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EFFECT OF STATE OF FABRIC ON WICKING CHARACTERISTICS OF KNITTED FABRICS SUITABLE FOR SPORTS APPLICATIONS

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SUMMARY

This study examines the wicking properties of different fabrics produced from 100% Polyester, 100% Soybean, and bilayer (Polyester and Soybean), under various conditions (relaxed, static deformation, and dynamic deformation). The study evaluates the wicking area, liquid spread, and maximum wetted radius to understand moisture transport and absorption inside the fabric structure. According to the results, polyester textiles typically have better wicking qualities than soybean fibers, while bilayer fabrics frequently show better wicking qualities than single-layer fabrics. Dynamic deformation shows the tendency to improve wicking properties more significantly, especially in multidirectional stretching; suggesting potential applications for sports materials that need to manage moisture better. The results of this study provide insights into fabric design for enhanced comfort and utility by highlighting the significance of fabric composition and state when evaluating moisture-wicking ability.

Key words: *deformation, dynamic, liquid spread, static, stretching, wicking*.

INTRODUCTION

Physiological comfort involving moisture/sweat is one of the key parameters in selecting fabric for clothing, especially a very vital aspect for sportswear. All humans sweat during various levels of activities to balance the heat generated in the body. The rate of sweat generated during vigorous sports activities is high. The generated sweat is absorbed by the textile material next to the skin. The accumulated moisture in the clothing increases discomfort to the wearer. This discomfort makes the wearer get tired very quickly and it directly influences the sports performance of the player.

Effective management of moisture can be achieved by effective moisture vapor transmission, wetting, and wicking. According to much research, wicking is the actual phenomenon happening during the interaction between sweat and the fabric, where the sweat from the skin is transported to the outer environment for drying. Fast and immediate transfer of sweat to the wider area of the fabric through its capillary action facilitates faster evaporation. This immediate transfer and drying of sweat from the skin make the wearer feel comfortable and dry. Thus, this wicking action offers a direct effect on clothing comfort.

Vertical wicking and transverse wicking methods do not provide realistic results of the common phenomenon happening in the real case and may not help to conclude the wicking behavior of the fabric. Hence measurement of wicking other than these methods is also important.

Many studies on wicking, evaporation, and absorption are conducted using a variety of approaches. The wicking behavior of various textiles was examined in studies by [1] and [2], and identified that hydrophilic fibers and open-knit structures improve wicking efficiency. In [3] assessed the wicking in intricate fabric structures by computer modelling which assists in the design of high-performance textiles. [4], attempted to improve quick absorption and evaporation through nanotechnology.

The liquid spreading speed was examined using electrical resistance [5], an image processing technique to study the spreading behavior [6], and the transverse wicking (along the plane/surface) of elastic knitted fabrics along the extension and recovery using cyclic stress instrument [7], evaluated the capacity to absorb moisture using a sweating cylinder [8], evaluated the moisture managing characteristics of fabric using Moisture Management Tester (MMT) [9]. The impact of fabric structure, moisture management finishes, and treatments was analyzed and showed greater constructive outcomes [19] [11] [12].

The techniques established to evaluate the wicking height or rate of vertical wicking under a controlled state [13] [14]. Real-time monitoring of wicking kinetics and dynamic wetting behavior has been made possible by advancements in sensor technology and data-collecting systems [10, 20]. A deep understanding of the method of wicking happening at the micro level has been made possible by the very precise image capturing and detailed processing of the captured images during the process of interaction between the liquid and the textile material [16].

In the real scenario, the garment worn by the sportsperson undergoes many deformations such as uniform stretch throughout the wear as in the case of tight-fitted garments, or repeated stretching and relaxing during the sports action. These deformations may be in the form of tensile stress (axial stress), shear stress (diagonal stress), bending, buckling, twisting, compression, and so on. This deformation can be created by motionless stress (static deformation) or by repeated movement causes of stressed and unstressed (dynamic deformation) [15].

To understand the realistic wicking behavior of fabrics used for different applications, the investigation on multidirectional wicking under relaxed, static deformation, and dynamic deformation is carried out using a multidirectional wicking instrument [17] and [21].

