HEAT AND MOISTURE TRANSPORT BEHAVIOR OF COTTON-DYNEEMA FABRICS

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Abstract

This paper looked at the influence of Dyneema content on the comfort related properties such as heat energy dissipation, water vapor diffusion, and air permeability of the cotton/Dyneema fabrics. 100% cotton fabric showed the least resistance to water vapor diffusion. The diffusion resistance increased with the increasing Dyneema content in the fabric. 100% cotton fabric also showed maximum airpermeability, and this was true for airpermeabilities measured on both dry and wet fabrics. The blended fabric showed progressively lower airpermeability with increasing Dyneema content. The heat energy dissipation through the fabric was not found to be related to the Dyneema content, and this was true for dissipations through both dry and wet fabrics.

Introduction

Past work on cotton/Dyneema fabrics [1] has shown that fabric durability properties such as tensile strength, tear strength and abrasion resistance show significant improvement with the inclusion of just 10% Dyneema in the fabric. The high tenacity and modulus as well as the relatively low density of the Dyneema fiber contribute to the enhanced durability properties of the blended fabric. However, Dyneema being a low-density polyethylene fiber, can be expected to influence the absorption, breathability, and thermal conductivity properties of the blended fabrics, and these properties are important in the intended tenting applications. This work attempted to define how sensitive these properties are to the Dyneema content of the fabric.

Material and Methods

Test Fabrics

We used six types of fabrics made from intimate blend yarns and core-wrap yarns. The fabrics thus represented four different blend compositions and two different fiber arrangements in the yarn. The intimate blend yarns were made on the conventional spinning system using weigh-pan blenders to produce different blend compositions. The core-wrap yarns were made on the SRRC core-wrap spinning system, with a single cotton/Dyneema intimate blend roving as core material and two cotton rovings for the wrap. For comparison, an equivalent 100% cotton fabric was also included in this study. All yarns were of the same count and they had the same twist in the singles and 2-ply states. The fabrics had a plain weave, heavy duck construction with 52 ends and 34 picks per inch, and each weighed approximately 9.5 oz/sq. yd. The greige fabrics were boiled off and caustic scoured by conventional procedures. The scoured fabrics were treated with a standard flame-retardant finish. Test specimens were conditioned at 65 $\pm$ 2% RH and 20 $\pm$ 1°C before measuring their properties.

Thermal Property

Kawabata thermal tester "Thermolabo-II" was used to measure the thermal energy dissipated through the fabric in a unit time. The instrument contains a constant temperature hot plate (BT-Box) and it is used to measure the heat energy dissipated through the fabric. The energy dissipation through fabric was determined by the difference in the electrical power required to maintain the hot plate at the body temperature with and without the test specimen placed on the tester. We obtained the energy dissipation values on both dry and wet conditions, at both normal fan speed and high fan speed. We also measured the energy dissipation values when the fabric was directly placed on the surface of the hot plate, and when the fabric was placed on the top of an elevated hood, i.e. with a substantial air gap maintained between the fabric and the hot plate.

Air Permeability

The air permeability of the fabrics was measured on the Frazier Air Permeability Tester. In order to measure the dry and wet airpermeabilities at exactly the same spots on the fabric samples, we made circular marks with waterproof ink on the face of the fabric. After measuring the dry airpermeabilities in the marked spots, we soaked the fabric samples in distilled water for 10 minutes. We then removed the wet samples and placed each sample in the middle of a stack of absorbent tissue paper (hand towels). We also placed a standard weight on the top of the stack and allowed the paper stack to absorb the loose water from the wet fabric specimen. We removed the specimen from the stack after 5 minutes and weighed the squeezed specimen immediately after it was removed from the stack. The difference between the wet and dry weights of the specimen gave the weight of water contained by the specimen at the time of measuring its wet airpermeability. We measured the rate of airflow in exactly the same places under both dry and wet conditions, and attempted to keep the same amount of water in each sample.

Diffusion Resistance

The resistance to water vapor diffusion was measured on the Shirley Water Vapor Permeability Tester. Diffusion resistance is expressed as the height in centimeters of a still

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air column presenting an equivalent resistance as that of the fabric. Three different thicknesses of the air layer between the water surface and the cover fabric were used in the control dishes to obtain the relationship between the thickness of the contained air layer and rate of loss of water vapor from the dish. The rate of diffusion of water vapor from the dish covered by a standard fabric and a test specimen was compared with the rates of the diffusion from control dishes covered only by the standard fabric. The resistance of the test specimen to water vapor diffusion was derived from the relationship.

