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Comparative Study of Comfort Properties of Five Different Common Apparel Textiles

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Abstract

One of the most important properties desired by consumers when they purchase clothing is comfort. There are various methods for determining the factors that control the comfort of a piece of clothing. Some of those factors are thermal resistivity and evaporative moisture resistivity through the fabric. This thesis investigates the comfort factors of cotton, rayon, polyester, silk and wool fabrics. Fabric parameters such as yarn count, fineness of thread, cover factor, and weight result in different degrees of moisture resistance and thermal resistivity. These factors can make a piece of clothing more or less comfortable. The results of this investigation can be used to specifically design clothing for comfort under different atmospheric conditions.

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Comparative Study of Comfort Properties of Five Different Common Apparel Textiles

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TABLE OF CONTENTS

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ABSTRACT

One of the most important properties desired by consumers when they purchase clothing is comfort. There are various methods for determining the factors that control the comfort of a piece of clothing. Some of those factors are thermal resistivity and evaporative moisture resistivity through the fabric. This thesis investigates the comfort factors of cotton, rayon, polyester, silk and wool fabrics. Fabric parameters such as yarn count, fineness of thread, cover factor, and weight result in different degrees of moisture resistance and thermal resistivity. These factors can make a piece of clothing more or less comfortable. The results of this investigation can be used to specifically design clothing for comfort under different atmospheric conditions.

INTRODUCTION

In order for a company to effectively market clothing, the visual appeal of a piece of clothing is important. Even more important, though, is how comfortable a piece of clothing is. In order for a consumer to return to a company to consistently buy clothing, the clothing they produce must keep the body comfortable. The human body usually regulates temperature automatically because the body constantly generates carbon dioxide (CO_2) and water (H_2O), also known as sweat, by the metabolism of food and muscle activity. The most comfortable skin temperature is 33.4° C, or 92.12°F. If the body temperature changes by more than 4.5° C or 40.1°F, the human body feels uncomfortable. Similarly, a core body temperature of 36.5° C or 97.7°F is essential and if that temperature changes beyond 1.5° C or 34.7°F it can cause serious health problems. Clothing has an important role in regulating human body temperature by transferring some of the heat into the environment and retaining the rest. Similarly, the clothing absorbs some part of the sweat while the rest is released as moisture vapor into the environment since some of the sweat turns to vapor due to body heat. In this study, five of the most commonly used apparel fabrics were tested for their ability to transfer body heat and moisture vapor quantitatively using sensors implanted in a sweating hot plate placed in a highly controlled environmental chamber. The five fabrics, cotton, rayon, silk, polyester, and wool, have been tested on the TPS Lunaire Controlled Chamber and Sweating Hot Plate.

The testing done on the TPS Lunaire Controlled Chamber and Sweating Hot Plate enables the researcher to see how each fabric reacts to the natural heat generated by the body, and how the fabric reacts to water, or sweat, which also emits from the body. The level of transfer or absorption of heat and water will determine how comfortable a garment is. According to a study done on the comparison of test methods for measuring the water vapor permeability of a fabric, "the sweating hot plate best simulates the actual clothing wearing situation and the results can be related to thermophysiological responses of people" (Huang and Qian 2008). The results from that study assure that the TPS Lunaire Sweating Guarded Hot Plate is the correct machine for simulating the human body's natural heating and sweating process and how fabric will react to these conditions.

So as to thoroughly examine the major fabric characteristics, each fabric was additionally studied for parameters such as yarn count, or the number of warp and weft (vertical and horizontal, respectively) threads per inch, fineness of thread, or denier, cover factor, and weight as these can result in the different degrees of moisture resistance and thermal resistivity.

EXPERIMENTAL METHODS AND EQUIPMENT

In order to look at the comfort factors of fabric, the characteristics that make up the fabric were investigated. These characteristics included looking at the yarn count, fineness of thread, weight, and cover factor of the fabric.

First the yarn count was calculated. The process involved counting the number of warp and weft threads, also know as ends and picks, per square inch of each fabric. This gives one an idea of either how tightly woven and/or how fine the thread is in a piece of fabric. A higher thread count would mean that the yarn is finer and woven more tightly.

Next the weight of the fabric was found. Eight circles of fabric with a 2-inch diameter were cut and weighed on a scale. The result of this measurement was used to calculate the weight of the fabric in ounces per square yard.

