EFFECT OF CHEMICALS AND BINDERS ON THE DURABILITY OF FLAME RETARDANT TREATED COTTON NONWOVENS

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Abstract

Most of the approaches to produce flame retardant (FR) cotton-based nonwovens 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 cotton nonwoven webs using a binder fiber, going through the through-air bonding process, and treating them with commercially available FR chemicals and binders. It is important to select the right combination of flame retardants and binders such that some degree of permanency can be achieved. These treated webs have been evaluated for their FR characteristics before and after washing. Both, selected FR chemical and the binder, have an effect on the durability of the produced webs. A model is being developed to understand these effects, so that it can help in selecting the best combination for optimum FR performance.

Background

Cotton is a comfortable material, a natural product, a renewable resource and an environmentally friendly material. Cotton-based nonwovens have been used in consumer goods such as pillows, upholstered furniture and mattresses for years. Like all textile fibers, cotton has a higher proneness to burning [1]. In case of fire, flammable home furnishings and textile materials can ignite easily and contribute to the development of fire. These materials are considered as the main fire risks and called as the first ignited materials [2]. In the US, every year over 3 million fires are reported and these have resulted in 29000 injuries, 4500 deaths and US$8 billion in property losses [3]. Mattress fires are responsible for 440 deaths 2230 injuries and $274 million in property loss from 1995 through 1999 [2]. Government and textile industries have been involved in investigating and developing new methods to prevent fires and reduce fire risks, and their effects [4]. 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 [5]. The major aim of using flame retardants is to provide more time for people to escape from fire and reduce death and injuries.

During the past decade, extensive research has been going on to develop new products to enhance FR of cotton and its consumer usefulness. The inherent properties of cotton make FR cotton the most comfortable flame retardant fabric. For some textile applications durability against water is another concern for manufacturers. Large volumes of FR chemicals used in textile industry are nondurable, which wash off completely after washing [6]. If a fabric can survive water soaking to various degrees this is called a semi durable flame retardant treatment. This type of treatment loses its effectiveness with alkaline detergent or hard water [9]. If fabrics can maintain their FR properties after multiple laundering cycles, these are called as durable flame retardant fabrics [7]. An ideal FR fabric for textile applications must be comfortable, eco-friendly, durable and cost effective. An ideal durable FR cotton treatment must impart durability to washing, be easy to apply, have sufficient air permeability, cause no big change in mechanical and aesthetic properties and has a quality and cost balance [8]. The focus of this research has been to develop semi-durable FR treatments for cotton rich nonwovens using a blend of cotton and FR fibers. Cotton based fiber webs were treated with several commercially available nondurable, semi-durable and durable FR chemicals in the presence of chemical binders to impart flame retardancy and wash durability. The main objective has been to obtain the desired level of flame retardancy with good performance properties in cotton-based nonwovens.

Experimental

In this research, all the fibers and chemcials used were commercially available materials. Blends of mechanically cleaned unbleached greige cotton, binder fiber and other FR fibers were obtained from various companies. Using a laboratory 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 were 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, Noflan (firestop Chemicals), Saffron (ICI Industrial Chemicals), Ecoshield (Eastern and Color), 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, Airflex 4500 or Permafresh CSI-2) using a Mathis Laboratory equipment through dipping and squeezing (0.5 bar pressure), and cure-dried at 150°C.

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 with the formula below and total weight loss of the samples were recorded after 2 wash tests.

$$\frac{M1 \quad M2}{M1} \quad 100 \quad Weight\ loss\ of\ the\ treated\ sample(\%) \qquad (1)$$

Where M1 is the initial dry weight of the treated sample, M2 is the dry weight of sample after water soak 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 oxygen 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 is adjusted until the sample supports combustion. The reported concentration is the volume percent. This is a laboratory scale test for items such as bed clothing, mattress pads, comforters and pillows. For this test, washed samples were cut into 12x12 inch pieces and placed between two bottoms and two tops of 50% cotton and 50%polyester fabric. Then the sample, together with cotton fabrics are placed on an insulation board horizontally. The insulation board is 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° oriented 35mm height flame for 20 seconds. Then the burner was removed from the surface of the material. After ignition the flame starts to propagate over the sample and allowed to burn for 6 minutes until the flame extinguishes. While conducting the TB604 test, the video records weight of the pad and temperature of the sample center. To measure the temperature of the sample center a sensor was located under the web sample. The sample passes the test if weight loss does not exceed 25% and there is no flash over. A mattress pad passes the test if the flame does not create a void more than 50mm in diameter. Also tensile properties and bending length were measured as per the ASTM standard methods for selected samples.

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 related weight loss (%) results for one of the binders are shown in Figure 1. Since the produced samples had different FR chemical add-on levels, to make comparison of durability of FR chemicals using the weight loss results directly may be erronous. So, the following calculation was used for durability comparison of chemicals . The formula below

$$\frac{weight\ \ loss\,(gr)}{chemical\ add\ on\,(gr)} \times 100 \qquad (2)$$

can be related to the durability of each flame retardant chemical for different binder percentages.

