Effect of Number of Fibres per Yarn Cross-section on Moisture Vapour Transport in Knitted Garment

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Abstract: With increasing demand for garment comfort, many studies have focused on the comfort properties of the fabrics. Comfort here refers to the psychological comfort such as the moisture vapor transport rate (MVTR). For wearer comfort, this sweat should be transported away from the skin surface, in the form of liquid or vapour, so that the fabric touching the skin feels dry. The rate at which water vapor moves through a fabric plays an important role in determining the comfort as it influences the human perception and the cool/warmth feeling. Cloth that forms a barrier for MVTR between the skin and the environment, and can enhance or spoil physiological comfort. The problem of MVTR through clothing is discussed. The article focuses on mechanisms of MVTR that could take place in textiles and factors affecting this process.

The aim of this paper is to present the effect of number of fibres per yarn cross-section on MVTR. Two samples with different number of fibres per cross-section and the same linear density were knitted. Samples were produced with the same machine and loop-length to obtain the same fabrics specification. Results indicate that there is a relationship between MVTR and number of fibres per yarn cross section. Water vapour permeability increases with the lower of number of fibres per yarn cross section. Spaces between the fibres per yarn cross-section had the greatest effect in increasing MVTR. However this result has to be followed up with a thorough study. This study, for the first time has attempted to link effects on the number of fibres per yarn cross-section and MVTR.

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Key words: Moisture Vapour Transport Rate (MVTR) - Clothing Comfort **-** Mechanism of Moisture Vapour Transmission- Evapourative dish method

1. Introduction

Water vapour permeability of a clothing fabric is its ability to transmit vapour from the body. If the moisture resistance is too high to transmit heat by the transport of mass and at the same time the thermal resistance of the textile layers considered by us is high, the stored heat in the body cannot be dissipated and causes an uncomfortable sensation [(1)].

In last decades, increased attention is paid to comfort properties of textiles and garments. As general, personal well-being and high living standards nowadays become certainly important. The significance of comfort is well recognized by the people. Modern and conscious consumers consider comfort as one of the most important garment properties. This fact should not be surprising since well the strong relation between the comfort properties of garment and human sensations is well known. There is general agreement that the transfer of heat, moisture and air through the fabric are the major factors for thermal comfort. [(2)]

The heat and moisture transport play an important role in many engineering areas. In many sweat transport systems, such as clothing assembly, the moisture concentration(or sweat) is relatively small and the air concentration reaches a steady state quickly.[(3)] In the case of hard physical exercise or in tropical climates, the heat loss by evapouration is accompanied by sweating and the skin becomes covered with a film of water. For wearer comfort, this sweat should be transported away from the skin surface, in the form of liquid or vapour, so that the fabric touching the skin feels dry. The transport of both moisture vapour and liquid away from the body is called moisture management. [(4)]

Water vapour transport through textile structure is complicated and governed by various factors, including fabrics openness, fabric thickness, pore size, and intrinsic fibre properties.[(5)]

Clothing is designed to maintain a hygienic and comfortable zone for the human body in which one feels well, even if inner or outer influences change rapidly. The zone in which the temperature, moisture and air circulation are properly matched is called the "comfort zone". [(6)]

Water vapour transmission is an important factor related to thermal comfort. Water vapour transmission is the speed at which water vapour passes through a textile material. The transfer of moisture vapour is usually occur in the direction from the wetter environment to the dryer environment until equilibrium is reached. The ability of a fabric to carry away moisture vapour or to maximize the evapouration of liquid moisture contributes to the thermal comfort of a garment, especially for summer clothes and sportswear [7]

Moisture management property is an important aspect of any fabric meant for apparels, which decides the comfort level of that fabric. Every human being sweats during different kinds of activities. An important feature of any fabric is how it transports this water out of the body surface so as to make the wearer feel comfortable. [8]

1-1 Cloth-Body System:

Moisture vapour transportation functions may be determined in two main points:

- Regulation of body temperature – when the human body core temperature exceeds 37^0 C, sweat is produced.
- Transporting the sweat away from the skin and evapourating it to the atmosphere, reduces body temperature.[4]

Human body is a very complex thermodynamic system that needs to be in thermal balance with the surrounding environment at all given time for survival and proper functioning [9]. Humans usually wear clothing all day long - even in bed. We are surrounded by textiles, therefore it is often characterized as a “second skin”.

