NONWOVEN COTTON PROTECTIVE CLOTHING

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Abstract

Recent prices of bleached cotton have created the need to develop new market ideas for keeping this fiber as a recognizable contender in nonwoven fabrics production. Properly cleaned cotton can be made into hydroentangled fabrics that can be used in its natural (greige) state or that can be readily dyed and finished for a variety of end uses. A study was designed to compare this nonwoven cotton fabric with currently used synthetic nonwovens for protective apparel applications. Cotton's advantages in this product application were clearly established at significant levels of performance.

Introduction

In a past Beltwide proceeding[1] the importance of maximum cleaning and opening cotton fiber prior to bleaching was adequately described. The LINTMASTER™ Opener/Cleaner, a cotton processing machine, was the main focus in that report. Thoroughly cleaned cotton such as that obtained using the LINTMASTER™ Opener/Cleaner is vital to the production of hydroentangled cotton nonwovens as described below:

- LINTMASTER™ Opener/Cleaner processing can remove 80% of non-lint content of raw fiber.
- Unbleached fiber processes more efficiently than bleached cotton allowing more uniform webs to be made for hydroentangle bonding.
- High water pressure impingement on the fiber web removes practically all the non-lint residue including the natural wax on the fiber.
- Hydroentangled fabric is extremely hydrophilic making it suitable for dyeing and/or finishing.
- The final fabric contains a small amount of particulate vegetative matter that is readily removed by bleaching if fabrics of high purity are needed.
- The nonwoven fabric is strong, durable, drapable and has the desired feel of cotton.
- Fabric made in this manner is much less expensive than conventional textile goods.

Depending on fabric weight and integrity, hydroentangled (HE) nonwoven cotton can be processed on many of the same systems as regular, woven or knitted, textiles. If the end product is to be reused, the fabric must be finished with a chemical binder treatment that will prevent fiber disentanglement. Properly treated fabrics can survive twenty or more launderings. This type durability makes it practical to finish HE nonwoven cotton fabrics with wash-fast, flame retardant treatment for safety purposes.

An important market opportunity for this fabric is available in protective clothing. Protective apparel business is growing at 9% annually, and as might be expected, most of this growth is in medical products where hydroentangled fabrics make up 60% of the business (120 MMyd^2). Protective clothing for industrial areas amounts to 375 MMyd^2 annually. Spunbond polyethylene (Tyvek®) dominates this market segment with a 72% share. The common complaint associated with protective clothing made from synthetic fabric is discomfort. Cotton clothing will provide the desired comfort as well as wearer protection for many industrial applications.

Fabric Development

Cotton fabrics used in this study were made from selected bales of high micronaire, upland cotton, and the steps involved in fabric formation are listed below:

- Bale opening, coarse opening/cleaning.
- LINTMASTER™ Opener/Cleaner to remove most short fibers, dust and non-lint content.
- Web to be bonded was formed via carding/crosslapping for desired web weight.
- Fabric was formed by water jet impingement on both sides; first side water pressures ranged from 300 to 800 psi; second side bonding came from water jet forces ranging from 800 to 1500 psi.
- The web was supported on a 100 mesh conveyor during hydroentanglement, thus the final fabric had an almost paper smooth appearance.
- Part of the fabric was then treated with a fluorochemical finish to impart liquid repellency.
- Another portion of the fabric was laminated with a microporous membrane designed as a barrier to blood borne pathogens.

These fabrics were tested for physical properties along with synthetic fabrics currently used in protective apparel for industrial situations. Test results are shown in Table I and it is obvious that the two cotton fabrics were competitive with the synthetic products.

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Table I. Physical Properties of Cotton and Synthetic Fabrics

Fabric Type	Weight oz/yd^2	Tensile (lbs)		Trapezoid Tear (lbs)		Burst Strength (lbs)
		MD	CD	MD	CD	
HE Unbleached Cotton, 40 g/L Fluorochemical	3.4	26.7	20.5	14.1	8.8	48
HE Unbleached Cotton/ Microporous Film	2.5	25.5	22.5	8.9	7.3	43
Tyvek® 1422	1.4	21.4	25.4	4.3	5.1	46
Comfort-Guard™ Type 100	1.8	21.6	15.2	15.5	11.9	29

NOTE: MD, Machine Direction
CD, Cross-Machine Direction

These same fabrics also were tested for properties more related to protective performance and comfort value. As shown in Table II, coated and uncoated cotton fabrics were very different in these important properties as were the spunbond polypropylene (Comfort Guard™ 100) and spunbond polyethylene (Tyvek® 1422).

