A Study on Fiber Size and Cross Sectional shape on Moisture Transmission Properties of knitted active sports Wear

Dr.K.M.Pachiyappan, Head, Dept of Costume Design & Fashion PSG College of Arts & Science.
Dr R Divya,Asst Professor, Dept of Costume Design & Fashion , PSG College of Arts & Science.
K Dr M Kantharaj, Manager, NTC, Coimbatore.

Abstract

Moisture transmission through textiles has a great influence on the thermo-physiological Comfort of the human body which is maintained by perspiring both in vapour and liquid form. The clothing to be worn should allow this perspiration to be transferred to the atmosphere in order to maintaining the thermal balance of the body. Diffusion, absorption- desorption and convection of vapour perspiration along with wetting and wicking of liquid perspiration play a significant role in maintaining thermo-physiological comfort. The current work incorporates an experimental study on the effect of fiber cross sectional shape and fibre diameter on moisture transmission properties of the single jersey knitted fabric. With the change in fibre diameter and cross sectional shape, it is seen that with increase in fibre specific surface area, wicking rate through fabric increases and where as permeability of the fabric reduce.

Key Words: Fiber Size, Sports Fabrics, Air Permeability, Cross Sectional

1. Introduction

Moisture flow through textile materials is important in diverse range of textile applications, including casual wear, sportswear, and protective wear from their comfort point of view, textile processing and cleaning, composite manufacturing liquid transfer through perform and in many other areas. From the comfort point of view, moisture transmission through textile material both in liquid and vapour forms are equally important. Water vapour transmission through the textile material is governed by Fick's Law [1] (equation (1))

$$J_{Ax} = -D_{AB} \frac{dC_A}{dx} \quad \text{............ Equation 1}$$

Where, JAx is the rate of moisture flux; dCA/dx is the concentration gradient in x direction; and DAB is the diffusion coefficient or mass diffusivity of component A (water vapour) diffusing through component B (porous media). Mass diffusivity of a particular fluid at a specific atmospheric condition depends on the nature of the porous media, such as its porosity and moisture regain.

Liquid moisture flow through textile materials is controlled by two processes-wetting and wicking. Wetting is the initial process, involved in fluid spreading; it is controlled by the surface energies of the involved solid and liquid. In case of textile material as soon as water wets the fibre, the water enters the inter fibre capillary channel and is dragged along by the action of capillary pressure. The magnitude of the capillary pressure is given by the following Laplace equation [2]

$$P = \frac{2\,\gamma_{LV}\,\mathrm{Cos}\theta}{R_c} \quad \text{........ Equation 2}$$

It is the simplified form of the following relation (equation (3))

$$P = \gamma_{LV}\,\mathrm{Cos}\theta\;\frac{\text{Perimeter of the capillary}}{\text{Area of the capillary}}$$

$$\text{Say, } \frac{\text{Perimeter of the capillary}}{\text{Area of the capillary}} \quad \text{Ratio as } \psi$$

$$\text{Where as, } \gamma_{LV}\,\mathrm{Cos}\theta = \gamma_{SV} - \gamma_{SL} \quad \text{.......... Equation 3}$$

This equation is known as Young-Dupre's equation [3].

Where *P* is the pressure developed in the capillary channel, *Rc* is the radius of the capillary formed in the fibrous structure. γ represents the surface tension at the interface between the various combinations of fibre (*S*), liquid (*L*) and air (*V*), and θ is the contact angle between the liquid drop and fibre surface. γ_{LV} Cosθ is the resultant surface tension between fibre and liquid interface. It is an experimental fact that the surface tension is a function of state i.e. of chemical composition, pressure and temperature [4,5]. For a single liquid at constant pressure and temperature, the surface tension at liquid vapour interface (γ_{LV}) is constant regardless of whether or not the surface area is being changed. As the fibre cross sectional shape and fibre type change cosine of the contact angle get changed which alters the P value (equation (3)).

Size and shape of the capillary is expected to be varied with the change in fibre cross section; as the specific surface area of the fibre get changed with fibre diameter and cross sectional shape. Change in capillary shape and size will alter the value influencing capillary pressure. The change in the area of the capillary is expected to change the water vapour transmission through the fabric as well.

2Materials and Methods

2.1Materials

In order to study the effect of cross-sectional shape, polyester filaments with three different types, i.e., circular, trilobal and Microdenier have been used. The cross-sectional view of the filaments has been given in Figures 1(a), 1(b) and 1(c).

