

## REVIEW ARTICLE

## Medical Textiles: The Spunlace process and its application possibilities for hygiene textiles

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### Abstract

Hydroentangling, spunlacing, hydraulic entanglement and water jet needling are synonymous terms describing the process of bonding fibres (or filaments) in a web by means of high-velocity water jets. The interaction of the energized water with fibres in the web and the support surface increases the fibre entanglement and induces displacement and rearrangement of fibre segments in the web (Mechanical intertwining or bonding of fibers by water jets). This review focuses on spunlace or hydroentangling process and its application possibilities for hygiene textiles.

**Keywords:** Spunlace, mechanical bonding, web entanglement, water jets, medical textiles.

### Introduction

Nonwovens are extensively used in the medical field and in protection against biological agents in other sectors. Nonwoven materials with improved finishes such as liquid repellent, virus proof and bacterial resistance have been developed for applications such as surgical masks, gowns, drapes etc. (ICRA Management Consulting Services Limited, 2009). For the production of medical textiles in nonwoven route, three main technologies are employed namely Hydroentanglement (Spunlace process), Spunbonding and Meltblown (Adanur, 1995; Horrocks and Anand, 2000; Chellamani and Vignesh Balaji, 2010). The manufacture of Meditech products using spunlace technology is briefly dealt in this review.

### Spunlace manufacturing process

Spunlacing is a process of entangling a web of loose fibers on a porous belt or moving perforated or patterned screen to form a sheet structure by subjecting the fibres to multiple rows of fine high-pressure jets of water (Fig. 1). The essential steps in producing hydroentangled spunlace nonwoven fabric includes (Huang and Xiao Ga, 2004; Madhavamoorthy and Shetty, 2005):

1. Precursor web formation
2. Web entanglement through water jet application
3. Dewatering
4. Web drying and winding

**Precursor web formation:** The precursor web is formed by air-laid or wet-laid process or through carding (roller-clear card).

**Web entanglement:** The formed web is first compacted and pretwetted to eliminate air pockets and then water-neededled by passing through a series of water jets (injectors). The water pressure applied on the web generally increases from the first to the last water injectors.

Fig. 1. Spunlace process (Chellamani *et al.*, 2012).

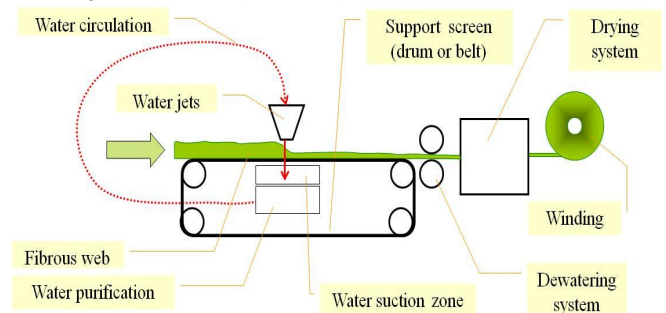


Fig. 2. Shape of the spunlace support wire and the resultant product (Huang and Xiao Ga, 2004; Madhavamoorthy and Shetty, 2005).

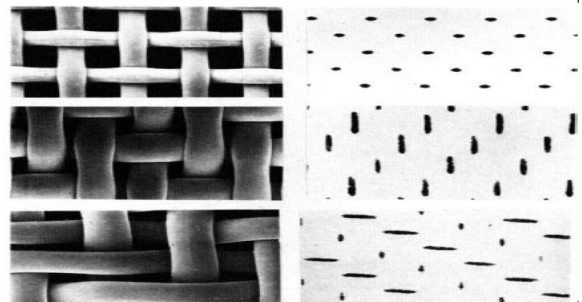
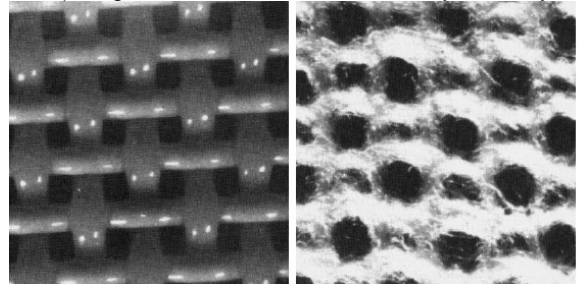


Fig. 3. Shape of the spunlace support wire and the resultant product (Huang and Xiao Ga, 2004; Madhavamoorthy and Shetty, 2005).



