HIGH-VOLUME UTILIZATION OF COTTON IN NONWOVENS

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Abstract

This article briefly explores possible utilization of cotton in volume in the traditional textile sector and in the growing nontraditional nonwovens sector and covers the challenges and opportunities that may exist on the way. Some new concepts in the development of predominantly cotton-based textile products are explored for research investigations. Mainly because of the fiber entanglements and orientation, a nonwoven fabric structure inherently lacks the desired strength, stability in subsequent processing and usage, durability, uniformity, and drape in the end-uses where cotton is enormously popular historically. Furthermore, for certain cotton nonwoven products for certain medical and hygienic end-uses, the U.S. (machine-picked and ginned) cotton must be thoroughly cleared of its significant amount of foreign matter and then bleached in the fiber state only, because a needle-punched NW cotton structure generally is too weak and unstable to be bleached and wet-finished in the fabric form. This makes cotton very uncompetitive with other available fibers that can be efficiently used for producing similar products. Thus, to resolve some of the problems facing the utilization of cotton in nonwovens, some new concepts to develop certain viable cotton NW structures for certain applications are discussed.

Introduction

Since the advent of manufactured fibers, such as rayon, nylon, polyester, etc., just a few decades ago, the global market share of cotton fiber has been steadily declining, say, from more than 55% in the forties and fifties to less than 35% today. Manufactured fibers, certainly due to their quite a few desirable attributes, have replaced cotton to a large extent in many end-use applications other than the apparel and certain household fabrics. The use of cotton in furnishing, industrial, technical, geo, military and many other applications has considerably diminished in last few decades. However, with the rapidly growing world population of relatively well-to-do people and mainly due to cotton's own unique characteristics of excellent absorbency, substrate, breathability, soft hand, and supple drape, the worldwide cotton production (tonnage) and consumption has also been continually rising. In fact, its market share in the apparel and household articles has increased in recent years, mainly due to the fact that the world population continues to admire the excellent attributes that are offered by cotton clothing and household fabrics and (nicely) promoted by Cotton Inc., National Cotton Council, and other cotton affiliates.

The methods of converting cotton fibers into fabrics continue to be the traditional weaving and knitting. The weaving still remains by far the largest sector in textile manufacturing. However, it is a costly and environmentally-sensitive process, especially from the U.S. perspectives, and thus puts additional pressure on the ailing U.S. textile industry. In recent years, the global competition indeed has caused a considerable decline in the U.S. and West European domestic textile manufacturing industries. And it appears likely that this trend will continue. Current statistics of the U.S. domestic cotton production and utilization (by user mills) clearly indicate that in 2006, the U.S. cotton growers produced 21 million bales of cotton and the U.S. indigenous mills merely utilized about 6 million bales. Thanks to China, who purchased most of surplus cotton crop and sold the cotton goods back to the U.S.A. Obviously, this temporary relief from a short-term boom in cotton exports is not a permanent solution of a rather very serious problem that the U. S. cotton industry today faces. Therefore, the U.S. must explore alternatives to profitably sustain the cotton industry, which certainly has a considerable impact on the national economy and well-being.

[Incidentally, it may be noted here that the U.S. production of cotton for 2007 is projected at only 17 million bales, mainly because of the reduced acreage and not the yield (which, in fact, is up). The decline in cotton production stems from the fact that because of increases in bio fuels and their prices, the prices of many other agricultural

organic commodities, such as corn, have also gone up considerably, which encouraged the cotton growers to switch to more profitable crops. It is reported that for the same underlying reason of relatively higher profits in other commodities, the Australian cotton producers have cut down their cotton acreage by 99% this year, compared to the previous season. The bright side of all of this may be that, due to eventual shortage of supply, cotton may also fetch higher prices, as well! The cotton prices indeed have been "depressed" for decades].