MATERIALS AND METHODS

Materials

Micro denier polyester yarn for 150 deniers, soybean yarn for 89 deniers, and cotton yarn for 36s were obtained from the yarn retailer from the single lot. Single jersey (S/J) fabric with 100%microdenier polyester and 100% soybean yarn were produced for this study. Bi-layer fabrics were produced to utilize the benefit of micro-denier polyester, soybean, and cotton yarns in one fabric. Bi-layered fabric structure with micro denier polyester as inside layer and soybean as outside layer by feeding all feeders and choosing plated structure using M/s Year China circular knitting machine. The knitting machine particulars are as follows:

- Gauge - 24
- Cylinder diameter - 20 inch
- Feeders– 66

The particulars of the fabrics produced are presented in Table 1.

Table 1. Particular Fabrics

S. No	Sample	Construction details		Thickness (mm)	Areal Density (GSM)	Loop length (mm)
		CPI	WPI			
1.	100% Polyester fabric	51.08	62.41	0.4	136	3.0
2.	100% Soybean fabric	53.21	62.69	0.49	148	3.0
3.	Bilayer fabric Microdenier polyester - Inner layer Soybean fabric - Outer layer	55.55	71.32	0.57	201	2.8

Methods

Measure of Maximum Wetted Radius Through Moisture Management Tester

To assess the ability of the fabrics to control moisture, which is critical for comfort and functionality in a variety of applications, moisture management testing is required. The moisture management characteristics of the fabric samples prepared and conditioned were assessed following AATCC 195-2009 using the SDL Atlas Moisture Management Tester. The measure of liquid spread was recorded when the liquid started to spread along the surface as radial multidirectional spread and also it travels from the inner side to the outer side of the fabric using concentric moisture sensors. Wetting time (WT), absorption rate (AR), spreading speed (SS), maximum wetted radius (MWR), accumulative one-way transport index (AOWT) and overall moisture management capacity (OMMC) can be assessed using a moisture management tester. In this study, the maximum wetted radius is presented and taken for discussion, since it is in line with the results obtained in the multi-directional wicking instrument.

Measure of Area of Liquid Spread Through Multidirectional Wicking Instrument

The multidirectional wicking instrument is utilized to investigate the realistic wicking behavior of materials under relaxed state, static deformation, and dynamic deformation states. It has a deformation chamber with four holders to hold the fabric and has a provision for applying different deformations to the fabric. Each clamp receives its drives for clockwise and anticlockwise rotation through a stepper motor which in turn deforms the fabric. This instrument has the provision for producing a relaxed state, static deformation (1 way, 2 ways, and 4 ways), and dynamic deformation (1 way, 2 ways, and 4 ways) to the fabric. 2 cameras are fixed focusing both the sides of the fabric and record the area of simultaneously. The liquid input unit was filled by preparing artificial sweat by following the standards given in the AATCC test method 15-2009. The Input liquid flow rate was adjusted to supply 1 drop per second to the fabric sample [18].

It has the option to select

- Deformation mode

  (1 way, 2 ways, and 4 ways),

- Rate of deformation

  (10– 50 mm per second)

- Percentage of deformation

  (1% - 60% extension from its original dimension),

- Number of cycles (1-100)

- Number of snaps after each cycle (1-50snaps)

The wetted area is assessed using the images taken after the completion of each cycle from this multi-directional wicking instrument.

RESULT AND DISCUSSION

Results

The fabrics prepared were taken for measuring the area of wicking using a moisture management tester (MMT) and multi-directional wicking instrument. The effect of knitted fabrics and the state of fabric on the area of wicking were examined. The rates of liquid/moisture transport from the inner to outer side of fabrics were also studied using this instrument.

