NONWOVEN
TECHNOLOGY

For Unconventional fabrics

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<table>
<thead>
<tr>
<th>Sr. no.</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>INTRODUCTION TO NONWOVEN FABRICS</td>
</tr>
<tr>
<td>2</td>
<td>RAW MATERIALS</td>
</tr>
<tr>
<td>2.1</td>
<td>FIBROUS MATTER</td>
</tr>
<tr>
<td>2.1.1</td>
<td>FIBER DESCRIPTION CONSIDERATIONS</td>
</tr>
<tr>
<td>2.1.2</td>
<td>PROPERTIES OF NONWOVEN FABRICS PRODUCED USING DIFFERENT FIBROUS MATTER</td>
</tr>
<tr>
<td>2.2</td>
<td>BONDING AGENTS USED IN NONWOVEN FABRICS</td>
</tr>
<tr>
<td>2.2.1</td>
<td>PROPERTIES DESIRED IN A BONDING AGENT</td>
</tr>
<tr>
<td>2.2.2</td>
<td>WORKING OF BINDERS</td>
</tr>
<tr>
<td>2.2.3</td>
<td>CLASSIFICATION OF BINDERS</td>
</tr>
<tr>
<td>2.2.4</td>
<td>TYPES OF BINDERS</td>
</tr>
<tr>
<td>3</td>
<td>CLASSIFICATION OF NONWOVEN FABRICS</td>
</tr>
<tr>
<td>4</td>
<td>PRODUCTION STEPS FOR DIFFERENT METHODS</td>
</tr>
<tr>
<td>4.1</td>
<td>GENERAL PRODUCTION STEPS FOR MFG. NONWOVEN FABRICS</td>
</tr>
<tr>
<td>4.2</td>
<td>DRY BONDED FABRIC PRODUCTION STEPS</td>
</tr>
<tr>
<td>4.3</td>
<td>SPUN BONDED FABRIC PRODUCTION STEPS</td>
</tr>
<tr>
<td>4.4</td>
<td>WET BONDED FABRIC PRODUCTION STEPS</td>
</tr>
<tr>
<td>5</td>
<td>TYPES OF WEBS AND THEIR FORMING TECHNIQUES</td>
</tr>
<tr>
<td>5.1</td>
<td>STAPLE FIBER WEBS</td>
</tr>
<tr>
<td>5.1.1</td>
<td>WET-LAID WEBS</td>
</tr>
<tr>
<td>5.1.2</td>
<td>DRY-LAID WEBS</td>
</tr>
<tr>
<td>5.1.2.1</td>
<td>FIBER PREPARATION</td>
</tr>
<tr>
<td>5.1.2.2</td>
<td>OPENING, CLEANING, BLENDING AND MIXING</td>
</tr>
<tr>
<td>5.1.2.3</td>
<td>CARDING</td>
</tr>
<tr>
<td>5.1.2.4</td>
<td>WEB LAYING</td>
</tr>
<tr>
<td>5.1.2.4.1</td>
<td>PARALLEL-LAID WEBS</td>
</tr>
<tr>
<td>5.1.2.4.2</td>
<td>CROSS-LAID WEBS</td>
</tr>
<tr>
<td>5.1.2.4.3</td>
<td>RANDOMLY-LAID WEBS</td>
</tr>
<tr>
<td>5.2</td>
<td>CONTINUOUS FILAMENT WEBS</td>
</tr>
<tr>
<td>5.2.1</td>
<td>SPUN-LAID WEBS</td>
</tr>
<tr>
<td>5.2.2</td>
<td>MELT BLOWN WEBS</td>
</tr>
</tbody>
</table>
### 6. NONWOVEN FABRIC BONDING TECHNIQUES

#### 6.1. MECHANICAL BONDING

- **6.1.1.** NEEDLE PUNCHING TECHNOLOGY
- **6.1.2.** STITCHED BONDING TECHNOLOGY
- **6.1.3.** HYDROENTANGLEMENT

#### 6.2. ADHESIVE BONDING OR CHEMICAL BONDING

- **6.2.1.** SATURATION ADHESIVE BONDING
- **6.2.2.** SPRAY ADHESIVE BONDING
- **6.2.3.** FOAM BONDING
- **6.2.4.** APPLICATION OF POWDERS
- **6.2.5.** PRINT BONDING
- **6.2.6.** DISCONTINUOUS BONDING

#### 6.3. THERMAL BONDING

- **6.3.1.** HOT CALANDERING
  - **6.3.1.1.** AREA BONDING
  - **6.3.1.2.** POINT BONDING
  - **6.3.1.3.** EMBOSsing
- **6.3.2.** BELT CALANDERING
- **6.3.3.** THROUGH-AIR BONDING
- **6.3.4.** ULTRASONIC BONDING
- **6.3.5.** RADIANT HEAT BONDING

#### 6.4. BONDING OF SPUN-LAID WEBS

### 7. FINISHING OF NONWOVEN FABRICS

#### 7.1. INTRODUCTION

#### 7.2. CLASSIFICATION OF FINISH APPLIED TO NONWOVEN FABRICS

#### 7.3. SHRINKAGE

#### 7.4. WRENCHING AND CREPING

- **7.4.1.** WRENCHING
- **7.4.2.** CREEPING: THE MICREX-MICROCREPE PROCESS

#### 7.5. PROCESSCRABBING, CALENDERING AND PRESSING

- **7.5.1.** GLAZING OR ROLLER CALANDERING
- **7.5.2.** MOIRE OR GOFFERING CALENDER
- **7.5.3.** ROLLER PRESSES

#### 7.6. PERFORATING AND SLITTING

- **7.6.1.** PERFORATING
- **7.6.2.** SLITTING
### NONWOVEN FABRICS

#### 7.7. SPLITTING, GRINDING, VELOURING AND SINGEING
- **7.7.1.** SPLITTING
- **7.7.2.** GRINDING AND VELOURING
- **7.7.3.** SINGING

