2002 BELTWIDE COTTON CONFERENCES, ATLANTA, GA – JANUARY 8-12

EFFECT OF BINDER FIBERS ON THE PROCESSING AND PROPERTIES OF THERMAL BONDED COTTON-BASED NONWOVENS

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Abstract

Over the past few years, research has been done at the University of Tennessee, Knoxville to produce and evaluate nonwoven products containing cotton with different binder fibers. Using a thermoplastic binder fiber is the best route to produce quality nonwovens using the most convenient and simple method of bonding, i.e., thermal calendering. The challenge is to find the right binder fiber that is biodegradable and works better with cotton. Several combinations of cotton and biodegradable thermoplastic fibers, traditionally available and new varieties, are being investigated. Whereas some of the newer polymers/fibers show a great deal of promise, having the right type fiber, and in right combination is important in achieving the desired properties. The production of nonwovens by the thermal bonding process from such compositions, and the structure and properties of the resulting products will be discussed.

Introduction

Thermal bonded nonwovens have "come of age" in the 1990s because of favorable process economics, the absence of chemical binders, the availability of new fibers and machinery, and process and product enhancement. The adhesive component, distributed in a nonwoven web is in the form of a unicomponent binder fiber, bicomponent binder fiber, or powder particle that is subjected to heat. As the adhesive approaches the melting point, its surface softens and contacts areas with more stable fibers to form potential bonding sites. Upon melting, the adhesive becomes attached to a network fiber; flows along the network fiber into a crossing of two or more fibers, or forms an adhesive bead. When the nonwoven is cooled the adhesive solidifies and forms a bond or thermal fusion at each fiber/binder contact. In addition to the melt-flow properties of the adhesive, individual bond strength is a function of the amount of fiber surface area joined or shared at fiber intersections and the inherent strength of the bonding adhesive. Bond effectiveness is also dependent on initial placement (binder distribution) and binder concentration (amount). Fabric properties such as strength, resilience, softness, and drape are affected by individual bond strength, bond placement, and total bonded area. In a sense, a properly produced thermal bonded nonwoven can approach the idealized nonwoven structure, namely, one in which individual fibers are attached flexibly at every fiber crossing.

During the early stages of the cotton-based nonwoven research, synthetic fibers such as low melting polyester, polyester copolymer, polypropylene and polyethylene were used as binder fibers. However, the synthetic binder fiber could not be biodegraded. With the growing environmental awareness throughout the world, it has been important to find the proper biodegradable binder fiber. Research on cotton-based nonwovens has been carried out at the University of Tennessee, Knoxville (UTK) by incorporating different kinds of binder fibers through thermal calendering. Cellulose Acetate (CA) fiber has been applied most successfully as the binder fiber since it is thermoplastic, hydrophilic and biodegradable fiber. A modifies cellulose acetate with a lower softening temperature was also used. Quite recently, a kind of biodegradable polyester, Eastar *Bio*® Copolyester, unicomponent and bicomponent fiber was selected as the binder fiber for thermal calendered cotton-based nonwovens. The structure and properties of these cotton-based nonwovens are discussed in this paper.

Experimental

Fiber Selection and Properties

There are five different kinds of fiber involved in this research. Cotton fiber is the base fiber, and four types of binder fiber, ordinary cellulose acetate (OCA), plasticized cellulose acetate (PCA), Eastar *Bio*® Copolyester unicomponent (Eastar), and Eastar *Bio*® Copolyester bicomponent (Eastar/PP) fibers. For comparison, a commercial (non-biodegradable) bicomponent fiber was also investigated. Cotton fiber used in this research was supplied by Cotton Incorporated. The scoured and bleached commodity cotton fiber had a moisture content of 5.2%, a micronaire value of 5.4 and an upper-half-mean fiber length of 24.4 mm. Eastar *Bio*® copolyester staple fibers selected for this study were produced by Eastman Chemical Company and the cellulose acetates ere provided by Celanese Corporation. Table 1 lists the properties of these selected fibers.

Processing

Fibers were first opened by hand and then weighed according to the desired blend ratio and fabric weight. The blend of fiber was then carded to form a web using a modified Hollingsworth card. The resulting carded fabric weight was around 40 g/m^2 (1 ounce/yd^2). The carded webs were then thermally point-bonded using a Ramisch Kleinewefers 60cm (23.6 inches) wide calender. Two blend ratios (75/25 and 50/50 of Cotton/Binder) were used. All the webs were calendered under the same pressure (25KN) and speed (10 m/min). Different calendering temperatures were used according to the different softening temperatures of the binder fibers.