The reporters of this paper envision a window of opportunity that may perhaps partly assist the U.S. domestic cotton industry. And that is to fully explore possibilities of deploying existing or modified technologies of nonwovens (NW) to develop new and novel cotton fabric structures, especially for certain mass markets and applications. Although the nonwovens initially (~ 60 years ago) grew because of widely available, cheap, low-end or waste materials that could easily be converted into less-expensive, non-durable products (that both the producers and consumers liked), using relatively much less complicated manufacturing processes compared to the traditional weaving, the nonwovens of today are highly qualitative, cost effective, and Earth friendly and produced on much sophisticated machinery and processes that are an order of magnitude more productive than the traditional weaving. In an extremely high-speed, almost continuous, uninterrupted process, a valuable nonwoven product today can be produced directly from any fibrous material or polymer chips. Based on published statistics, the nonwovens industry today represents ~ 5 to7% of the total global textile (classic) production. However, the industry at present is mostly comprised of companies that are mainly involved in production of numerous disposable, semi-durable, and durable nonwoven products containing ~98% manufactured fibers, such as polypropylene, polyethylene, polyester, rayon, pulp, and the like. In other words, cotton's market share in the above stated "7% NW market" is ~ 2%, which is only ~ 0.0014% of the global textile production of all fibers. Virgin, greige cotton fiber has rarely been used in nonwovens, obviously for valid economic, technical and product-performance reasons. Since the raw material cost and the product performance generally dictate any new product development, there indeed are some really complex factors in mass-scale commercialization of cotton nonwovens. But, as they say, there are no problems that cannot be successfully resolved, if proper efforts are focused to identify/analyze the problems and appropriate resources are devoted to resolve them. And that is the underlying theme or objective of the USDA-ARS-supported research on cotton nonwovens. Our mission at USDA is to devise projects and resources for developing new NW-based products containing cotton in predominance, in order to ultimately achieve the required "value-added, high-volume utilization of the USDA commodity (cotton)." Cotton undoubtedly is ideally suitable for clothing and certain household products and provides the ultimate in hand softness, breathability, unsurpassed comfort, sustainability, and biodegradability. We want to fully explore possibilities of mainly using the baled, virgin/greige cotton in the development of value-added, high-volume products, using the nonwovens technologies or the modifications thereof.

Why is Cotton not a Major Participant in Today's Rapidly Growing NW Industry?

The following are valid reasons (limitations, disadvantages or real problems):

1. Cotton realistically is not an economical raw material for existing nonwoven products that mostly use other cellulosic fibers, such as pulp, that relatively are darn cheap.
2. Cotton nonwovens, mainly due to the unidirectional fiber orientation inherent to nonwovens, generally are weak and unstable and, hence, difficult to wet finishing, such as bleaching, dyeing, and/or any special chemical treatment. Hence, bleached, dyed, or specially-treated cotton stock becomes a mandatory raw material for certain applications, which is costly as well as quite cumbersome in down-stream processing. For example, for a few NW medical applications, bleached cotton is necessary, which is not cost- and process- effective.
3. Cotton needs a lot of preparatory processes to clean and homogenize it for the ultimate product's uniformity and consistency. Its price, supply and quality to some extent are also unpredictable.
4. Single fiber characteristics, such as the tensile strength, modulus, dirt and mildew resistance, etc., of cotton generally are not comparable with those of equivalent manufactured fibers, such as PP, PE and PET, that are widely used in industrial durable nonwovens.
5. Cotton nonwovens are stiff like paper and do not drape well for apparel and household textiles, where cotton really is the best suited fiber.
6. Classical cotton textiles efficiently utilize stress-strain relationship of constituent fibers and yarns, whereas the nonwovens inherently lack that relationship, because the constituent fiber bundles are mechanically or chemically bonded together, resulting in a plastic-like rigidity. Constituent fibers in a nonwoven structure exhibit little flexibility, slippage or yield, which is essential especially for apparel.

Why Should Cotton be considered for Major Participation in Nonwovens, Anyway?

Well, there are some very good reasons for that too:

1. Cotton has a sustainable life cycle. It is biodegradable and hence easily disposable, as well. So, to protect the efforts should be made to replace petroleum-based fibers with cotton, where affordability and functional performance of the new products are reasonably justified.
2. Cotton nonwovens, if functionally and commercially acceptable, may be produced at speeds that are considerably greater than those of the traditional textile processes, which should help the U.S. cotton industry that is partly suffering from high manufacturing costs. The processes of nonwovens relatively are much less labor-intensive and environment-sensitive, compared to the traditional.
3. Because of its unique characteristics of absorbency, static-freedom, ease of blending with other fibers, and excellent substrate for functional chemical derivitization, cotton should be the fiber of choice for many nonwoven applications, such as certain uniforms, undergarments, high-tech NW denims, and other clothing articles; towels, sheeting and other household and furnishing products; certain carpets; all kinds of wipes; medical, cosmetic and sanitary products; and composites for certain industrial and technical applications, as well.

