UNDERSTANDING STRUCTURES AND ACTIONS OF NONWOVEN FABRICS THROUGH MICROSCOPICAL EXAMINATIONS

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Abstract

Structures of nonwovens are different from those of traditional textile materials. Nonwovens, using a wide variety of fibers are finding an increasing market not only in short-term use disposable fabrics, but also as upholstery and carpet linings and pads. Because of this wide range of use, nonwovens are produced in a great range of patterns by different methods of bonding. These bonding methods provide materials of varying thickness, air permeability and absorption. Fiber composition, structure and bonding materials affect nonwoven properties. These structural properties of nonwovens are better understood when microscopical techniques are used to study their nature.

Introduction

Traditionally, textile fabrics have been formed by weaving, or knitting. More recently, less complicated methods have been developed for providing economical, generally disposable textile fabrications. While fibers in traditional fabrics are usually paralleled and often twisted into yarns in formation of fabrics, orientation of fibers in nowovens is more random. In wovens and knits it is the interlacing of yarns that gives fabrics structural stability. Nonwovens are bonded for stability by several different methods, none of which provide the same dimensional fiber relations as do weaving or knitting. Three bonding systems used in nonwovens are: chemical bonding (resins), mechanical bonding (needle punch and hydro-entanglement), and thermal bonding (requires presence of heat activated material). Type of bonding system depends on the end use of the product. Nonwovens intended for short term, low stress use do not require high strength, and are usually intended to be low cost. However, in meeting needs of expanding markets, products with different and improved properties must be designed. Understanding the structures produced by various methods of bonding, and the relationships of fibers within the structures provides insight into producing nonwovens of with improved specific properties. Variations in fiber content provide nonwovens with different properties.

Materials and Methods

Nonwoven products examined included:

1. 100% cotton web, hydroentangled
2. A series of cotton/polypropylene blends thermobonded on a calender (1): 80/20 C/P, 70/30 C/P, 50/50 C/P, 25/75 C/P, and 100% P, all 60g/m^2
3. 100% cotton chemically bonded (latex)
4. Four hydroentangled “gauze” webbings: 100% cotton, 50/50% cotton/polyester, 100% polyester and 100% rayon
5. An airlaid hiloft woodpulp
6. Printbonded 100% polyester, and printbonded, (spunbonded) polypropylene, bonded on a calender

All samples were examined using the scanning electron microscope (SEM) to show details of their structures, and relationship of fibers in blended samples. Fabrics from series 1, 2, and 3 were used in a study of biodegradation [Goynes et al., 1995]. They were tested according to ASTM procedure G 21-70, exposing four replicate strips of each fabric up to 98 days to a combination of fungi commonly found in soil. Fabric strips were placed on a medium of nutrient-salts agar [ASTM 1988] in bioassay dishes with lids. The surfaces of the agar and specimen strips were inoculated with a composite spore suspension by spraying with an atomizer, then incubated at 30^o C, and evaluated after 14, 28, 56, and 98 days. Samples with maximum damage after the first evaluation were re-exposed and evaluated after 2, 4, and 11 days. Breaking strengths were measured by ASTM Method D-1682 [ASTM 1988]. Fungal growth rates (FGR) were visually evaluated by three examiners on the four specimen strips exposed from each sample. Fungal growth rates were reported as (0)-- no growth, (1)--less than 10% coverage, (2)--10 to 30% coverage, (3)--30 to 60% coverage, (4)--60 to 100% coverage. After exposure, samples were washed with HgCl, rinsed, and dried. Swatches of exposed fabrics were taken for microscopical examination before and after washing.

Four hydroentangled, 1.2 oz/yd^2 “gauze” samples, 100% cotton, 50/50% cotton/polyester, 100% polyester, and 100% rayon were evaluated for water absorption using AATCC Test Method 39-1952 [AATCC 1970].

The sample that was labeled as 100% cotton, chemically bound was dyed using Dupont Identification stain # 4 to show areas of the fibers covered by the binder [Heyn, 1954].

Results and Discussion

Visual examination of nonwovens cannot reveal the structures produced in the fabrics fabricated by various processes. However at magnifications of the scanning

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electron microscope (SEM) bonding patterns can usually be seen. Hydroentangled cotton nonwovens that are fabricated without a pattern appear as a matt of intertangled fibers. Fabrics containing fusable fibers, such as polypropylene, exhibit regular indentation patterns where fibers are fused.

