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A Review of Spun Bond Process*

Hosun Lim, Ph.D.
NCSU College of Textiles
North Carolina State University
2401 Research Drive
Raleigh, N.C. 27695-8301

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ABSTRACT

The spun bond process is widely used to produce nonwoven fabrics. Components of a spunbond process typically include a polymer feed, an extruder, a metering pump, a die assembly, a filament spinning, a drawing and deposition system, a web formation, a bonding zone, and a winding. Spunbond products are variously used in disposable and medical applications, automotive industry, filtration, civil engineering, packaging applications, carpet backing applications, geotextiles, durable papers, bedding, pillows, furnishings, etc. In the future, the consumption of spunbond fabrics is expected to continue to grow in both durable and disposable products. Spunbond products will also continue to rapidly increase its market share and penetrate new markets. The purpose of this paper is to have a comprehensive of spunbond technology, processes, markets, and the producers.

Keywords: Spunbond process, Nonwoven fabrics, Spinning, and Web formation

1. Introduction

Spunbond process is widely used to produce nonwoven fabrics. The nonwoven products made by the spunbond process are expected to rapidly increase in market share. The spunbond process is a nonwoven manufacturing system which combines the spinning process with the sheet formation process by placing the bonding device in the same continuous line (Dahiya, Kamath, & Hegde, 2004).

This paper will discuss the spunbond widely used of producing nonwoven fabrics by reviewing the history of spunbond technology, processes and their applications.

1.1. History of Spunbond Technology

Spunbonding process was attempted to be commercialized through 1940's and 1950's. The spunbond process was patented by Slather and Thomas of Corning Company for the production of glass wool (*US Patent 2206058*). In 1945, Callender patented similar spunbond processes for the production of mineral wool (*US Patent 2382290*).

Spunbonded nonwovens made of synthetic polymers were commercialized by the technology of Freudenberg (Germany) and Du Pont (USA) in the 1950's and 1960's (Hill, 1990). After that, various spun bond processing technologies such as

Lutravil® (1965, Freudenberg Company), Dacron® (1971, Lurgi Kohle & Mineral öltechnik GmbH), Reicofil® (1984, Reifenhäuser), REX® (Amoco Fibers and Textiles), and S-TEX® (Sodoca) have been introduced. But all of them are similar in technology. They integrate filament extrusion (spinning), drawing, deposition (lay-down), and bonding and winding into roll goods (McCulloch, Pourdeyhimi, & Zamfir, 2003).

In 1990's equipment suppliers including Kobelco, Nordson, Hills, and others offered complete spunbond lines. In 2000's Reifenhauser, the main turkey supplier of PP spunbond, offered bico-spunbond and meltblown using Hills technology.

Spunbonded production was originally limited to Western Europe, the United States, and Japan, but has since spread to virtually all areas of the world. Production lines, mainly nonproprietary, have been installed throughout Asia, South America, and the Middle East, areas and countries that previously did not participate in the technology (INDA, 2004).

1.2. Raw Materials

Many polymers including polypropylene, polyester, polyethylene, polyamide, polyurethane, etc. are used in the spunbond process. Among various polymers, isotactic polypropylene (PP) is the most widely used polymer for spun bond nonwovens production, because polypropylene is relatively inexpensive and provides the highest yield (fiber per kilogram) (Wilhelm, Hilmer, & Walter, 2002). Also, it has the lowest specific gravity and the highest versatility for the nonwovens (Editorial Staff, 1992a).

Polyester (PET) has fabric property (tensile strength, modulus, and heat stability) superior to those of polypropylene fabrics is used in almost every nonwoven process technology. However, polyester is more expensive and difficult to process than polypropylene (Editorial Staff, 1992a; Brenk, 2004).

Polyethylene (PE) has good chemical resistance and hydrophobicity, and excellent electrical insulation properties and it is one of the important polymers for nonwovens (Editorial Staff, 1992a).

Polyamide including nylon 6 and nylo6,6 has the properties which are highly energy intensive than PET or PP and is used to spunbonded nonwovens for packaging materials (Editorial Staff, 1992a; Smorada, 2004).

Polyurethane (PUR) has an elastic property and it is also used in spunbonded nonwovens for the applications such as disposable wear, diaper, mask, medical tape, and elastic stuffing materials. However, it has a disadvantage of high price (Editorial Staff, 1992a).

3. Spun Bond Process

The spunbond process consists of several integrated steps; a polymer feed, an extruder, a metering pump, a die assembly, a filament spinning, a drawing and deposition system, a collecting belt, a bonding zone, and a winding (see Figure 1). Figure 1 shows the schematic diagram of Hills' spunbond process.

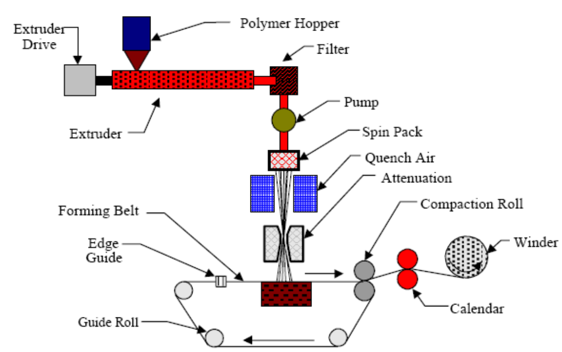

Figure 1. Schematic diagram of the spunbond process
From Fedorova, N. (2006). *Investigation of the utility of islands-in-the-sea bicomponent*. p. 36.

