Influence of Loop Length on Thermal Resistance in Polyester Single Jersey Plated Knitted Fabrics

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I. INTRODUCTION

Thermal resistance is a critical parameter in achieving thermal comfort through the prevention of heat transfer between the body and the environment. Fabric manufacturers receive requests for clothing with specific thermal resistance properties that ensure desired comfort levels. The easiest parameter that can be changed in the manufacturing stage of a knitted fabric is the knit loop length. Therefore, this research aims to investigate the influence of loop length towards the thermal resistance of single jersey fabric. The proposed approach involves varying the loop length of the fabric and analyzing its behavior in response to temperature variations. The fabric under investigation is a plated fabric consisting of a polyester face yarn with a backing of polyester-covered Lycra. The thermal behavior of these plated fabrics is tested for thermal conductivity and studied the cooling gradient of a hot body. The fabrics are knitted on a seamless knitting machine of gauge 28. The observed increase in thermal resistance with loop length can be attributed to the size of air gaps within the fabric structure. These air gaps, known for their excellent thermal insulation properties [1], acted as barriers for heat transfer, effectively trapping more heat within the fabric tube. This highlights the significant effect of loop length on thermal resistance that contributes to understanding and control of thermal resistance with loop length.

II. LITERATURE REVIEW

The regulation of heat within the human body is essential for maintaining thermal comfort and overall well-being. The human body continuously generates heat through metabolic processes, and the ability to effectively release this heat to the environment is critical for maintaining a healthy body temperature. Clothing plays a vital role in regulating body temperature, providing protection from external factors, and facilitating the maintenance of an appropriate body temperature [1]. One of the fundamental functions of clothing is thermal resistance, which prevents heat transfer between the body and the environment, thereby enabling the body to achieve thermal comfort [2]. As a result, customers often request fabric manufacturers to produce clothing with specific thermal resistance values that cater to their desired level of thermal comfort [3].

However, regulating the thermal resistance value of fabrics during the manufacturing stage poses significant challenges. The thermal resistance of a fabric is influenced by various factors, including its composition, structure, and thickness [4]. Regulation of one parameter may affect the other negatively. In the current context of increasing demand for comfort garments, contribution to the thermal conductivity by each of the above factors must be accurately known by the fabric developer. Consequently, there is a pressing need for a more efficient method to regulate the thermal resistance value of fabrics during manufacturing [5]. This approach is to study the effect of one factor of the fabric structure: the loop length.

The primary objective is to contribute to the development of more efficient methods for producing textiles with desired thermal resistance properties. This introduction provides an overview of the research methodology employed, covering the selection of materials, the knitting process, and the testing procedures. The fabrics are knitted utilizing a seamless weft knitting machine. Following knitting, the fabric samples undergo dyeing and relaxation processes prior to thermal testing. Two main testing methods are utilized: the thermal conductivity test, and a novel method specifically designed to measure the cooling gradient of a hot body [6]. This unique approach enables the analysis of heat entrapment characteristics within the fabrics.

III. MATERIALS AND METHODS

A. Knit single jersey fabrics varying the loop length on TOP 2 circular knitting machine

Single jersey plated knitted fabrics are produced on a 28-gauge machine using three different yarn counts as the face yarn. Gauge 28 was used as it is the most common for sportswear garments. Polyester fabrics as face yarn and polyester covered lycra are the most common in the industry of seamless knitting for sportswear. Therefore, three different yarn counts in polyester as the face yarn for three different sets of experiments with the constant polyester/lycra as the back yarn were used in this study. The back yarn was kept constant in all parameters in all fabric structures.

The choice of a constant backing was deliberate to ensure that the backing will not introduce on the the results. The counts of face yarns (polyester) are: (50D/36/1 RE CDP), (75D/72/1 RE CDP), and (100D/96/1 RE CDP). Using each yarn count, five fabric samples were knitted, setting the loop lengths to 0.298, 0.305, 0.313, 0.320 mm, and 0.327 mm. The loop lengths were adjusted by changing the machine settings for 'yarn length' ('yarn length' is the length of yarn for one revolution of the knitting machine) to 400, 410, 420, 430, and 440cm, respectively.

