APPROACHES TO IMPROVING THE DURABILITY OF FLAME RETARDANT TREATMENTS ON COTTON NONWOVENS

Hatice Mercimek
M. G. Kamath
Gajanan Bhat
University of Tennessee
Knoxville, TN
D. V. Parikh
Brian Condon
USDA
New Orleans, LA
Janet O'Regan
Cotton Incororated
Cary, NC

Abstract

Over the past few years we have been working on improving the flame reatardancy of cotton nonwovens in an economical way. Most of these approaches result in good FR properties, but they are not durable to washing. For some of the applications wash durability is desired, and we are conducting research to develop some durable or semi-durable FR treatments in an economical way. The approach is to produce loftier cotton nonwoven webs using a binder fiber, going through the through-air bonding process, and treating them with commercially available FR chemicals and binders. Care is being taken to select the combination of flame retardants and binders such that some degree of permanency can be achieved. These treated webs will be evaluated for their FR characteristics before and after washing. Preliminary results from this ongoing research are presented.

Introduction

Cotton is a comfortable, natural, renewable and environmentally friendly material. Cotton based nonwovens have been used in consumer goods such as upholstered furniture, pillows and mattresses for centuries (1). Cotton, however, has a higher affinity to burning. In the cse of fire, flammable interior furnishings and textile materials can constitute so called the first ignited material and contribute to the development of fire in dwellings (2). The most effective method to prevent cotton from catching fire is the flame retardant treatment, which improves thermal resistance of cotton, increases ignition temperature, reduces combustion rate, and decreases the amount of heat released from burning of cotton based textile material (3).

Large volumes of chemicals are used in the textile industry for nondurable finishes, which are mostly removed completely in the first laundering (4). If fabrics are permanently treated for the life of product and the fabrics maintain primary properties after multiple laundering cycles and regular wear on usage, then they are known as durable flame retardant fabrics. In recent years, the textile industry has become aware of the increasing market potential for viable products to meet the flammability and durability regulations. American Association of textile chemists and colorists (AATCC) developed a standard test method for the assesment of fabrics after repeated home launderings (5). Cotton based goods manufacturers are looking for FR treatment of their products to meet flammability and wash durability standards at minimum add-on cost. There are great difficulties in meeting the durability requirements of cotton while imparting desired flame retardancy to the fabrics. Most of the durable flame retardant treated materials exhibited lowered strength properties and permeability (6). A research conducted at SRRC revealed that durable FR THPC had the disadvantage of a significant loss in fabric strength. The combination of APO and THPC is proved to be one of the most effective flame retardants but since APO is toxic this formulation can not be used commercially (7). Today nonwoven technologies are available to overcome these drawbacks and impart softness, resilience, strectch and strength. Most bedding products are made up of high loft nonwovens consisting of intimate blends of cotton and other fibers. One of the most common processes to make an intimate blend of fibers is carding. Through air oven is an absolute method for thermo bonding to develop strong and integrated highloft nonwovens (8).

This research is focused on developing durable and semi durable cotton- based FR nonwoven fabrics using a blend of cotton with inherently flame retardant fibers, flame retardant chemicals and crosslinking agents that are

commercially available at a reasonably low price. Cotton based fiber webs will be terated with durable and semi durable FR chemicals in the presence of bonding agents to enchance the wash durability of the blend. The chemical treatment onto the fabric surface can be made by passing the carded webs through a solution containing FR chemical and binder using the pad-dry-cure technique. The treated nonwoven fabrics will be characterized for durability against washing and the flame retarding performance of the fabrics will be evaluated before and after washing cycles. The product of this research would be a possible candidate for products such as pillows, mattress pads and barrier materials in mattress sets conforming to desired wash durability and flame resistancy.