3.1. Extruder

A polymer is melted by heating and mechanical action when it is conveyed to an extruder. It is mixed with stabilizers, additives, color master-batch, resin modifiers, or other additives in the extruder (Nanjundappa & Bhat, 2005). Figure 2 shows the schematic of the extruder. The polymer mixture conveys through the screw and it is melted through the heated screw. Then, the molten polymer moves through the screen (Aipma, 2009).

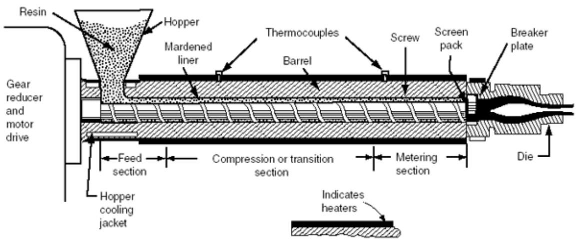

Figure 2. Screw plasticizing extruder
From Aipma. (2009). *Plastic Process*. Retrieved from http://www.aipma.net/info/plasticprocess.htm

The extruder needs to have a progressive heating and the melt pressure and temperature need to be controlled. Operation pressures and temperatures depend on resin material (Fourné, 1992).

3.2. Metering Pump

The molten polymer is conveyed to a filter and foreign particles such as metals, solid polymer particles, and others are separated from the molten polymer. The filtering is very important, because the unfiltered polymer may cause problems such as blocking the spinneret holes or creating filament breaks. Then it is conveyed to a metering pump which plays an important role in a precise volumetric flow rate of the molten polymer. The important thing is that once the polymer is melted and liquefied uniform temperature must be maintained to a die block assembly (Wilhelm, Hilmer, & Walter, 2002).

The metering pumps need to be insulated on all sides. The heated temperature is usually in the range of 40kg/h to 100 kg/h and the speed is generally between 10rpm and 40 rpm (Fourné, 1992).

3.3. Spin Pack

The die block assembly (spin pack) is one of the most important part in the extrusion unit and consists of a polymer feed distribution and a spinneret. The polymer feed distribution needs to control uniform polymer distribution and uniform temperature to keep a balance of the molten polymer flow and the residence time across the die assembly. The molten polymer is conveyed from the feed distributor to the spinneret (Fedorova, 2006).

The spinneret is a single block of metal having thousands of drilled orifices or holes on it, and the designing and fabrication of this part affect web uniformity (see Figure 3).

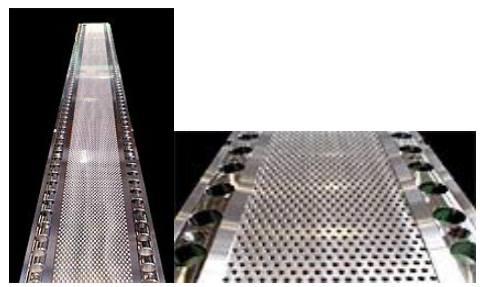

Figure 3. Die block assembly
From Kasen Nozzle Mfg. Co., Ltd. (2007). *Spunbond Spinnerette*. Retrieved from http://www.kasen.co.jp/english/product/line/spanbond.html

To produce a wide web, several grouping of spinnerets called a block or bank is placed side by side to generate sufficient fibers across the total width. In commercial production two or more blocks are used in tandem in order to increase the coverage of fibers (Kasen Nozzle Mfg. Co., L., 2007). When processing two different blends of fibers with different melting points, they must be melted separately and joined in the spin pack or metering pump (Smorada, 2004). The spin pack is normally designed to withstand 300℃ and 400℃ bar inner pressure over the entire die plate and its temperature needs to be uniformly (Fourné, 1992).

3.4. Quench Air/Attenuation

The molten polymer is emitted through the spinneret holes. When the emitted filaments pass through quench chambers, cool air is directed across the filament bundle to cool the molten filaments sufficiently to cause solidification. The quenching can be done by blowing air with either a one sided system or a two sided system. But, with a two-sided inflow quench air supply box, the fabrics can be cooled in a shorter distance than that of one-sided cross flow quench box (Wilhelm, Hilmer, & Walter, 2002).

In the attenuation the filaments are led into a tapered conduit by high velocity air, causing acceleration and accompanying attenuation or stretching of the individual filaments. The attenuation leads to a polymer molecular orientation making up the continuous filament and a modification of fiber diameter (Editorial Staff, 1992a; Wilhelm, Hilmer, & Walter, 2002). The spinning speeds of the process range from 1,000 to 8,000 m/min, depending on the polymer characteristics, process productivity, etc. For example, polypropylene (PP) usually spins at about 2,000 m/min, polyamide spins at about 4,000 m/min, and polyester (PET) usually spins at about 6,000 m/min (Fedorova, 2006).

