COMPARATIVE STUDY OF THROUGH-AIR BONDED AND THERMAL CALENDERED NONWOVENS

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Abstract

Over the years there has been increasing interest in developing flame retardant (FR) cotton-based nonwovens. Whereas majority of the work has been done with high loft nonwovens, since this has been of interest to bedding and home furnishing industry, the effect of web density on flame retardancy is not studied. To investigate these effects, FR cotton composites were manufactured via, carding and thermal bonding. Carded webs were bonded via two different methods namely through-air bonding and hot calendaring. These webs with similar composition but different web density due to differences in bonding were investigated for their performance characteristics. The limiting oxygen index (LOI) for the samples did not show large differences. However, blend composition, method of bonding and fiber length showed the influence on burning mechanism of samples.

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 (Ramachandran et al, 2005). Government and textile industries have been involved in investigating and developing new methods to prevent fires and reduce fire risks, and their effects (Bajaj, 2004).

During the past decade, extensive research has been carried out to develop new products to enhance FR properties of cotton and its consumer usefulness. Application of flame retardant chemicals 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 and Duquesne, 2007). FR treatments impart resistance to combustion, reduce flame spread, suppress smoke formation, and prevent polymer from dripping.

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, retain aesthetic properties and has a quality and cost balance (Perkins et al, 1971). For some textile applications durability against water is another concern for manufacturers. The fabrics that can maintain their FR properties after multiple laundering cycles are called as durable flame retardant fabrics (Weil and Levchik, 2008). Large volumes of FR chemicals used in textile industry are nondurable, which go off completely after washing (Tesoro et al, 1968). The most commercially viable FR compounds include halogenated types, phosphorus based types, and metallic hydroxides. These flame-retardants can have some adverse effects on fabric. In the case of nonwoven fabrics containing cellulosic fibers as well as synthetic fibers, 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).

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. High loft nonwovens have a high ratio of thickness to weight, which is an indication of high void volume. The high loft cotton composite, which are through-air bonded using a thermoplastic binder fiber can be obtained without chemical binders.

Recently bi-component fibers (recycled PET core and low-melt PET sheath) are popularly used as binder fibers in cotton nonwovens (Hegde et al, 2008). 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 core polymer of binder fiber maintains homogeneity and structural integrity while sheath fiber function as glue to bond the fibers (Parikh et al, 2003). 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 (Henderman, 2004).

Even though significant research has been done to understand burning mechanism of cotton based FR composites (Kamath et al, 2009), structure and properties of the webs obtained from through-air bonding and calendering methods, (entrapped air and air permeability) and its influence on the FR properties is not understood. 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. The main objective has been to obtain the desired level of flame retardancy with good performance properties in cotton-based nonwovens. FR composites were successfully manufactured with carding, calendering and through air bonding technology and tested for structure property relationship. Influence of composite web structure on the burning mechanism and limiting oxygen index (LOI) results is elucidated in this paper.

Experimental Methods

Materials and Processing

Using the different blends (Table 1), carded webs of about 300 GSM were prepared using the 30cm wide SDS Atlas carding machine. In all the samples, a bicomponent binder fiber without any FR treatment was used either at 15, 20 or 25% level. Rest was either Visil or FR treated cotton at various proportions.

Bonding time was optimized based on the visual appearance and consistency of the webs. For producing high loft nonwovens, the carded webs were bonded using the Mathis hot air assisted drying oven at a temperature of 175°C for 2 min. The bonding temperature of 175°C for the through air bonding was selected based on our earlier research (Bhat, et al, 2009). Thermal calendaring of the webs was carried out using a BF Perkins calendar equipped with flat calendar rollers. Temperature, pressure and calendaring speeds were optimized based on the consistency in consolidation, visual appearance, and optimum drape in the final product. At a higher temperature of 175°C and 1000 PSI pressure, even though webs were well bonded, required drape in the end product to make it as successful FR cotton composite was lost due to over bonding. All the webs were calendered at roller speed of 4.4 meters/min, a temperature of 155°C, and consolidation pressure of 500 PSI.

Table 1. Blend compositions (* - cotton without FR).

	Fiber Composition (%)		
Blend #	FR cotton	Visil	Binder
1	85	0	15
2	0	85	15
3	42.5	42.5	15
4	80	0	20
5	0	80	20
6	40	40	20
7	75	0	25
8	0	75	25
9	37.5	37.5	25
10*	75	0	25
11	0	75	25
12*	37.5	37.5	25

Testing and Characterization

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% ± 2% RH. Thicknesses of the webs were measured using a TMI thickness tester. Tensile strength of the fabrics was tested on 2.54 cm wide, 7.62 cm gauge length sample at strain rate of 25 cms/min using a United tensile tester. Air permeability of the bonded webs was determined using the FX3300 tester. Limiting Oxygen Index (LOI) 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. Thickness of the through-air bonded webs was not measured since the sample were lofty and not fitting in between clamps of TMI thickness tester and also Stiffness of the calendered webs were not measured since all the calendered webs had similar high stiffness.