All knitted fabric samples were dyed using the same dye (00A-Black) after pre-setting at a temperature of 115°C. This approach was essential to ensure the reliability and validity of our research findings.

Fig.1. Knitted and Dyed fabric samples

B. *Testing the fabric samples*

- *Cooling Curve test*

In this test method, the cooling gradient of a hot body method was used to obtain a comparative measure of the thermal resistance of fabric samples. A prototype testing device was developed based on the cooling curve method in thermodynamics.

A copper cylinder with a wooden cap and a base was used to simulate the heat dissipation from the human body. The cylinder was filled with boiled water and wrapped with a fabric sample developed for the experiments. Temperature readings were taken in the range of 50˚C to 30˚C, representing the normal working temperature range of the human body. A contact thermal sensor-thermocouple (MAX6675) connected to an Arduino UNO board was used to monitor the temperature of the water inside the cylinder, and data was recorded at one-second intervals. All the testing were conducted in a standard condition room with the conditions of 20˚C temperature and 65% relative humidity This method provided a comparative measure of the thermal resistance of different fabric samples.

Figure 2_ Bare and test subject wrapped copper Cylinder with lids and the thermocouple equipped.

IV. Results and Discussion

A. *Cooling Curve test*

In this test method, cooling gradient of the hot water inside the cylinder is studied by taking temperature readings of the water continuously with one second interval. The test data obtained is categorized based on the yarn count of each fabric sample, and subsequently utilized for analyzing the time required for each fabric sample to cool down to 30˚C of varying loop lengths. The time taken to cool down and the cooling gradient allows a comprehensive evaluation of the impact of loop length on the thermal resistance of fabrics. The results obtained from this analysis can therefore be utilized to validate the effects of loop length on the thermal resistance of fabrics in a rigorous and systematic manner. The test allows for a comparative analysis of the thermal resistance variation among different fabrics resulting from changes in various parameters. The cooling curve test serves as a practical method to evaluate and compare the thermal resistance characteristics of fabrics.

The results obtained from the cooling method test conducted on single jersey fabrics manufactured with loop lengths 0.298, 0.305, 0.313, 0.320, and 0.327 from 50D,75D, and 100D polyester yarns are presented in Figures 5,6 and 7. The experimental methodology employed in this study involved the utilization of the moving average method to plot the graphs.

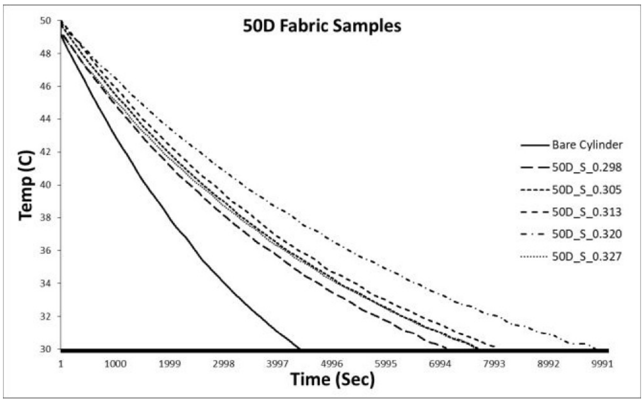

Fig.3_ Moving average of 50D fabric samples.

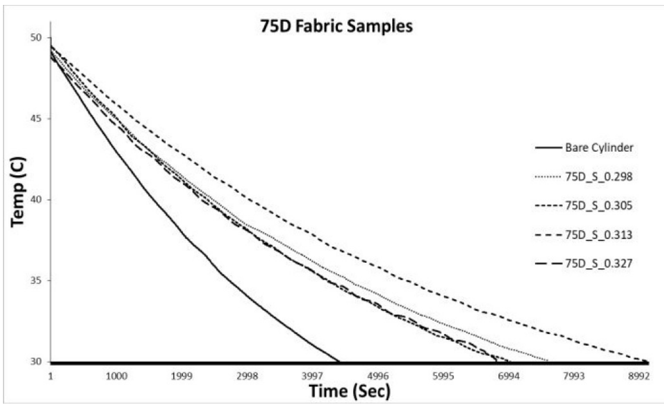

Fig.4_ Moving average of 75D fabric samples.