Wicking Characteristics of Fabrics using Moisture Management Tester

In this study, the maximum wetted radius is presented, which is the furthest distance from the center of a fabric sample that is reached by moisture during a wicking test. This parameter is important for understanding the extent of moisture absorption and transport within the fabric structure which facilitates faster drying and improved comfort. The results are presented below:

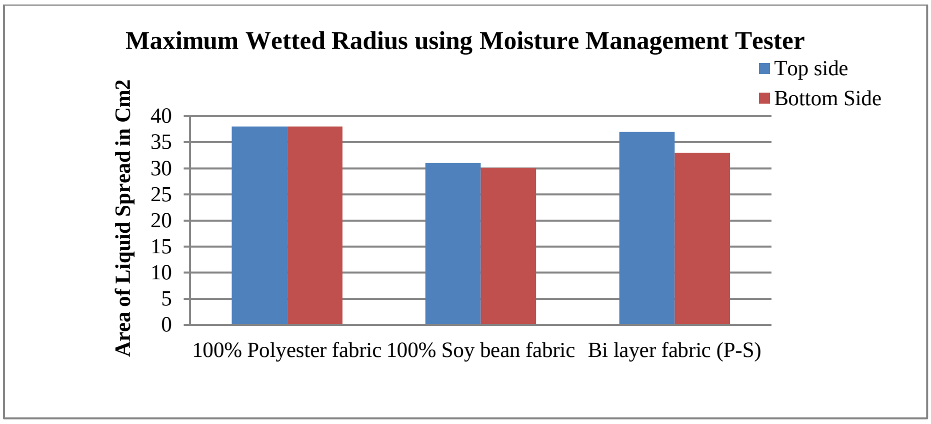

Figure 1. Wicking Character - Maximum Wetted Radius Using Moisture Management TESTER

Wicking Characteristics of Fabrics using Multi Directional Wicking Instrument

In this study, the maximum wetted radius is presented, which is measured using a multi-directional wicking tester. This device is used for understanding the extent of moisture transport within the fabric during movement. The results obtained are given as a chart.

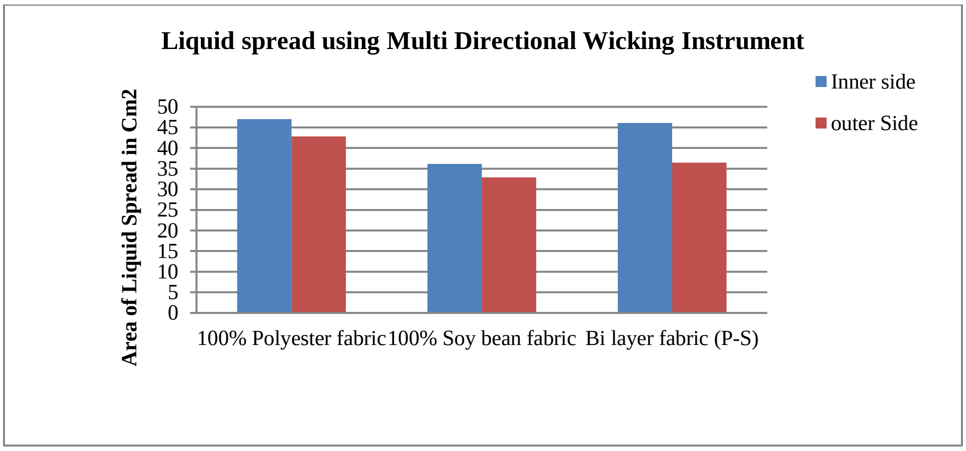

Figure 2. Wicking Character - Liquid Spread Using a Directional Wicking Instrument