#### 7.8. WASHING

#### 7.9. DYEING

#### 7.10. PRINTING

#### 7.11. CHEMICAL FINISH
- **7.11.1.** ANTISTATIC FINISH
- **7.11.2.** ANTIMICROBIALS
- **7.11.3.** WATER REPALENT FINISH
- **7.11.4.** LUBRICANTS
- **7.11.5.** UV ABSORBERS AND POLYMER STABILIZERS
- **7.11.6.** FLAME RETARDENT
- **7.11.7.** SOFTNERS
- **7.11.8.** ABSORBENCY AND REWETTERS
- **7.11.9.** THERMOPLASTIC BINDERS, RESINS AND EMULSION POLYMERS
- **7.11.10** THERMOSETTING RESINS AND CROSSLINKING AGENTS
- **7.11.11.** SOIL RELEASE
- **7.11.12.** OPTICAL BRIGHTNERS

#### 7.12. COATING

#### 7.13. LAMINATING
- **7.13.1.** WET-LAMINATING
- **7.13.1.** DRY-LAMINATING

#### 7.14. FLOCKING

#### 8. TESTING AND EVALUATION OF NONWOVEN FABRICS
(1.) INTRODUCTION TO NONWOVENS
We know that nonwoven fabrics are one of the oldest and simplest textile fabrics. Its classic example is felt. The first well documented discovery of felt dates back 3500-3000 BC. It was made from hairs of various animals. The term “Nonwoven fabrics” was applied to new modern techniques, which were totally based on new principles, by U.S.A. in 1965. “Non woven fabrics” is being defined into different ways by different literatures; the term defined by “Textile oregano” in 1965 is as follows:

“Nonwoven fabrics are products made of parallel laid, cross laid or randomly laid webs bonded with application of adhesive or thermoplastic fibers under application of heat and pressure.”

In other words nonwoven fabric can be simply defined as a fabric those can be produced by a variety of processes other than weaving and knitting.

The nonwoven fabric properties depends on following particulars to an great extent,

1. The choice of fibers.
2. Technology which determines how the fibers are to be arranged.
3. The bonding process and the bonding agent.

Fabric properties of nonwovens range from crisp to that soft-to-the –touch to harsh, impossible-to-tear to extremely weak. This leads to a wide range of end products such as nappies, filters, teabags, geotextiles, etc. some of which are durable and others are disposable.

The first stage in the manufacturing process of nonwoven fabrics is “production of web” and another is “bonding of web by using several methods”. Some of those (binding methods) are felting, adhesive bonding, thermal bonding, stitch bonding, needle punching, hydro-entanglement and spin laying.

(2.) RAW MATERIALS

(2.1.) FIBROUS MATTER

The definition of nonwoven fabrics states that fibers are held together by a bonding agent to form a fabric. The art of choosing the right fiber to combine with the right binder by the most efficient process to obtain a desired fabric is the absolute goal of nonwoven manufacturing.
Virtually all types of fibrous material can be used to make nonwoven bonded fabrics, the choice being dependent on:

- The required profile of the fabric
- The cost/use ratio (cost effectiveness)
- The demands of further processing.

Since nonwoven bonded fabrics are almost always developed to meet specific requirements, the correct choice of fiber is of supreme importance. It is not only a question of finding the best kind of fibers, but of taking special properties of the fiber concerned into consideration.

It is essential for the development and production of nonwoven bonded fabrics for a comprehensive study to be made of the properties of different fibers. This can be done by comparing the requirements to be met by the particular fabric with results obtained from the various individual fibers.

The fibers used in the greatest volume in nonwoven fabrics today are cotton, rayon, acetate, nylon and wool. The synthetics, such as polyesters and acrylics, are being used increasingly, not necessarily to replace cheaper fiber but in fabrics intended for new and more exacting applications. Finally the very newest fibers are modifications of standard types to make them especially adaptable to nonwovens, e.g. self-bonding viscose rayon and the synthetic polymeric fibers known as ‘fibrids’.

**Cotton**

Although the early cotton nonwoven made exclusively from low-cost, low-grade cotton waste has almost disappeared from the market, cotton in various forms is still used extensively in nonwoven fabrics. The cotton used today may be a waste, such as a comber, and will produce a soft, absorbent nonwoven fabric with good bulk and bonding properties. The practice of blending various fibers affords the opportunity to use clean inexpensive grades in blends with the more uniform man-made fibers. The principle uses for cotton are in disposables and medical textiles, which together absorbed about 30% of the total poundage, although many other fibers are now used in these fields along with cotton.

**Rayon**

Of the man-made fibers rayon (viscose) has been the leader in bringing about changes in the industry and today finds practical use in a wide variety of fabrics. This popularity is due to the following factors:

- Low cost
- Ease of processing on all types of web-forming and bonding equipment
A wide variety of description, i.e., range of deniers, range of lengths, range of finishes, crimped and uncrimped, bleached and unbleached.

Where added softness, dull whiteness, high bulk and absorbency are essential, as in surgical and sanitary application, the low-denier, dull, bleached, crimped fibers are generally used. For filtration of fine particles one denier finds application, while deniers as coarse as 40 or more may be used in air filters where the semi-rigid, coarse open structure is desired. Blending of a variety of deniers is often necessary in a single product.

**Acetate**

Prior to the use of rayon in nonwovens a plasticized acetate had been developed as a bonding fiber for cotton webs, and it is still used in this way with both rayon and cotton. However, in the unplasticized form in both fine and coarse deniers as regular, bright or dull crimped fiber. Its low price, good dimensional stability, thermo plasticity, mildew resistance and low moisture absorption combine together to make this fiber particularly attractive for many dry-processed nonwovens where strength is not a major factor.

**Wool**

The use of wool in nonwovens has been limited by its price and by the inability to utilize its characteristics to the best advantage in the early types of nonwovens. Now wool is being used in applications where bulk, warmth, and loft retention are important. Usually either a waste or a reworked staple is blended with synthetics to reduce fabric cost.