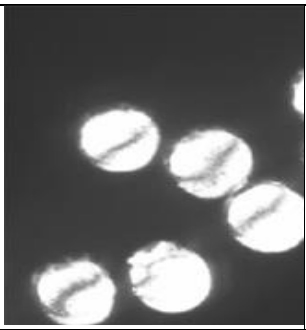


Fig. 1(a) circular

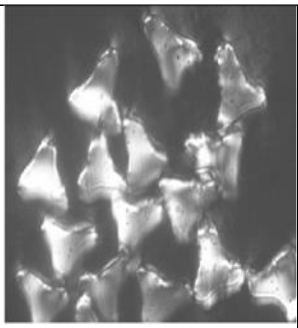


Fig. 1(b) Trilobal

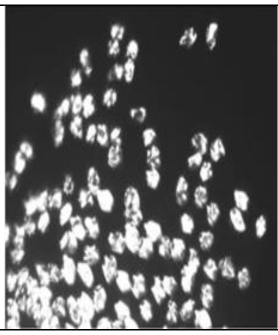


Fig. 1(c) Microdenier

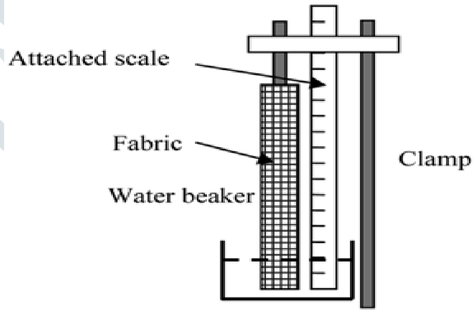
2.2Fabric development and Particulars

The fabric were knitted on the 24” dia meter Single jersey machine of 24 Gauge, 72 feeders and details of the fabrics have been given in Table

Cross sectional shape	Fibre fineness (dpf)	Fibre Shape factor	LL mm	CPI & WPI	Fabric Tightness factor	Fabric mass (g/m2)	Fabric thickness (mm)
150/108 D Circular	1.39	1.0	2.5	29&60	16.33	132	0.62
150/108 D Trilobal	1.39	1.32	2.5	30&62	16.33	128	0.45
150/288 D Circular	0.52	1.0	2.5	32&60	16.33	135	0.69

2.3 Measurement Methods

2.3.1 Vertical Wicking Test



(a) Vertical wicking tester

The effect of fibre parameters on the vertical wicking of the fabrics have been determined by measuring the wicking height against gravity. The test has been conducted using a vertical wicking tester according to DIN 53924 method [6].The schematic diagram of the instrument is shown in Figure 2. A strip of fabric (200 mm×25 mm) was suspended vertically with its lower end (30 mm) immersed in a reservoir of distilled water. At a regular interval, the height reached by water in the fabric was measured by the clamped scale.

2.3.2 Air Permeability

Air permeability of the fabric has been measured using TEXTEST FX III 3300 air permeability tester at a pressure of 125 Pa; ASTM D737 has been followed.

2.3.3 Drying Velocity

Quick drying capability of the fabric was evaluated by its drying rate. The specimen of the size 10x10 Cm2 was put on the plate of the balance and the dry weight was recorded as w_f(g) The weight of water previously added in fabric was equal to 25% of the dry weight and then the weight was recorded as w_o(g). The change in weight of water w_i(g) at regular intervals was continuously measured. The remained water ratio (RWR) was calculated using the following equation to express the change in water weight remained in the specimen over the time for drawing the evaporating curve from 100% to 0%.

$$\text{RWR (\%)} = [w_i(g) - w_f(g) / w_o(g) - w_f(g) \times 100\%]$$

3. Results and Discussion

The effect of fibre cross section on vertical wicking of the fabric is shown in Figure 4. Analysing the results it is found that height reached by water along fabric with the increase in shape factor of the fibre.