Characterization of Fiber and Nonwoven Fabrics

Tensile properties of single filament and nonwoven fabrics were tested according to ASTM D 3822-91under the standard atmosphere. Thermal analysis of binder fiber was done under Mettler DSC25 machine at a scanning rate of 10°C/min. Basis weight of nonwoven fabrics was determined by INDA Standard Test 130.1-92 Standard Test Method. Thickness of fabrics was obtained by a TMI 49-70-00 Micrometer according to ASTM D 1777-64. Scanning Electron Microscopy (SEM) pictures were taken for bonding points and failure structure under a Hitachi S – 3500 N Scanning Electron Microscope.

Results and Discussion

Cotton/Cellulose Acetate Biodegradable Nonwovens

The first studied biodegradable cotton-based nonwoven fabrics were produced by cotton and ordinary cellulose acetate (OCA) fiber. Bonding temperatures used here for thermal calendaring are 150˚C, 170˚C, and 190˚C due to the ordinary cellulose acetate's high softening temperature (T_s: 180-205˚C). However, the tensile strength along machine direction of the bonded fabrics are pretty low even at bonding temperature of 190˚C (Figure 1 and Figure 2), indicating that the bonding temperature is not high enough to form a well-developed bond structure.

Plasticizer is a chemical added to polymers and resins to impart flexibility, workability, or stretchability, or a bonding agent that acts by solvent action on fibers. The primary role of a plasticizer is to reduce the rigidity of a plastic, e.g., to render it more flexible. Besides providing desirable application properties to polymers, plasticizers lower processing temperatures by virtue of both glass transition temperature depression and internal lubrication. Based on this, a kind of plasticized cellulose acetate (PCA) fiber (T_s: ~110˚C) has been selected as a binder fiber as an alternative to ordinary cellulose acetate. The tensile strength values of the resulted fabrics (Cotton/PCA) are much higher than that of the Cotton/OCA fabrics at higher bonding temperature (Figure 1 and Figure 2). A fabric with tensile strength of 9 mN/tex was produced at 190˚C with a blend ratio of Cotton/PCA at 50/50.

Cotton/Eastar Biodegradable Nonwovens

The desired calendering temperature of PCA bonded nonwovens is still much higher for achieving good tensile properties. So, a kind of Eastar Bio copolyester unicomponent (Eastar) fiber, which has a relatively low softening temperature (~80˚C), was selected as a binder fiber instead of cellulose acetate fiber. It has been reported that this binder fiber can be totally degraded into CO_2, H_2O and biomass. Because of the low softening temperature of the binder fiber (T_s: ~80˚C), bonding temperature used are 90˚C, 100˚C, 110˚C, and 120˚C. The tensile strength along machine direction of the Cotton/Eastar fabrics are higher than that of Cotton/OCA fabrics, but much lower comparing to Cotton/PCA fabrics (Figure 3 and Figure 4).

Unicomponent Eastar Bio copolyester fibers are soft and somewhat difficult to crimp due to the high elasticity of the fiber. For carding process, relatively stiffer fibers are preferred. We found that one disadvantage in using Eastar as a binder fiber is that it is hard to get the binder fibers well distributed, which may cause the low tensile properties of the final calendered nonwoven fabrics. Thus, a kind of bicomponent fiber with Eastar Bio copolyester as a sheath on a stiffer core, in this case PP, was produced by Eastman Chemical Company to offer more stiffness than a 100% unicomponent Eastar Bio copolyester fibers and further improve the distribution of binder fibers and the tensile properties of the nonwoven fabrics. The tensile strength of Cotton/(Eastar/PP) nonwovens are shown in Figure 3 and Figure 4. It can be clearly seen that the tensile strength of the fabrics are much higher than those of Cotton/Eastar nonwovens, and even higher than Cotton/PCA nonwovens. At bonding temperature of 100˚C with a blend ratio of Cotton/(Eastar/PP) at 50/50, the tensile strength of the nonwoven fabrics can reach 11.2 mN/tex. Therefore, low celendering temperature can be used to produce good quality cotton-based nonwovens by using Eastar/PP bicomponent binder fibers.

