“Nonwoven Technologies: A critical analysis”

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Abstract

Nonwoven fabrics have quietly revolutionized consumer, medical, and industrial market places throughout the world. They have been the ingredient through which many traditional products have been made better and the means by which many new products have been made possible. Nonwovens are the fabrics that you don’t see, but are there where you need them; they are the fabrics that you don’t recognize, but are performing in ways that others can’t.

In this paper an overview regarding the manufacturing of Non-woven have been elaborately emphasizing on fiber usage, various web laying technology, conversion of webs into fabrics along with the fabrics characteristics, market application and conclusion on the market usage.

Keywords: Bonding technique, fiber interlocking laminate nonwoven, sanitary products, tissue, use and throw materials

1. Introduction:

Nonwoven is an engineered fabric structure made directly from fibers, to provide specific function to ensure fitness for purpose. The term “nonwoven” is often used as a generic description of a fabric that is not produced by process of weaving or knitting, more broadly, a fabric that is different from a traditional textile fabric. Like textile fabrics, nonwoven is a planar structure that is produced with varying degrees of integrity, surface texture, thickness, flexibility, and porosity that involves low cost and production process. In fact, the technologies used to make nonwoven fabrics are based on fundamental principles used to produce textiles, papers,
and plastics. In this regard, nonwovens are fabrics that are made by mechanically, chemically, or thermally interlocking layers or networks of fibers or filaments or yarns.

In spite of this mass-production approach, the nonwovens industry produces wide range of fabric properties from open wadding suitable for insulation containing only 2–3% fibers by volume to stiff reinforcing fabrics where the fiber content may be over 80% by volume. One of the major advantages of nonwoven manufacturing is that, it is generally done in one continuous process directly from the raw material to the finished fabric. When compared to other fabric manufacturing techniques non woven technique is found to the best in terms of production ratio.

The production ratio of various techniques are tabulated below

<table>
<thead>
<tr>
<th>Technology</th>
<th>Machine</th>
<th>Production Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weaving</td>
<td>Automatic with shuttle</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Automatic without shuttle</td>
<td>2</td>
</tr>
<tr>
<td>Knitting</td>
<td>Circular knotting</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Warp knitting</td>
<td>16</td>
</tr>
<tr>
<td>Nonwoven</td>
<td>Dry method</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stitch bonding</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Fine fiber carder</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Coarse fiber carder</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>Tufting machine</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>Aerodynamic web making machine</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>Spin bonding machine</td>
<td>200-2000</td>
</tr>
<tr>
<td>Wet method</td>
<td>Rotoformer</td>
<td>2300</td>
</tr>
<tr>
<td></td>
<td>Paper making</td>
<td>40000-100000</td>
</tr>
</tbody>
</table>

2. Raw materials and their properties

The end use of materials has been the driving force for the development of products and technology. Raw material is the key factor in designing of material, the selection of raw material affects the function and quality of the product.
Fiber as raw material with their advantages and disadvantages are tabulated in Table 1.

<table>
<thead>
<tr>
<th>FIBERS</th>
<th>RESULTANT PROPERTY</th>
<th>POSITIVE</th>
<th>NEGATIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>POLYESTER</td>
<td></td>
<td>• Good recovery</td>
<td>• High pilling tendency</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Good Heat setting property</td>
<td>• Formulation of static charge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• High elasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Good drape</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• High wet strength</td>
<td></td>
</tr>
<tr>
<td>ACETATE FILAMENTS</td>
<td></td>
<td>• Good handle</td>
<td>• Low wet strength</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• No pilling</td>
<td>• Low abrasion resistance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Good recovery</td>
<td>• Low softening point</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Good drape</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Easy bonding</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low price</td>
<td></td>
</tr>
<tr>
<td>POLYAMIDE</td>
<td></td>
<td>• Good wet strength</td>
<td>• Bad handle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Good resistance to soiling</td>
<td>• Bad light fastness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Quick drying</td>
<td>• High pilling tendency</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Good chemical resistance</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Good elasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Good heat poecessability</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• High price</td>
</tr>
</tbody>
</table>
### Viscose Filaments
- Good strength
- High bulk
- Good drape
- No pilling
- Easy cleaning
- Low price
- Low wet strength
- Low abrasion resistance
- Slow drying
- Hard handle