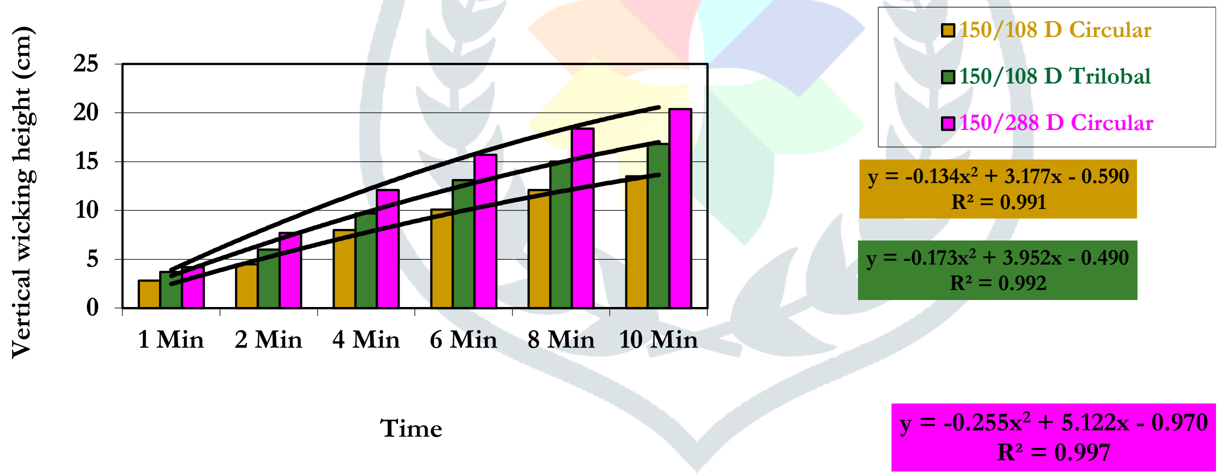
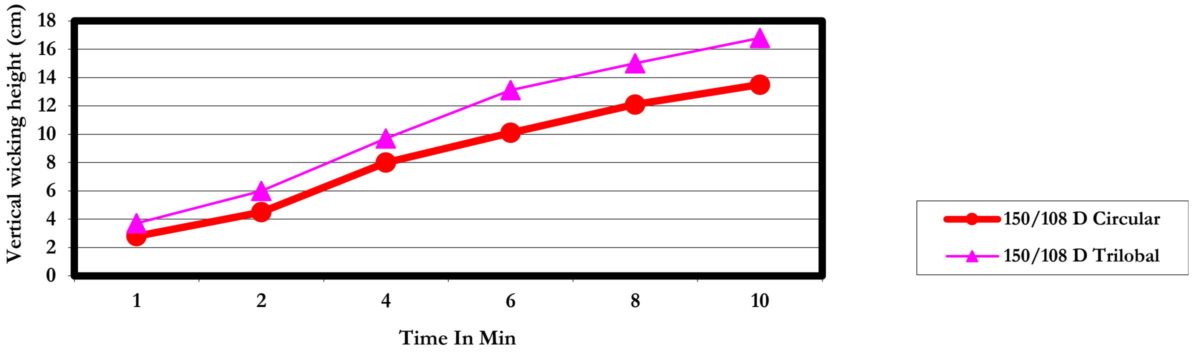


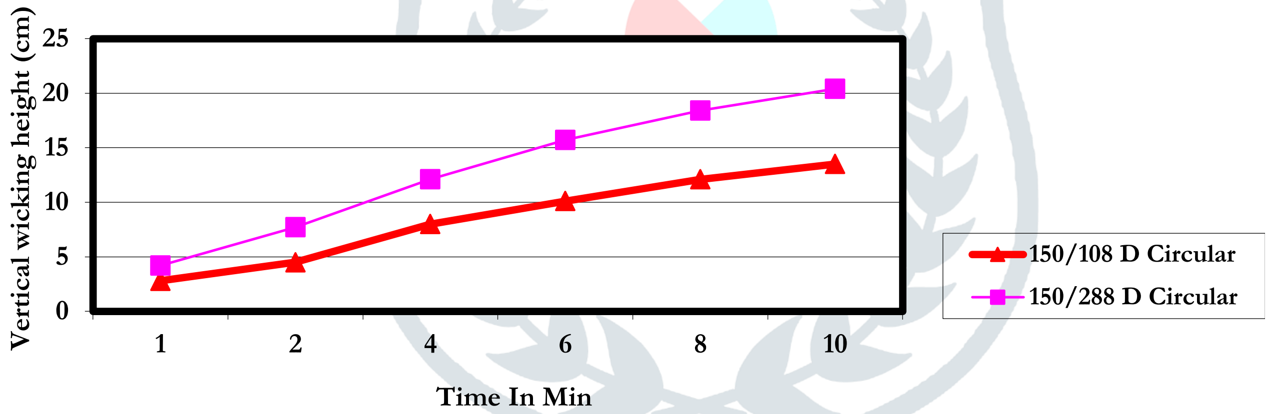
Fig 3.Wicking of different cross sectional and microdenier fabrics

Fig 4. Effect of fibre Shape on vertical wicking



As the shape factor of the fibre increases, specific surface area of the fibre increases. Higher specific surface area signifies, fibre having same cross-sectional area will have higher perimeter.So in that case capillaries formed by these fibres, will provide higher perimeter for the liquid to wet. This will increase the ψ value, resulting higher capillary pressure. From equation (3) it is identified that capillary area being same as the perimeter increases, capillary pressure will be increased, which should raise the capillary flow.