Because many nonwovens are used in disposable products, it is important to determine how well they deteriorate on disposal. An indication of this can be found from measuring biodegradability. Measurement of fungal growth rates (FGR) and breaking strengths on unwashed cotton and polypropylene samples exposed to fungi found in soil showed that rates of growth on hydroentangled 100% cotton was highest, with ratings of (2) after four days, and (4), the highest rating, after 11 days. This sample lost 100% of its breaking strength after 14 days exposure. After 11 days, the integrity of the fabric was lost and it could not be lifted from the agar. Fabrics with 80% cotton reached the maximum FGR at 14 days, but lost only 48% of its breaking strength after 98 days exposure. Maximum FGR occurred during the first 8 days for all tested samples except the latex coated cotton, and samples containing 50% or more polypropylene. The 50/50 blend fabric lost very little strength even after 98 days exposure, yet had a FGR of (4) due to the presence of the cotton. After washing, the fused, bonded areas of the fabric cracked, probably due to deterioration of the cotton fibers that had been bound within the melted polyethylene. Even though polypropylene fibers were not affected by the fungus, the fabric exhibited reduced structural integrity because removal of the cotton within the fused areas caused the fused polypropylene to separate.

The sample that was chemically bonded reacted differently to fungal exposure than other cotton samples. This sample had initially low FGRs, (2) at 14 days, but growth rates increased rapidly with exposure, (4) by 28 days. It had lost only 2% of its breaking strength after 2 days. Breaking strength losses rapidly increased from 21% at 4 days to 95% after 11 days. Although the sample was labeled 100% cotton and cotton was the only fiber present, cotton represented only 80% of the total sample because it contained 20% latex binder. Visual inspection of the fabric could not show how much of the fiber surfaces were covered with the binder. However, staining of the fabric with Dupont fiber identification stain #4 dyed the exposed fibers green, and the binder gold. The surface contained more gold than green color, indicating that initially a large percent of the cotton was covered by the binder. This covering apparently protected the cotton from fungal damage on initial exposure. However, longer-term exposures allowed the fungi to penetrate through the fibers, and after 56 days the fabric became a thin web of binder, with only a few fragments of cotton still embedded. Breaking strengths could not be measured on the fabric after 14 days incubation because of lack of structural integrity

Patterns in nonwovens, such as gauze, can be formed during the hydroentanglement by use of a template under the fibers. Force of the water jets causes the fibers to take the pattern of the plate. Structures of “gauze” formed from a.) 100% cotton, b.) 50/50% cotton/polyester, c.) 100 % polyester, and d.) 100% rayon, were observed at low and high magnification. At low magnifications the structures appeared very similar, but at higher magnifications the differences in appearance of the fibers present could be seen. Although the structures of fabrics using different fibers appeared the same, water absorption among the samples was quite different. When water was dropped on the surfaces of the fabrics stretched over circular hoops, the drop remained on the surface of the polyester longer than the three-hour timing period used for testing, and no dispersion could be seen even when the fabric was shaken. Water drops did not stand on the surface of any of the other fabrics. The water could be seen spreading into the cotton/polyester fabric, but absorption was so fast that it could not be timed. When water was dropped onto the surfaces of the 100% cotton, and 100% rayon fabrics absorption occurred instantaneously, and no water was ever viewed on the fabric surfaces. While these tests are limited in scope, they do indicate that even 50% cotton fiber content greatly increases the water absorption of polyester fabrics, and that cotton and rayon are the most absorbent of the four fabrics. These samples were hydroentangled, and SEM showed no binder present, so water absorption is directly related to fiber content.

Structures of some hydroentangled nonwovens have no pattern and are simply an entangled “felt” of fibers. Degree of entanglement may depend on the length of the fibers used. Woodpulp fibers are much shorter than textile fibers, thus often have a more matted appearance.

Thermal-bonded nonwovens (printbonded or spunbonded) often have an appearance similar to wovens because of the alternating thick and thin areas produced by fiber fusion. These structures are more readily seen and more easily understood when viewed at the higher magnifications of the SEM. Blended fabrics used in the biodegradation study showed this pattern, as did the thin polyester and polypropylene samples examined. These materials are used as covers for absorbent pads and gain their strength not only from the fibers used, but from the fusion bonding that provides dimensional stability. SEM shows that thicker pads have heavier bonding because more fibers are fused to form the bonds.

Conclusions

As nonwoven textile materials are finding greater markets, more different fiber blends and bonding methods are being used. These products are intended for specific markets and are developed to have desired properties. Studying the structures that result from various methods of bonding helps to better understand the function of the product.

Microscopical examination can show how fibers are held together, what fibers are present, and how they are blended. In studies of biodegradability, microscopical examination, and measurement of breaking strength losses indicated that cotton fibers degrade much more readily than does polyethylene. Even cotton blended with polypropylene degrades more rapidly than 100% polypropylene. Thus for environmental purposes, it is important to use cotton in nonwovens that will be used in disposables. Cellulose fibers, cotton and rayon specifically, are much more highly absorbent than is polyester. Blends of 50% cotton with polyester produces a highly absorbent gauze, even though it is not as absorbent as 100% cotton. Scanning electron microscopy provides a helpful tool in evaluating these features of nonwovens.

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