Wicking Characteristics of Microdenier Polyester Fabrics Under Different States

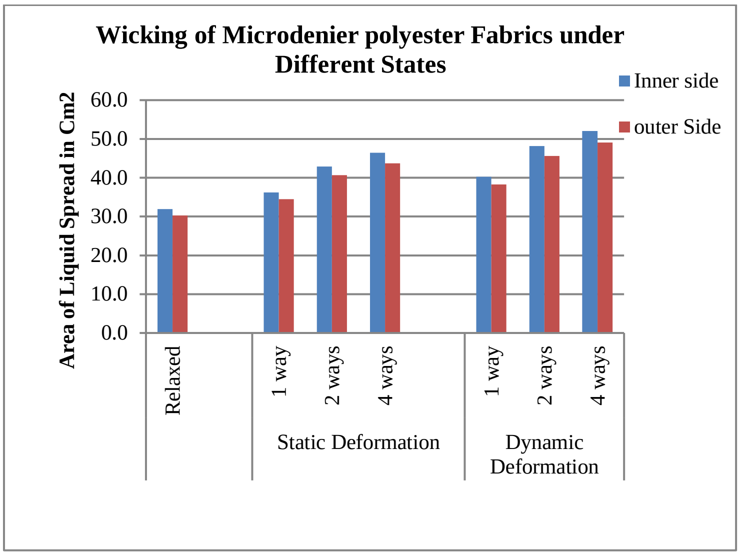

Figure 3. Wicking of Micro Denier Polyester Fabrics under Different States

The area of liquid wicking in square centimeters (cm²) varies depending on the state of the fabric and the direction of deformation. Generally, it is observed that the wicking area tends to increase for the deformation (both static and dynamic) compared to the relaxed state. This suggests that the deformation of the fabric facilitates greater liquid wicking, likely due to changes in the fabric's pore structure or surface properties.

Wicking Characteristics of Soybean Fabrics under Different States

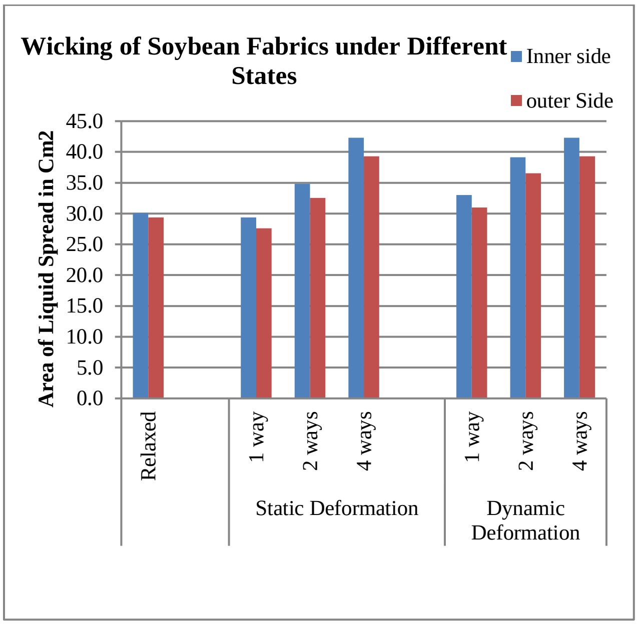

Figure 4. Wicking of Soybean Fabrics Under Different States

The soybean fabric always shows lower wicking areas in the relaxed state compared to the fabric, indicating potentially superior moisture-wicking properties. The soybean fabric exhibits a decrease in the wicking area when stretched in different ways under static deformation, similar to the polyester fabric. under dynamic deformation, the soybean fabric shows a trend of increasing wicking area with the number of corners stretched, similar to the polyester fabric.

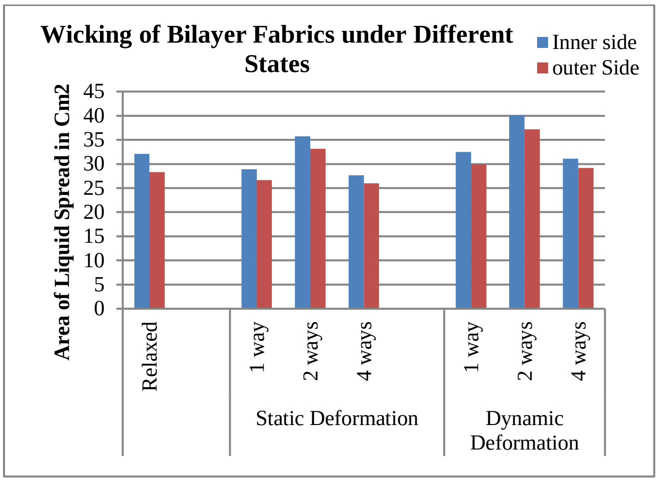

Figure 5. Wicking of Bi-layer Fabrics under Different States

The wicking properties of Bi-layered fabrics (consisting of polyester on the inner layer and soybean on the outer layer) under different states (relaxed, static deformation, and dynamic deformation) are as follows.