High pressure of the order of 2200 psi (pounds per square inch) is used to direct the water jets onto the web. This pressure is sufficient for most of the nonwoven fibres, although higher pressures are used in specialized applications. Diameters of the injector holes range from 100-120 mm and the holes are arranged in rows with 3-5 mm spacing, with one row containing 30-80 holes per 25 mm (Huang and Xiao Ga, 2004; Madhavamoorthy and Shetty, 2005). The impinging of the water jets on the web cause the entanglement of fibres. The jets exhaust most of the kinetic energy primarily in rearranging the fibres within the web and secondly, in rebounding against the substrates, dissipating the energy to the fibres. Usually, hydroentanglement is applied on both the sides of the fibrous web in a step-wise manner. The first entanglement roll acts on the first side a number of times in order to impart the desired amount of bonding and strength to the web. The web then passes over a second entanglement roll in a reverse direction in order to treat and, thereby, consolidate the other side of the fabric. The fibrous web, which is subjected to water jet application is supported by a support screen (drum or belt) the spunlace machine (Fig. 1) in its passage to the drying and winding section. The shape of the hydroentangled web depends on the shape of the support screen. Two examples showing the shape of the support screen and the shape of the resultant hydroentangled fabric are given in Fig. 2 and 3. A vacuum in the water suction zone (Fig. 1) removes used water from the entangled web, thereby preventing the flooding of the web (Chellamani *et al.*, 2012).

**Dewatering:** The hydroentangled product is then passed through a dewatering system where excess water is removed (Fig. 1).

**Web drying and winding:** Web drying is the final phase of the spunlace process. After the dewatering process, the spunlace fabric is in wet condition and these fabrics are dried by applying hot air and then wound on spools (Chellamani *et al.*, 2013).

### Materials used in spunlaced technology

Hydroentanglement could be carried out using dry-laid (carded or air-laid) or wet-laid webs as a precursor. Precursors are mixtures of cellulose and man-made fibers (PET, nylon, acrylics, Kevlar etc). In general, cellulosic fibers are preferred for their high strength, pliability, plastic deformation resistance and water insolubility. Cellulosic fibers are hydrophilic, chemically stable and relatively colorless. Another advantage is that cellulose has an inherent bonding ability caused by the high content of hydroxyl groups, which attract water molecules. As the water evaporates from the fabric, the hydroxyl groups on fiber surfaces link together by hydrogen bonds. Generally, low micronaire cotton is not recommended for hydroentangled nonwovens due to higher number of neps and small bundles of entangled fibers causing poor fabric appearance.

Greige cotton is widely used in spunlacing technology. The absorbency rate increases with increasing hydroentanglement energy. This is the result of oil and wax removal from the fiber surface (while using cotton). The nonwoven fabrics can be subsequently bleached, which generally raises the strength of the fabric.

**The choice of the fibers:** The essential characteristics for fibres to be used in spunlaced technology are as follows (Adanur, 1995; Madhavamoorthy and Shetty, 2005).

1. **Modulus:** Fibers with low bending modulus requires less entangling energy than those with high bending modulus.
2. **Fineness:** For a given polymer type, larger diameter fibers are more difficult to entangle than smaller diameter fibers because of their greater bending rigidity. For PET, 1.25 to 1.5 deniers appear to be optimum.
3. **Cross section:** For a given polymer type and fiber denier, a triangular shaped fiber will have 1.4 times the bending stiffness of a round fiber. An extremely flat, oval or elliptical shaped fiber could have only 0.1 times the bending stiffness of a round fiber.
4. **Length:** Shorter fibers are more mobile and produce more entanglement points than longer fibers. Fabric strength, however, is proportional to fiber length; therefore, fiber length must be selected to give the best balance between the number of entanglement points and fabric strength.
5. **Fiber wettability:** Hydrophilic fibers entangle more easily than hydrophobic fibers because of the higher drag forces.

### Application possibilities of hydroentangled fabrics

Hydroentangled fabrics are widely used in medical applications due to their relatively high absorption abilities (Adanur, 1995). Another important criterion for the large scale use of hydroentangled fabrics in medical field is the absence of a binder in the fabric allowing sterilization of the fabric at high temperatures. Major meditech products manufactured through spunlace process are discussed in the following sections.

**Wipes:** Commercially, hydroentangled fabrics for wipes have been produced for a long time. The soft, strong, flexible and in most cases, absorbent characteristics of the fabrics combined with increasingly attractive economics and a textile like handle have brought hydroentanglement to the fore in this sector. One of the earliest applications was replacements for woven gauze in products such as laparotomy and x-ray detectable sponges. The wipes industry is now remarkably diverse encompassing hygiene (e.g., baby wipes), personal care, facial cleansing and make-up removal, food service, industrial and household cleaning products (Russell, 2007). In last five years air-laid thermal bonded wipes have been increasingly substituted by hydroentangled fabrics because of their softer handle, good strength and low thickness.