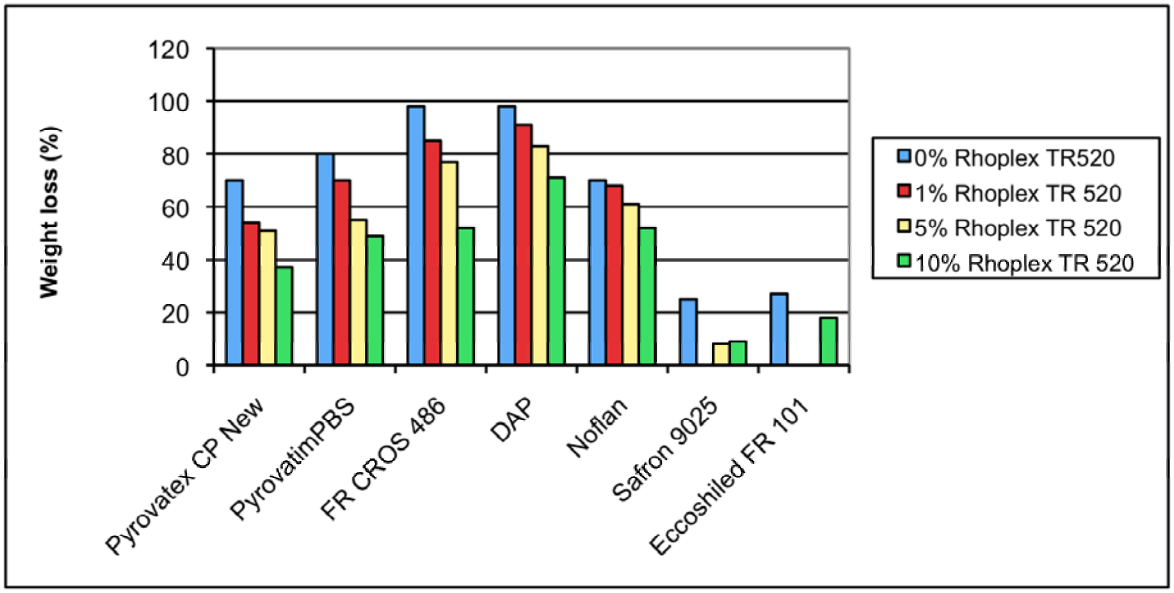

Figure 1. Weight loss due to washing for different FR additives with the Rohoplex binder.

As the binder level increases in the solution the weight loss of FR chemicals decreased with varying percentages. Without binder most of 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 phosphor-based flame retardant chemicals studied. Ecoshield, a nitrogen-based additive and Safron, a brominated additive showed much lower weight loss.

After water soak tests, the flame retardancy of the FR chemical treated cotton nonwoven samples was determined by LOI tests. The LOI test results for Rhoplex binder are shown in Figure 2.

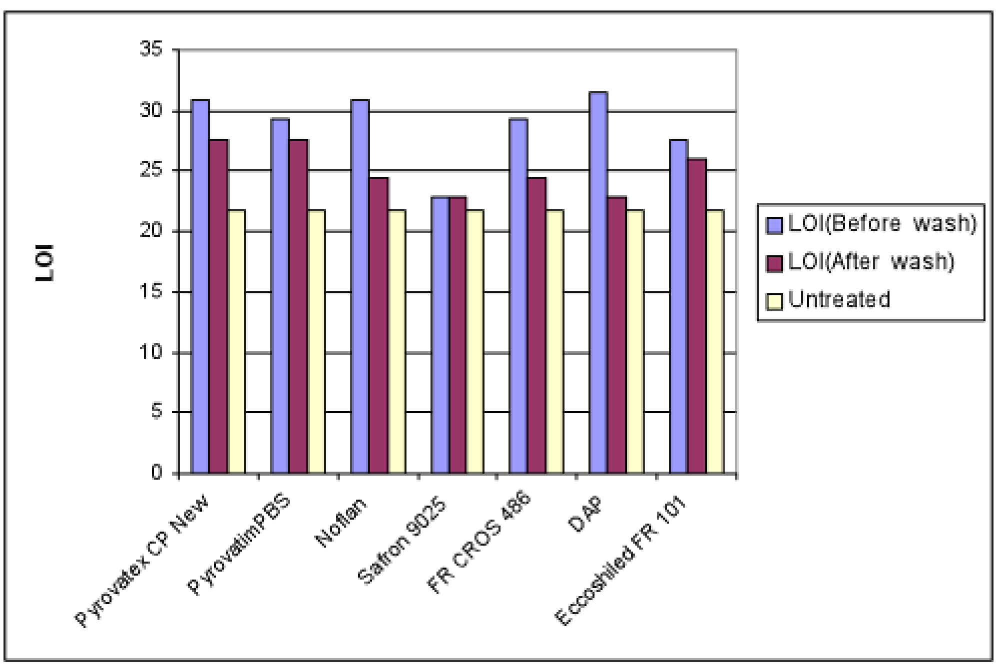

Figure 2. LOI results for samples treated with different FR additives using the Rhoplex binde

From the results, it was seen that pyrovatex cp new 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 7.9 % (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 CpNew is claimed to be durable, but in our studies, the chemical did not bond well enough and it performed as a semi-durable additive. This could also be due to the fact that we were using greige cotton. Saffron treated samples had low LOI values before washing itself. As expected DAP treated samples showed lower LOI after washing. Other tests and modeling studies are continuing.

Summary

The chemical binders have an important effect on wash durability of the cotton-based flame retardant nonwoven webs. As chemical binder level increases the chemical loss percentage decreases for the flame retardant treated samples studied in this research. Without binder, Pyrovatim PBS, FR CROS 486 and DAP had poor resistance to wash and most of the of the additive was lost after water soak tests. Without binder pyrovatex cp new treated sample had low level of wash resistance and this sample lost the 70 % of FR chemical after water soak tests. These results indicate that to achieve wash durability to cotton based nonwoven webs, chemical bonding agent is a must for the investigated flame retardant chemicals. Being a nondurable FR, diammonium phosphate (DAP) has the lowest resistance to wash for all binder levels as expected. Statistical analysis showed the effect of different FR additives and binders as well as binder levels. 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, and the laboratory mattreess burning test. In other words, desired flame retardancy and durability can be achieved for cotton based nonwoven webs using the right combination of FR addtives and binders.

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