Research Approaches and Methodologies

Let us briefly discuss the previously stated (valid) reasons that supposedly limit a major participation of cotton in the nonwoven sector of textile manufacturing. In development of any textile product, the cost and properties of basic fiber play vital roles. As it stands, cotton apparently does not satisfy these two basic factors in the present nonwovens market. The main reason for cotton being economically uncompetitive to other fibers in the nonwovens business today is that the cotton, for one viable reason or another, is not being utilized where it really belongs and is most advantageous, i.e., in the apparel, household, and home-furnishing segments. Another significant reason for uneconomical use of cotton in certain disposable (medical and the like) nonwovens is that cotton in fiber form needs to be thoroughly cleaned and bleached, which certainly causes economic limitations as well as technical processing difficulties. Yet another realistic reason for little utilization of cotton in today's nonwovens is that its single fiber properties really are not suitable for the present NW products and markets, which are heavily (~98%) focused towards industry, geo, construction and roofing, filtration, mobile/transportation, institutional furnishing, packaging and the like. Although opportunities are abound for the nonwovens industry, participation of cotton in manufacturing value-added, high-volume cotton-rich products especially for apparel, home-furnishing, medical and hygienic end-uses has some very serious technical and economic difficulties that need to be addressed.

So, we, the promoters of cotton, must find new, viable avenues to let our "baby fiber" grow and flourish with rest of the rapidly growing nonwovens industry. Keeping in focus the two previously stated critical factors that are vital in the development of any textile product, it is abundantly clear to this reporter that we must struggle to develop only those NW products where cotton's unique characteristics and properties are most efficiently and cost- effectively utilized to ultimately provide the end-product attributes that both the convertors and consumers would like. And keeping that objective in view, the following research concepts are suggested for developing nonwovens of cotton predominance for certain potentially viable applications:

Work Uniforms, Undergarments, Bottom-weight Fabrics, and Even NW Denims

The nonwoven fabrics inherently are weak, unstable and stiff/rigid. They also lack drape, which is essential for apparel and other similar applications. However, there are real good opportunities for use of cotton in nonwovens, if the above challenges are squarely and economically met. To resolve some of the above challenges, we plan to initially develop a kind of *layered or multi-component/composite fabric,* Figure 1, that will be comprised of a finely perforated, thin and yet strong, flexible or elastic, inner core of certain manufactured fiber, film or fabric (say, a spun-bonded or a melt-blown polypropylene fabric with numerous fine holes of optimum shape, size and frequency), which will be sandwiched between two layers of either 100% cotton or a strong, cotton-rich blend and then optimally impacted either on one face or on both sides (if required), by means of a suitable high-speed

nonwovens bonding technology, or a suitable modification thereof, to selectively interact, orient and entangle constituent (sheath) fibers and anchor or bond them with the core material to produce a sort of *reinforced* fabric structure of desired linear density, uniformity, stability, flexibility and drape. The high-speed nonwovens technology involved may include mechanical bonding (needle-punching, hydro- or steam- entangling, stitch-through, industrial sewing, etc., or a combination thereof) and/or chemical bonding, as well. The fabric thus produced will be appropriately finished to attain desired surface and functional characteristics.