Table 1. Composition of commercial available hydroentangled wipes.

Product	Fabric weight	Composition
Baby wipe	50 g/m <sup>2</sup> or 55 g/m <sup>2</sup>	70% viscose rayon, 30% polyester
Baby wipe	55 g/m <sup>2</sup>	50% viscose rayon, 50% wood pulp
Food service wipe	68-80 g/m <sup>2</sup>	80% viscose rayon, 20% polyester
Swiffer type dry wipe	68 g/m <sup>2</sup>	Carded polyester + polypropylene scrim + carded polyester

Hydroentangled fabrics are also important in the impregnated wipes market. Some examples of the composition of commercial hydroentangled wipes are shown in Table 1.

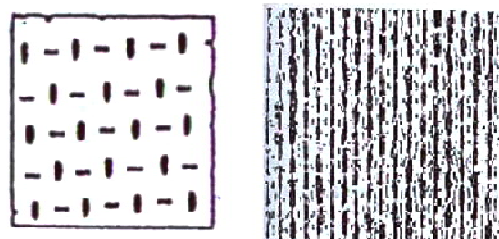
**Bacteria-proof cloth:** These are produced using 100% viscose or viscose/cotton blends (Fig. 4). Due to the adoption of special water-processed method, the fluffed cotton in the cloth cannot easily float away. Easy to wash and quick drying capabilities of the cloth results in a bacteria-proof environment (Madhavamoorthy and Shetty, 2005).

Fig. 4. Bacteria proof cloth (Madhavamoorthy and Shetty, 2005).



**Spunlace nonwoven wound dressing:** Wounds are defined as skin defects caused by mechanical, thermal, electrical and chemical injuries or by the presence of an underlying medical or physiological disorder. Wound dressings are materials used to cover the wounds. The primary function of wound dressings is to avoid strike through and to protect the wounded site from contamination and further injuries. Mostly non woven gauze, wadding material and composite wound dressings are used in wound care application (Yimin Qin, 2001; Mao and Russell, 2004; Van Langenhove, 2007; Rajendran, 2009; Chellamani and Vignesh Balaji, 2010). From the last decades, spunlaced nonwoven gauze replaced the woven gauze with production and sale wise, because of its better cost effective, functional advantages, aesthetic and physical characteristics than traditional woven gauze products. Gauze in the form of sterile dressings, sponges and bandage rolls have been used for decades to cover, protect, absorb body fluids and support wounds. Figure 5 shows the spunlaced structure and spunlaced gauze fabric for wound care purpose.

Fig. 5. Spunlaced structure and spunlaced gauge fabric for wound care purpose (Chellamani and Vignesh Balaji, 2010).

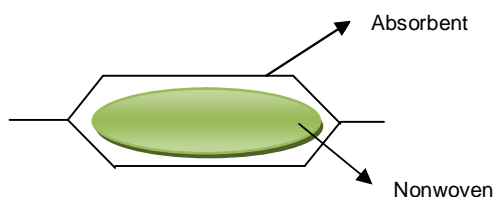


**Surgical fabrics:** Hydroentangled fabrics have long been favoured for surgical gowns, scrub suits, sheet and drapes for their excellent comfort and softness (VeluTech, 2010). In surgical gowns, infection control is paramount and spunmelts and composites containing breathable films are favoured over hydroentangled fabrics where there is a need for improved barrier protection. In surgical gowns, hydroentangled fabrics such as Softesse®, formerly known as Sontara® for medical protection garments and warming gowns, are well established and composites composed of wood pulp from paper hydroentangled onto a PET layer are produced. Disposable hot-water soluble PVA hydroentangled fabrics for surgical scrub suits, gowns and drapes have also been developed.

**Medical gauze fabrics:** Traditionally, yarn-based fabrics found in wound dressings are composed of cotton or cotton blended with 50% viscose rayon. As an alternative, apertured hydroentangled fabrics have led to significant cost savings in this market due to the fact that these fabrics require only fewer layers. Commercially, hydroentangled gauze fabrics composed of 70% viscose rayon and 30% polyester provide high absorbency and low linting properties (Parikh *et al.*, 1999; Russell, 2007).

While absorbent woven gauze has been widely used for wound care, the newer spunlaced nonwovens are an attractive alternative to woven gauze for medical/surgical use (Parikh *et al.*, 1999). Wadding materials is also used for wound care applications. They are a high absorbent materials covered with a nonwoven fabric to prevent wound adhesion or fibre loss (Fig. 6). The absorbent layer made of cellulose pulp, wood pulp, wet laid cotton or viscose fabrics etc.

Fig. 6. Nonwoven wadding materials (Chellamani and Vignesh Balaji, 2010).