**Polyamides and polyester**

From 25-50% of polyamide or polyester may be used in nonwoven fabrics for interlinings, particularly where wash-and-wear characteristics are important. Applications requiring exceptional resistance to flexing, abrasion, or chemicals, with price only a secondary factor, may use 100% of these fibers in blends of low and high softening type to form both structure and bonding media, e.g., nonwoven polyester tapes for electrical applications. The heat setting properties of these fibers can be employed with advantage in the manufacturing of nonwoven fabrics by needle punching.

**Acrylic**

In spite of the comparatively high price of acrylcs they are being used extensively in high-grade fabrics, especially those made by spray bonding, because of high bulk of the fibers, good recovery, comfortable cushioning effect, resistance to moisture and chemicals, wash ability and suitability for dry cleaning. Produced in coarse deniers with high crimp, the acrylcs are especially good for furniture and automotive cushioning. In needle looms they are showing promise
in apparel applications. The heat-setting properties of these fibers can be employed with advantage in the manufacturing of nonwovens by the needle punching technology.

Other fibers

Fibers that are finding limited use for special products or on specially adapted machinery are glass fibers for reinforcing mats for lamination, ceramic fibers, thermoplastic vinyl resin type for bonding with heat and pressure, asbestos and sulfite used in blends. Most of this fibers uses are too specialized to be within the scope of this book and are not in the range of products marketed as nonwovens, although they are nonwovens further processed and fabricated.

(2.1.1.) FIBER DESCRIPTION CONSIDERATIONS

In selecting fiber for use in nonwoven fabrics the fiber description, i.e. the crimp, length, deniers per filament and finish, is fully as important as fibers.

Crimp

It is almost impossible with most equipment to produce a nonwoven fabric from a completely straight fiber. The natural fibers have varying amount of crimp and, just as the cut filament must be crimped for spinning, a crimp is necessary for formulation of manageable web for nonwoven fabric production. Curly fibers are better than straight and usually curlier the better. Highly crimped fibers tend to form more uniform web which will retain its original structure during the subsequent process.

The amount and type of crimp may be determined by the requirements of the finished product. For example a nonwoven intended for padding or cushioning in automobiles or furniture applications where loft and resiliency are required must be made from fiber having a permanent crimp. In spray process the penetration of a binder is directly dependent on the crimp and the relation ship between crimp and denier.

Denier

The choice of denier per filament for fiber to be used in nonwovens is governed primarily by the requirements of the end product. The use of the finer fibers results in great density, strength and softness and at the same time a more opaque sheet (fine fiber has more “covering” power).

Heavy deniers are easier to open for production of a uniform web at higher speeds than fine deniers. The adjustment of the processing equipment of the denier of the fiber used is a very important factor in successful nonwoven fabric production.
Length

The staple length of the fibers to be used depends on the type of web forming equipment selected for production line in most cases longer fibers can be used in cards and garnets better than in air lay machines, but there is no advantage in fabric strength derived from longer fiber. In any type of web forming nonwoven fabrics, manufacturers have learned through the experience that low production rates and poor quality fabrics usually result from the use of fibers that are too long. Another result of long fibers may be excessive breakages.

Finish

The finish on the fiber surface is usually designated as “bright”, “dull”, or “semi-dull” and the selection is arbitrary depending on the lusture or appearance desired in the end product.

(2.1.2.) PROPERTIES OF NONWOVEN FABRICS PRODUCED USING DIFFERENT FIBROUS MATTER

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<tr>
<th>FIBERS</th>
<th>RESULTANT PROPERTY</th>
</tr>
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<tbody>
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<td>POSITIVE</td>
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<tr>
<td>POLYESTER</td>
<td>• Good recovery</td>
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<td></td>
<td>• Good Heat setting property</td>
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<td></td>
<td>• High elasticity</td>
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<td></td>
<td>• Good drape</td>
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<tr>
<td></td>
<td>• High wet strength</td>
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<tr>
<td>ACETATE FILAMENTS</td>
<td>• Good handle</td>
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<td></td>
<td>• No pilling</td>
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<tr>
<td></td>
<td>• Good recovery</td>
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<td></td>
<td>• Good drape</td>
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<td></td>
<td>• Easy bonding</td>
</tr>
<tr>
<td></td>
<td>• Low price</td>
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<tr>
<td>POLYAMIDE</td>
<td>• Good wet strength</td>
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<td></td>
<td>• Good resistance to soilin</td>
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<tr>
<td></td>
<td>• Quick drying</td>
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<tr>
<td></td>
<td>• Good chemical resistance</td>
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<tr>
<td></td>
<td>• Good elasticity</td>
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<td>• Good heat processability</td>
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</table>
### Sheet-2 nonwoven fabric fiber usage table

**10. BONDING AGENTS USED IN NONWOVENS**

The bonding agents are the ‘glue’ as it binds the web firmly together to give the nonwoven fabric. These agents largely determine the wear properties of the nonwoven fabrics.
Fabrics made from a combination of fibers and bonding agent is defined as a nonwoven bonded fabric (DIN 61210- German Standards Committee).

The bonding agents have such a great influence on the properties of the fabric that the requirements of the finished product determine the choice of bonding agent. The following characteristic features of nonwoven fabrics decide which bonding agent is most suitable:

- Strength / stretch (resistance to pilling, tearing and ripping)
- Elastic tenacity and bend-ability (‘spring elasticity’)
- Handle and draping qualities
- Washing and dry cleaning fastness
- Resistance to chemicals
- Resistance to air and oxygen
- Resistance to light and heat
- Flame resistance property
- Hydrophilic or hydrophobic properties

The bonding agents used might be liquid bonding agents or solid bonding agents in form of fibers, powders or paste. The range of chemical substances that can be used in polymer dispersion is exceptionally wide, but the most important are:

- Butadiene polymers, often known as synthetic latex or as unsaturated polymers,
- Acrylic acid polymers, also called saturated polymers
- Vinyl polymers (vinyl acetate, vinyl ether, vinyl ester, vinyl chloride)

Bonding fibers are usually made from thermoplastic polymers. The most important of the former kind are polyvinyl alcohol (PVA), co-polyamide, polyolefin, polyester and polyvinylchloride. Among the powders and pastes made from them, those used are co-polyamides, polyethylene and ethylene vinyl acetate (EVA) copolymers.