When the human body temperature rises above a certain level, an effective cooling is provided by the evapouration of sweat coming out of the glands. [10] The main part of the heat release occurs through the skin, only a small percentage accounts for the heat transfer via respiration. Since the skin is usually largely covered with clothing, the heat release of the human body is strongly influenced by the heat and moisture transfer. [9]

The thermal comfort of a garment depends on several factors:

1- Heat and vapour transport.
2- Sweat absorption.
3- Drying ability.

Total heat loss from skin results from the heat loss promoted by evapouration and the heat loss conveyed by conduction, convection and radiation. Under mild environmental conditions the loss of heat by evapouration takes place in the form of insensible perspiration which accounts for approximately 15% of the heat loss through the skin. [4]

For the garment that is worn next to skin should have:

a) Good sweat absorption and sweat releasing property to the atmosphere.

b) Fast drying property for getting more tactile comfort. [11]

As shown in Figure 1, when human body is covered with cloth (both outerwear and innerwear) a microclimate is formed between the skin and the fabric where humidity builds up as sweating proceeds. The moisture vapour should leave the microclimate before condensation to avoid the clinging of fabric on to the skin which creates sticky and uncomfortable feeling. [9]

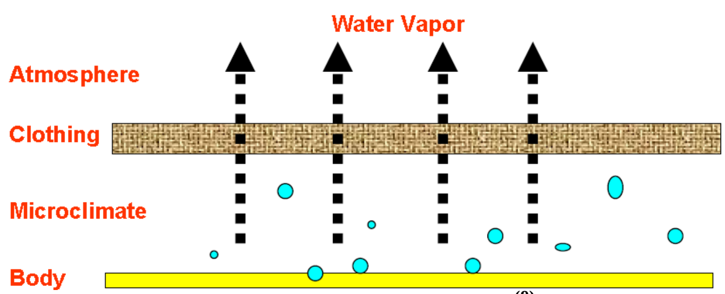


Figure 1: Cloth-body System[9]

The heat and moisture vapour transmission from human being to the environment through textile materials can be given by the following heat balance equation: $M - W = C_k + C + R + E_{sk} + (C_{res} + E_{res})$

Where

C_k	Heat transfer by conduction
C	Convection
R	Radiation
E_{sk}	Radiation and evapouration respectively
M	The metabolic heat generation in W/ m^2
W	The external work done in W/ m^2
C_{res}	Heat loss by respiration such as sensible heat loss
E_{res}	Evapourative heat loss respectively [12]

1-2 Moisture Vapour Transport Rate (MVTR) and Clothing Comfort

The rate at which water vapour moves through a fabric, measured in terms of moisture vapour transport rate (MVTR) plays an important role as it influence the human perception and the cool/warmth feeling. MVTR is measured in terms of mass of moisture vapour escaped through unit area of fabric per unit time (g/m^2/day).

Moisture vapour transport property of textile materials therefore becomes a critical factor in determining the comfort and performance of a clothing system. Comfort here does not refer to the psychological comfort but to the physiological comfort which relates to the movement of heat and moisture vapour through clothing systems.[9] For That the most important feature of functional clothing is to create a stable microclimate next to the skin in order to support body's thermoregulatory system, even if the external environment and physical activity change completely.[4] When a fabric allows the transport of water vapour at a faster rate, it is said to be a breathable fabric. In other words, the faster a fabric breaths, the better is its comfort. This property has direct implications on the end-use applications, consumer appeal and sales value of the fabric.