Wound dressing is mainly used to cover the wound after operation (Mao and Russell, 2004).

1. The network structure of spun-laced nonwoven cloth can make skin breathe freely. Due to this, the occurrence of wound-infection reduces considerably.
2. A medical pressure-sensitive adhesive is used in the spunlace wound dressing to bind the dressing on the skin. This has moderate viscosity and has no irritation to wound.
3. Being soft, light and elastic, the spunlace wound dressing can comply with body outline and curves without any obstacle to muscle action. Figure 7 show the spunlace nonwoven wound dressing (Mao and Russell, 2004; Chellamani and Vignesh Balaji, 2010).

Fig. 7. Spunlace nonwoven wound dressing (Chellamani and Vignesh Balaji, 2010).



**Baby diaper/Adult incontinence products:** Spunlaced fabrics show high drape, softness and comfortable handle. Due to this, spunlaced nonwovens are preferred for the manufacture of baby diapers/adult incontinence products (AIP). Figure 8 shows the spunlace nonwoven top sheet for baby diaper/adult incontinence products. The softness of these products is due to the fact that entangled structures are more compressible than bonded ones and they have better mobility and partial alignment of fibers in thickness direction. These are a relationship between absorbency capacity and hydroentangling energy used. An increase of hydroentangling energy results in a decrease of absorbency capacity and absorbency rate. Shear modulus is virtually independent of the degree of entanglement (Horrocks and Anand, 2000; Anand *et al.*, 2005; EDANA, 2010).

Fig. 8. Spunlace nonwoven top sheet for baby diaper /adult incontinence products (Chellamani and Vignesh Balaji, 2010).



**Sanitary napkin:** Spunlace nonwoven top surface evacuate liquid quickly and prevent liquid from leaking (Fig. 9). Due to this, spunlaced nonwoven fabrics are preferred for the manufacture of sanitary napkins. Super absorbent polymer (SAP) used for the making of spunlace fabric absorbs liquid quickly and locks it away without rewetting (Horrocks and Anand, 2000; EDANA, 2010). Sometimes healthcare herbs are also added with the nonwoven substrate for remission of pain of ladies, particularly during menstrual period.

Fig. 9. Spunlace fabric used as top layer in sanitary napkin (Chellamani and Vignesh Balaji, 2010).



**Skin care spunlace facial face mask:** Spunlace nonwoven fabric is widely used in facial mask sanitation. Figure 10 shows the spunlace nonwoven facial mask. If the facial mask is often used, it can improve the fatigue level of the skin; rough, dry and dark skin becomes tender. The spunlace nonwoven facial masks are produced using natural wood pulp, bamboo, cotton polyester and viscose fibre (Guangzhou Jiebao Daily Necessities Co., Ltd.).

Fig. 10. Spunlace nonwoven facial mask (Guangzhou Jiebao Daily Necessities Co., Ltd.).



**Other applications of spunlace nonwoven fabrics:** Hydroentanglement is considered to be a highly versatile process because it can be used to produce nonwovens with a broad range of end-use properties. These differences are achieved as a result of a wide range of fibers that are available and also because of the wide range of possible parameter adjustments. The versatility of the hydro entanglement processes is seen as an advantage because this process can be used to combine conventionally formed webs with melt-blown webs, spunbonded webs, paper and scrims in order to get a combination of properties that cannot be achieved by the use of a single web.

Spunlace fabrics can be further finished, dyed and/or printed. They can be treated with binders to allow for wash durability, or with fire retardants to resist burning. The fabric can be treated by antimicrobial agents to enhance resistance against microorganisms. The market for spunlaced fabrics spans from surgical packs and gowns, protective clothing as chemical barriers to wipes, towels and sponges for industrial, medical, food service and consumer applications (Horrocks and Anand, 2000; Adanur, 2005; Russell, 2007; Chellamani and Vignesh Balaji, 2010, EDANA, 2010).

### Conclusion

Nonwovens are heart of the medical and hygiene sector and it is a part of medical textiles, which find applications predominantly in disposable and health care sectors and it will be playing vital role in coming decades in technical textiles. Spunlace Non woven fabrics hold an excellent position in medical textiles, because of its ability to be required performance and excellent features of fabric. This makes exact requirement for health and hygiene sector application. Application of spunlace non woven fabrics has become increasingly in medical hygiene sector, important for a variety of reasons like comfort, safety, user friendly, relatively high absorption abilities, etc. Another important criterion is absence of a binder in the fabric allowing sterilization of the fabric at high temperatures.

### Acknowledgements

Authors are thankful to Dr. Prakash Vasudevan, Director, SITRA for his keen interest in this study.

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