Table II. Comfort Related Properties of Test Fabrics

Fabric Type	Weight oz/yd^2	Hydrostatic Head (cm)	Moisture Vapor Transport g/m^2/24 hr	Air Permeability ft^3/ft^2.min ASTM D737
HE Unbleached Cotton with Chemical	3.4	20	1088	150
HE Unbleached Cotton with Film	2.5	>100	939	0
Tyvek® 1422	1.4	>100	214	0
Comfort-Guard™ Type 100	1.8	63	1063	49

Hydrostatic head values are useful only in pointing up comparative liquid penetration resistance. This resistance is highly related to fabric openness and does not take into account the fabric's resistance to wetting. However, moisture vapor transport testing is highly predictive of comparative comfort performance. As might be expected, cotton fabrics without a barrier film transmits the most water vapor. Surprisingly, the film laminated cotton transmitted almost as much moisture. Comfort Guard™ 100 had values close to the two cotton fabrics because of its porous nature (see hydrostatic and air permeability values). The Tyvek® fabric was found to be the poorest vapor transmitting (least breathable) fabric. The continuous film-like characteristics of this fabric work against vapor permeation, thus garments made of Tyvek® are found to very uncomfortable in hot, humid environments. Air permeability, like hydrostatic head values, define fabric porosity but have little to do with protection or comfort value.

Protective Performance Testing

The scope of this testing was to use a spraybox designed to subject test fabric assemblies to water based spray mist conditions typical of pesticide field exposure. Samples to be tested were mounted over cotton gauze pads on four vertical stainless steel arms. The spray mist was generated with a horizontal moving nozzle with the application rate standardized at 73 ml/minute at 50 psi. The liquid media was water containing sodium fluorescein dye and a surface active agent that was added to reduce the surface tension of the solution to 30 dynes/cm in accordance with ASTM F23.50.06.

The spray period was six minutes, after which the gauze pads were retrieved and any penetrating dyestuff was extracted with distilled water, and tested quantitatively via spectroscopic equipment. Test results for the different fabrics are shown in Table III.

Table III. Dye Penetration Tests

Fabric Type	(mg)	Pass/Fail*
HE Cotton with Chemical Repellent	0.5	Pass
HE Cotton with Film Barrier	0.7	Pass
Tyvek® 1422	0.7	Pass
Comfort Guard™ 100	9.4	Fail

**More than 4.9 mg dye constitutes failure*

The Comfort Guard™ 100 was the only fabric to fail this test. At this point of the study, Comfort Guard™ 100 was dropped from further consideration. Cotton fabric treated with liquid repellent provided protective performance based on reduction of fabric surface energy. The surface energy characteristics of film coated cotton and the Tyvek® product were shown to be effective repellent fabrics.

Heat Stress Testing

The physiological burden of performing work tasks is directly related to exertion demands, environmental conditions and clothing influences. Clothing affects heat stress through fabric insulation for dry heat exchange and the resistance to evaporative cooling. These influences on heat transfer are best determined on human, volunteer subjects responding to experiences resulting from realistic heat stress conditions.

Wear tests were conducted in the College of Public Health, University of South Florida, Tampa, Florida, to determine the influences of protective clothing on human responses to heat stress. One phase of the study involved comparisons of the different garments at fixed environmental conditions and a regulated level of work. The test conditions were:

- Clothed subjects were tested in an environmentally controlled chamber with conditions of 38°C (100°F) and 60% RH.
- Work was performed by walking on a treadmill to create 260 watts (225 Kcal/hr) internal heat energy.

- During the test period, they human subjects were continuously monitored for heart rate, body core temperature by rectal thermometer and skin temperatures at four sites.

The work minutes that the subjects were able to complete before reaching a body core temperature of 38.5°C (101°F) are shown in the Figure I. These data show that a worker wearing the chemically treated cotton garment can work 115 minutes longer than he could wearing the Tyvek® garment in the same environments. The advantage in work time performance is 37 minutes when comparing microporous film coated cotton over the Tyvek® product. This is the advantage cotton protective apparel provides and it can be related to reduced labor cost due to increased efficiency.

Conclusions

1. Unbleached cotton can be made into high performance fabric via hydroentangling that can be cost competitive with synthetic nonwovens.
2. Nonwoven, unbleached cotton fabrics can be treated on conventional textile equipment to meet protective performance requirements.
3. Protective clothing made of hydroentangled nonwoven cotton fabrics allows the wearer to work much longer in heat stress conditions than was possible while wearing synthetic apparel.

References

1. Allen Jr., H. C. and P. E. Dabbs. 1994. A New Development In Cotton Opening/Cleaning Equipment for Nonwoven and Conventional Equipment. 1994 Cotton Textile Processing Conference. Proc. Beltwide Cotton Conferences, Vol. 3, pp. 1625-1627.

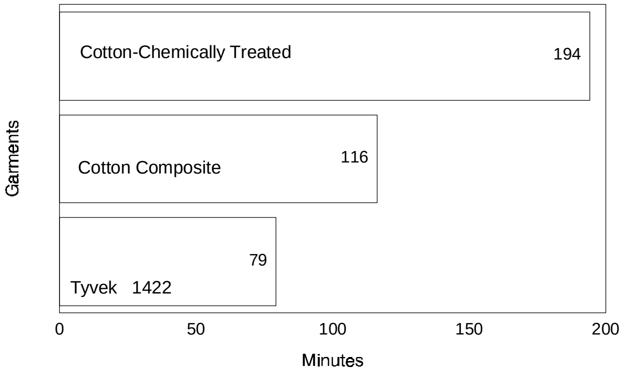

Figure 1. Heat Stress Evaluations