Results and Discussion

Through air bonding formed lofty consistent webs for all the blend composition listed in Table 1. Blends with greige cotton (higher staple length), bonded via calendaring had lots of lint in the final FR composite which influenced its burning mechanism. Structure and properties of carded and calendered webs is summarized in Table 2 and 3 respectively.

Table 2. Structure and properties of carded and through-air bonded webs.

Blend #	GSM	Air Permeability (cm3/cm2/sec)	Stiffness	Tensile strength(N)	LOI
1	329	65.3	20	38	23.4
2	329	99.8	19.8	53	22.1
3	349	61.5	20	40	22.1
4	364	47	20	55	22.1
5	287	99.3	21.3	69	21.5
6	357	68.8	21.5	62	22
7	368	45	19	10	23.4
8	349	83	19.3	88	22
9	349	61	21.5	101	21.5
10	310	58.3	19.8	13	*
11	372	75.5	19.9	106	21.5
12	306	72	19	48	20

* O_2 index less than 20

Through air bonding formed lofty consistent webs for all the blend composition listed in Table 1. Blends with greige cotton (higher staple length), bonded via calendaring had lots of lint in the final FR composite which influenced its burning mechanism. The LOI for the samples did not show significant difference. However, blend composition, method of bonding and fiber length showed the influence on mechanism of burning of samples. In case of carded and calendered webs, all blends with more than 20% binder fibers formed strong composites.

In the case of carded and through-air bonded webs, increase in binder percentage (higher than 15%) decreased the air permeability. Composites with lower air permeability showed higher LOI. Fro example, webs 4 and 6 showed higher LOI and lower air permeability, which indicates the influence of entrapped air on the burning mechanism and LOI results.

Table 3. Structure and properties of calendered webs.

Blend #	GSM	Thickness (microns)	Tensile strength (N)	LOI
1	271	0.0014	42	23.7
2	283	0.0006	290	21.1
3	349	0.0008	136	21.1
4	349	0.0012	145	24.7
5	310	0.0008	484	21.1
6	310	0.0015	198	25
7	349	0.0013	167	19.5
8	310	0.001	405	23
9	349	0.0007	484	23
10	310	0.001	326	18.5
11	349	0.0006	484	22
12	349	0.0006	325	20.2

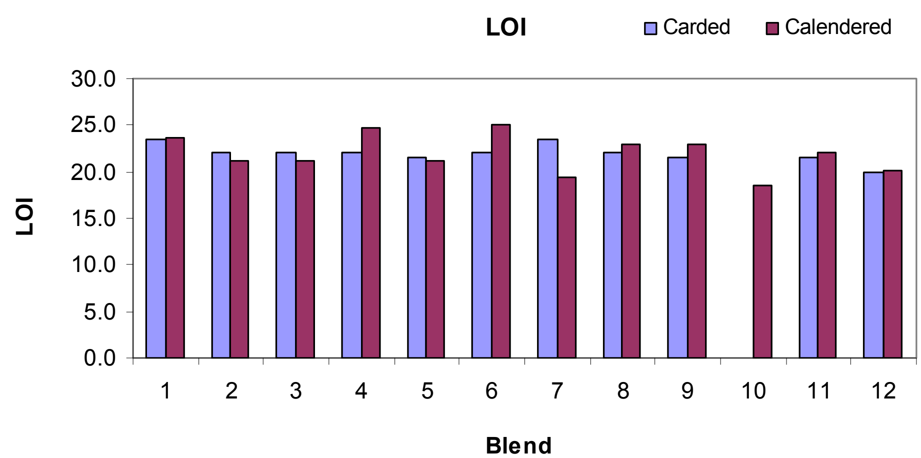

Figure 1. LOI results for different blend composite, higher LOI indicates better FR properties.

Summary

Nonwoven webs were formed from FR treated greige cotton fibers, Visil and a thermoplastic binder, using the typical textile process of carding and then thermal bonding. Through air bonding and calendaring were used to produce the nonwovens. The two processed resulted in lofty and compact nonwovens, respectively, as expected. These result in significant differences in the web structure and correspondingly in physical properties. These result in differences in FR response of these samples, and further studies are being conducted to understand the differences in burning mechanisms in the two different structures.

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