Sheet 2- Specific property requirements of a selection of nonwoven fabrics and areas of use of important bonding agents.

(2.2.1.) PROPERTIES DESIRED IN A BONDING AGENT

The construction of a nonwoven with suitable binders is to achieve improved characteristics such as strength, softness, adhesion, firmness, durability, stiffness, fire retardence, hydrophilicity, hydrophobicity, anti-microbial properties, organic compatibility, reduced surface tension, improved dimensional stability and solvent, wash and acid resistance.
The following list illustrates some general considerations required for an ideal binder. The required properties can be varied depending on the end-uses.

- **Strength**: The strength of a nonwoven fabric is more closely related to the strength of the applied binder.

- **Adhesion to Fibers**: Even though the mechanism of adhesion is not completely understood, the adhesion strength of the binder-to-fiber bond has to be considered.

- **Flexibility/handle**: The some movements of fibers should be allowed, especially when a soft hand is desired.

- **Elastic Recovery**: To avoid the permanent deformation of fabric, good elastic recovery is required under strain.

- **Minimum film forming temperature**: At this temperature a bonding film will dry without cracking which will occur if the temperature falls below this point. It can be reduced by adding softeners or optical brighteners.

- **White point (ISO standard 2115)** is the temperature at which the layers of polymer particles that has not yet turned into the film below this point. The whitening point is always 1-2°C below the minimum film forming temperature.

- **Glass or brittle temperature** is the average temperature of the range in which the polymer passes from being hard and brittle to being soft and rubber like. This temperature will give an indication of the feel, the flexibility and the hardness of bonding film.

- **Resistance to washing/ Drying cleaning**: Some nonwoven products need durability in cleaning processes according to their end-uses.

- **Resistance to aging**: The binder should be stable and not be degraded in the fabric during storage and use.

- **Good color and color retention**: Diverse ranges of colors are required, and the colorfastness and yellowing problems should be considered.

- **Economical**: Minimizing the cost is an on going requirement.

- **Other special requirements**: Such as Flame resistance, resistance to chemicals, air, oxygen, light, heat, etc.
(2.2.2.) WORKING OF BINDERS

The working of binder mainly involves three stages viz.

1. Binder application to nonwoven web.
2. Removal moisture or solvent.
3. Formation of strong bond between binder and nonwoven web.

The general binders applied to the nonwoven fabrics are mostly produced using *emulsion polymerization*.

- **Emulsion polymerization**

Drops of monomers (single or group) which are polymerisable and insoluble in water are dispersed in an aqueous phase containing an emulsifier. The radical reaction is started by the presence of catalyst (hydrogen-peroxide, per-sulphate). It takes place in the droplets of monomer that are surrounded by the emulsifiers. The polymer particles which forms are very much smaller than the monomer droplets and they form the inner phase (the polymer, either a homo-polymer or a copolymer).

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![Figure 1 Emulsion polymerization](image)

The polymer binder can be also produced by using other polymerization methods such as *Graft polymerization*, *solution polymerization* and *suspension polymerization*.
After application of the binder to the nonwoven web the polymer particles in the dispersion come closer to each other as the water evaporates until coagulation occurs. At this moment strong capillary forces are activated which are responsible for the deformation of the particles and merge them together. The film forms, the process is irreversible. This phenomenon is shown in fig 2.

Binder factors influencing nonwoven performance are:

1. Backbone Structure
2. Functional Group
3. Surfactant
4. Process

(2.2.3.) CLASSIFICATION OF BINDERS

The binders available are mainly classified according to their chemical structures. There are three main kinds of binders viz.

- Butadiene copolymers
- Acrylates
- Vinyl copolymers

1. Butadiene copolymers

The butadiene polymers are cross-linked by poly-sulphides, and their properties are modified by different copolymers. The butadiene monomers provide elasticity while styrene and acrylonitrile monomers give tensile strength, and oil and solvent resistance, respectively. Their disadvantages are oxidation and discoloration due to residual double bonds in their polymer chains

2. Acrylates (Acrylic acid derivatives)

Acrylic binders are the most widely used and versatile binders available with various modifications. The properties of acrylic binders differ according to their derivatives and copolymers. They are frequently copolymerized with styrene, acrylonitrile, vinyl chloride or vinyl acetate, depending on the desirable
properties. Some of these properties are hardness from styrene, solvent resistance from acrylonitrile, flame retardence from vinyl chloride, and cost benefits from vinyl acetate.

3. Vinyl copolymers

There are two main binders for vinyl copolymers: vinyl chloride and vinyl acetate. Since the vinyl binders are stiff, they are plasticized externally or internally. As internal plasticizers, ethylene and acrylate monomers are used, and external plasticizers consist of vinyl chloride. Vinyl acetate is not that stiff, and its advantage is low cost. The chlorides cause yellowing problems. The chemical structures are closely related $T_g$ and stiffness of binders.