Results and Discussion

Energy Dissipation

Table I and Table II give energy dissipation values measured in watts (W). Table I gives the dissipation values when the wet or dry fabric is in contact with the hot plate while table II gives the same values when the fabric is not in direct contact with the hot plate. Significance tests carried out between dry and wet energy dissipations show that wet dissipations are significantly higher than dry dissipations. This is true for all the six fabrics and also for the contact and noncontact conditions of measurement. However, significance tests on the individual energy dissipations suggest that the energy dissipated through the different fabrics is not statistically different. This again is true for both wet and dries energy dissipations and for high and low fan speeds (airflow rates). It can thus be concluded that the addition of Dyneema to the extent of 30% in the blend does not lead to any significant difference in the heat energy dissipation through the fabric.

Air Permeability

It can be seen from Table III that the blend fabrics show lower airpermeability in both dry and wet states. It can also be seen that the air permeability of the fabrics containing the core-sheath yarns is lower than that of the fabrics containing the random blend yarns for both dry and wet measurements. Significance tests confirm that the airpermeabilities of the fabrics containing the core-sheath yarns are statistically different compared to that of the corresponding random blend fabrics in both dry and wet states. Significance tests also suggest that increasing Dyneema composition in the fabric results in lower air permeability. The amount of Dyneema carried by the fabric therefore has an influence on the airpermeability of the fabric.

Diffusion Resistance

From Figure 1, it can be seen that the 100% cotton fabric shows the least resistance to water vapor diffusion and the diffusion resistance increases as the Dyneema content is increased. The fabrics made from core-wrap yarns show slightly higher resistance to water vapor diffusion than that of the intimate blend fabrics. Significance tests confirm that the difference in diffusion resistance of fabrics containing different levels of Dyneema is statistically significant. Significance tests also confirm the statistical significance of the diffusion resistance values shown by the random blend and core-sheath yarns. The diffusion resistance, therefore, appears to bear an inverse relationship with airpermeability.

Summary and Conclusions

1. Results suggest that Dyneema content has no major influence on the heat energy dissipated through the fabric.
2 Results also suggest that the Dyneema content influences the airpermeability and the water vapor diffusion resistance

References

1. Properties of Fabrics Made from Cotton/Polyethylene Blend Yarns
A. P. S. Sawhney, G. F. Ruppenicker, and J. B. Price, Text. Res. J. 68(3), 203-208 (1998)

Table I: Energy Dissipation Values

		Energy Dissipation with Fabric in Contact			
		Normal Fan Speed		High Fan Speed	
	Fabric Type	Dry	Wet	Dry	Wet
A	70C/30D-I	1.998	2.606	2.590	3.183
B	80C/20D-I	2.057	2.591	2.598	3.402
C	90C/10D-I	1.957	2.420	2.450	3.171
D	100% C	2.007	2.635	2.563	3.243
E	80C/20D-CW	2.078	2.808	2.549	3.404
F	90C/10D-CW	2.042	2.603	2.504	3.382

Table II: Energy Dissipation Values

		Energy Dissipation with Air Gap	
		Normal Fan Speed	High Fan Speed
	Fabric Type	Dry	Wet
A	70C/30D-I	1.088	1.695
B	80C/20D-I	1.044	1.798
C	90C/10D-I	1.041	1.793
D	100% C	1.032	1.834
E	80C/20D-CW	1.050	1.827
F	90C/10D-CW	1.064	1.756

Table III:

		Rate of Air Flow (cubic feet per square foot, per minute)			Weight Change (g)
	Fabric Type	Dry	Wet	D/W Ratio	
A	70C/30D-I	19.733	5.933	3.326	6.364
B	80C/20D-I	20.369	5.887	3.460	6.508
C	90C/10D-I	27.557	8.437	3.266	6.498
D	100%C	37.904	12.507	3.031	5.939
E	80C/20D-CW	19.521	4.677	4.174	6.112
F	90C/10D-CW	22.579	4.474	5.047	6.975

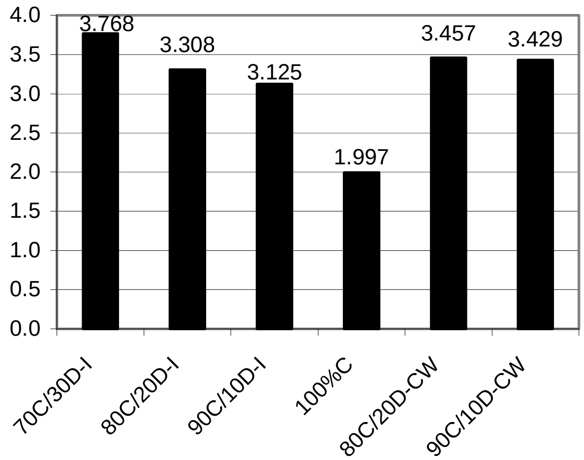

Figure 1. Water Vapor Diffusion Resistance (mm)