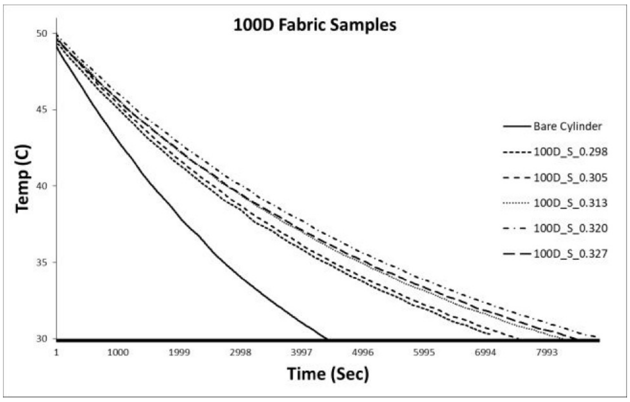

Fig.5_ Moving average of 100D fabric samples.

Each set of fabric samples underwent the test three times. The resulting data from these three tests were averaged to obtain an average value. The moving average method enhances the accuracy and precision of the dataset generated from the fabric samples, thereby facilitating more reliable and insightful analysis.

It is observed that the change in loop length has an impact on the thermal resistance of the fabric samples. Among the samples, the fabric with a loop length of 0.327cm displayed exceptional characteristics, The increase in thermal resistance with loop length may have resulted from the creation of larger air gaps in the fabric structure. Since air is a highly effective thermal insulator, it may have acted as a barrier for heat flow and trapped more heat inside the fabric tube. Figures 3,4, and 5. provides a comparative graph between the cooling curves of the 0.327cm loop length fabric and the bare copper cylinder. A difference in thermal resistance can be observed from the gap between these two curves.

The results show thermal resistance characteristics of single jersey knitted fabrics can be influenced by changing in loop length. Specifically, increasing the loop length up to 0.320cm results in a decrease in thermal resistance. However, further increasing the loop length beyond 0.327cm leads to an increase in thermal resistance across all fabric samples.

Figure 6 demonstrates a clear trend: increasing loop length results in higher air permeability. The air permeability assessment, conducted according to EN ISO 9237 standards using the M02IA Air permeability tester, this suggests that longer loop lengths promote better air circulation within the fabric. Even though the air permeability of the fabrics increased with the increase of the loop length thermal resistance has increased. This is due to the higher influence of the remaining air pockets is greater than the influence of the increased air permeability till the threshold limit.

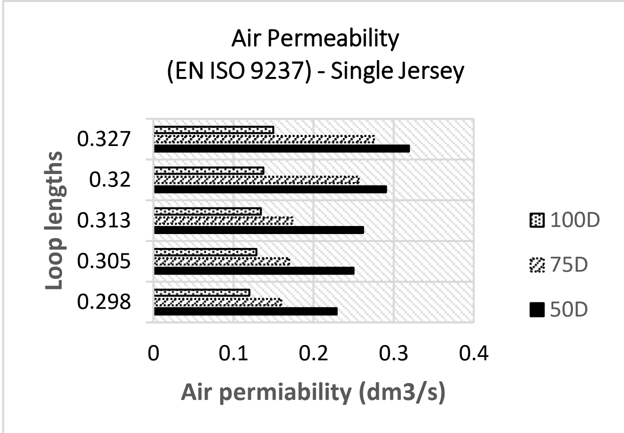

Fig.6_ Air permeability test data of all fabric samples.

V. Conclusion

The study examines thermal behavior in polyester plated single jersey knitted fabric, focusing on thermal resistance variation with loop length. The thermal conductivity test is limited for thin fabrics, so the cooling curve test is proposed for comparative observations. Air pockets within the loops enhance thermal resistance up to a threshold, but beyond it, resistance decreases due to fabric structure change. Thicker fabrics with higher yarn counts show increased thermal resistance at larger loop lengths. Manufacturers can use this insight to optimize fabric properties for specific applications.

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