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FLAME RETARDANT COTTON BLEND HIGHLOFTS

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Abstract

Highloft nonwovens are low density fabrics characterized by a high ratio of thickness to weight per unit area. They are usually made of synthetic fibers. Introducing cotton into highloft fabrics is the focus of the present research effort. The major problems with cotton are its high flammability and lack of resiliency. The objective of this research was to carry out single bath chemical finishing of perpendicular-laid highlofts to impart improvements in both flame resistance and fiber resiliency. We developed a finishing formulation containing the flame retardant diammonium phosphate/urea and a crosslinking agent DMDHEU. The formulation was successful in imparting flame resistance to these highly flammable fabrics, protecting 100% of the fabrics. Using the vertical flame test, the damage sustained was limited to charring in the vicinity of the instigating flame. The crosslinking agent was effective in improving compressional resistance and recovery. The finishing treatment produced value-added FR/resilient P-laid cotton blend highlofts.

Introduction

Perpendicular-laid (P-laid) highlofts were developed in the Czech Republic in 1988. Their properties and end uses have been described in several papers. P-laid layering produces fabrics with a predominantly upright position of their fibers (Figure 1). Georgia Textile Machinery (GTM), Atlanta, GA has a P-laid line and has cooperated with us in producing the cotton blend highlofts.

Highloft fabrics are usually made with synthetic fibers. Incorporating cotton into P-laid fabrics is the focus of the present research effort. The major problems with the use of cotton are its high flammability and lack of resiliency. Cotton blend highlofts are categorized with highly combustible brushed pile fabrics, flannelettes, and are characterized by high rates of flame propagation.

The objective of this research was to carry out single bath chemical finishing of the P-laid highlofts to simultaneously impart improvements in flame resistance and fiber resiliency.

Experimental

P-laid fabrics (33mm thickness), varying in cotton contents, were produced using comber noil cotton, polyester (regular) and co-polyester binder fiber. Mechanically cleaned comber noil (CN) having an average fiber length of 16mm, polyester fibers: 65 mm, 15 denier, and core/sheath co-polyester bonding fibers: crimped, 55mm, 4 denier were used to produce P-laid highlofts.

Thirty percent by weight of co-polyester bonding fiber was used in all highlofts produced while varying the cotton percentage and adjusting the polyester percentage to make a total of 100 percent. Cotton fiber (CN) of 0, 20, 40, 60, 70 weight percent were respectively blended with polyester of 70, 50, 30, 10, 0 weight percent, producing three fiber composite fabrics.

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All three fibers were individually opened and intimately blended. Carded web from the blended fibers was processed and perpendicularly laid highlofts were produced on an experimental 32-inch wide line at GTM. They supplied us with one square meter of the samples for the present investigation.

The fabric identification contains percent content of comber noil (CN) followed by a dash and "P" for P-laid layering. For example, CN_{40}-P refers to a P-laid fabric containing 30 percent of bonding fiber, 40 percent of comber noil cotton, and 30 percent of polyester.

Formulation

A formulation was developed to impart both flame retardancy and compressibility to the highlofts. Dimethyloldihydroxyethyleneurea (DMDHEU) ultra low formaldehyde was used to improve the resiliency of the cotton. A mixed catalyst system of magnesium chloride hexahydrate and citric acid (1:1) was used to carry out the low temperature cure. A low temperature cure was essential to maintain the dimensional stability of the highloft fabric. Triton X-100 was used to ensure efficient wetting of the highloft containing greige cotton. Diammonium phosphate and urea were used as flame retardants.

The finishing technique involved treating all of the highlofts by thoroughly wetting and saturating them with the formulation. The saturated fabrics were centrifuged on a spin cycle of a Kenmore washing machine (70 Series model 110) for 1 to 4 minutes to obtain wet pickup of more than 100%. The samples were dried thoroughly in a forced-air oven at 85°C for 30 to 40 minutes and cured at 105°C for 10 minutes.