(2.2.4.) TYPES OF BINDERS

The following comparison of binder chemical types provides an indication of the relative performance, as well as the advantages and disadvantages of each type of binder. As indicated, the binder properties can be modified considerably by the presence of co-monomers.

i) Acrylic: These binders offer the greatest durability, color stability, and dry/wet performance. Acrylic binders have the widest range of fabric hand properties. They can be formulated to vary from very soft to extremely hard. These binders can be used in virtually all nonwovens applications, although they tend to be more costly. These polymers can be made to cross-link, with substantial improvement in durability.

ii) Styrenated Acrylics: These are tough, hydrophobic binders. The resulting textile hand ranges from soft-to-firm. These binders can be used in applications where there is a need for some wet strength without crosslinking. The use of this type of latex binder does involve some sacrifice in UV and solvent resistance.

iii) Vinyl Acetate (VAC): The vinyl acetate binders are firm; however, they are relatively low cost and find extensive use. They offer good dry strength and toughness, but are somewhat hydrophilic and have a tendency to yellow when subjected to heat.

iv) Vinyl Acrylics: These binders are more hydrophobic than the straight VAC binders. They provide excellent toughness, flexibility, and better color stability. They are the compromise between VAC and acrylic, and can compete on a cost/performance basis. The hand range is limited to intermediate softness to a firm hand.
v) Ethylene Vinyl Acetate (EVA): These binders exhibit high wet strength, coupled with excellent absorbency. In general, they are less costly than acrylics. They do have a tendency to have more of an odor compared to other binders. They are used primarily in wipes, air-laid pulp fabrics and similar applications.

vi) Styrene-Butadiene (S/B, SB, or styrene butadiene rubber): These binders have an excellent combination of flexibility and toughness. They range in hardness from very soft to very firm. The styrene-to-butadiene ratio (S/B ratio) is the most common method for describing the relative hand resulting from the use of these binders. When cross-linked, this class of binder is very hydrophobic and durable. They are affected somewhat by heat and light because of their tendency to oxidize.

vii) Polyvinyl Chloride (PVC): The homopolymer of polyvinyl chloride is a very hard, rigid polymer. This polymer must be plasticized to provide flexibility and film-forming properties. Normally, the (PVC) binders used in nonwovens are softened internally by co-polymerizing the vinyl chloride or with softer acrylic monomers. The hand range of most of these polymers is still relatively firm. Because this type of polymer is a thermoplastic, it performs well in heat and dielectric sealing applications. This can be an advantage in some uses. The chlorine content of the polymer promotes flame retardence. This feature is one of the primary benefits of utilizing this type of binder. However, the chlorine also conveys the tendency to yellow upon heat aging, due to elimination of hydrogen chloride from the polymer.

viii) Ethylene/ Vinyl Chloride: Binders in this class have a slightly broader hand range without the external plasticization required of (PVC) binders. The presence of the chlorine again conveys some flame retardence. These binders exhibit good acid resistance, fair water resistance, and excellent adhesion to synthetic fibers. There is some tendency to yellow upon aging. In essence, this is an internally plasticized (PVC) binder, considering the ethylene monomer to be the softener.

ix) Butadiene acrylonitrile (NBR copolymers): As the proportion of acrylonitrile in the copolymer rises so the hardness of the bonding film increases and the extent to which it will swell in fat, oil, and organic solvent decreases. But the solvent resistance is never as high as a numerous acrylates. The abrasion resistance is favorable and has low thermo-plasticity. They are preferred in manufacturing synthetic leather. They provide softness and spring elasticity to the fabrics.
x) Polyvinylalcohol (PVA): they are used in their solid state or aqueous solution. The outstanding features of PVA copolymers are their particularly good film formation, and that they are very resistant to oils, grease, and organic solvents. Adhesion of fiber is good. PVA bonding agents are used in glass fiber materials and pre bond wet process.

(3.) CLASSIFICATION OF NONWOVENS

The different types of nonwovens can be classified into the different ways as follows:-

- According to the method of production, viz.:-
  1. wet bonded
  2. dry bonded
  3. spun bonded

- According to the technology of raw materials, viz.:-
  1. staple fiber nonwoven
  2. filament fiber nonwoven

- According to the end use of material, viz.:-
  1. durable
  2. semi-durable
  3. disposable

- According to their properties, viz.:-
  1. flame retardant
  2. water repellent
  3. water absorbent, etc.
(4.) PRODUCTION STEPS FOR DIFFERENT METHODS

(4.1.) GENERAL PRODUCTION STEPS FOR NONWOVEN FABRIC MANUFACTURING.

(4.2.) DRY BONDED FABRIC PRODUCTION STEPS

(4.3.) SPUN BONDED FABRIC PRODUCTION STEPS

(4.4.) WET BONDED FABRIC PRODUCTION STEPS
(5.) TYPES OF WEBS AND THEIR FORMING TECHNIQUES

The different types of webs can be classified as follows:

- **Staple Fiber Webs**
  - **Wet-Laid Webs**
    - The wet-laid web forming technique is similar to paper making technique. The fibers are dispersed in water and then laid on a wire mesh to filter the liquid and form a web, which is transferred to a drying felt before finally being heat cured in a continues process. This produces a web in which fibers are randomly oriented. These webs are then superimposed on one another in a parallel fashion; hence it is termed as wet-laid parallel-laid webs. It is the combing of the web that is directional, not the fibers within each web.
Figure 3 principle of wet laid web formation

Wet-laid parallel-laid webs accounts 15% of web production and are produced on modified paper machines. The advantages of low cost and high production rates are offset by the limitations of fiber length (this technique is only successful with short fibers) and the papery handle of the web.

The wet laying technique is particularly appropriate for large scale production of a particular quality in order to be economical. This technique lends itself to the production of fabrics of low cost and limited durability.

The strength of the random oriented web is rather similar in all directions in the plane of the fabric. A wide range of natural, mineral, synthetic and man-made fibers of varying lengths can be used.

Disposable end products include handkerchiefs, napkins, aprons, gloves, tea bags and surgical gauzes. While more durable applications include interlinings, filter cloths and carpet under laying.