When quenching using air, other parameters like temperature and humidity must be controlled (Vargas, 1989). The air is the most common method of the attenuation and the take-up rolls or electrostatic method is also used to the attenuation (Fedorova, 2006).

There are generally three spinning methods including melt, dry, and wet spinning for spunbonding. The melt spinning is widely used to spunbonding and there are several systems.

Reicofil system was been developed by Reifenhauser GmbH of Germany. The system is based on the short spin with considerably lower production speeds and lower line capacity. This system is closed system. Many nonwoven companies have licensed this technique from the Reifenhauser GmbH for commercial production (Russell, 2007; Vargas, 1988).

Lutravil system was first developed by Carl Freudenberg Company of Germany in 1965. In the system, the filaments continuously cooled with conditioned air. There are the individual flows of air including primary, secondary, and tertiary air. The primary air and secondary air serve to cool and draw the filaments, while tertiary air serves to take down the filaments in bunches. This system is not available for commercial licensing (Wilhelm, Hilmer, & Walter, 2002; Russell, 2007).

Doncan system was been developed by Lurgi Kohle & Mineral-Oltechnik GmbH of Germany in 1970.

This system is based on a long spinning with a high speed and it requires four floors for production equipment (Russell, 2007; Malkan & Wadsworth, 1992). Many companies have been licensed by Lurgi GmbH and practice this technique (Russell, 2007).

3.5. Web Formation

The filaments are deposited on a moving belt. High pressure air through a pneumatic gun is used to move the filaments and a vacuum under the belt helps in forming the filament web on the forming belt. The filaments are separated by mechanical force, aerodynamic force, or electrostatic charge before reaching the belt, to achieve maximum uniformity and cover (Editorial Staff, 1992a). There are some processes: mechanical oscillation, electrostatic charging, slot attenuators, air foils, full-width draw rolls, and centrifugal foaming used for separation and lay down (Gilmor, 1992).

In the mechanical oscillation method, the filaments are separated by mechanical or aerodynamic forces. Figure 4 shows a method and apparatus for producing nonwoven webs patented by Du Pont Company in 1967 and Figure 5 shows a process and device for the manufacture of non woven webs from filamentspatented by

Hoechst in 1979.

To uniformly separate the filaments, the filament stream is oscillated by mechanical or pneumatic oscillation of attenuator gun or the filament bundle itself as shown in Figure 4 and 5. Figure 5 illustrates a method that utilizes a rotating deflector plane to separate the filaments by depositing them in overlapping loops; suction holds the fiber mass in place.

FIG. 11

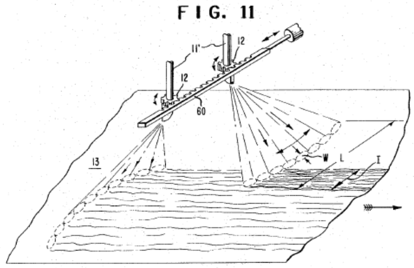

Figure 4. Mechanical and pneumatic filament bundle oscillators
From Bundy, R.W. (1967). *Method and apparatus for producing nonwoven webs.* p.5.

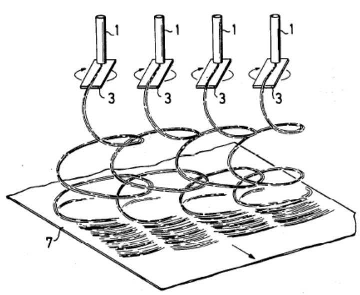

Figure 5. Rotating deflector distribution device
From Semjonow, V. & Foedrowits, J. (1979). *Process and device for the manufacture of non woven webs from filaments.* p. 4.

The electrostatic charging is one method to spread and separate filaments.

Figure 6 shows a method for triboelectric filament charging patented by Du Pont Company in 1967.

The triboelectric charging is the most common and it is charging via rubbing contact of the filaments with a suitable dielectric material (Kinney, 1967).

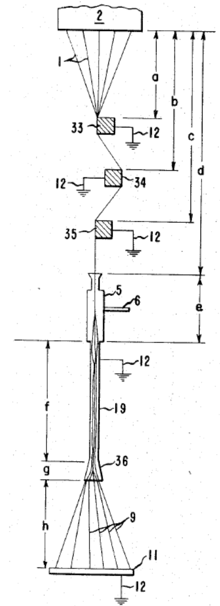

Figure 6. Triboelectric filament charging
From Kinney, G.A. (1967). *Process for forming non-woven filamentary structures from fiber-forming synthetic organic polymers*. P.2.

Figure 7 shows a method for corona filament charging patented by Monsato in 1977.

In the corona charging, the filament bundle passes through a corona developed between high voltage electrodes (Sternberg, 1977).

