Effect of Drying Time on Sweat Patch Visibility in Weft-Knitted Reverse Plated Structures

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I. INTRODUCTION

Sweating regulates body temperature, especially during physical activity, but traditional garments often trap sweat, leading to visible patches that reduce both aesthetics and functionality. While textile technologies have improved moisture management, they still struggle with the issue of sweat patch visibility due to inconsistent absorption and evaporation rates[1].

Research has examined various fabric structures, but reducing sweat patch visibility remains a challenge. This study introduces a new approach using reverse-plated textile structures[2], strategically placing polyester micro-denier and water-repellent yarns on the fabric's technical face and back sides to enhance sweat evaporation. The drying times of these fabrics were tested using the Heated Plate Method (AATCC TM 201)[3]. The study's main goals were to design fabrics that reduce sweat patch visibility and dry quickly. Advanced weft-knitting techniques were used, enhancing both comfort and flexibility, with development conducted on a Shima-Seiki 14-gauge flatbed knitting machine using SDS-ONE Knit Paint software for precision.

II. MATERIALS AND METHODS

A. *Concept Development: Generating Fabric Construction Concept*

The primary objective of this initial phase was to determine the most effective method for reducing sweat patch visibility in fabrics. The "I-Plating" feature on the Shima-Seiki 14-gauge flatbed knitting machine was utilized to create reverse plating fabrics. This feature allows for the production of knitted structures that replicate those made with seamless circular knitting machines and can be adapted to various design requirements. In this approach, the wicking layer on the technical back absorbs sweat from the skin and transfers it to the technical front, where it is exposed to the environment for rapid evaporation. The evaporation is targeted to occur through a specific design on the fabric's outer surface.

A comprehensive literature review highlighted that the reverse-plated textile structure, with its lower bulk, is well-suited for achieving faster drying rates[4]. In this structure, the repellent yarn is placed primarily on the fabric's outer surface (technical face), while the wicking yarn follows a specific pattern. According to the reverse plating concept, the yarn arrangement on the technical face side is mirrored on the technical back side, where most of the wicking yarn is positioned, while the repellent yarn forms the predefined pattern. As shown in Fig. 1, if the repellent yarn is in position 'A' on the fabric's face, the same position 'A' on the reverse side will have the wicking yarn. This strategic yarn placement facilitates inter-yarn moisture transfer, effectively moving moisture from the skin side to the outer surface of the fabric for quicker evaporation.

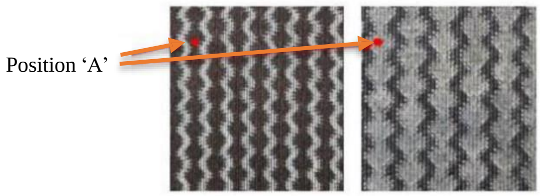

Fig. 1. Yarn Swap in face and reverse side analysis

Micro-denier polyester yarn, used as the wicking yarn, is primarily placed on the technical back of the fabric, in contact with the skin. Its micro-pores between tightly packed filaments enhance capillary action, improving moisture absorption and transport[5]. This inter-filament porosity, combined with water-repellent yarn on the fabric's outer surface, helps reduce sweat patch visibility. Table I provides the technical specifications of the yarns used in the fabric development.

TABLE I. YARN TECHNICAL DATA

Function	Moisture Repellent Yarn	Wicking Yarn
Composition	Polyester	Polyester DTY
Yarn Count	50D/36F	83dtex/100
Filament Count	36	100
Color	Black	White

B. Fabric Sample Preparation

This structure uses two yarn types and two repeat units to assess the impact of design on performance: (1) 75/25 reverse-plated structure and (2) 50/50 reverse-plated structure. In the 75/25 structure, the face side contains 75% repellent yarn and 25% wicking yarn, while the reverse side has 75% wicking and 25% repellent yarn. The 50/50 structure has an equal 50% distribution of each yarn on both sides.