The bi-layer fabric shows similar wicking areas compared to both the single-layer polyester and soybean fabrics at the relaxed state, indicating the potential synergistic effects of the two materials. The area of wicking of the bi-layered fabric decreases when stretched in different ways under static deformation, similar to the single-layer fabrics. However, the area of wicking of the bi-layered fabric is generally higher compared to the single-layer fabrics in all stretching directions.

The bi-layer fabric (polyester on the inner layer, soybean on the outer layer) demonstrates enhanced wicking characteristics compared to single-layer polyester and soybean fabrics across all states and stretching directions. This suggests that the combination of polyester and soybean in a bi-layer structure may lead to improved moisture-wicking properties, potentially due to the complementary effects of the two materials. These findings highlight the advantages of bi-layer fabrics for applications requiring superior moisture management performance.

Discussion

Wicking Characteristics of Fabrics Using Moisture Management Tester

The 100% Polyester fabric exhibits consistent wicking characteristics on both the top and bottom sides which show the immediate transfer of wicking from the top to the bottom side of the fabric which is presented in Figure 1. The 100% Soybean fabric shows lower wicking characteristics compared to Polyester, as soybean fibers are known to be hygroscopic and can absorb moisture rather than spread. [11] The Bi-layer fabric demonstrates higher wicking characteristics on the top side (Polyester layer) compared to the bottom side (Soybean layer) as the result of the hydrophobic Polyester layer and hygroscopic soybean fibers.

Wicking Characteristics of Fabrics using Multi Directional Wicking Instrument

The results obtained which are presented in Figure 2 show that the 100% Polyester fabric and 100% Soybean fabric shows moderate wicking with slightly higher values on the inner layer compared to the outer layer [17]. The wicking characteristics of different fabric samples are consistent across both testers. For bi-layered fabrics, the inner layer (Polyester) generally shows higher wicking characteristics compared to the outer layer (Soybean). This trend is observed in both testing methods.

Wicking Characteristics of Microdenier Polyester Fabrics under Different States

When the fabric is stretched in different directions (1 way, 2 ways, or 4 ways), stretching the fabric in multiple directions (2 ways or 4 ways) results in a larger wicking area compared to stretching it in a single direction (1 way) which is shown in Figure 3. This indicates that multidirectional stretching enhances the fabric's wicking capabilities, perhaps by increasing the accessibility of liquid to the fabric's inner structure.

Comparing the results of static deformation (stretching without movement) and dynamic deformation (cyclic stretching), dynamic deformation generally leads to a higher wicking area compared to static deformation, and because the repetitive movement involved in dynamic deformation enhances the fabric's wicking characteristics further, possibly by promoting better liquid penetration and distribution within the fabric structure.

Wicking Characteristics of Soybean Fabrics under Different States

From Figure 4, it is clear that the wicking areas of the soybean fabric are consistently lower in the relaxed state compared to the polyester fabric on both the inner and outer layers. The wicking areas of the soybean fabric are consistently lower when compared to the polyester fabric when stretched in different ways under static deformation [18]. Similarly, the wicking areas of the soybean fabric are consistently lower when compared to the polyester fabric under dynamic deformation. The soybean fabric generally demonstrates lower wicking areas compared to the polyester fabric across all states and stretching directions

Wicking Characteristics of Bi-layer Fabrics under Different States

The bi-layer fabric (polyester on the inner layer, soybean on the outer layer) demonstrates enhanced wicking characteristics compared to single-layer polyester and soybean fabrics across all states and stretching directions and is presented in Figure 5. This suggests that the combination of polyester and soybean in a bi-layer structure may lead to improved moisture-wicking properties, potentially due to the complementary effects of the two materials. These findings highlight the advantages of bi-layer fabrics for applications requiring superior moisture management performance.

CONCLUSIONS

The 100% polyester fabric generally shows higher wicking areas compared to the other fabrics in all states and is Suitable for applications requiring effective moisture management. 100% Soybean fabric exhibits moderate wicking characteristics than polyester and is suitable for better absorption. Bi-layer Fabric (Polyester/Soybean) provides a balance between moisture absorption and moisture-wicking properties and is suitable for complex moisture management profiles due to the combination of different fiber types, suitable for specialized applications of sports requiring specific moisture control properties.

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