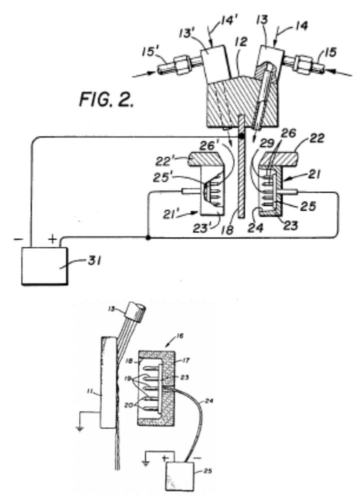

Figure 7. Corona filament charging
From Sternberg, E.M. (1977). *Method for forwarding and charging a bundle of filaments*. P.2.

In the slot attenuators, the filaments are put in the moving lay down belt.

Figure 8 shows the slot attenuators patented by Du Pont Company in 1976. Debbes used two rows of narrow slot attenuators covering the full width of the machine. As shown in Figure 8, one row of attenuators had the slots lined up across the web, while the other row had the slots lined up in the machine direction. The two slots are oscillated in the different directions and the filaments are put on the surface of the moving belt in a zig-zag pattern. The result was the fabric with balanced properties in the two directions (Debbes, 1976).

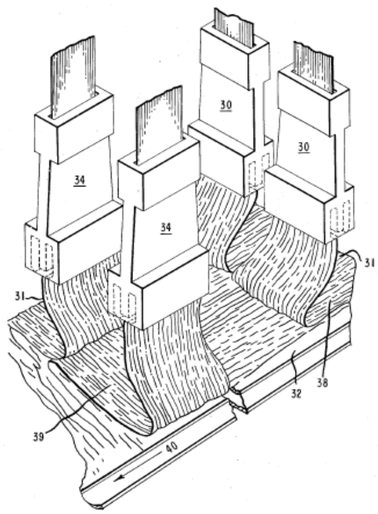

Figure 8. Slot attenuators From Debbes, S.C. (1976). *Nonwoven polypropylene fabric*. p.3.

3.6. Bonding

Many bonding methods can be used to bond the filaments in the spunbond process. These include hydroentangle bonding, needlepunching bonding, thermal bonding, chemical bonding, etc.

The hydroentangle bonding is more complex and expensive, but this technology can produce very different continuous filament structures. This technology helps the tensile strength of the fabrics is improved and the fabrics can be processed at higher line speeds with a higher efficiency (Editorial Staff, 1992a; Smorada, 2004).

The needlepunching bonding provides more comfortable and bulky fabrics than thermal or chemical binder bonding. In the technology, the barbed needles are rapidly passed through the plane of moving spun web (Smorada, 2004).

Thermal bonding is more common and economical than chemical binder bonding. Area-thermal bonding bonds large regions and is based primarily on temperature. Point-thermal bonding, however, bonds small regions and makes use of both temperature and pressure to effect fiber fusion. It is more flexible, since the fibers between the point bonds remaining relatively free (Dahiya, Kamath, & Hegde, 2004).

Chemical binder bonding is used less frequently for spunbond process (Smorada, 2004).

3.7. Winding

After the fabrics are bonded, they encounter treatments such as embossing, resin treatment, flame retardancy, rewet agent, dyeing, printing, antistat agent (Editorial Staff, 1992a). In a slitting section, the fabrics are slit to provide the fabric rolls with precise dimensions. Then, the fabrics are rolled and they are wrapped and shipped (Editorial Staff, 1992a).

4. Spunbond Composites

The spunbond technology can be widely used in conjunction with various technologies for nonwoven product.

4.1. SMS (Spunbon/Meltblown/Spunbond)

The spunbonded nonwovens provide the manufacturer to make nonwoven composites in a continuous process. The nonwoven composites combining several processes are made depending on the nonwoven products such as the geotextiles, filtration textiles and in protective textiles which require the special fabric properties (Wehamann, 1992).

Figure 9 shows an example of the combination of SMS (spunbond/meltblown/spunbond) which is known as multidenier processes.

Otherwise, there are many varieties of multilayer such as multilayer spun bond nonwovens (SS, SSS) and multilayer spunbond and melt blown nonwovens (SM, SMS, SMMS).The air volume in the meltblown process is much greater than that in the spunbond process, because the meltblown process has the high velocity. The fiber length of the meltblown process is relatively shorter than the spunbond process, for example, that of the spunbond process is generally in the range of 10,000 to 15,000 fiber/m die, while that of the meltblown process is in one single row with approximately 1,000 or 2,000 fiber/m die (Wehanmann, 1992).

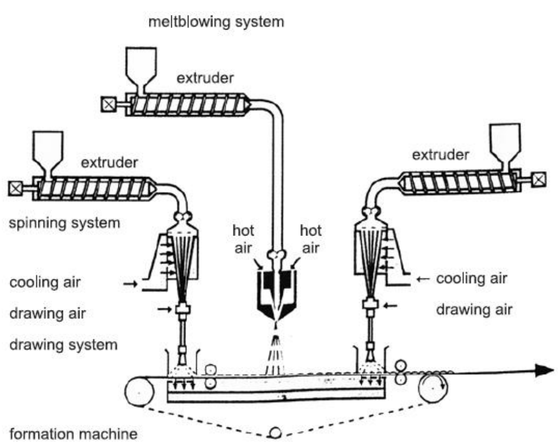

Figure 9. SMS spunbond technology (Zimmer AG)
From Wilhelm, A., Hilmer, F., & Walter, K. (2002). *Nonwoven Fabrics.* p.211.

