly determined by the second stage, & the mainly Governed by the contact angle & the capillary system.

What is next???

Now the concept of wicking mechanism, wicking kinetics, moisture transportation & different wicking testing is applied to single component & blended production of air-jet textured yarns & their fabrics from polyester, viscose & nylon etc. and deciding the comfort property of each type of air-jet textured yarns and their fabrics by applying statistical analysis to testing results obtained.

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