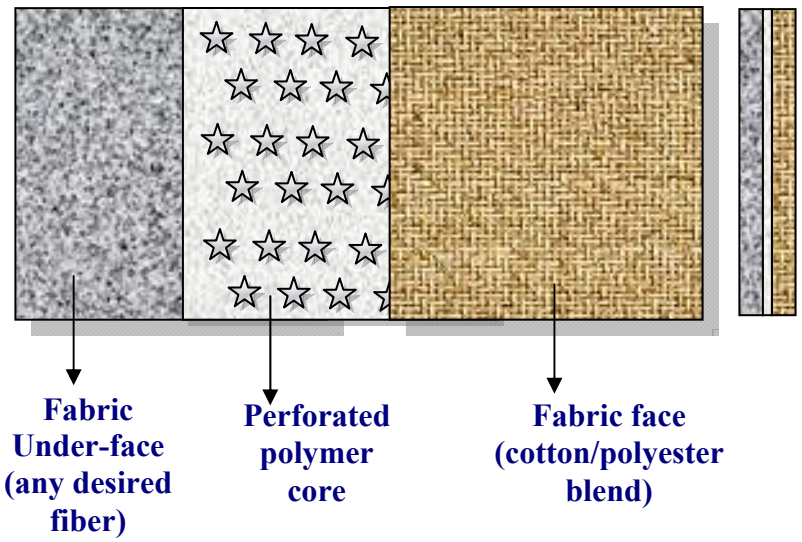

Figure 1: A representative hydro-entangled sandwich composite structure

Health-care, Cosmetic, Wiping, Hygienic, and other similar products

In this special arena, we plan to "thoroughly clean" greige (baled) cotton to try to get rid of almost all of the solid foreign matter/contaminants (such as stems, bark, leaves, trash, etc.) and then either partly wash the stock in plain water with a wetting agent or partially scour it with only 1%, by weight (half of normal concentration) of caustic, in order to dissolve any soluble sugars and other contaminants. The drying of treated stocks will be done by a most economical suction technique only. Processing of the various treated stocks and the nonwoven products made thereof will be evaluated. Fabrics will be solely engineered for the required properties, aesthetics and performance of these auxiliary, nontraditional (non-mainstream) products for special-end-use applications, such as wipes.

Fiber Processing

Initially, several preliminary experiments will be done to determine the effects of typical cotton properties and processing parameters on the quality and characteristics of certain experimental nonwoven structures produced on a needle-loom, hydro-entangling process, stitch-through, or a combination thereof, deploying appropriate NW machinery and processing parameters, including any appropriate chemical treatment or modification that may be deemed necessary. For example, an Upland baled cotton of ~ 1" staple will be thoroughly cleaned by using two, three, or even more passages through a step cleaner, intentionally disregarding the associated risk and normal fear of fiber damage, which certainly is critical in traditional cotton spinning but may not be as important in case of nonwovens for certain applications. The thoroughly opened and cleaned cotton stock will be further processed 1) as it is (i.e., 100% cotton) and 2) in a 50:50 blend with a suitable manufactured fiber (say, a regular-tenacity polyester staple, 1.5", 1.5 denier) on a tandem card. Depending on the cleanliness and quality of the carded stock achieved, the latter may be carded twice to completely remove almost all the foreign solid matter, again ignoring the valid risks of the fiber damage and of some economic losses due to double carding, which certainly are most critical in the traditional textile processing (spinning and weaving) but which may not be as critical for certain NW applications.

It is hoped that if greige cotton can be almost completely cleaned of solid foreign matter, it may be used as it is, i.e., without bleaching or any other chemical treatment, for certain NW products, which then may be bleached and finished in the fabric form. If successful in this strategies for certain NW applications, the extra fiber damage and/or extra costs, if incurred any, should be overwhelmingly off set by the ultimate advantages of any successful nonwoven product thus produced. A preliminary attempt will be made to use the carded stock as it is on an appropriately modified nonwoven technology to impart adequate fabric strength, flexibility and stability. The fabric, if sustainable, may be bleached, dyed, printed, and/or specially finished to attain satisfactory surface characteristics for a particular end-use. In another, rather serious attempt, a perforated, sheen, manufactured fabric of ~ 15-20 g/m^2 will be sandwiched with layers of the carded material and then subjected to an appropriate nonwovens technology and, subsequently, to a finishing treatment for desired surface modification and/or functional performance, using the applicable basic and/or applied textile chemistries. In addition to providing the basic structural reinforcement by using the intermediate (inner) fibrous core material, the latter's specially designed perforations are expected to permit optimally "selected" flow of energy (whether mechanical, hydro, steam, chemical, electrostatic, etc.) to the carded cotton layers, in order to achieve the desired intra-fiber orientation to further improve the integrity, strength and durability of the NW end-product. Emphasis in this exercise will be focused on developing a technique/technology to ensure that, only if required, no intermigration of different constituent fibers takes place on either face of the NW product.

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