(5.1.2.) DRY-LAI D WEBS

Dry laid webs are mainly produced using staple fibers, natural or manmade. Dry laid webs formation mainly consists of 4 steps as mentioned below

1. **Staple fiber preparation**
2. **Opening, cleaning, mixing & blending**
3. **Carding**
4. **Web laying**
(5.1.2.1.) FIBER PREPARATION

The most natural fibers used to produce nonwovens are obtained directly in Staple form from the nature, but manmade fibers are produced in filament form. Thus manmade fibers are needed to be cut into the staple fibers. The preparatory process of manmade fibers includes following steps:

(5.1.2.2.) OPENING, CLEANING, MIXING & BLENDING

The fibre preparation process is usually the second operation in a nonwoven production line after the fibre preparation. The variety of nonwoven products and their different manufacturing methods, as well as the individual market demand situation applicable to the producer, require a custom-made layout for the fibre opening and blending section, to guarantee both a top quality product and a high production capacity. The correct choice of a fibre opening, cleaning and blending system is therefore of utmost importance to ensure a profitable nonwoven manufacturing operation. For example, poor fibre opening, cleaning and mixing creates faults that the subsequent production steps are unable to rectify. This has a negative effect on the efficiency and overall economics of the plant, in terms of limiting production capacity, poor quality, or both.

The different machines used for opening, cleaning and mixing are as mentioned in sequence as follows:

1. Bale opener or bale pluckers
2. Carding willow
3. Cleaning machine (mono cylinder or dicylinder)
4. Oiling system
5. Blending machine (uni-mix, uni-blend, mix master, etc.)
6. Fine opener or line opener.
(5.1.2.3.) CARDING

This process follows the initial opening of the raw material. It is particularly important process because it is responsible for the separating, still further, the tufts of the fiber fed into the machine and reducing them to an individual fiber state. The individualization of fibers allows the removal of the much of the impurities. Finally the carding machine reduces the overall thickness of the material into the form of light web.

Carding is carried out by passing the entangled fibers between the closely spaced cloth surfaces (surface covered with sharp metal teeth). The surfaces move at relative speed to each other and the fibers gets disentangled. The distance between two surfaces decides the degree of opening and cleaning. The action carried out between the clothed surfaces is also known as “carding action”.

The carding action is carried out on machine known as “card”. There are mainly two types of cards viz. roller and clearer card (for medium and long staple fibers) and the revolving flat card (for short staple fibers up to 5-65mm).

(5.1.2.4.) WEB LAYING

There are mainly three types of web laying techniques or dry-laid webs viz.

i. Parallel laid webs
ii. Cross laid webs
iii. Randomly laid webs or air laid webs

(5.1.2.4.1.) PARALLEL-LAID WEBS

Several carding machines are placed one behind another in a long line. The web from the first card is allowed to fall on a conveyor which runs along the full length of the production line underneath the cards. As the web from the first card passes from the second card, the web from second card is superimposed upon it. This process is repeated along the line until a fleece of the correct mass per unit area is achieved.
The parallel laid web system is used extensively in the production of fleeces for relative light weight adhesive bonded nonwovens, such as cleaning cloths.

![Diagram of parallel laid web system](image)

There are mainly three disadvantages of parallel laid web system viz.

a. Even though some width way stretching of the fleece is possible, it cannot be increased more than the width of carding machine.

b. The fibers in web lie predominantly in the machine direction which means that the web is five to six times stronger along its length than across its width.

c. The mass per unit area of the final fleece is limited because it is not economical to use more than 12 cards.

(5.1.2.4.2.) CROSS-LAIDED WEBS

The cross laying, the web deposited on an inclined lattice as it leaves the card and is subsequently laid in cross wise manner on a wider lattice which is moving in a direction at right angle to the original direction of laying.

This cross layer enables three important characteristics of resulting fleece to be controlled.

1. The width of the fabric, with cross laid fleece of up to the meters in width being possible.

2. The mass per unit area of the fleece, which is dependent on the take up speed, so that slow take off allows many layers to be superimposed and produce heavy fabrics, while fast take off produces fewer layers and a more open zigzag of lay to create lighter fabrics.

3. The strength characteristics of the fleece as cross direction than in the machine direction though the ratio can be varied by altering the angle of lay and the subsequent drafting of the cross laid fleece.
The cross laid web techniques overcomes the difficulties encountered with parallel laid webs and has an added advantages. By stretching the cross laid webs the ratio of strengths of the fleece in the machine and cross directions can be controlled to suit the requirements of the end product.

(5.1.2.4.3.) RANDOMLY-LAID WEBS

In alternative means of producing fleeces is offered by machines using aerodynamic feed of the fibers. In this case, those fibers from a carding cylinder are carried in air currents and deposited onto a condenser cage, from which they are drawn off in sheet form. The condenser cage is usually a hollow cylinder formed from a mesh; this enables it to be drawn through the mesh into the center of cylinder, but fibers into the air current cannot pass through mesh and is collected on a surface.

The air or random laying techniques allows fabrics with a wide range of mass per unit area to be produced, in which fiber orientation can be made very much more random than is the case with traditional web layering. Short fibers can be processed easily, allowing textile waste materials to be used in nonwovens.
Random laid webs are made as a single layer and are claimed to have equal properties in all directions. However they are the most expansive to produce, when compared to parallel laid webs, which are the cheapest and cross laid webs, which lie between the two from the production cost point of view.

(5.2.) CONTINUOUS FILAMENT WEBS

There are mainly two types of continuous filament webs viz.

1. spun-laid webs
2. melt blown webs
(5.2.1.) SPUN-LAIDED WEBS

In this technique, a melt solution of a fiber forming polymer is extruded through a systems of spinnerets in a high velocity current of air or other gas. The fibers formed are deposited on to a support, which may be conveyor, a scrim (a very open weave fabric) or screen drum (condenser cage), to form a web. If necessary the extruded filaments are drawn and internally oriented prior to web formation, either by rollers or high velocity air current, in order to increase their strength. The support than carries the web to a bonding stage where consolidation of web occurs.

Figure 9 technique of spun-laid web formation

Spun laid fabrics tend to have low bulk and high tensile and tearing strength. This leads to numerous industrial applications such as protective clothing, filters, packaging and geotextiles.