Summary

A variety of biodegradable thermoplastic fibers can be used as binders to produce nonwovens from cotton fibers. Good quality thermal bonded cotton-based biodegradable nonwoven fabrics can be made by using Eastar/PP bicomponent binder fiber instead of ordinary cellulose acetate and Eastar unicomponent binder fiber. The tensile strength of Cotton/(Eastar/PP) nonwoven fabrics are better than or at least comparable to Cotton/PCA nonwoven fabrics. Eastar *Bio*® Copolyester fibers show a great deal of promise as an ideal binders for thermal bonded cotton-based nonwovens. Also, relatively lower bonding temepratures can be used for cotton/Eastar combinations.

References

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Table 1. Properties of selected fibers (Single filament).

	Cotton	**OCA**	**PCA**	**Eastar**	**Eastar/PP**
Filament density (g/cm^3)	1.5	1.3	1.3	1.2	1.1
Filament denier (denier)	2.2	1.1	2.9	4.0	4.0
Staple length (inches)	1.02	1.65	1.77	1.00	1.50
Filament tenacity (g/denier)	1.7	1.2	-	1.6	3.0
Peak load (gram)	3.7	1.3	-	6.2	12.0
Peak extension (%)	5.4	25	-	144.0	96.0
Peak strength (mN/tex)	152.22	-	-	138.0	269.6
Initial modulus (mN/tex)	360.86	-	-	204.6	392.5
Crimps	-	more	more	less	more
Softening temperature (°C)	---	~190	~110	~80	~80*

* Sotening temperature of sheath.

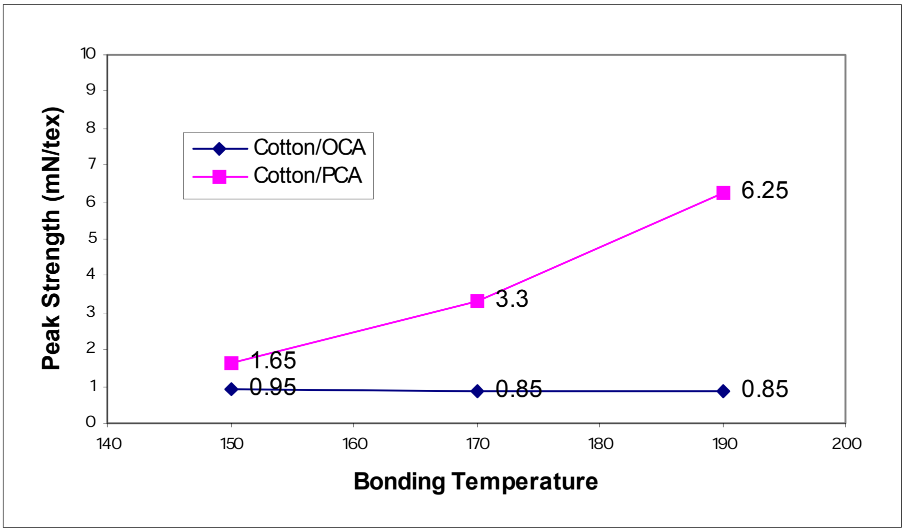

Figure 1. Peak strength along machine direction of Cotton/CA at a blend ratio of 75/25.

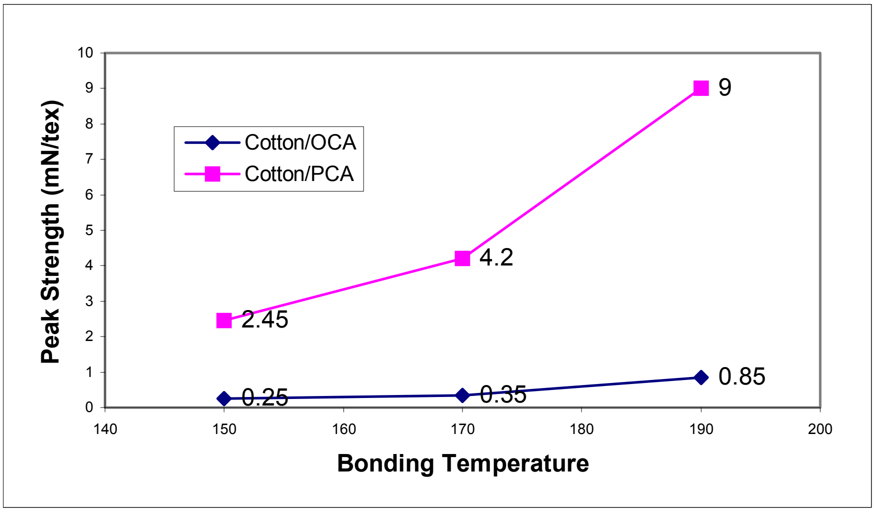

Figure 2. Peak strength along machine direction of Cotton/CA at a blend ratio of 50/50.

