FLAME RETARDANT COTTON BASED HIGH LOFT NONWOVENS

Rohit Uppal
Hatice Mercemik
Gajanan Bhat
The University of Tennessee
Knoxville, TN
Sunghyun Nam
Dharnid V. Parikh
Brian Condon
USDA-SRRC
New Orleans, LA

Abstract

Flame retardancy has been a serious bottleneck to develop cotton blended very high specific volume bulky High loft fabrics. Alternately, newer approach to produce flame retardant cotton blended High loft fabrics must be employed that retain soft feel characteristics desirable of furnishings. Hence, the present research effort was directed to study cotton-blended High loft fabrics. The objective of this research was to improve flame resistance (FR) and physical resiliency of cotton high lofts. Flame retardant cotton fibers that have been chemically treated with FR chemical developed at USDA-SRRC. Hence, there is no need for a coating and the product retains a soft feel. In this study, SRRC FR cotton or FR Rayon were blended of with a binder to form high loft s and were evaluated. Using the LOI test, SRRC FR cotton with a binder yielded an LOI of up to 31.5, whereas FR Rayon with a binder yielded an LOI of up to 26. The formulations imparted flame resistance to the high lofts.

Introduction

In the US, every year about 14000 household fires occur, leading to 330 deaths and $300 million property loss. The safety of humans and their possessions has become a very important issue due to increasing potential of flammable textile materials. FR treatment may reduce flammability hazards of flammable high loft and reduce the risk of damage by increased protection by providing more time for people to escape from a fire with fewer injuries, and result in savings of life. In the recent years, stricter flammability regulations (Chapter 16, Code of Federal Regulations4 - CFR parts 1602 through 1634), hence, the demand for flame retardant fibers and fabrics is increasing to comply with these regulations. The cotton goods and nonwoven manufacturers are seeking methods to develop FR treatments for their products to meet the stricter open mattress flammability standard, at minimum add-on cost. This highlights the vast market potential for a techno-economically viable product with a desired degree of flame retardancy.

As customers look for comfort properties, generally cotton fiber high-loft nonwovens are used for making upholstery, mattresses, pillows, bedclothes, carpets, work clothes, sleepwear, clothes, children's sleep wear, home furnishings and mattresses. Cotton fiber high-loft nonwovens are comfortable, lightweight, and flexible. Cotton is an environmentally friendly material. It has good moisture absorption. Major drawbacks of using cotton are high flammability and lack of resiliency.

To prevent cotton from burning, flame retardant treatment is one of the most effective methods, which improves thermal resistance of cotton to ignition, reduces flame propagation rate, elevates ignition temperature and prevents continuous burning [Kozlowski et al., 2007]. Flame retardant chemicals act in one or more components of combustion: heat, fuel and oxygen [Bourbigot et al., 2007].

High loft nonwovens have a high ratio of thickness to weight, which is an indication of high void volume. Cotton high lofts, which are through-air bonded using a thermoplastic binder fiber can be obtained without chemical binders. The core polymer of binder fiber maintains homogeneity and integrity while sheath fiber function as glue to bond the fibers [Parikh et al., 2003]. Recently bicomponent fibers (recycled PET core and low-melt PET sheath) are popularly used as binder fibers in cotton nonwovens. They have lower melting point (80 to110°C). On applying heat they soften, melt, and fuse together at the contact points of the surfaces of fibers within a web. The proportion of these bonding fibers within the web can be varied from 10 to 20% to achieve the desired performance properties such as strength, drape, and resilience. Thermally bonded cotton blend high lofts are used widely in mattress and furniture industries and provide comfort, absorbency, soft hand, wash ability, cost and quality balance in the final product [Handermann, 2004].

FR treatments impart resistance to combustion, reduce flame spread, suppress smoke formation, and prevent polymer from dripping. The most commercially viable FR compounds include halogenated types, phosphorus based types, and metallic hydroxides. During the last decade extensive research has been going on to develop new products to enhance FR of cotton and its consumer usefulness. With nonwoven technology, it is possible to overcome drawbacks of durable FR treatment and impart desired resilience, strength and softness. Flame-retardants can have some adverse effects on fabric. In case of the nonwoven fabrics containing cellulosic fibers as well as synthetic fibers, while imparting FR properties affects few desirable properties. Challenge is how to minimize the detrimental effects like change in mechanical properties such as loss in abrasion resistance, harsh handle and lowered air permeability [Lewin, 2005].