### Polyacrylonitrile
- Good recovery
- Good drape
- Excellent chemical resistance
- Soft hand
- High bulk
- Good moisture resistance
- Excellent sun light fastness
- Low abrasion resistance
- Tendency to pilling
- High price

### Cotton
- Good abrasion resistance
- Good bulk
- High wet strength
- Soft handle
- Easy bonding
- Excellent absorption power
- Low price
- Non elastic recovery
- Low resistance to soiling
- Low uniformity of fibers

### Wool
- Good bulk
- High elasticity
- Soft, warm handle
- Quick recovery
- Good absorption power
- Tendency to pilling
- Low abrasion resistance
- High shrinkage
- Low strength
- Unstable price

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General production steps for non woven manufacturing

- **Fibrous matter**
- **Web bonding process**
- **Bonding process**
- **Finishing**
The manufacturing processes for nonwoven fabrics invariably consist of two distinct phases, web formation and followed by subsequent bonding.

3. Web forming Techniques

**Web Formation**

3.1 **Dry laid process:**

In dry laid process, web is produced from staple fibers. These fibers are directly laid from a carding machine to form the matt ranging from 10-2500 gsm. The carding machine used is not the regular ones they are equipped with worker and stripper rollers. There are three methods for dry lying of web.

3.1.1 **Parallel lying:**

The mass per unit area of card web is normally too low to be used directly in a nonwoven. They are increased by laying several card webs one over the other to form the matt. The simplest and cheapest way of doing this is by parallel lying. Figure 1 show five cards raised slightly above the floor to allow a long conveyor lattice to pass underneath. The webs from each card fall onto the lattice forming a matt with five times the mass per unit area.
3.1.2 Cross lying:

In cross lying, the cards (or cards) are placed at right angles to the main conveyor as shown in Fig. 2. In this case the card web is traversed backwards and forwards across the main conveyor resulting in a zig-zag motion as shown in Fig 2.

3.1.3 Air lying:

The air-laying method produces the final matt in one stage without first making the intermediate lighter weight web. It is capable of running at high production speeds but is similar to the parallel-lay method. The width of the final matt is the same as the width of the air-laying machine, usually in the range of 3–4m.

Opened fiber from the opening/blending section is fed into the back of hopper (A), which delivers a uniform sheet of fibers to the feed rollers. The fiber is then taken by the toothed roller (B), which is revolving at high speed. The worker and stripper rollers set to the roller (B) to improve the opening power. A strong air stream (C) dislodges the fibers from the surface of roller B and carries them onto the permeable conveyor on which the matt is formed.
stripping rail E prevents fiber from reticulating round the cylinder B. The air flow at D helps the fiber to stabilize in the formation zone.

![Diagram](image1)

**Fig 3: Air laying technique**

### 3.2 Wet lying

The wet-laid process was mainly developed from papermaking. This was undertaken because the production speeds of papermaking are very high compared with textile production. Textile fibers are cut very short by textile standards (6–20mm), but at the same time these are very long in comparison with wood pulp. The fibers are then dispersed into water and the rate of dilution has to be great enough to prevent the fibers aggregating.

Wet-laid nonwovens represent about 10% of the total market, but this percentage is tending to decline. They are used widely in disposable products, for example in hospitals as drapes, gowns, sometimes as sheets, as one-use filters, and as cover stock in disposable nappies etc.

![Diagram](image2)

**Fig 4: manufacturing of spun laced fabric**
3.3 Polymer lay

3.3.1 Spun lying

Spun lying includes extrusion of the filaments from the polymer raw material, drawing the filaments and laying them into a matt. As laying and bonding are normally continuous, this process represents the shortest possible textile route from polymer to fabric in one stage. When first introduced only large, very expensive machines with large production capabilities were available, but later much smaller and relatively inexpensive machines have been developed. Further developments have made it possible to produce microfibers on spun-laid machines giving better filament distribution. Smaller pores present between the fibers for better filtration, softer feel and also the possibility of making lighter-weight fabrics. For these reasons spun-laid production are increasing more rapidly than any other nonwoven process.