4.2. Spinforming Process

The spinforming process is a process developed to form a new group of nonwovens with fluff pulp for hygienics. Using this spinforming process, superabsorbent polymers (SAP) and endless filaments are spun and bonded together. The spinforming technology combines the air-laid process for short fibers with spun bond technology. The filaments are drawn to enhance strength and sucked into a blending chamber. They are blended with defiberized short fibers and powder is intermingled in this blending chamber. Then, the mixture is laid down on a conveyor belt. Homogenously mixed with the short fibers, they are distributed into the void volumes of the filaments matrix (Wilhelm, Hilmer, & Walter, 2002).

Spinforming structure, coming out of the machine without further treatment such as bonding, is used to the excellent absorbent layers for hygiene products. The unique structure of spun bond web contributes to keep the skin of the user to stay dry and comfortable (Smorada, 1992; Wilhelm, Hilmer, & Walter, 2002). Figure 10 shows the spinforming called VAPORWEB process. In this process, the composite is coated and biaxially drawn, after thermal bonding of the spun bonded nonwoven.

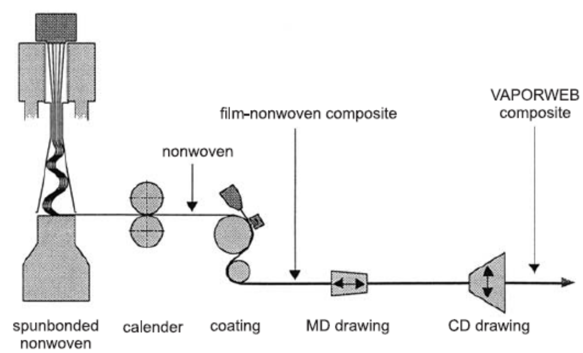

Figure 10. VAPORWEB process
From Wilhelm, A., Hilmer, F., & Walter, K. (2002). *Nonwoven Fabrics.* p.220.

6. Test Methods

A standard test method describes a definitive procedure which produces a test result. It may involve making a careful personal observation or conducting a highly technical measurement. A number of national and international standards organizations are involved in drawing up standards relating to usage and testing on the basis of the latest state of technology (Wilhelm, Hilmer, & Walter, 2002). Standards organizations include ISO (International Organization for Standardization), ASTM (American Society for Testing and Materials), and DIN (Deutsches Institut für Normung). Within the nonwovens industry, several groups are concerned with developing, refining, evaluating, approving, and disseminating test methods. These groups include the following organizations: INDA (Association of the Nonwoven Fabrics Industry), EDANA (European Disposables and Nonwovens Association), and TAPPI (Technical Association of the pulp & Paper Industry).

Table 1. INDA test methods for nonwoven
From Editorial Staff. (1992b). *Standard Test Methods*. p. 264.

Property	**Description**	**IST Number**
absorbency	amt of liquid absorbed and speed of absorption	10.1–3
abrasion	resistance of nonwovens to being worn away	20.1–5
bursting strength	force to rupture nonwoven under water pressure	30.1
electrostatic properties	amt of charge that can build up on a sample	40.1–2
optical properties	opacity: resistance to light being passed brightness: whiteness	60.1–2
permeability	ease of air or water vapor passage under pressure	70.1–2
repellency	resistance of nonwovens to wetting and penetration after exposure to water, salt solutions, alcohol, and hydrocarbon solvents and oils	80.1–9
bacterial	resistance of a nonwoven to penetration by bacteria in a salt solution under water pressure	
stiffness		
cantilever	tendency for a nonlimp nonwoven to droop as it is pushed over the edge of a surface	90.1
curly	ability of a heavy, stiff nonwoven to push a pendulum aside as it is moved past it	90.2
handle-O-Meter	ability of a soft, lightweight nonwoven to flex and not drag as it is pushed through an opening	90.3
tear	resistance of a nonwoven to continue to tear after being cut and pulled from both sides	100.1–3
breaking load and elongation	force to break a nonwoven when it is pulled from both ends; extent of stretching before breaking	110.1–4
seam breaking	force needed to break a seam holding two pieces of nonwoven together when the sample is pulled from both ends	
bond strength of laminates	force to separate a nonwoven from another material after they have been laminated together	
internal bond strength	force to pull a nonwoven fabric into two plies	
thickness	how thick a nonwoven is when it is held between a weight and a surface	120.1–2
coefficient of friction	drag when a nonwoven is slid over itself or over a polished surface	140.1
dry cleaning and laundering	shrinkage, loss of strength, ability to be peeled apart experienced by a single fabric or laminate	150.1
linting	extent of particles loosened from nonwoven as it is bent and flexed in air stream	160.1
extraction	amt of material leached out of nonwoven after exposure to hot solvents	190.1