The ability of clothing materials to transport moisture vapour is a critical determinant of wear comfort, especially in conditions that involve sweating.[13] Human body is exposed to different kinds of climatic conditions like wind, snow, sunlight etc., and hazardous atmospheres like chemicals, bacteria, fire and sharp objects. Textiles materials are therefore expected to protect us from all these adverse situations, at same time provide enough comfort. [9]

A garment for daily use should have a degree of moisture vapour transmission, in which the hotter the environment or the greater the activity level, the higher the water/moisture vapour transmission is required. For example, when people do exercise in a hot environment, the function of perspiration as a factor in body-temperature regulation will be most effectively achieved if insensible evapouration can take place immediately. [7] The build-up of humidity in the clothing microclimate, or the air space between a clothing layer and sweat-wetted skin, is known to contribute to sensations of dampness and clamminess, especially during the cooling period that follows intervals of sweat-generating exercise. As sweating proceeds, the clothing microclimate humidity rises to a high value (Figure 2). [13].

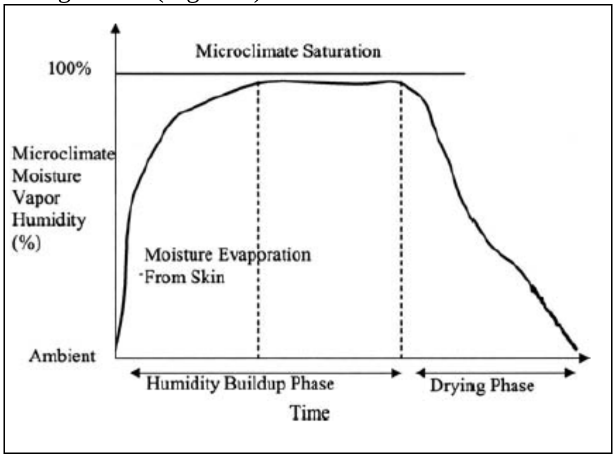


Figure 2. Illustrations of dynamic moisture vapour transport in fabrics [13]

The influence clothing materials have on such build-up depends on their ability to transport vapour. A fabric that is perceived as comfortable should transmit moisture vapour during the period the body sweats actively, and when the body has stopped sweating, the fabric should release the moisture vapour held in the space to the atmosphere to reduce the humidity at the skin. Yoon and Buckley [13] showed the importance of construction variables on moisture vapour transmission characteristics of fabrics. If people wear clothing with a low moisture vapour transmission property under hot situations, the heat transfer from people's skin outward will be suppressed or reduced, and thus, people may feel uncomfortable. However, for some products, fabrics with low water/moisture vapour transmission capability are required. [7]

1-3 Mechanism of Moisture Vapour Transmission

Moisture vapour transmission is the rate at which moisture vapour diffuses through a fabric. The moisture transport from the skin to the outer environments through clothing materials, often referred to breathability of the clothing material.[11,4] The transfer of moisture vapour is usually from the wetter environment to the dryer environment until equilibrium is reached. As moisture is evapourated from the skin surface, a moisture-vapour-permeable fabric allows moisture vapour to go through, keeping the fabric and skin dry and permitting evapourative cooling [7]

The mechanism involved in water vapour transmission through fabric from the skin to the outer surface by diffusion and absorption desorption method.

In absorption transmission-desorption method hygroscopic material acts as a sink, by absorbing the perspiration from the skin and water vapour get transmitted from it to the outer surface. It maintains a constant vapour concentration in the air immediately surrounding it absorption desorption method.

During a movement cycle, it will absorb and desorbs small amounts of moisture while maintaining a constant relative humidity in the adjoining air. The moisture vapour transmission during the transient stage is higher in case of hygroscopic material due to the combined effect of diffusion and absorption desorption.

Water vapour transmission plays very important role when there is only insensible perspiration or else very little sweating. An amount of moisture slightly in excess of the equilibrium regain for the surrounding ambient conditions, produce sensations of dampness during skin contact. When the moisture content in the fibres reaches saturation capillary action starts and at saturation or above that moisture level, capillary wicking is the major mechanism of moisture transport; although diffusion takes place but the amount of moisture transported due to the diffusion reaches maximum at around 30% regain for cotton cloth and after that remains constant.