![Spun lying technique diagram](image)

**Fig 5: spun lying technique**

**Melt blown**

Melt blowing is another method of producing very fine fibers at high production rates without the use of fine spinnerets. Figure 6 shows that the polymer is melted and extruded in the normal way but through relatively large holes. As the polymer leaves the extrusion holes it is hit by a high speed stream of hot air at or above its melting point, which breaks up the flow and stretches the many filaments until they are very fine. At a later stage, cold air mixes with the hot and the polymer solidifies. Then the jet of fiber are collected on the collector in the foam of membranes.
4. Bonding Techniques

Bonding is the sequential process in manufacturing of nonwoven product. The web that is formed in the above mentioned process is not sufficient enough to hold them together they have to bonded to ensure no loss of material is found during usage.

4.1 Needle punching technology

The needle punching system is used to bond dry laid and spun laid webs. The needle punched fabrics are produced when barbed needles are pushed through the fibrous web, forcing fibers to form self interlock. This action occurs in needle punching around 2000 times a minute.
In needle punching the bonding of the fiber web is the result of intertwining of the fibers and of the inter fiber friction caused by the compression of the web.

**Product characteristics**

Needle felts have a high breaking tenacity and also high tear strength but the modulus is low and the recovery from extension is also poor. Their unique physical properties like elongation in all (x, y, & z) directions for mould able applications is good. High strength makes them an overwhelming choice of geo-textiles. The principal advantage is that the nonwoven is practically homogeneous in comparison with a woven fabric so that the whole area of a nonwoven filter can be used for filtration, whereas in a woven fabric the yarns effectively stop the flow, leaving only the spaces between the yarns for filtration.

**Applications of a needle punched nonwovens**

<table>
<thead>
<tr>
<th>Geotextiles</th>
<th>Automotive fabrics</th>
<th>Hometech</th>
<th>Sportech</th>
<th>Furniture</th>
<th>Other technical felts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road and railway construction, dams, roofing and drain felts, shore protection,</td>
<td>Head liners, door trim, parcel shelves, carpets, insulation felts, gas filters</td>
<td>Carpets, wall coverings, decor felts, wipe blankets...</td>
<td>Shoe, bags, sport goods</td>
<td>Shoulder pads, waddings, mattresses</td>
<td>polishing felts, abrasive felts, mineral fiber felts for insulation</td>
</tr>
</tbody>
</table>
4.1.2 Hydro entanglement/Spun lace technology

The process of producing an entanglement by means of heavy water jets at very high pressures through jet orifices with very small diameters is spun lace technique. This is similar to a needle loom, but uses lighter weight mat. A very fine jet of this sort is liable to break up into droplets, particularly if there is any turbulence in the water passing through the orifice. If droplets are formed the energy in the jet will spread over a much larger area of mat so that, the energy per unit area will be much less. Consequently the design of the jet to avoid turbulence and to produce a needle-like stream of water is critical.

![Diagram of Hydro entanglement technique](image)

**Fig 8: Hydro entanglement technique**

**Product characteristics**

Products made from spun lace technique have very good textile drape (low stiffness) and very soft to handle. No chemical or melt binder is required thereby making its product possible to prepare 100% natural fibers suitable for sanitary products.

A uniform surface can be obtained due to more fine interlacing of fibers (compared to needling). Very high textile production: up to 300 m/min for carded airlaid webs and of up to 500 m/min for wetlaid and spunbond (meltblown) can be made. Fabric width up to 6000 mm can be produced. So wide range of textile structure (depending especially on the perforated belt structure) can be designed and manufactured.
Spunlace applications:

<table>
<thead>
<tr>
<th>Hospital</th>
<th>Medical</th>
<th>Sanitary products</th>
<th>Household products</th>
<th>Industrial textiles</th>
<th>Automotive products</th>
<th>Other applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>surgical gowns and drapes, operational cover sheets, bed sheets, towels</td>
<td>wound dressings, gauze, wet tissue, cotton products, pads.</td>
<td>baby wipes, facial clean wipe, face masks, disposable pants.</td>
<td>cleaning wipes, protection fabric for electronics, home furnishing fabrics, table cloths and napkins, curtains.</td>
<td>industrial wipes, filtration, roofing, water insulation, protective apparell, liquid absorbents</td>
<td>headliners, cleaning wipes</td>
<td>Interlinings Coating substrates for synthetic leather.</td>
</tr>
</tbody>
</table>

**Stitch bonding technique**

It is a technique in which fibers in a web are bonded together by stitches sewn or knitted through the web to form a fabric. The finished fabric usually resembles corduroy. The fibers are bonded into the loops but the thread does not contribute to loop formation. The basic types of structure are pillar-stitch and tricot-stitch (Fig.9). It is also possible to use two systems of threads, so both the types of structure can be simultaneously applied.