Methods

In this research, an approach similar to the one in our earlier work [9-11] was used, except thst durble binders were used. Blends of mechanically cleaned unbleached greige cotton, binder fiber and other FR fibers obtained from various industries were used. Using a carding machine these fibers were mixed in the desired proportion to acquire a uniform blend of fibers. The carded webs with a basis weight of 300 g/m^2 are used in all experiments. The FR chemicals such as Pyrovatex CP new (supplied by Huntsman) as a durable FR , Pyrovatim PBS (supplied by Huntsman) as a semi durable FR , FR CROS 486 (Ammonium polyphosphate, supplied by Budenheim) as a semi-durable FR and diammonium phosphate as a non durable FR were used. The FR chemicals were incorporated to the blend fiber webs as a solution in water in the presence of necessary dispersing and bonding agent (Rhoplex TR 520) using Mathis Laboratory equipment through dipping and squeezing (0.5 bar pressure) and cure-dried at 150°C.
Since the moisture regain of webs will affect the accuracy of weight loss measurements the webs were weighed just after the drying process in the Mathis equipment. These dry weight measurements were recorded as the dry weight of treated webs and used for chemical add-on calculations. Samples were tested for wash durability with water soak tests at 40°C for 30 min. Treated nowoven web samples of size 6 inch by 6 inch were used for wash tests. After water soak tests the samples were dried in the oven at 120°C for 30 min. The weight loss (%) of the samples were calculated on the treated web basis and total weight loss of the samples were recorded after 2 wash tests.

Samples were tested for Limiting Oxygen Index (LOI) levels using the General Electric flammability tester according to ASTM D 2863 Method. LOI is the minimum concentration of oxgen that will support combustion in a flowing mixture of nitrogen and oxygen gases. The sample is positioned vertically in a transparent test column and ignited at the top with a flame. The oxygen concentration was adjusted until the sample supports combustion. The reported concentration is the volume percent.

Results and Discussion

Chemical binder was used in FR solution to enhance the wash durability of cotton- based webs. In order to determine the effect of binder amount on wash durability of cotton webs chemical treatments were applied using durable, semi durable and non durable FR chemicals with changing percentage of chemical binder (no binder, 1% binder, 5% binder and 10% binder based on solution). Water soak tests were applied to the samples twice after FR chemical treatment. The produced samples and the weight gain (%) results are listed in Table 1.

Table 1. Flame retardant chemical add-on (%) on fabrics treated with different combinations.

FR Chemical	No binder	1% binder	5% binder	10 % binder
Pyrovatex CP New	16.0	17.5	19.0	19.9
Pyrovatim PBS	26.4	13.7	16.4	18.8
FR CROS 486	27.2	15.3	17.6	18.2
Diammonium phosphate	14.6	22.0	21.3	19.6

As it can be seen from Table 1, produced samples have different FR chemical add- on levels. As a result of this, to make comparison of durability of FR chemicals using the weight loss results directly may be erronous. So, an assumption was used for durability comparison of chemicals . The formula below

$$\frac{weight\ loss(g)}{chemical\ add\ on\ (g)} \times 100 \qquad (1)$$

can be related to the durability of each flame retardant chemical for different binder percentages. This formula is based on the correlation of these components; chemical add on amount (g) applied to web, the weight loss of the sample (g) after water soak tests. Results are listed in Table 2.

Table 2. Weight loss of flame retardant chemicals based on formula 1

	No binder	1% binder	5% binder	10 % binder
	Weight loss (%)	Weight loss(%)	Weight loss (%)	Weight loss (%)
Pyrovatex CP New	71	57	52	37
Pyrovatim PBS	100	71	68	54
FR CROS 486	100	79	73	61
Diammonium phosphate	100	94.2	77	70

As it can be seen from Table 2, as the binder level increases in the solution the weight loss of FR chemicals decreased with varying percentages. Without binder all the FR chemical incorporated into webs was lost after wash tests. Results showed that the samples containing Pyrovatex CP new had a lower weight loss percentage compared to other flame retardant chemicals studied.

After water soak tests, the flame retardancy of the FR chemical treated cotton nonwoven samples was determined by LOI tests. The LOI test results are listed in Table 3. The values in column 2 are weight percent of FR additives remaining after washing for 1% binder and 5% binder.