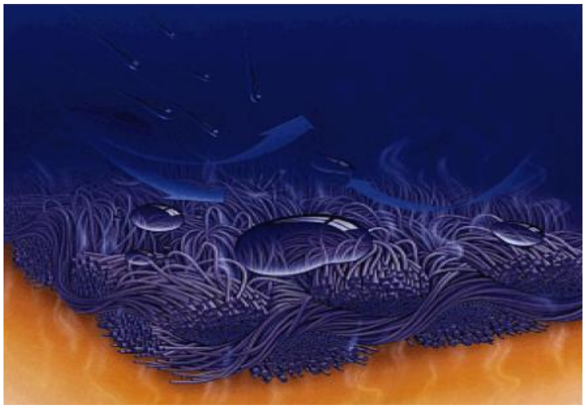


Figure 3. Moisture Vapour Transmission

So at higher activity condition when liquid perspiration production becomes high, to feel comfortable the clothing should possess good liquid transmission property. Wicking characteristic of the material determines how fast it can transfer the sweat to another layer or to the outer surface. (14)

1-4 Factors influence moisture vapour transmission through textiles

In order to understand the movement and transmission of moisture vapour to the environment, it becomes mandatory to understand the various factors that affect the moisture vapour diffusion through textiles.(3)

Fibre content and fabric geometry are two main factors that may affect the water/moisture vapour transmission of textiles.

1-4-1 Fibre Content:

Fibre content is one of the determinants of moisture vapour transmission because moisture vapour is absorbed by fibres, transported through fibres, and then desorbed to the environment. In this process, the inherent absorbency of the fibres or their affinity for water will determine the process of moisture vapour transmission. For example, rayon and wool absorb moisture readily from the body, but polyester and olefin do not.

The different types of fibres had different influences on moisture vapour transmission because they had different moisture absorption characteristics. Lower resistance to moisture vapour transmission was exhibited in more hygroscopic fabrics.

As the moisture-absorption capacity decreased, the resistance to water transfer increased.

Fabrics with different wicking characteristics may also have different Influences on moisture vapour transmission.(7) Knowledge of moisture vapour transport by textile materials is highly required to understand the problems associated with clothing comfort if one has to engineer next generation materials.(9) Hygroscopic_fibres have the capability to absorb water vapour when they are surrounded by humid air and_release water vapour in dry air. (7)

1-4-2 Fabric Geometry

The spatial/geometric distribution of fibres in a fabric might also play a significant role in moisture vapour transmission properties. The changes of thickness and percentage fibre volume would affect the resistance to water/moisture vapour transmission of any particular cloth. As the fabric thickness and percentage fibre volume increased, the resistance of the fabric to water/moisture vapour transmission increased. The fabric geometric parameters of porosity and thickness are affected by yarn diameter, which is determined by the fibre composition. (7)

Water vapour transport through a fabric is mainly governed by the differential pressure across the fabric layer and if the porosity of the fabrics is similar, the permeability of the fabrics is nearly identical regardless of fibre type being used.(**11**)

1-5 Measurement of MVTR Properties

A number of test methods are available to quantify the MVTR through fabrics and the most commonly used methods are in Table (1).

2. Material and Methods

Materials

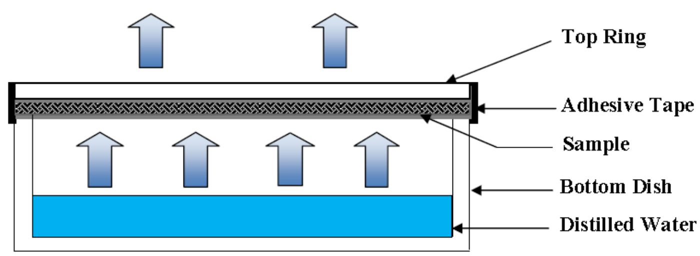
The experimental part of the present study is to investigate the influence of the number of fibres per yarn cross-sectionwith the same linear density on the MVTR. For that was chosen two different numbers of fibres per yarn cross section: 78/23/2 and 78/68/2.

Yarn 78/23/2 that means: The yarn consists of two yarn each one is 78 dtex and number of fibres per each yarn cross-sectionare 23. Yarn 78/68/2 the same previous description but with 68 fibres per yarn cross section.