Taking one meter of yarn from the fabric, weighing it, and multiplying the weight by 9,000 found the denier, or linear mass density, of the fabric. The denier was then converted into British Cotton Count because the cover factor calculation uses the measure of yarn size in British Count. Dividing 5,315 by the denier does this.

Cover factor was then tested. Cover factor is the percent of a piece of fabric that warp and weft yarns cover. The area a piece of fabric warp or weft yarns do not cover is accounted for by interstices. To find the cover factor, first the compact cover factor must be found.

The compact cover factor, or CCF, of cotton yarn was developed empirically and the compact cover factor for any other yarn is derived from the compact cover factor of cotton yarn. Table 1 illustrates the compact cover factors of each of the yarns used in this investigation while Figure 1 shows the equation to use to achieve the number of the maximum number of yarns that will lie side by side in one inch of fabric (McCreight 2001).

Table 1.

	Standard Compact Cover Factor
Cotton	28
Rayon	28.2
Polyester	26.8
Silk	26.3
Wool	26.2

Figure 1.

CCF $\sqrt{\text{British Cotton Count}}$ = maximum ends/in.

In order to find the percent of a piece of fabric that warp or weft yarns cover, or the yarn cover factor, the equation in Figure 2 is used once to find the warp cover and again to find the weft cover.

Figure 2.

warp or weft count per inch ÷ maximum ends/in. = yarn occupation percentage

From this stage the cloth cover factor, known in the results section as Cover Factor, is found. This is the percent of cloth that warp and weft yarns cover, with interstices accounting for the rest of the percentage. The equation in Figure 3 is used to calculate the percentage of cloth that warp and weft yarns cover (McCreight 2001).

Figure 3.

(warp occupation percentage [as decimal] + weft occupation percentage [as decimal])

- (warp o. p. [as decimal] + weft o.p. [as decimal]) x 100%

Testing for thermal resistivity and evaporative moisture resistivity commenced after all of the characteristics of the fabric were tested and identified. The TPS Lunaire Sweating Guarded Hot Plate, a machine that objectively and precisely measures the amount of thermal transfer and evaporative moisture transfer through the fabric, was used to conduct this testing. The design of the machine consists of a control panel for altering the humidity and temperature of the attached controlled chamber, a controlled chamber with a sweating guarded hot plate and sensors, an external water tank, and a computer program that records and compiles the test data. The machine can be seen in Figure 4. The fabric to be tested is placed inside the environmentally controlled chamber, which is maintained at 65% relative humidity and 70°F, which is the universal textile testing temperature.

Figure 4.

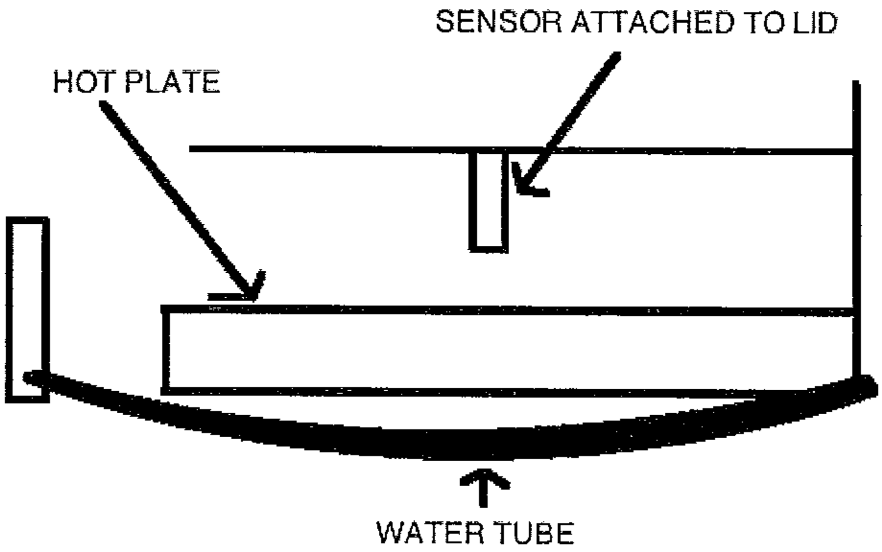
TPS Lunaire Sweating Guarded Hot Plate Machine