Test Methods
The compressional study was carried out on a Gustin-Bacon Measure-matic thickness gauge with a pressure foot having an area of 930 cm^2. The test procedure of the compressional study is described in detail in our earlier papers. Flame retardant properties of the highlofts were analyzed using the AATCC vertical flame test method 5903. The standard procedure was performed with a flame contact time of 12 seconds. The after-flame time, after-glow time, and charred area were recorded for the unfinished and finished fabrics.

Results and Discussion

The composition and density of the P-laid fabrics studied are shown in Table I. Their compressibility and flame retardant finishing results are discussed. To obtain a multifunctional treatment, it is necessary to combine several agents into a single pad bath formulation. An important property of a finishing agent is its compatibility with other finishing agents. Chemicals used in the present formulation were compatible (Table II).

The finishing technique adopted for the present study was saturate-centrifuge-dry-cure. The conventional pad-dry-cure was not suitable because of the high thickness of the highlofts. Table III shows the percent wet pickup and percent add-on obtained. Wet pickups of 110% plus were necessary to impart improvements in both flame retardancy and the compressional resistance.

Improvements in Compressibility
Chemical finishing with DMDHEU and the flame retardants were carried out with the objective of simultaneously improving compressional and FR properties of P-laid highlofts . Finishing imparted greater resistance to compression and better recovery from compression to the highlofts (Table IV). Typical compressional and recovery curves before and after finishing of the fabrics, CN20-P and CN40-P are shown in Figures 3-4. At maximum compression (52 gf/cm^2), a treated low level cotton fabric, CN_{20}-P, was compressed only 10% compared to 33% for the untreated fabric and it recovered to 99% compared to 96% for the untreated fabric (Figure 4).

Improvements in Flammability
Cotton fabric ignites under flame, the flame propagates and an after-flame continues after the flame source is removed. Flameless smoldering (after-glow) continues until the entire cotton fabric has been consumed. Vertical flame test results of unfinished fabrics are shown in Table V. Unfinished fabrics, CN_{20}-P and CN_{40}-P, burned and the flame consumed 100% of the fabric. Flammability of polyester fiber is different from that of cotton. Since the 100% polyester fabric (CN_0-P) does not contain cotton, flaming, after-flaming and after-glow are absent. Under flame, the polyester fabric melts where the flame impinges and the molten polyester drips away creating an arc-shape dent in the fabric.

Flammability test results of finished fabrics showed consistently excellent results without any after-flame or after-glow (Table VI). The damage sustained to the fabrics was limited to charring in the vicinity of the instigating flame (Figure 5). This is the highest degree of protection that could be given to these highly flammable fabrics. Apparently, high wet pickup of 107% to 170% (percent add-on of 26% to 61%) is required to impart good FR properties to the fabrics. Fabrics finished with low wet pickup produced inferior FR performance. For example, CN_{20}-P finished with a wet pickup of 64% was completely consumed.

Summary

The P-laid highloft fabrics are three fiber composites of cotton, polyester, and co-polyester and are recognized as highly combustible fabrics. A finish formulation containing flame retardants diammonium phosphate/urea and DMDHEU was used. The objective of this research was to carry out one-bath finishing of these highlofts to simultaneously impart improvements in flame retardancy and fiber resiliency. Finished fabrics performed well in flame retardancy, protecting 100% of these extremely combustible fabrics. Damage sustained to the cotton blend highlofts was limited to a charring in the vicinity of the instigating flame. The FR highlofts would provide great fire protection and the injury inflicted to personnel in their immediate vicinity will be greatly reduced. We recommend incorporating cotton up to 40% in the cotton blend highlofts.

The DMDHEU crosslinking agent was effective in improving resistance to compression and recovery from compression of the P-laid highlofts. P-laid highlofts containing cotton are environmentally benign and also have an advantage in improved biodegradability. These chemically finished highlofts are a value-added product exhibiting FR properties and high resiliency.