Production of Knitted Fabric:

- The two yarns with different number of fibres per yarns cross sections were used to produce single jersey fabrics on Meyer & Cie knitting machines with the following specifications: Single jersey machine, gauge 28 GG, diameter 30”, feeders 96 and number of needles 2637.
- Samples were produced with the same loop-length 2.3 mm, to obtain the same fabrics specification.
- The knitting process was completed with constant machine settings.

Table (1) The commonly test methods to quantify the moisture vapour transport [9]

	Method	Standard	Principle
1	**Sweating guarded hot plate method**	**ISO 11092**	In this method, the water vapour transmission is measured in terms of evapourative heat resistance (Ret) of the material, i.e. amount of power required to maintain the heated plate at skin temperature (35°C) when moisture vapour evapourates from the plate and diffuse through test sample place kept on top of it. A sample measuring 5 inch X 5 inch is placed on the hot plate (or membrane) that is saturated with water to simulate sweating. The heat resistance **(Ret)** is given by the equation: **Ret (m^2 Pa W^{-1}) = A (Ps – Pa)/H** **Where, A = test area in m2, Ps = vapour pressure at plate surface, Pa = vapour pressure in air, and H = input power**
2	**Evapourative dish method**	**(BS 7209)**	According to the British standard BS 7209:1990, the test specimen is sealed over the open mouth of a test dish which contains 46 ml of distilled water and the assembly is placed on a rotating turntable and allowed to rotate in a controlled atmosphere of 20°C and 65% relative humidity. Following a period of one hour to establish equilibrium of water vapour pressure gradient across the sample, successive weighing of the assembled dish at first and fifth hour gives the amount of water permeated (M) through the specimen. The MVTR is then calculated using the equation: **MVTR (g/m2/24hr) = 24M/At Where, M = mass of water vapour in grams lost in t hours** **A = area of the sample exposed to vapour (0.0054113 m^2)**  **Figure 4. Evapourated Dish(9)**
3	**Upright cup method**	**(ASTM E 96-80)**	In this method, sample being tested is placed on top of a 155ml aluminum cup that is filled with 100ml of distilled water and covered with gasket and clamps. This assembly is kept inside a controlled chamber where temperature, relative humidity and air velocity are maintained at 21 ± 0.6°C, 50 ± 2% and 2.8 ± 0.25 ms-1 respectively. The weight of the cup assembly is measured after 3, 6, 9, 13 etc. respectively. The water vapour transmission is then measured using the following equation:**WVT (g/h/m2) = (G/t) / A (2.9) Where, G = weight change in grams, t = time during which G occurred in hours, G/t = slope the straight line (wt. loss/unit time) in g/h/m^2, A = sample area in m^2**
	Desiccant (inverted cup) method	**(ASTM E 96-80)**	The test specimen is sealed on top of the open mouth cup that contains the desiccant (anhydrous calcium chloride, dried at 400°F before use). The assembly is then kept inside the controlled chamber as in the upright cup method. Periodical weighing of sample assembly will determine the water vapour transport through the specimen.
5	**Dynamic moisture permeation cell**	**(ASTM F 2298)**	It measures the moisture vapour diffusion resistance of the sample by passing mixture of dry and wet-saturated nitrogen streams above and below the sample. By carefully measuring the relative humidity of input and output streams the vapour diffusion resistance is determined. A humidity gradient of 90%, air temperature of 20 ± 1°C and gas flow rate of 200 cm3/sec is maintained throughout the experiment. The water vapour diffusion resistance is calculated using the equation:

Testing:

- The samples after dying and finishing were kept in standard atmosphere for 24 hours to allow for relaxation and conditioning.
- The fabric structural and physical fabric properties like weight (ASTM D 3776), thickness (ASTM D 1777), wales and courses per unit length (ASTM D 3887) and loop length (ASTM D 3887) were evaluated (Table 2).
- The weight of the knitted fabrics was measured by cutting the sample size of 10x10 cm. The sample was weighed in the electronic balance and the value was multiplied by 100.
- The loop length was derived by unraveling 12 courses and their total length was measured.