![Fig 9: Formation of stitch bonding](image-url)
Product characteristics

They are highly voluminosity, softness and have good absorbent behavior, good elasticity and air-permeability. Finishing the raw web-knitted material by means of raising, cropping or tumbling, an even raised pile is achievable in heights ranging from 2 to 17 mm. Such pile web-knitted fabrics with base material are suitable for the manufacture of blankets, shoe lining, soft toy material and lining for winter garments.

Applications of stitch bonded fabrics:

<table>
<thead>
<tr>
<th>Applications of stitch bonded fabrics:</th>
<th>Automotives</th>
<th>Upholstery</th>
<th>Sport tech</th>
<th>Apparel</th>
<th>Others application</th>
</tr>
</thead>
<tbody>
<tr>
<td>surface covers for various molded components, parcel shelves and head liners</td>
<td>covering material for mattresses and beds, decorative fabric, base material are suitable for the manufacture of blankets</td>
<td>Fabric in training shoes, shoe lining</td>
<td>Lining for winter garments.</td>
<td>For insulation, soft toy material, filtration materials as well as packing materials.</td>
<td></td>
</tr>
</tbody>
</table>

Adhesive/Chemical Bonding

Chemical bonding involves treating either the complete matt or alternatively isolated portions of the matt with a bonding agent with the intention of producing cohesion between fiber layers. Although many different bonding agents could be used, the modern industry uses only synthetic lattices, of which acrylic latex represents at least half, and styrene–butadiene latex and vinyl acetate latex roughly a quarter each. When the bonding agent is applied it is essential that it wets the fibers, otherwise poor adhesion might result. Most lattices inherently contain a surfactant to disperse the polymer particles, but in some cases additional surfactant may be needed to aid wetting. Followed by drying of latex by evaporating the aqueous component and leaving the polymer particles together with the additives. During this stage the surface tension of the water pulls the binder particles together forming a film over the fibers and a rather thicker film over the fiber intersections. Smaller binder particles will form more effective film than
larger particles, other things being equal. The final stage is curing and in this phase the matt is brought up to a higher temperature than drying for the fixation to take place.

There are different ways to carry out the chemical bonding process. Some of the commonly used ones are:

- **Saturation bonding**: saturation bonding wets the whole matt with bonding agents, so that all fibers are covered in a film of binder.
- **Foam bonding**: Application of chemicals as foam. The binder solution and measured volume of air are passed continuously through a driven turbine which beats the two components into consistent foam.
- **Spray bonding**: Similar latex binders may also be applied by spraying, using spray guns similar to those used in painting, which may be either operated by compressed air or be airless.
- **Print bonding**: Print bonding involves applying the some types of binder to the matt but the application is to limited areas and sets a pattern
- **Powder bonding**: the bonding agent in the powder form is sprinkled.

**Product characteristics**

The fabric property is governed by the elastic nature of the fiber and the resin. Hence the fabric modulus is of the order of the fiber modulus that is extremely high. A high modulus in a spatially uniform material means that it will be stiff, which explains why saturation-bonded fabrics are very stiff relative to conventional textiles. At the same time tensile strength is low, because the bonds tend to break before most fibers break.

Print-bonded fabrics are much softer in feel and also much more flexible owing to strong effect of the free fibers in the unbounded areas. They are also significantly weaker than saturation-bonded fabrics owing to the fibers slipping in unbounded areas, but knowing the fiber length and the fiber orientation distribution it is possible to design a print pattern which will minimize the strength loss.

Each spray application alters the thickness of the matt slightly, but it is still left substantially lofty, the drying and curing stage also causes some small dimensional changes. The
final product is a thick, open and lofty fabric used widely as the filling in quilted fabrics, for duvets, for some upholstery and also for some types of filter media.