In Figure 5, it can be seen that the basic design of the hot plate inside the controlled chamber is that of a horizontal hot plate with a sensor hovering above. The machine includes a water tube attachment for moisture tests. In order to prepare the machine for testing, an initial test without any fabric or moisture was conducted. The machine must first be turned on and have reached the desired conditions of 65% relative humidity and 70°F or 21.1°C. Following this, a 7mm block was placed under the sensor in order to ensure the sensor was at the right height above the hot plate. This procedure was repeated prior to the start of each test. A knob on the side of the device can adjust this height accordingly. The machine is then directed by a computer program to start one dry bare plate test in order to have a constant to compare data from the thermal resistivity tests with fabric. The test will run for approximately 30 to 60 minutes until the machine reaches a steady state and stays within tolerance. The test completes automatically after the test has stayed in tolerance and in a steady state for long enough to get an accurate reading.

Figure 5.

Hot Plate Cross

Section



Thermal resistivity, or the insulation value of typical indoor clothing, was measured first. The thermal resistivity test is similar to the dry bare plate test. The only difference is the inclusion of the desired piece of fabric to test. The fabric is cut to a 12"x12" sample size. As seen in Figure 6, the fabric is placed over the hot plate and secured with 2" wide blue tape. The testing takes approximately 30 to 60 minutes to complete until the machine reaches a steady state and stays within tolerance. The test completes automatically after the test has stayed in tolerance and in a steady state for long enough to get an accurate reading.

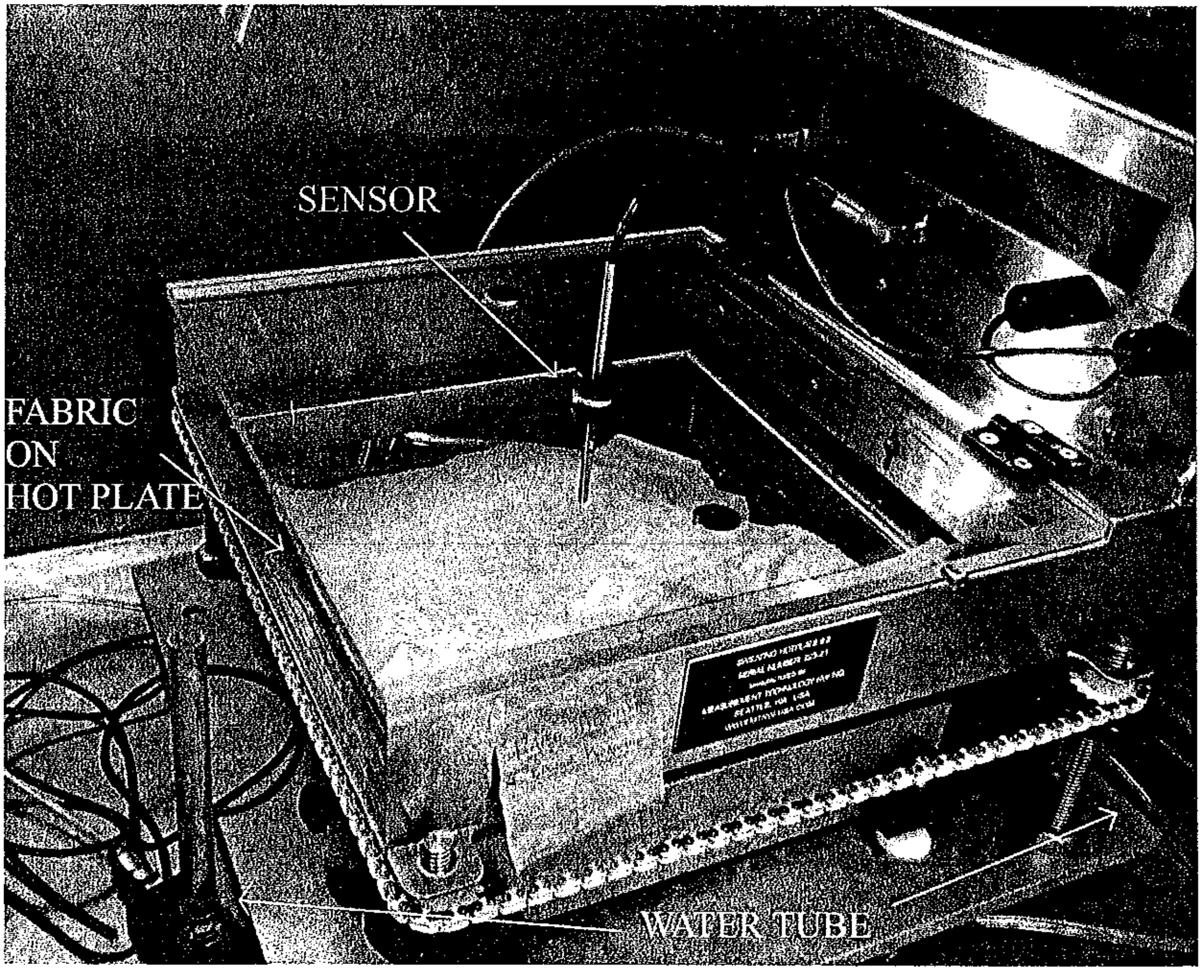
In order to have a control without fabric with which to compare data, an initial wet bare plate test similar to the dry bare plate test must be completed before testing for moisture vapor resistivity with fabric. For the wet bare plate test a water tube, as seen in Figures 5 and 6, is connected to the hot plate devise. The water is distilled and comes from a reservoir tank located outside of the controlled chamber. The water is pumped through the tube and is released from pores located on the hot plate. A piece of Mylar paper is then soaked in distilled water and placed over the wetted hot plate. After the creases have been smoothed from the Mylar, a black cord is pressed over the Mylar and in to the edges of the hot plate to secure it. The 2" wide blue tape is placed over the edges of the hot plate to ensure that the Mylar does not come free. After the sensor height has been adjusted, the test can begin and will run for approximately 30 to 60 minutes until the machine reaches a steady state and stays within tolerance. The test completes automatically after the test has stayed in tolerance and in a steady state for long enough to get an accurate reading.