Moisture Vapour Transport Rate (MVTR) Test

MVTR was measured on a evapourative dish method based on the British Standard, BS 7209. As per the British standard the test specimen is sealed over the open mouth of a test dish which contains water and the assembly is placed in a controlled atmosphere of 20°C and 65% relative humidity. Following a period of one hour to establish equilibrium of water vapour pressure gradient across the sample, successive weighing of the assembled dish were made and the rate of water vapour permeation through the specimen is determined.

Each dish is filled with sufficient distilled water to give a 10 mm air gap between the water surface and the fabric. A wire sample support is placed on each dish to keep the fabric level. Contact adhesive is applied to the rim of the dish and the specimen, which is 96 mm in diameter, is carefully placed on top with its outside surface uppermost. The cover ring is then placed over dish and the gap between cover ring and dish sealed with PVC tape as shown in fig.5.

A dish which is covered with the reference fabric is also up in the same way. All the dishes are then placed in the standard a atmosphere and allowed to stand for at least 1 h to establish equilibrium. Each dish is then weighed to the nearest 0.001 g and the time noted. After a suitable time for example overnight the dishes are reweighed and the time noted again.

The fabric on the evapourative dish and the MVP turntable equipment are shown in Figures 5 and 6. Evapourative dishes with fabrics were mounted on the turntable and were allowed to rotate for one hour to establish equilibrium. Then the turntable was allowed to rotate for five more hours in the controlled atmosphere and the assemblies were reweighed at the end. The MVTR in g/m2/day is calculated as given in Equation: MVTR = 24 M/At where,

M = is the loss in mass of the assembly over the time period t in grams;

t = is the time between successive weighing of the assembly in hours and A= is the area of the exposed test fabric (0.005413 m2).

Figure 5: MVTR Turntable [15]

Figure 6: Evapourative Dish Assembly [15]

Yarn Cross-section microscopic image test:

To interpret the results it was taken microscopic image to the cross-section of the two yarns which were used to manufacture the samples. This test was carried out by using microscope video Camera (MVC).

Fibres and Yarn Diameter test

In this part was measured the diameter of the Fibres and the yarn for yarns (78/2/23 and 78/2/68) to find a mathematical relationship to explain the relationship between the fibres inside the yarn, or in other words to determine the spacing between fibres within the yarn.

The projectina (projection microscope) is the standard method for measuring fibre and yarn diameter. The method involves preparing a microscope slide short lengths of fibre which is then viewed using a microscope that projects an image of the fibres onto a horizontal screen for ease of measurement. Techniques are followed that avoid bias and ensure a truly random sample.

3. Results and Discussion

3.1 Structural and Physical Properties of the Knitted Fabrics

It may be clear from the data in Table 2 that fabric thickness, fabric weight, wales and courses per unit length and loop length show nearly the same values.

3.2 MVTR test results

Table 2 shows that water vapour permeability value decreases as the number of fibres per yarn cross-section increases.

That means sample which was produced using yarn with 23 fibres in yarn cross-section gave the highest value of water vapour permeability.

3.3 Yarn Cross-section Microscopic Image

It is clear from the Microscopic images that:

1- The size and number of the spacing between the fibres in yarn cross-section(78/23/2) are clearly shows, however yarn 78/68/2 the spacing are not entirely clear and all the shots appeared fibres per yarn cross-section are overlapping and contiguous blocks with each other, It has found it difficult to take a clear image with a different light source. (**See Fig.8, 9**).

2- In other words it is clear that the distances between fibres in yarn 78/23/2 are more than yarn 78/2/68.