Table 3. LOI test results of samples after water soak tests

	FR remained after wash (%)	LOI
Pyrovatex Cp New	7.4	24.4
	9.1	24.4
Pyrovatim PBS	5.1	<21
	5.2	24.4
FR CROS 486	3.2	<21
	4.7	21
Diammonium phosphate	1.2	<21
	4.9	21

From Table 3, it can be seen that Pyrovatex CPnew treated samples showed a low level of flame retardancy after wash tests (classified as slow burning). Also, Pyrovatim PBS treated web sample showed a low level of flame retardancy if FR chemical remained after wash tests was 5.2 % (classified as slow burning). FR CROS 486 and DAP treated samples failed in the LOI test, and these samples can be classified as flammable based on LOI data. Although Pyrovatex CP New is claimed to be durable, because we used greige (instead of bleached) cotton in our studies, the chemical did not bond well enough and it performed as a semi-durable additive.

Summary

Our results revealed that chemical binder has an important effect on wash durability of the cotton-based flame retardant nonwoven webs.The binder effect on durability of webs is much more pronounced for samples which has 10% binder in their FR solution formulation. As chemical binder level increases the chemical loss percentage decreases for the flame retardant chemical treated samples studied in this research. Without binder Pyrovatim PBS, FR CROS 486 and DAP had no resistance to wash and 100 % of chemical was lost after water soak tests. Without binder Pyrovatex CP new treated sample has low level of wash resistance and this sample lost the 70 % of FR chemical after water soak tests. This result is a proof that to achieve wash durability to cotton based nonwoven webs, chemical bonding agent is a must for the investigated flame retardant chemicals.

Pyrovatex CP new have been one of the most successful durable flame retardant chemical for cotton. It was reported in the literature that Pyrovatex CP new was covalently bound to cellulose by the reaction between its N-methylol group. Our results confirmed that Pyrovatex CP new has a higher wash durability compared to other chemicals investigated in this study. If we had used bleached cotton, may be the treatments should have shown much higher level of wash durtability. As a result of being a nondurable FR Diammonium phosphate (DAP) has the lowest resistance to wash for all binder levels as expected.

Pyrovatex CP new treated samples showed a low level of flame retardancy based on LOI data. Most of the FR chemical treated samples investigated in this study failed in LOI tests and can be classified as flammable and marginally stable based on LOI data. The most probable reason for that may be FR chemical bound to webs has a lower resistance to washing. One possible reason for low LOI results may be attributed to the low flame retardant chemical amount remained after water soak tests. It is expeceted that if the desired level of flame retardant chemical can be reached (even after washing) the cotton webs will pass the LOI test. In other words, desired flame retardancy and durability can be achieved for cotton based nonwoven webs.

References

acswebcontent.acs.org/landmarks/cotton/flame

Guiliaro C. Tesoro, Textile finishes, Central Research Laboratory, J.P. Stevens company

G. S. Bhat, M. G. Kamath, H. Marcimek, D. V. Parikh* And B. D. Condon, “Practical Approaches To Impart Flame Retardancy To Cotton-Based Nonwovens," Proceedings of the 4th International Textile and Design Conference, Magic of Textiles, Dubrovnik, Croatia, October 3-5, 2008. (Refereed)

http://etd.utk.edu/2004/KamathManjeshwar.pdf

Kozlowski R, Intumescent flame retardant treatments

Lewin M., Polymer Degradation and Stability 88 (2005)13-19

M. G. Kamath, G. S. Bhat, D. V. Parikh and B. Condon, “New Approaches to Improving Flame Retardancy in Cotton Nonwovens,” *Journal of Industrial Textiles* (Accepted).

M. G. Kamath, G. Bhat, D. V. Parikh and B. Condon, “Cost Effective Approaches to Impart Flame Resistance to Cotton nonwovens,” Proceedings of the Beltwide Conference, Nashville, TN, January 8-11, 2008.

www.consumerreports.org/cro/aboutus/mission/tougherfiresafetystandardmattresses605

www. cpsc.gov/businfo/frnotices/froo/matt.html

www.natbat.com/docs/safety.htm

Wu W. and Yang C. Q., Polymer degradation and stability 91(2006)2541-2548