Acknowledgement

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Table 1. Fabric Composition and Density.

Sample #	**Cotton (CN) (%)**	**Bonding Fiber (%)**	**Polyester (%)**	**Thickness (mm)**	**Areal Density (g/m^2)**	**Density (kg/m^3)**
CN_0-P	0	30	70	26.44	808.58	30.58
CN_{20}-P	20	30	50	26.34	687.16	26.09
CN_{40}-P	40	30	30	27.10	880.91	32.51
CN_{60}-P	60	30	10	26.87	764.66	28.46
CN_{70}-P	70	30	0	26.92	855.08	31.76

Table 2. Formulation.

Chemicals	**Formulation (%)**
DMDHEU (permafresh UF)	10.0
Diammonium Phosphate (Dibasic)	10.0
Urea	10.0
Triton X-100	0.7
$MgCl_2$, $6H_2O$	1.0
Citric Acid	1.0
H_2O	67.3
Total	100.0

Table 3. Finish Wet Pickup and Add-On.

Sample #	Wet Pickup (%)	Add-On (%)
CN_0-P	161	61
CN_{20}-P	107	26
CN_{40}-P	139	44
CN_{60}-P	170	48
CN_{70}-P	148	42

Table 4. Thickness Recovery (% of initial thickness).

	5 minutes of recovery			
Treated Fabric	**6.89 (gf/cm^2)**	**13.78 (gf/cm^2)**	**34.44 (gf/cm^2)**	**51.67 (gf/cm^2)**
CN_0-P	99.7	99.4	99.0	98.8
CN_{20}-P	99.4	99.0	98.8	98.3
CN_{40}-P	99.3	99.1	98.7	98.4
CN_{60}-P	99.1	98.5	97.8	97.2
CN_{70}-P	99.2	98.6	98.1	97.5

Table 5. Flammability of Unfinished Fabrics.

Sample #	After-flame Time (sec)	After-glow Time (sec)	Remarks
CN_0-P	0	0	No flaming, polyester drips away making arc shaped dent 3.05cm(width) x 5.08cm(height) where flame touches the sample, 5% of sample consumed
CN_{20}-P	166	148	Flaming, burning, after-glow is continued until 100% of sample consumed
CN_{40}-P	142	803	Flaming, burning, after-glow is continued until 100% of sample consumed
CN_{60}-P	30	164	Small flame, flame spread up on sides only, after-glow is continued charring 40% of the fabric surface
CN_{70}-P	10	180	Small flame, flame spread up on sides only, after-glow is continued charring 25% of the fabric surface

Table 6. Flammability of Finished Fabrics.

Sample #	After-flame Time (sec)	After-glow Time (sec)	Remarks
CN_0-P,	0	0	No flaming, no after-glow, polyester drips away making arc shaped dent 4.00cm(width) x 1.05cm(high) where flame impinges the sample, 99% of sample protected
CN_{20}-P, CN_{40}-P, CN_{60}-P, CN_{70}-P	0	0	No flaming, no after-glow, great integrity, charring only where flame impinges, 3.7cm(w) x 0.6cm(h), protecting nearly 100% of sample

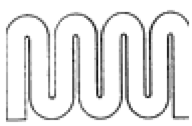

Figure 1. Schematic fiber layering for perpendicular-laid nonwovens.

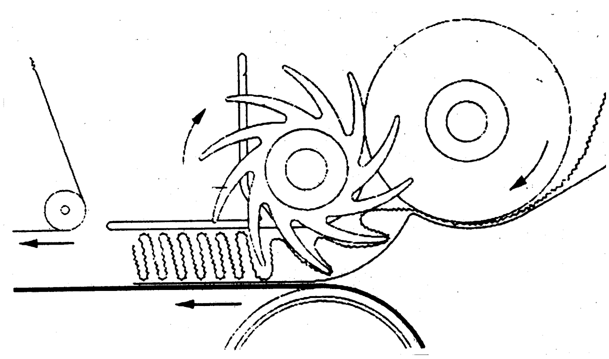

Figure 2. Perpendicular-Laid Line.