That means the spaces between the fibres had the greatest effect in increasing the rate of moisture vapour transportation in sample no.1 more than sample no.2

Table (2) Tests Results

Sample	Yarn (dtex)	Weight (gm^2)	Thickness (mm)	Wales /cm	Course /cm	WVP(g/m^2/ 24hrs) of test fabric	WVP(g/m^2/ 24hrs) of control fabric	WVP I (%)	Yarn diameter (micron)	Fibres diameter (micron)
A	78/23/2	198	0.494	27	19	689.4	695.9	99.1%	248	26.4
B	78/68/2	197	0.487	27	19	684.4	695.9	98.4%	246	16.6

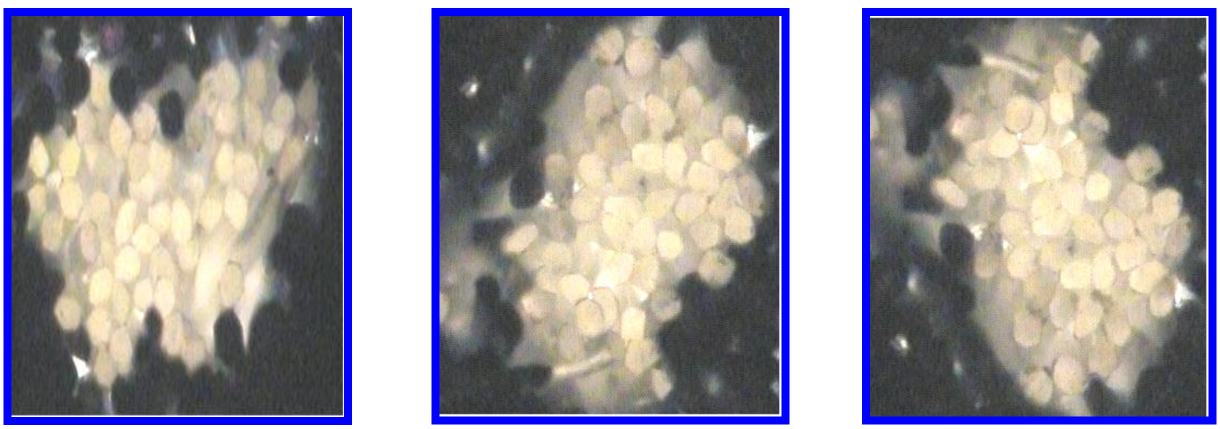


Figure 8: Spacing between fibres clearly shows.

Figure 9: Fibres are overlapping and contiguous with each other and spacing between fibres are not entirely clear

Fibres and Yarn Diameter test

From the table 2 it is clear that:

- Fibres diameter in the first sample is greater than fibres diameter in the second sample.

To find a mathematical relationship assume that :

- The cross-section of yarn and fibres are circular (See Fig. 10)
- $\mathbf{A_S = A_Y - A_{TF}}$

$\mathbf{A_S}$ = Area of spacing between fibres.

$\mathbf{A_Y}$ = Area of yarn cross-section

$= \pi r_y^2$ (r_y= radius of yarn).

$\mathbf{A_{TF}}$ = The total area occupied by the fibres in yarn cross section.

= $\mathbf{A_F}$ × Number of fibres per yarn cross section.

$\mathbf{A_F}$ = Area of fibre cross section.

$= \pi r_f^2$ (r_f= radius of fibre).

$\mathbf{A_{Y1}}$ $= \pi r_{y1}^2$ (r_{y1}= radius of yarn cross-section of yarn78/23/2)

$\mathbf{= 3.14 \times (248/2)^2 = 3.14 \times (124)^2}$

= 48280.64 micron^2

$\mathbf{A_{TF1}}$ $\mathbf{= A_F\ (\pi r_f^2) \times 23 \times 2^*}$ ***** 78/23/2

$\mathbf{= (3.14 \times (13.2)^2) \times 23 \times 2}$

= 547.1 × 23 × 2 = 25167.22 micron^2

$\mathbf{A_{S1}}$ $\mathbf{= A_{Y1} - A_{TF1}}$

= 48280.64–25167.22 = 23113.42 micron^2...(1)

$\mathbf{A_{Y2}}$ $\mathbf{= \pi r_y^2}$ (r_{y2}= radius of yarn cross-section of yarn78/68/2)