(5.2.2.) MELT BLOWN WEBS

These are produced initially in the same manner as spun-laid webs. With polymer extruded through the holes in a spinneret into a high velocity current of air. The difference between these two methods is an increased force used the current which breaks the filaments rather than just drawing them to produce staple fibers of varying lengths, Thus consequently not a true continuous filament web.
The different types of bonding methods can be classified as follows:

(6.1.) MECHANICAL BONDING

The term mechanical bonding is taken to mean the bonding together of fibers in the web either by felting or fulling, using pressure, heat, moisture and mechanically or by using needles and the jets of air and water. The webs can also be reinforced by working in threads or fabric e.g. layer of threads, woven or knitted fabrics, spun web or a film.
(6.1.1.) NEEDLE PUNCHING TECHNOLOGY

Needle punching is the oldest method of producing nonwoven products. The first needle punching loom in U.S. was made by James Hunter machine co. in 1948. Then in 1957, James Hunter produced the first high speed needle loom, the Hunter model 8 which is still used today.

The needle punch webs offer a wide range of product characteristics such as:-

1. Unique physical property. I.e. elongation in all (x, y, &z) directions for mould able applications.
2. Ability to attach layers of different types of fiber webs to produce composites
3. High opacity per unit area.
4. High strength makes them overwhelming choice for geotextiles fabrics.

![Diagram of Needle Punching Technique](image)

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 a fibrous cross laid web forcing some fibers through the web, where they remain when the needles are withdrawn.

The needles are normally triangular in cross section. The three barbs on each three corners, at different distance along the edge. The figure illustrates the main parts of needle punching machine.

If sufficient fibers are suitably displaced the web is converted into a fabric by the consolidating effect of these fibers plugs or tufts. This action occurs in needle punching machines where a board usually containing several thousand barbed needles, in reciprocated at speed of around 2000 strokes per minute, depending
on the machine width. This action normally occurs in vertical direction and some machines may have two sets of needles, one operating downwards and other upwards, so that both sides of web are needled.

Fabric properties are dependent on number of factors, the two main ones being punch density and needle penetration. The needle density, when increased, increases fabric density and strength up to an optimum limit, after which further needling will result in decrease breaking load of fabric. The operation consists of pre-needler, drafter and a finish needle loom.

Uses

Needle punched fabrics find its applications as blankets, shoe linings, paper makers felts, coverings, heat and sound insulation, medical fabrics, filters and geotextiles.

(6.1.2.) STITCHED BONDING TECHNOLOGY

Stitched bonding invariably uses a cross-laid web, which is fed directly to the stitch bonder in a continuous process. The machine used in stitched bonding is basically a modified warp knitting machine which bonds the fabric by knitting columns of stitches down the length of the web.

In some cases, the web is fed initially to a needle puncher to achieve a light needling operation (known as tacking), before the rolls of fleece are passed to a stitched board. Tacking enables the fleece to unroll easily and improves the mechanical interlocking between the fibers. This is of vital importance because a very serious shortcoming of many stitch bonded fabrics is that under heavy or severe use, they tend to lose fibers from the mobility of the knitted structure cannot provide sufficient anchorage of the fiber in the fleece. Other steps minimize this weakness include the use of fibers of longer staple length and the inclusion of some relatively low melting point fibers, which can provide additional bonding during subsequent heat setting.

The Mali watt stitch bonder is shown in figure. The web is fed to the machine in vertical direction via a lattice arrangement. During stitch bonding it is normally supported, while the needles contained to the needle bar penetrates the web, when the needle emerges through the web, the yarn guides lay threads into the open hook and, as the needle retract, the hook is closed by the tough. The closed needle draws the new loop through the previous off course which is held round the needle stream. Course spacing during knitting is largely governed by the take-up tension applied to the fabric by the take-up roller.
The structure and the performance of stitched bonded fabrics are affected by a large number of variables, some of which are controllable, for instance web area density, fiber characteristics and course spacing. Mail watt machines are used to produce certain drapes, mattress thinking and fabrics for automotive industry, such as surface covers for various molded components, parcel shelves and headliners. Other types of machines are available for the production of specialized fabrics such as medical and electrical products.
(6.1.3.) HYDROENTANGLEMENT

Hydro-entangled nonwoven fabric relies on the mechanical entanglement of staple fibers for their coherence. Fiber entanglement is achieved by using jets of water under pressure and further measure such as adhesive bonding, is usually needed to fully bond the web.

As shown in fig. 13, the hydro-entangling process consists of following four steps:-

1. The nonwoven web is passed through an image processing device (described by red color) which typically imparts a final pattern to the web.
2. Now, the web is passed through a three nozzle (water jet) assemblies (described by blue color) at a liner speed of approximately 35 yards per minute and an entangling pressure of 150 bar to carry out entangling of fibers.
3. After hydroentangling, the web is passed through an application station (described by green color) where polymeric binder composition is applied to the web.
4. Than the web is passed through a series of drying rollers (described by orange color) arranged one above the other which are operated at around 310°C. With this the manufacturing of nonwoven fabric is completed.
Nonwoven Fabrics

These fabrics have a softer handle and batter drape than one of fully bonded, nonwoven fabrics. There is a lack of liveliness, poor recovery from information and the difference in the properties between the machine and cross-directions. Hydroentangled fabrics are commonly made from polyester fibers and their end products include home furnishings, such as curtains and tablecloths, industrial fabric especially coated and garments.
(6.2.) ADHESIVE BONDING OR CHEMICAL BONDING

In adhesive bonding, the fibers in the web are bound together by a bonding agent. A substance consisting of the same polymer as the fibers, or a different one is used to create bond between fibers of the same polymer. The bond is a result of the combination of physical and chemical forces which acts on the boundary layer between the two polymers.

Typical adhesives used are polyvinyl alcohol (PVA), polyvinyl chloride, polyvinyl acetate and acrylic binders, though the number of binders are available, depending on the type of fiber and end use it is decided.

(6.2.1.) SATURATION ADHESIVE BONDING

Fabrics can be produced by total saturation of the dry laid web of fibers in suitable adhesive. This is the simplest technique of applying adhesives to such webs, which are often light weight (under 50 gsm). The webs are immersed in a bath containing adhesives, where the amount take up by the web is controlled by the concentration of adhesive in the bath and by the degree of squeezing applied to the impegrated material. When it passes between two pressure roller and emerge from the liquor. The saturation technique of adhesive bonding is only suitable for producing stiff highly compressed fabrics for very open and bulky product.