Spunbond fabrics are characterized by standardized test procedures originally developed for textile fabrics and paper products. INDA has published procedures (see Table 1) that are routinely used to determine specific physical characteristics of nonwoven and spunbonded fabrics (Smorada, 2004). Many tests are established for the evaluation of properties such as washability, stiffness, and softness. Advances permit the quantitative evaluation of the hand of materials for textile applications such as clothing (Kawabata, 1980)

7. Spunbond Market

The worldwide nonwovens market in 2007 reached 5,751 million tones equivalent to $20.9 billion dollars. The volume was about 144 billion square meters. Spunbond volume in 2007 was about 45.6% of the total output or 2.621 million tons. Spunbond includes spunbonded polypropylene (SBPP), spunbonded polyester (SBPET), spunbonded polyethylene (SBPE), spunbonded nylon and melt blown technologies. As a group, spunbond is growing about 9% per year worldwide and is forecast to reach 4.04 million tons by the end of 2012. It share of nonwoven production will be about 48% of the world's total nonwovens (INDA, 2007).

The area of largest growth for spunbonded fabrics continues to be disposable diaper coverstock accounting for 70% of the U.S. coverstock market. Forecasts for the future growth of spunbonded fabrics continue to be favorable as consumption in both durable and disposable areas continues to grow (INDA, 2006). Growth is forecast to generally exceed the growth of all other nonwovens, which itself is expected to grow at 3~6% per annum. In addition to diaper coverstock and hygiene, growth is anticipated in geotextiles, roofing, carpet backing, medical wrap, and durable paper applications (INDA, 2004).

According to INDA (2006), the spunbond products are expected to rapidly increase in market share and penetrate new markets including some portions of the apparel market in the future.

Nonwoven products made by using the spunbond process are variously used in disposable and medical applications, automotive industry, filtration, civil engineering, packaging applications, carpet backing applications, geotextiles, durable papers, bedding, pillows, furnishings, and others (Editorial Staff, 1992a).

The spunbond process has been used for diapers and incontinence products. It has been used in medical applications such as disposable operating room gowns, shoe covers and sterilization packaging, because it has the particular properties including breath ability, resistance to fluid penetration, sterilizability, and impermeability to bacteria (Wilhelm, Hilmer, & Walter, 2002).

In automotive industry, the spunbond webs are used for tufted automobile floor carpets, for trim parts, trunk liners, interior door panel, and seat covers (Smorada , 1992).

In filtration industry, the spunbond webs are used in various applications including pool and spa, air particulate, coolant, milk and sediment for household water (Smorada, 2004). The SMS/ SMMS structures which are the combination of spunbond and meltblown are widely used as air filters in the industry (Smorada, 2004).

In civil engineering, they are used in erosion control, revetment protection, railroad bed stabilization, canal and reservoir lining protection, highway and airfield black top cracking prevention, and roofing, because it has the particular properties including chemical and physical stability, high strength, and their highly controllable structure properties (Wilhelm, Hilmer, & Walter, 2002).

8. Spunbond Technology Suppliers

Many companies have engaged in spunbond nonwoven technology around the world (see Table 2).

Reemay polyester spunbond was produced by Du Pont Co. and Cerex and PBN-II nylon spunbond were produced by Mansato. Many spunbond nonwoven technologies have been adopted by

Freudenberg, Fiberweb, Veratec Canada, etc.

Spunbond technologies acquired through licensing have proliferated by many companies including Kimberly-Clark Corp., Novatex Brazil, Augul Israel, Corovin, Bonlan Mexico, Veratec Canada, Kami Brazil, Amoco Germany, etc. There are generally three kinds of license spunbond technology, for example, Docan process of Lurgi GmbH, Recicofil process of Reifenhäuser, and STP Impianti SpA process (Editorial Staff, 1992c).

As shown Table 2, the spunbond nonwoven suppliers are mostly in North America (Sanblue Enterprises Pvt. Ltd., 2009).

Table 2. International spunbond suppliers
From Sanblue Enterprises Pvt. Ltd. (2009). *Spunbond*. Retrieved from http://www.nonwovensupplier.com/Nonwoven-Fabric/spunbond.aspx