Incorporating cotton into High loft nonwovens fabrics is the focus of the present research effort. This research is set to produce durable FR treatments for cotton based nonwoven webs. The nonwoven webs are produced by through air bonding of cotton fiber, FR fibers and binder fiber. The high lofts were aimed to have simultaneously improved flame resistance and resiliency. The focus of this research was to develop FR treatments for cotton rich high loft nonwovens using a blend of cotton and FR fibers. Moreover, these fabrics are designed to obtain the desired level of flame retardancy with good performance properties.

Materials and Methods

Fibers Used in Construction of Nonwoven Webs

Cotton used in the research is from the commercial lot obtained from a roll of greige cotton needle punched nonwoven (NW) fabric, 100 m, 228.6 cm (90") wide, 150 g/m^2 (5 oz/yd^2), was donated by the Warm Company, Lynnwood, Washington. It was gray (unbleached) cotton, mechanically cleaned thus practically free of undesired contaminants such as leaves, twigs, stones, seeds, seed-parts etc. Naturally, cotton does not melt, but yellows if heated above 185°C and then degrades at temperatures above 290°C. Commercial grade bicomponent fiber with low-melt polyester sheath and PET core was obtained from Invista.

FR Formulation and Treatment

The formulation (Table 1) was developed to impart both flame retardancy and compressibility to the high lofts. In the formulation, dimethyloldihydroxyethyleneurea (DMDHEU) with ultra low formaldehyde was used to improve the resiliency of the cotton and impart some durability to washing. Diammonium phosphate (DAP) and urea were used as flame-retardants. Diammonium Phosphate (DAP) is a water-soluble ammonium phosphate salt, which can be produced when ammonia reacts with phosphoric acid. It contains nitrogen and phosphorous and it leaves char when it is exposed to heat. It is a non-durable FR chemical.

Table No.1: FR Formulation

Formulation	(%)
DMDHEU	5.0
Diammonium Phosphate	10.0
Urea	5.0
Triton X-100	0.7
Polyethylene Emulsion	1.5
MgCl2, 6H2O	1.0
Citric Acid	1.0
Water	75.8
Total	100.0

The SRRC formulation was applied to greige cotton NW fabric on a Mathis laboratory padder with a pickup of 80% - 85% with two immersions and two nips, dried for 2 minutes at 150^{o}C to obtain 15% add-on on the fabric.

Nonwoven Web Formation, Carding and Through Air Bonding Process

Cotton fiber, FR fibers and binder fibers were mixed in the desired percentages (Table 2). SDS Atlas carding machine was used to prepare uniform blend of fibers and the web. Carding is the most commonly known process used to produce nonwoven webs from staple fibers. Cotton, bi-component binder fiber, and Lenzing rayon fiber were mixed in the desired proportion in order to produce blend of nonwoven webs. Bicomponent binder fibers are blended in the desired proportion in carding operation and through air bonded in a conventional oven to form a nonwoven. Varying weight of copolyester bonding fiber was used in all high lofts produced. All three fibers were individually opened and intimately blended.

After the carding process, the web was bonded by through air bonding in an in the Mathis oven. In previous Cotton FR research the process conditions of through air bonding to impart good strength, loftiness and appearance were optimized. It was found that the optimum bonding conditions for cotton-based nonwovens should be at 175° C for 3 minutes. The sheath provides the fusing point while the core preserves the integrity of the nonwoven. Low melt bicomponent fiber sheath melts at ~80°C and the core melts at ~250°C. Moreover, the webs containing these fibers can withstand safe ironing and laundering conditions.

Table No.2: Blends numbers and blend ratios

Blend#	Fiber %			
	Greige cotton	SRRC FR cotton	FR lenzing Rayon	Binder
1	0	85	0	15
2	0	0	85	15
3	0	42.5	42.5	15
4	0	80	0	20
5	0	0	80	20
6	0	40	40	20
7	0	75	0	25
8	0	0	75	25
9	0	37.5	37.5	25
10	75	0	0	25
11	20	55	0	25
12	10	0	65	25
13	20	0	55	25

Characterization methods

The samples produced in the experiments were tested for physical properties and structure only after conditioning the samples for at least 24 hours under standard laboratory conditions: 21°C ± 1°C and 65% ± 10% RH.

Basis weight of bonded webs was measured according to ASTM D3776-96. Web samples were cut into a rectangular piece of 305mm x 305mm (12”x 12”) size and weighed. Basis weight is expressed as grams per square meter.