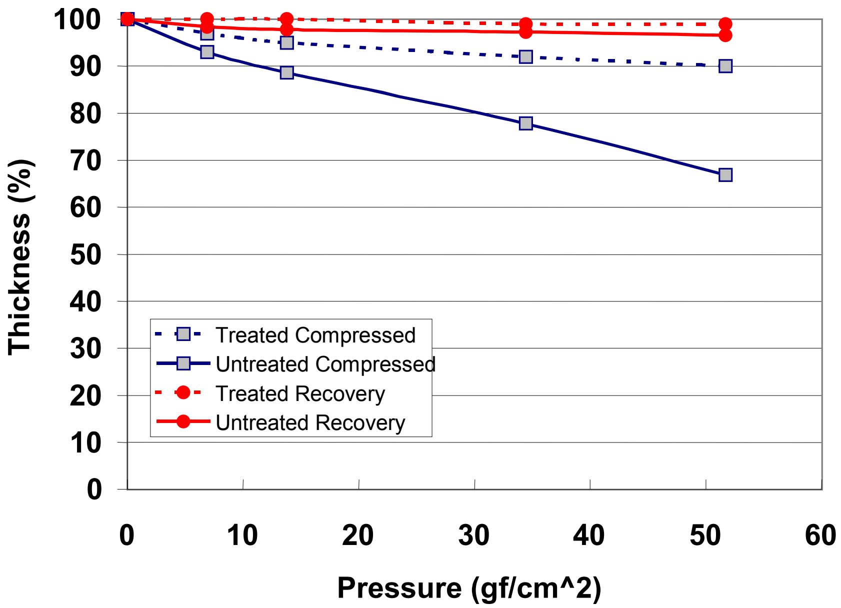

Figure 3. Compressive Curves for Treated and Untreated CN20-P Fabrics.

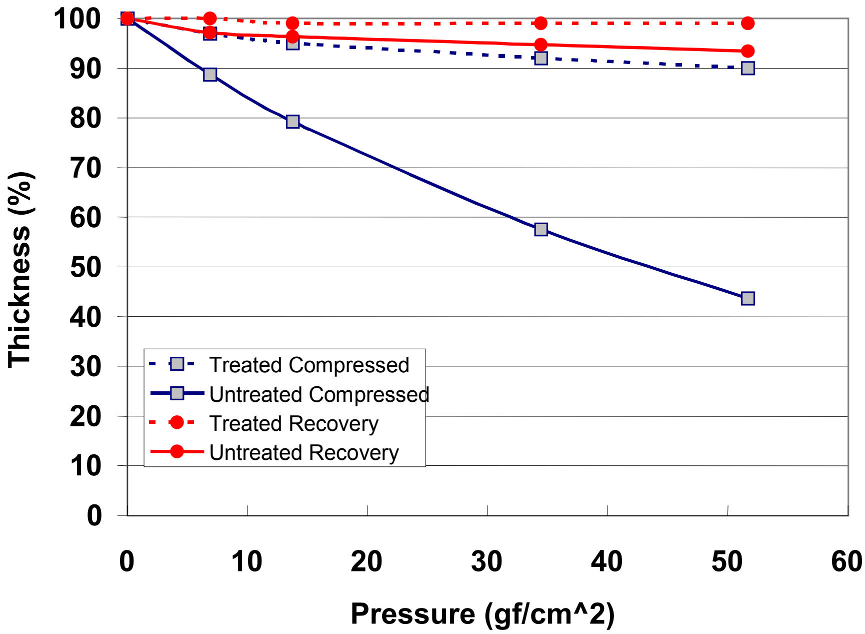

Figure 4. Compressive Curves for Treated and Untreated CN40-P Fabrics.