**Applications of chemical bonded fabrics:**

<table>
<thead>
<tr>
<th>Apparel purpose</th>
<th>Sanitary purpose</th>
<th>Home tech</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interlining fabric for textile clothing, disposable/protective clothing.</td>
<td>Some types of filter fabric, in some cover stock and in wiping cloths.</td>
<td>filling in quilted fabrics, for duvets, for some upholstery</td>
</tr>
</tbody>
</table>

4.3 Thermal bonding

Thermal bonding is increasingly used at the expense of chemical bonding for a number of reasons. Thermal bonding can run at high speed, whereas the speed production of chemical bonding is limited by the drying and curing stage. Thermal bonding takes up little space compared with drying and curing ovens. Also thermal bonding requires less heat compared with the heat required to evaporate water from the binder, so it is more energy efficient.

Thermal bonding requires a thermoplastic component to be present in the form of a homophile fiber, powder, film, web, hot melt ores a sheath as part of a bicomponent fiber. Heat is applied until the thermoplastic component becomes viscous or melts. The polymer flows by surface tension and capillary action takes place at fiber-to-fiber crossover points where bonding regions are formed.

![Fig 10: Thermal bonding technique](image_url)
Methods of thermal bonding
✓ Hot calendaring
✓ Belt calendaring
✓ Through-air thermal bonding
✓ Ultrasonic bonding
✓ Radiant-heat bonding, etc.

Product characteristics:
Products can be relatively soft and textile-like depending on blend composition and bond area. The material production does not involve any chemical use making it environmentally friendly and 100% recycling of fiber components can be achieved. High bulk products can be bonded uniformly throughout the web cross section.

Applications:

<table>
<thead>
<tr>
<th>Designing</th>
<th>Upholstery</th>
<th>Food processing</th>
<th>Medical textile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composites and Laminates</td>
<td>Interlinings, Carpet backings</td>
<td>Food coverings, Tea bags</td>
<td>Cover stock for sanitary products, Wiping cloths</td>
</tr>
</tbody>
</table>

Finishing
Non woven are considered finished products when they are out of the production line no external chemical or mechanical finishing is required to maintain its property. Special treatments like flame retardant, antistatic agents, antimicrobial, coloration might be applied to increase their functional property.

General overview
Needle felts have a high breaking tenacity and also high tear strength but the modulus is low and the recovery from extension is also poor. For this reasons, needle felts subjected to load has to have some form of reinforcement to control the extension to give better dimensional stability and increases the resistance to wear.

The wipes produced by hydro entanglement are guaranteed lint free, because it is argued that if a fiber is loose it will be washed away by the jetting process. It is interesting to note that
the hydro entanglement process came into being as a process for entangling mats too light for a needle loom, but that the most recent developments are to use higher water pressures (400 bar) and to process heavier fabrics at the lower end of the needle loom range. Fabric uses include wipes, surgeon’s gowns, disposable protective clothing and backing fabrics for coating.

Thermal bonding is much less energy intensive, kinder to the environment and more economical. The bonding method has a significant effect on product properties. Depending on the bonding method, product properties vary from nonporous, thin, and non extensible, and nonabsorbent to open, bulk, extensible and absorbent. All thermal bonding methods provide strong bond points that are resistant to hostile environment and to many solvents too. Bond strength increases up to a maximum and then decreases with increase in bonding temperature for both staple fiber thermal bonding webs. Bond strength increases with increase in bond area. Bond strength increases with increase in bond size. Effect of bonding temperature, bond area, and bond size on fiber morphology in the unbonded region is negligible.

**Conclusion**

Nonwoven fabrics have quietly revolutionized consumer, medical, and industrial Market places throughout the world. They have been the ingredient through which many traditional products have been made better and the means by which many new products have been made possible.

Nonwovens are the fabrics that we don’t see, but are there where we need them; they are the fabrics that we don’t recognize, but are performing in ways that others can’t. Each of the basic technology systems has its specific advantages and limitation. Researches and experimental works are being carried out to explore the best possible use of nonwoven.

Although the world market of nonwoven products continuously grows, it faces the structural readjustment followed by the change of global economic condition, raw material capacity and consumers’ needs and behavior. In addition, new expansionary manufacturers are emerging while the existing nonwoven producers are concerned by present consumers.
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