Sweat absorbed by the wicking yarn migrates through capillary action, spreading across the fabric. As per Long et al.[6], greater evaporation rates are achieved by maximizing the surface area of the wicking yarn. The effect of exposed wicking yarn, depending on the repeat unit, was tested using the Heated Plate method (AATCC TM 201) to evaluate drying rates and times. Structural differences between the two designs, shown in Table II, play a key role in achieving quick drying, with the arrangement of wicking and repellent yarn influencing sweat evaporation. The wicking yarn in white and repellent yarn in black visually highlight these differences in the fabric samples. The water-repellent yarn's cover factor decreased due to the lower gauge of the knitting machine. To address this, the wicking-to-repellent yarn ratio was adjusted to 5:3, while keeping takedown tension and stitch lengths constant. After knitting, the fabric samples were passed through a stenter machine at 190°C for 2 minutes, melting the polymer coating on the water-repellent yarn. This process allowed the coating to spread evenly and adhere to the fabric, enhancing moisture repellency and ensuring long-lasting performance.

C. Test for Sweat Patch Visibility Reduction

To conduct the AATCC 201 test, fabric samples were conditioned in a standard atmosphere for 24 hours, then wetted with 0.2 mL of water and placed on a hot plate at 37 ± 1°C. Airflow was applied at 1.5 ± 0.5 m/s, with an infrared thermometer monitoring temperature change[7]. The drying time was recorded from initial water contact until the fabric returned to its dry state. As the fabric dries, the temperature increases, with the machine automatically calculating drying time and rate. Quick drying helps reduce sweat patch visibility, as it prevents moisture buildup and ensures wearer comfort. The Moisture Management Tester (MMT) assessed moisture management by measuring key indices such as absorption rate, spreading speed, and one-way transport capacity. Overall Moisture Management Capacity (OMMC) was identified as the key indicator of the fabric's ability to manage moisture, which directly influences drying rates and reduces sweat patch visibility. OMMC was calculated using absorption rate (ARb), one-way transport (AOTI), and spreading rate (MSRb) with the (1) formula[4],

$$OMMC = 0.25 \times ARb + 0.5 \times AOTI + 0.25 \times MSRb \quad (1)$$

Fabric weight (GSM) was measured using ASTM D3776, and thickness was determined via Shirley thickness tester per ASTM D1777. Surface stitch density was calculated from the values for courses per centimeter (CPCm) and wales per centimeter (WPCm) for samples RP01 and RP02.

$$\text{Surface stitch density (loops/cm}^2\text{)} = CPCm \times WPCm \quad (2)$$

III. RESULTS AND DISCUSSION

A. Effect of Physical Properties on Quick Drying

As shown in Table III, both fabric samples, RP01 and RP02, have the same thickness values; however, RP01 has achieved a higher GSM, along with a higher overall stitch density. This indicates that RP01 is a denser fabric, which allows it to absorb, retain, and distribute moisture more effectively than RP02, which has a lower GSM. Additionally, RP01 has a higher number of courses per centimeter compared to RP02, a factor that enhances moisture spreading across the fabric surface. This improved moisture distribution can facilitate quicker drying, making RP01 more efficient in managing moisture.

B. Effect of Overall Moisture Management Capacity on Sweat Patch Visibility

Based on the OMMC (Overall Moisture Management Capacity) values illustrated on Fig. 2., RP01 is the more favorable fabric for achieving quick drying compared to RP02. The higher OMMC value of RP01 indicates that it has better overall moisture management, which includes moisture absorption, transport, and evaporation. A higher OMMC value directly correlates to more efficient drying, as the fabric is able to handle moisture more effectively by spreading it over a larger area and facilitating faster evaporation.

TABLE II. FABRIC STRUCTURE SPECIFICATION

Fabric Sample Code	**Wicking Yarn Type**	**Yarn Counts**		**Front Side**	**Back Side**
		Repellent Yarn (50D/36)	***Wicking Yarn***		
RP01	Polyester (83dtex/100)	250DD	249 dtex		
RP02	Polyester (83dtex/100)	250	249 dtex		

This enhanced moisture management in RP01 helps to reduce the visibility of sweat patches and improve wearer comfort by quickly drying the fabric. Conversely, RP02 has a lower OMMC value, which suggests it may not dry as quickly, making RP01 the superior choice in terms of quick-drying performance.