Moisture vapor resistivity, or the total evaporative resistance of a fabric, liquid barrier and surface layer when evaluated at a constant temperature, was measured next. The test is performed exactly the same as the wet bare plate test except with the inclusion of a piece of fabric placed and secured over the Mylar with 2" wide blue tape.

Figure 6.

View of Hot Plate From

Above



The resulting readings from the dry bare plate test, dry plate test with inclusion of fabric, wet bare plate test, and wet plate test with inclusion of fabric are averaged in order to get more precise data. These averages are then entered into a formula to correctly determine what the thermal resistance and evaporative resistance of the fabric are. The formulas to find thermal resistance and evaporative resistance are similar, as demonstrated in Figures 7 and 8 (Measurement Technology NW Inc.)

Figure 7.

Thermal Average of Fabric

- Bare Plate Average

Thermal Resistance of Fabric

Figure 8.

Moisture Value Average of Fabric

- Wet Bare Plate Average

Evaporative Resistance of Fabric

RESULTS

Certain fabric parameters were determined to have significance on the fabric's ability to transfer heat or moisture. Thicker fabric usually allows less heat or moisture to flow through, as compared to thinner fabric. A higher number of warp and weft yarns per inch means the fabric is woven tighter. The cover factor allows one to see how much of a piece of fabric is covered with thread (McCreight 2001).

In this study, cotton is used as a reference point for the other fabrics because it is the most used apparel textile for summer type clothing. As can be seen from Tables 2 and 3, some of the fabrics are similar to cotton, and some are not. Rayon is the most similar to cotton altogether. Similarities can be seen in cover factor, weight, thermal resistivity, and moisture transfer, though it has a slightly looser weave. It is also good for summer type clothing.

Polyester has the highest British Cotton Count, which means that it is the finest fabric. It also has the lowest cover factor resulting in poor heat retention. Polyester is a hydrophobic material meaning that it moves moisture away from the touch as opposed to absorbing it, resulting in the low moisture resistance. Polyester is also a good summer type fabric.

Silk is similar to cotton in weave structure, but has a higher cover factor resulting in higher heat resistivity. Silk also has some moisture absorption capabilities. These factors all make silk a bit cooler fabric in the summer and a bit warmer fabric in the winter.