In order to measure the thickness of the test specimens uniformly and consistently, the sample is set on a horizontal table and a square platen is placed on the specimen. The distance between the platen and table surface is measured in mm. The square platen has dimensions 305 mm X 305 mm (12” X 12”) and thickness ~3mm (1/8”). It was constructed of Plexiglas board with a handle to lift and position the plate. The total weight of the thickness measurement plate is 288(±1) grams. Average 16 readings (four readings from four sides) were taken for evaluation.

Untreated sample and FR treated cotton based nonwoven web samples were tested for flammability. FR tests are designed to determine the fire risk of materials and products for the application, which they are required. The most popular test for textile materials is limiting oxygen index (LOI) and small open flame test (TB604 or 16CFR part 1634). The samples produced in the experiments were subjected to flammability test after conditioning the samples for at least 24 hours under standard laboratory conditions (21±1 C and 65%±10 relative humidity).

Limiting Oxygen Index (LOI) Oxygen index method describes the tendency of a material to sustain a flame and is widely used to evaluate flammability of polymeric materials. LOI is the minimum oxygen concentration that is sufficient to sustain the flame in a controlled atmosphere of oxygen and nitrogen. It is a convenient reproducible and inexpensive way of determining numerical measure of flammability. LOI testing can be done according to ASTM 2863.

Small open flame test (TB604 or 16CFR part 1634) In January 2005, consumer product safety commission published an open flame standard for top of the bed items such as pillows, comforters and mattress webs etc. TB604 is a laboratory scale test for open flame standard. For this test washed samples were cut into 12x12 inch pieces and placed between two bottoms and two tops 50% cotton and 50% polyester fabric. Then the sample, together with cotton fabrics placed on an insulation board horizontally. The insulation board was placed on a scale to record the weight of the sample continuously. According to the test procedure, the center of the specimen was subjected to 30^0 oriented 35mm height flame for 20 seconds. Then the burner was removed from the surface of the material. After ignition the flame start to propagate over the sample and allowed to burn for 6 minutes until the flame extinguishes. The specimen passes the test if the weight loss does not exceed 25% of the initial weight. For a mattress pad the specimen passes the TB604 test, if the flame does not create a void more than 50mm in diameter, [CPSC Technical bulletin 604, 2007].

Results and Discussion

The basis weight of the samples was tried to be kept similar (Table 3). LOI values (Table 3) indicate that the sample 10 which was having 75% Greige cotton and 25% Binder was flammable. Some of the samples are slow burning such as sample no. 2, 5, 8, 11, 12, 13. The decrease in the LOI value for sample no. 2, 5, and 8 is because of presence of binder fibers. The decrease in the LOI value for sample no. 10, 11, 12, and 13 is because of presence of Greige cotton and binder fibers. Rest of the samples were self extinguishing.

Table No. 3: LOI of the samples

Sample No.	Basis Weight (gsm)	LOI
SRRC FR Cotton		29.3
Binder fiber		24.4
FR Lenzing Rayon		27.6
Blend 1	284	29.3
Blend 2	294	26.0
Blend 3	267	29.3
Blend 4	286	29.9
Blend 5	261	26.0
Blend 6	272	29.3
Blend 7	284	31.5
Blend 8	284	25.0
Blend 9	279	28.3
Blend 10	281	19.5
Blend 11	261	26.0
Blend 12	276	24.4
Blend 13	287	24.4

Small Open Flame Test (TB604)

Four of the samples were selected on the basis of LOI values for further Small Open Flame Test (TB604). Three samples selected passed the test based on the weight loss % and void formation and sample no. 10 did not. Sample no. 10 which was having 75% greige cotton and 25% binder was had a weight loss % more than 25%.

Table No. 4: Small Open Flame Test (TB604)

Sample ID	Original weight of the web (gms)	Weight of the web after the small open flame test (gms)	Weight loss %	Void
6	27.3	24.9	9.6	No
7	19.4	17.6	10.2	No
8	24.9	24.8	0.4	No
10	25.2	17.8	41.6	No

Conclusions

Flame retardancy of SRRC FR Cotton blends, with varying degrees of binder fibers from 15 to 25%, was the highest amongst all the blends tested. Blends samples, which were having greige cotton, had poorer LOI as cotton is highly flammable. Consequently, only those blends samples, which were having greige cotton failed in the small open flame test (TB604) and rest all the samples passed the test. The results emphasizes that the SRRC formulation for flame retardancy was quite effective.

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