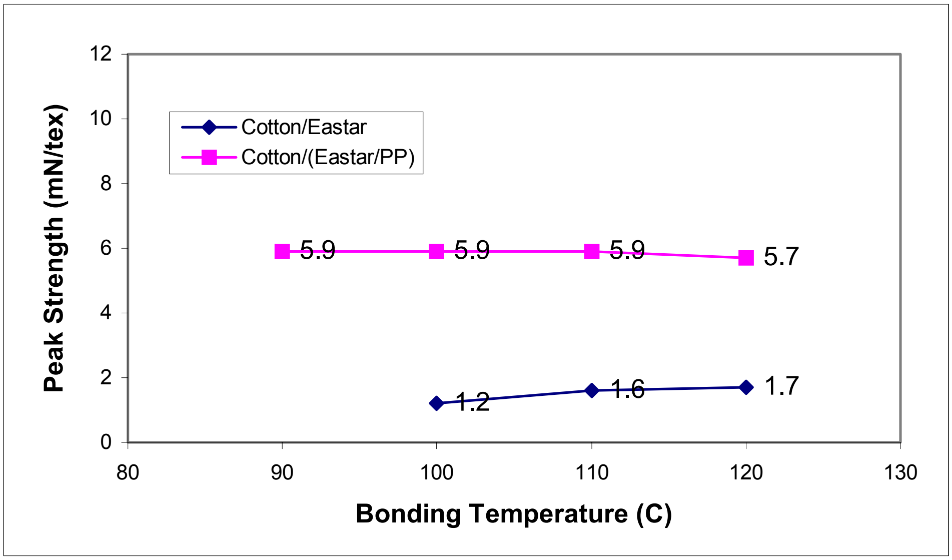

Figure 3. Peak strength along machine direction of Cotton/Eastar at a blend ratio of 75/25.

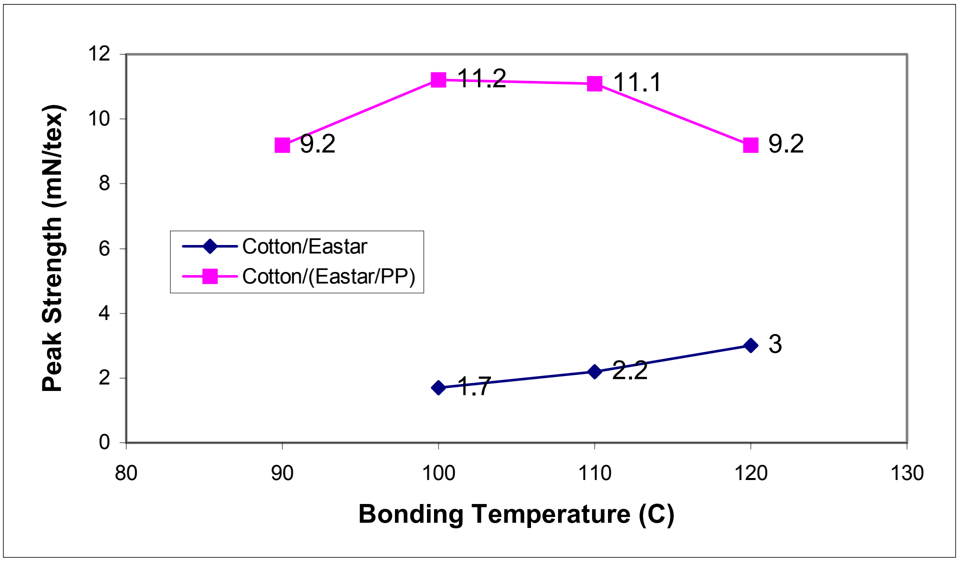

Figure 4. Peak strength along machine direction of Cotton/Eastar at a blend ratio of 50/50.