The final fabric investigated is wool. The wool had the lowest British Cotton Count, meaning the individual yarns were thicker. The cover factor is relatively similar to cotton, though the weight of the fabric was the heaviest and there were far fewer warp and weft yarns per inch. It can be seen in Table 2 that wool has a higher absorption than cotton, but since wool is heavier, the similarities to cotton even out. Wool also has a unique three-dimensional crimp, which creates air pockets and acts as an insulator. This makes wool a great winter fabric.

Included is a chart displaying all of the investigated characteristics and reactions tested on the five fabrics. Chart 1 is a comparative view of how the fabrics relate to each other.

Table 2.

Yarn Count, Construction, Weight and Cover Factor of the Fabrics

	British Cotton Count	Cover Factor	Weight in Ounces/Yard^2	Warp/Ends	Weft/Picks
Cotton	40.72	69.30%	3.2 oz/yd^2	86	74
Rayon	21.9	72.40%	3.4 oz/yd^2	65	61
Polyester	118	49%	2 oz/yd^2	118	91
Silk	38.4	81.10%	2.4 oz/yd^2	89	94
Wool	7.25	78.16%	6 oz/yd^2	41	34

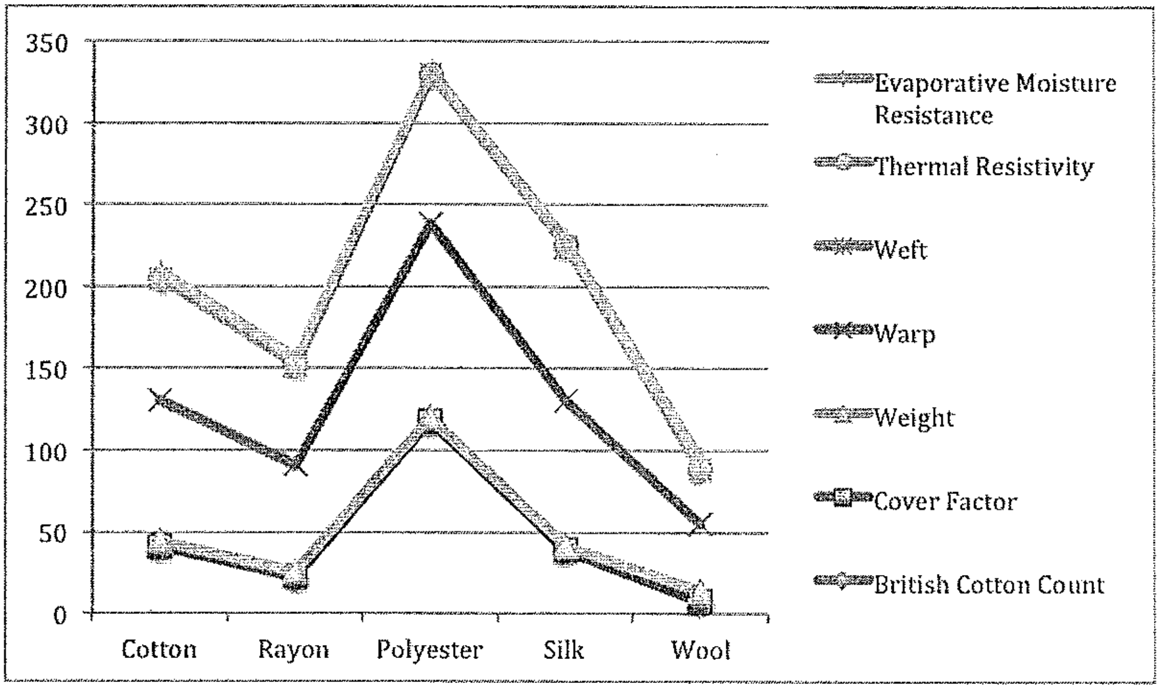
Table 3.

Thermal Resistance and Evaporative Moisture Resistance of the Fabrics

	Thermal Resistivity Average $m^2\,°C * W^{-1}$	Evaporative Moisture Resistance Average $m^2\,°C * W^{-1}$
Cotton	0.05171	4.78527
Rayon	0.04485	4.9309681
Polyester	0.02965	2.827664
Silk	0.07993	3.942091
Wool	0.0514	5.89238

Chart 1.

Comparative View



CONCLUSION

It is shown how to design fabric and select material in order to provide comfort to the wearer during various weather conditions. Certain fabric parameters and characteristics make a piece of fabric more or less comfortable in a specific weather condition. The use of the TPS