Company	**Country**	**Company**	**Country**
Airlaid Corporacion Industrial S.A.	Argentina	Freudenberg Far Eastern Spunweb Co. Ltd.	Taiwan
Softbond S.A.	Argentina	Shinih Enterprise Company, Ltd.	Taiwan
Excel Nonwovens	Australia	Nan Ya Plastics Corporation Plastics	Taiwan
Geofabrics Australasia Pty Ltd	Australia	CNC International Co., Ltd., A BBA Joint Venture Company	Thailand
Kimberly-Clark Australia Pty.	Australia	Mogul nonwoven	Turkey
Multapex Pty Ltd	Australia	Mogul Nonwovens	Turkey
PGI-Yuexin International (Australia) Pty. LTd.	Australia	Mogul Spunbond - Meltblown Nonwovens	Turkey
Sioen Nordifa Sa	Belgium	Branova Ltd.	U.K.
Nolar Industries Ltd.	Canada	Freshsign Ltd.	U.K.
Junqi Nonwovens Enterprise Co., Ltd.	China	ABC Wiping Cloth Inc.	U.S.A.
Qingdao Yihe Packing Plant	China	Air Filter Service Company Inc.	U.S.A.
China Worldbest Group Co., Ltd.	China	Bro-tex, Inc.	U.S.A.
Nhjinlong	China	Bruce J. Morris & Co., Inc.	U.S.A.
Shandong Kangjie Nonwovens Co.,Ltd.	China	Cerex Advanced Fabrics, Inc.	U.S.A.
Sunshine Nonwoven Fabric Company Ltd.	China	Convermat Corporation	U.S.A.
Fibertex A/S	Denmark	Crystal Filtration Co.	U.S.A.
Dounor S.A.	France	Fabric Sources International	U.S.A.
BECO Bermuller & Co. GmbH	Germany	First Quality Nonwovens, Inc.	U.S.A.
Johns Manville Sales GmbH	Germany	Freudenberg Nonwovens Limited Partnership	U.S.A.
Sachsisches Textilforschungsinstitut E.V.STFI	Germany	Gem Tex Sales Corporation	U.S.A.
Saehan Industries (Deutschland) Gmbh	Germany	Harodite Industries, Inc.	U.S.A.
Freudenberg Vliesstoffe KG	Germany	Kimberly-Clark Corporation	U.S.A.
Avion Group Company Limited	Hong Kong	Material Connections Incorporated	U.S.A.
U.S. Pacific Nonwovens Industry Ltd.	Hong Kong	Monarch Textiles, Inc.	U.S.A.
Alpha Foam Limited	India	N. Newman Associates	U.S.A.
Karan Polypack Pvt Ltd	India	National Wire Fabric Inc.	U.S.A.

R.K. Synthetics & Fibres Pvt. Ltd.	India	Nu-Tex Styles, Inc.	U.S.A.
Sonaa Impex	India	Overseas Nonwovens, Ltd.	U.S.A.
SONAA TEX	India	PGI	U.S.A.
Swabs Tapes India Pvt. Ltd.	India	Prairiefire Fibers And Resources	U.S.A.
Texbond Nonwovens	India	Precision Converters, Inc.	U.S.A.
Concord Nonwoven Industries Private Ltd.	India	Precision Fabrics Group Inc.	U.S.A.
Macropact	India	W. G. Steve Company, Inc.	U.S.A.
Avgol Nonwovens Industries	Israel	Wendell Textiles Inc.	U.S.A.
Fiberweb	Italy	Xamax Industries, Inc.	U.S.A.
Nowotec srl Nonwovens Systems	Italy	Ahlstrom Filtration LLC	U.S.A.
Tessiture Pietro Radici S.P.A.	Italy	BWF America Inc.	U.S.A.
Texbond Nonwovens	Italy	Chisso America Inc.	U.S.A.
Union Industries SpA	Italy	Chivic Trading Company	U.S.A.
ATEX S.r.l.	Italy	Colbond Inc.	U.S.A.
G. Sistemi S.r.l.	Italy	Deitsch Nonwovens	U.S.A.
O.R.V. SpA	Italy	Essen Polymers Inc.	U.S.A.
Nippon Kodoshi Corporation	Japan	Fiber Associates	U.S.A.
Shinwa Corporation	Japan	Impak Corporation	U.S.A.
Toyobo Company Ltd.	Japan	Madison Polymer Engineering	U.S.A.
Kolon Chemical Co., Ltd.	Korea	Meyers Brothers Kalicka PC	U.S.A.
Geo-Productos Mexicanos S.A. De C.V.	Mexico	New Avenue, Inc.	U.S.A.
Joint International B.V.	Netherlands	Nonwoven Marketing	U.S.A.
Erintra	Netherlands	Phoenix Elastic Nonwovens Development, Inc.	U.S.A.
Lantor BV	Netherlands	Primafab International	U.S.A.
Vanotex B.V.	Netherlands	Purolator Air Filtration	U.S.A.
Spunchem Africa (PTY) Ltd.	South Africa	RKW US, Inc.	U.S.A.
Nietos De Miguel Martinez Ramirez	Spain	Saehan America Inc.	U.S.A.
Cell International S.A.	Switzerland	Target Marketing Worldwide	U.S.A.

7. Conclusion

Typical spunbond process components are a polymer feed, an extruder, a metering system, a spin-pack, a quenching system, a drawing and deposition system, a web formation, a bonding, and a winding. The nonwoven products produced by using spunbond process are used in various applications. The usage of the spunbond nonwoven has continually been growing. Many companies have engaged in spunbond nonwoven technology around the world. In the future spunbond products will continue to rapidly increase market share and penetrate new markets including some portions of the apparel market.

8. References

Aipma. (2009). Plastic Process. *The All India Plastics Manufacturers' Association*. Retrieved from http://www.aipma.net/info/plasticprocess.htm

Brenk, J. (2004, Febuary 26). Higher added values for PET staple fibers and spunbonds. *Chemical Fibers International, 54*(1) , 37-40.