$\mathbf{= 3.14 \times (246/2)^2 = 3.14 \times (123)^2}$

= 47505.06 micron^2

$\mathbf{A_{TF2}}$ $\mathbf{= \pi r_f^2 \times 68 \times 2^*}$ ***** 78/68/2

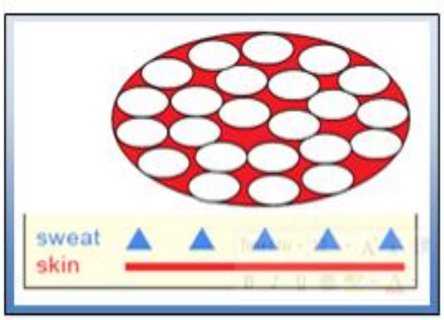
$\mathbf{= 3.14 \times (8.3)^2 \times 68 \times 2 = 216.31 \times 68 \times 2}$

= 29418.78micron^2

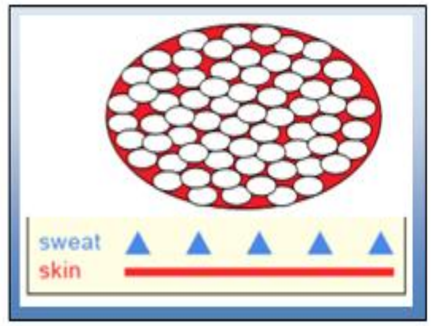
$\mathbf{A_{S2}}$ **=47505.06–29418.78=18086.27 micron^2…... (2)**

From (1) and (2) $\mathbf{A_{S1} > A_{S2}}$

That means Spaces between the fibres in the yarn with 23 fibres are more than in the yarn with 68 fibres which led to increase the rate of moisture vapour transportation in sample no.1 more than sample no.2



(10-A) shows a simulated sketch for the yarn cross-section with 23 fibres



(10-B) shows a simulated sketch for the yarn cross-section with 68 fibres

(Figure 10) shows simulated sketches of yarns cross-section, the researcher assumes the yarn and fibres cross-sections are circular

Data Analysis:

The higher water vapour permeability of sample No.1 which was manufactured by using yarn 78/23/2 can be attributed to the spacing between fibres inside the yarn cross-section which facilitate the easy passage of the water vapour through the yarn and the fabric.

Where that water vapour permeability rate depends on: Material, spacing between fibres inside the yarn and spacing between yarns inside fabrics (Fabric structure), and in this study the material is a constant factor, also spacing between yarns inside the fabric is a constant factor because the sample were manufactured using the same production parameters (Gauge, yarn linear density, loop length, and structure). Thus became clear the spacing between fibres inside the yarn cross-section (size and number) is a responsible here for the MVRT

Consolations

Moisture vapour transmission (MVTR) is an important factor related to thermal comfort especially for summer clothes and sportswear. MVTR is the rate at which moisture vapour diffuses through a fabric. The moisture transport from the skin to the outer environments through clothing materials often referred to breathability of the clothing material.

Cloth plays a very important role in creating microclimate near the skin. MVTR through textile structure is complicated and governed by various factors, including fabrics openness, fabric thickness, pore size, and intrinsic fibre properties.

For the garment that is worn next to skin should have: a) Good sweat absorption and sweat releasing property to the atmosphere. b) Fast drying property for getting more tactile comfort.

A number of test methods are available to quantify the MVTR through fabrics.

From the results it is evident that variation in number of fibres per yarn cross-section and fibre denier affects the MVTR behaviour of the fabrics. The findings are summarized as follows:

- There is a relationship between MVTR and number of fibres per yarn cross-section.
- MVTR increases with the lower of number of fibres per yarn cross-section with the same linear density.
- The Spaces between the fibres per yarn cross-section had the greatest effect in increasing the rate of MVTR in this study.
- MVTR depends on many factors and may occur by the following ways :

  — Through chemical nature of fiber.

  — Through space between yarns in the fabric (open porous) and that depends on the fabrics structure and yarn count.

  — Through space between fibres, in yarn cross-section, where diffusion take place of the fiber bundle and subsequent evaporation at the outer surface and that depend on the number of fibres per yarn cros-section.

Recommendations

For their importance , we recommend increasing the potentialities required for research in moisture management of fabrics, it has become a must, considering the present and future demands of Egypt climate , also all hot regions to meet temperature increases special in summer.

More research in the effect of number of fibres per yarn cross-section on the different physical and mechanical properties of fabrics.

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