Fig 5. Effect of fibre denier on vertical wicking



Effect of fibre denier on vertical wicking has been plotted in Figure 5. From the results it is observed in case of fabric with microdenier multifilament yarn there is a high improvement in wicking rate. Due to lower diameter the number of filaments per yarn will be higher, as denier of both the yarn is nearly same, which will increase the number of capillaries n the yarn. In addition, due to low linear density of the fibres, specific area of the fibre will be higher, reducing the diameter of the developed capillaries.

3.2 Drying Velocity

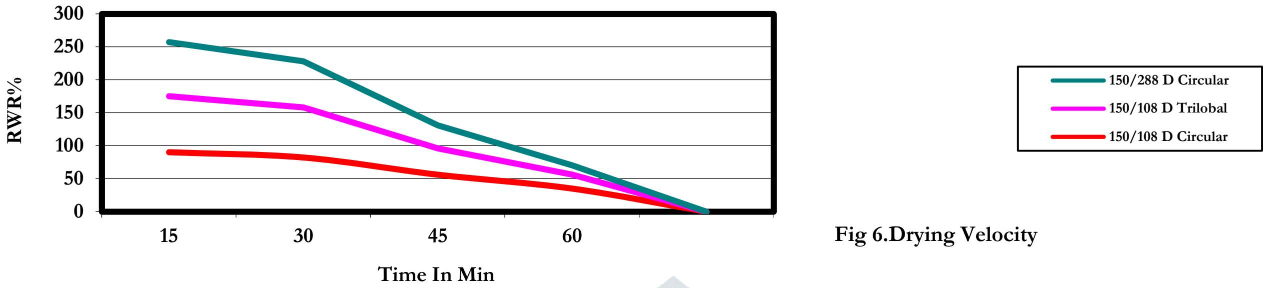


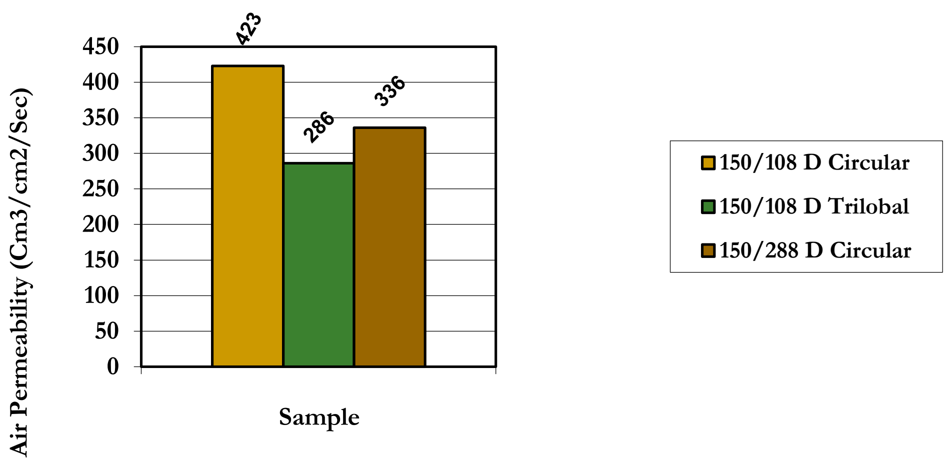
Fig 6.Drying Velocity

The Below Graph Shows the Drying Velocity of the fabric at Room Temperature. From the results it is observed in case of fabric with microdenier multifilament yarn there is a high improvement in drying rate and followed by other Fibers. It's due to lower diameter the number of filaments, which will increase the number of capillaries in the yarn and drying rate.

3.3 Air Permeability

The result obtained from is shown in Figure 7. As fibre shape factor increases specific surface area of the fibre also increase accordingly. In consequence of the higher specific surface area, space between the fibres in the fabric decreases and offers actually higher packing than the calculated one. Furthermore, the drag resistance to air [8] and the water vapour flow through the fibre surface increases, which results in lower air permeability for these fabrics. Air permeability is seen to be decreased with the decrease in fibre diameter. This result can also be explained by higher specific area of the fibres. In case of finer fibre as the specific area of the fibre is higher, total air space available in the fabric will be lower, lowering the air permeability of the fabric.

Fig.7 Air Permeability



4. Conclusion

A considerable change has been obtained in fabric wicking behaviour with the change in cross-sectional shape of the fibres, with same linear densities. With the increase in fibre shape factor wicking property of the fabric gets better, while permeability reduce to a certain extent. Fibre diameter has also been found to play an important role in moisture transmission through fabrics. By comparing micro-denier filament fabrics with standard denier fabrics, it may be concluded that a reduction in fibre diameter increases the wicking properties through the fabric, but air permeability are reduced. The understanding which has been obtained from this study will be helpful in designing functional work wear or sports wear by balancing between the high liquid as well as vapour transmission properties as per the specific requirement by suitably engineering the fibre

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