Bundy, R. W. (1967). Method and apparatus for producing nonwoven webs. *US Patent 3296678*. Du Pont Co.

Callander, M. E. (1945). Manufacture of mineral wool. *US Patent 2382290*.

Dahiya, A., Kamath, M. G., & Hegde, R. R. (2004, April). *Materials Science & Engineering 554, University of tenesse*. Retrieved from Nonwovens science and technology II: http://www.engr.utk.edu/mse/Textiles/index.html

Debbes, S. C. (1976). Nonwoven polypropylene fabric. *US Patent 3991244*. Du Pont Co.

Editorial Staff. (1992a). Spunbond Process. *In Spunbond technology today 2: Onstream in the 90's* (pp. 11-16). San Francisco, California: Miller Freeman, Inc.

Editorial Staff. (1992b). Standard Test Methods. *In Spunbond technology today 2: Onstream in the 90's* (pp. 261-268). San Francisco, California: Miller Freeman, Inc.

Editorial Staff. (1992c). Major Producer/Suppliers. *In Spunbond technology today 2: Onstream in the 90's* (pp. 201-205). San Francisco, California: Miller Freeman, Inc.

Fedorova, N. (2006). *Investigation of the utility of islands-in-the-sea bicomponent*. Unpublished doctoral dissertation, North Carolina State University, Raleigh, NC, USA.

Fourné, F. (1992). New processes for spunbond fabric production. *In Spunbond technology today 2: Onstream in the 90's* (pp. 169-174). San Francisco, California: Miller Freeman, Inc.

Gilmor, T. F. (1992). Spunbond Web Formation Processes: A critical Review. *In Spunbond technology today 2: Onstream in the 90's* (pp. 139-145). San Francisco, California: Miller Freeman, Inc.

Hill, R. G. (1990). Book of papers. *Fiber Production Conference*, Greenville, SC, USA.

INDA. (2004). *Worldwide Outlook for the Nonwovens Industry: 2004-2009*, Cary, NC, USA.

INDA. (2006). *The Absorbent Hygiene Industry in North America 2006-2011*, Cary, NC, USA.

INDA. (2007). *Worldwide Outlook for the Nonwovens Industry: 2007-2012*, Cary, NC, USA.

Kasen Nozzle Mfg. Co., L. (2007). *Spunbond Spinnerette*. Retrieved from http://www.kasen.co.jp/english/product/line/spanbond.html

Kawabata, S. (1980). *The Standardization and Analysis of Hand Evaluation, 2nded*. Osaka, Japan: Textile Machinery Society of Japan.

Kinney, G. A. (1967). Process for forming non-woven filamentary structures from fiber-forming synthetic organic polymers. *US Patent 3338992*. Du Pont Co.

Malkan, S. R., & Wadsworth, L. C. (1992). A review on spunbond technology: Part I. *INB, Nonwovens,3* , 4-14.

McCulloch, J., Pourdeyhimi, B., & Zamfir, M. (2003, June 1). Recent developments in spunbonding and meltblowing. *Nonwoven Industry, 34*, 48-52.

Nanjundappa, R., & Bhat, G. S. (2005). Effect of Processing Conditions on the Structure and Properties of Polypropylene Spunbond Fabrics. *Applied Polymer Science*, *98*, 2355-2364.

Russell, S. J. (2007). *Handbook of nonwovens*. Cambridge : Boca Raton, Fla.: CRC Press.

Sanblue Enterprises Pvt. Ltd. (2009). Spunbond. *Nonwoven Supplier.com.* Retrieved from http://www.nonwovensupplier.com/Nonwoven-Fabric/spunbond.aspx

Semjonow, V. & Foedrowits, J. (1979). Process and device for the manufacture of non woven webs from filaments. *US Patent 4163305*. Hoechst

Slater, G. & Thomas, J. H. (1940). Manufacture of glass wool. *US Patent*

2206058. Owens-Corning Fiberglass Corporation.

Smorada, R. (1992). Spunbonding: Characteristics, Applications, Technologies. *In Spunbond technology today 2: Onstream in the 90's* (pp. 17-33). San Francisco, California: Miller Freeman, Inc.

Smorada, R. L. (2004, February 13). Nonwoven Fabrics, Spunbonded. *Kirk Othmer Encyclopedia of Chemical Technology* .

Sternberg, E. M. (1977). Method for forwarding and charging a bundle of filaments. *US Patent 4009508*. Monsato.

Vargas, E. (1988). *Spunbond technology today*. San Francisco, California: Miller Freeman, Inc.

Vargas, E. (1989). *Meltblown technology today : An overview of raw materials, processes, products, markets, and emerging end uses.* San Francisco, Calif: Miller Freeman.

Wehamann, M. (1992). Production of Nonwovens According to the Spunbond and Meltblown System. *In Spunbond technology today 2: Onstream in the 90's* (pp. 149-152). San Francisco, California: Miller Freeman, Inc.

Wilhelm, A., Hilmer, F., & Walter, K. (2002, November). *Nonwoven Fabrics; Raw Materials, Manufacture, Applications, Characteristics, Testing Processes.* Weinheim: Wiley-VCH.