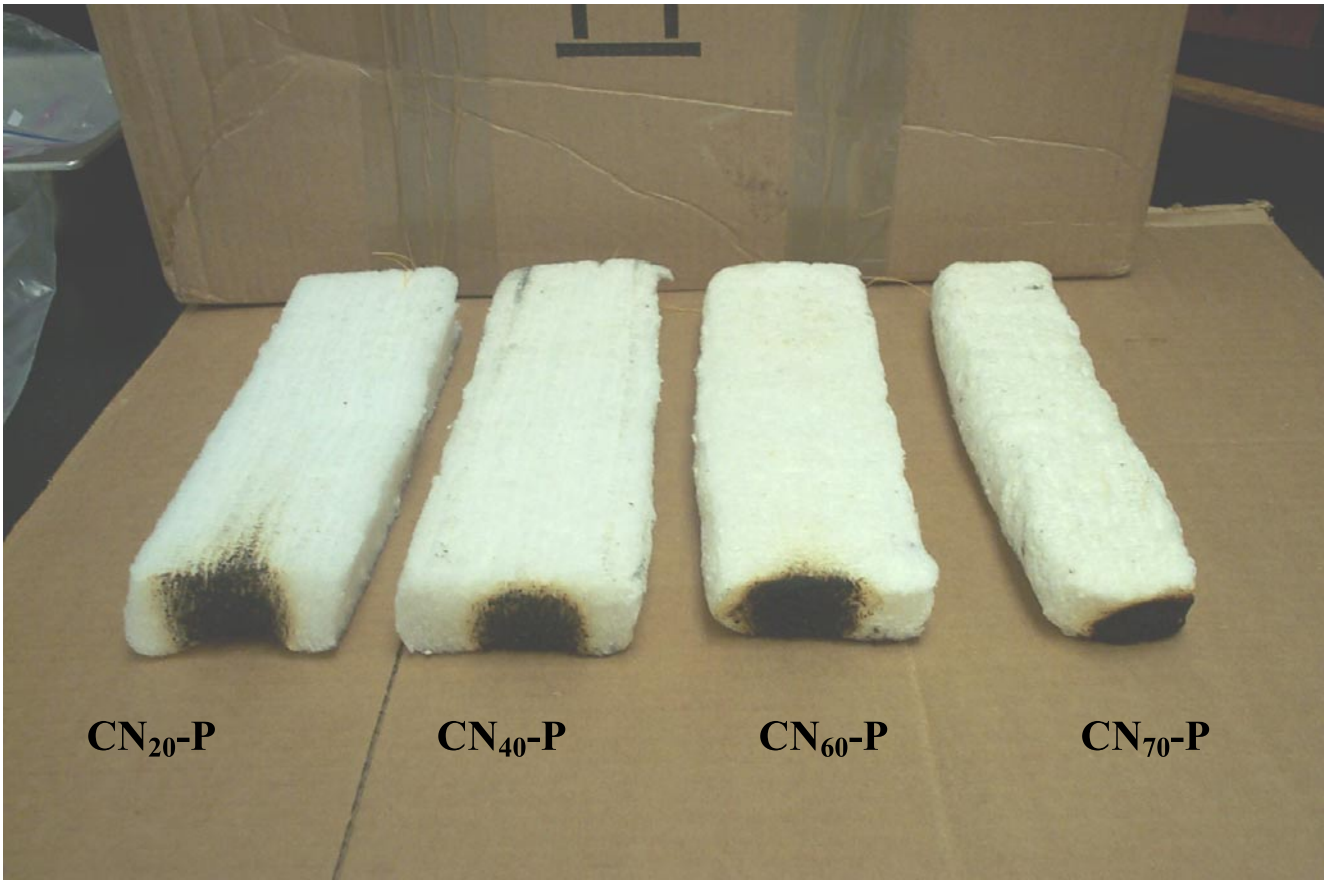

Figure 5. Charred where flame impinges finished fabric.