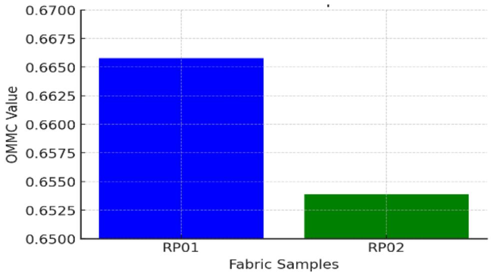

Fig. 2. OMMC values of the fabric samples

TABLE III. PHYSICAL PROPERTIES OF FABRIC SAMPLES

Fabric Sample Code	GSM	Thickness	Surface Stitch Density		
			Wales /cm	*Courses/ cm*	*Stitch Density (loops /cm²)*
RP01	321.79	0.7	9.1	15.67	142.597
RP02	312.08	0.7	9.43	14.51	136.8293

C. Effect of Drying Rate and Drying Time on Sweat Patch Visibility

As presented in Fig. 3., RP01 has a drying time of 6.18 minutes which is slightly lower than the drying time of RP02's 6.44 minutes. This indicates that RP01 dries faster compared to RP02 which might have caused due to moisture retention of RP02 structure where OMMC value is less compared to RP01. And the rapid temperature drops of RP01 compared to RP02 further supports the earlier claim of quick drying. As the drying rate of RP01 being 1.94ml/h higher when compared with RP02's drying rate of 1.86ml/h indicates the drying time difference in both fabrics. When following Fig. 3. And Fig. 4. graphs it is evident that the temperature rise of RP02 is less steep compared to RP01 and it might be due to the higher absorption rates on the inner/skin-side of the fabric. And this can lead to higher concentrations of sweat pooled in the RP02 fabric.

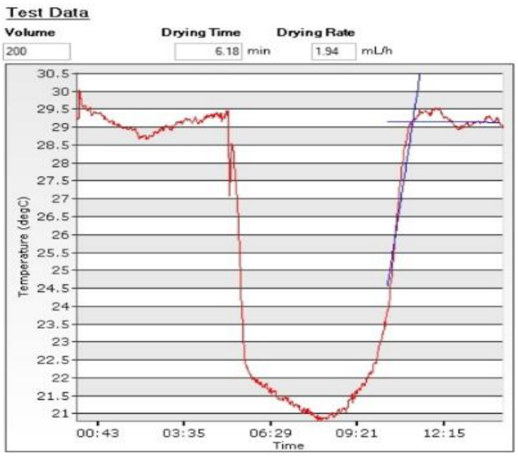

Fig. 3. Drying curve of RP01

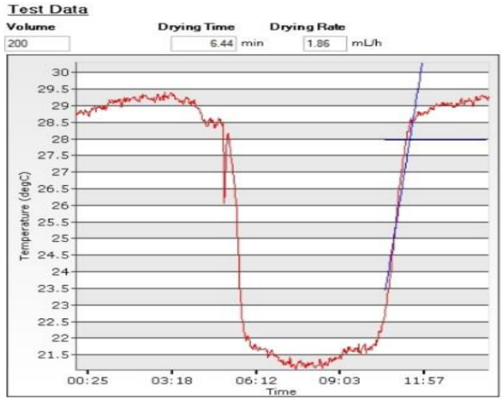

Fig. 4. Drying Curve of RP02.

IV. CONCLUSION

The results of this study demonstrate that fabric sample RP01 performs better in reducing sweat patch visibility and improving wearer comfort due to its superior moisture management and faster drying capabilities. The higher GSM and surface stitch density of RP01 allow for more effective moisture absorption, retention, and distribution compared to RP02. Additionally, RP01's higher Overall Moisture Management Capacity (OMMC) directly correlates with its ability to manage moisture more efficiently, facilitating quicker drying through better moisture spreading and evaporation. This is backed by RP01 exhibiting a faster drying time of 6.18 minutes compared to RP02's 6.44 minutes, supported by its higher drying rate (1.94 mL/h vs. 1.86 mL/h) and steeper temperature rise. These factors indicate RP01's greater ability to prevent sweat buildup and evaporate moisture more effectively, reducing sweat patch visibility. In contrast, RP02's lower OMMC, higher absorption rates, and slower spreading speed contribute to higher sweat pooling and longer drying times. In conclusion, higher wicking yarn portion on the skin-side proves to be better for applications requiring enhanced moisture management and quick-drying properties, making it a more suitable option for reducing sweat patch visibility in performance fabrics.

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