Figure 13 principle of saturation adhesive bonding
**(6.2.2.) SPRAY ADHESIVE BONDING**

The bonding by means of spraying the binders is produced into or onto the textile structure by means of sprayers arranged above the moving web. The binder is saturated on the surface layers and does not penetrate far in the structure, which is normally quite thick.

Advantages of adhesive bonding are an exact measure of the amount of binders applied, uniform binder distribution and a soft fabric handle.

**(6.2.3.) FOAM BONDING**

Spray bonding is now being replaced by foam-impegration process for light weight webs. This high speed process is carried out by the Fleisher static foaming box shown in fig. 11, where foam is produced directly at the foam padded with the binder and compressed air being supplied in metered quantities. The foam is applied over the full width of the fabric by means of an adjustable slot in the foam box.
(6.2.4.) APPLICATION OF POWDERS

The method for depositing a thermoplastic polymer bonding powder is by depositing the powder on to the web through a sprinkler. A sprinkler unit consists of a corrugated dosing roller and a brush roller has proved successful. The powder is poured from the feed container into the grooves running parallel to the axis of the dosing roller. When the powder comes into the area of contact of the brushing roller it is brushed out of the grooves and thrown on to the web in a finely distributed layer.

Softening of adhesive binder is achieved by hot air or stream ovens in the case of open, lightly compacted products or by heated rollers if dense, compact materials are required. The formation of the strong bonds between the fibers occurs as a softened thermoplastic adhesive material resolidifies on cooling. This can be accelerated in continuous processes where chilled embossed rollers can be used to create bonds, under tightly controlled conditions, in web which have been preheated by passing them through suitable ovens.
(6.2.5.) PRINT BONDING

In print bonding, the binders turned into the paste are transferred to the web by the surface of the rollers. This bonding process is suitable for use at high production speeds the web has to be wetted beforehand to prevent the fibers from sticking to the screen roller or matting roller or web for splitting. In this bonding process the binders are only applied in places as dictated by the pattern of the screen roller. This results in the fabric being highly flexible and having textile draping qualities.

In print bonding, the nonwoven fabric typically contains about 20% binders though this can be reduced by printing the cloth with cellulose xanthenes solution, making it possible to produce miniature patterns. The patterns vary with one of the more popular design being the cross-hatch design produces a fabric with bulky, three-dimensional structures, as found in disposable cloths.
(6.2.6.) DISCONTINUOUS BONDING

When reasonable strength coupled with adequate draping characteristics are required, a more sophisticated means of applying the adhesive must be used. To improve the textile like handle of the nonwoven material, binders are applied to the webs in the restricted areas only leaving areas completely unbonded. This is known as discontinuous bonding. Discontinuous bonding can be achieved by printing the bonding agent on to the fabric or by the introduction of powders, granules or rods which are than fused under conditions of high temperatures and low pressures, resulting in a fabric which will have innumerable anchor points.

(6.3.) THERMAL BONDING

The first thermally bonded nonwovens were produced in 1940s. Initial products used rayon as the carrier fiber and plasticized cellulose acetate (PCA) or vinyl chloride (PVC) as the binder fiber. The viability of the thermal bonding process is rooted in the price advantage obtained by lower energy costs. However, the thermal bonding process also addresses the demanding quality requirements of the market place. The development of new raw materials, better web formation technologies and higher production speeds have made thermal bonding a viable process for the manufacture of both durable and disposable nonwovens. Thermal bonded fabrics are produced by using heat in a variety of ways, often in addition to other bonding processes.

Figure 17 principle of thermal bonding
structures in the fuel tank, helicopters, which have 99% air by weight of fabric order to reduce the possibility of an explosion when the fuel tank is pierced by a bullet.

The different methods of thermal bonding are as follows

- Hot calendaring
- Belt calendaring
- Through-air thermal bonding
- Ultrasonic bonding
- Radiant-heat bonding, etc.

(6.3.1.) HOT CALANDERING

There are three main types of hot calendaring.

- Area bonding
- Point bonding
- Embossing

(6.3.1.1.) AREA BONDING

This process involves the use of a calendar with a hot metal roll opposed by a wool felt, cotton or special composition roll. Two, three or four roll calendars can be used, depending on the weight of the web to be bonded and the degree of bonding desired. The three-roll calendar has the heated roll in the middle while the four-roll configuration has the heated rolls on the top and bottom, with the two composition roll in the middle. The amorphous or co-polymeric binder fibers used in this process provide bonding at all cross-over points between the carrier and binder fibers. The resultant product - commonly used in electrical insulation and coating substrates - is smooth, thin and stiff. The material is always two sided, but this effect is most apparent in material processed through two and three roll calendars. Four roll calendars minimize this effect.

The application of heat from the outside produces a material whose inner area is less bonded than its outer surface. This becomes more pronounced as the product weight increases beyond 35 g/m² and can become detrimental unless corrective measures are taken. These include increasing heat, slowing speed, or increasing the binder/carrier fiber ratio. The two-roll calendar is used for low-to-medium weight products with light-to-medium bonding. The three-roll calendar is used for special bonding and finish effects on a single surface. The four roll
calendar produces the widest weight range of materials because it provides more flexibility in the application of heat.

Area-bond hot calendaring is influenced by five factors:

- Heat
- Pressure
- Speed
- Roll combination
- Cooling rolls

(6.3.1.2.) POINT-BOND HOT CALENDARING

Point-bond hot calendaring is the main method of thermally bonding in disposables as diaper, sanitary products, and medical products. This method involves the use of a two-roll nip consisting of a heated male patterned metal roll and a smooth or patterned metal roll (fig 1 a). This second roll may or may not be heated, depending on the application. In a typical production line, the web is fed by an apron leading to a calendar nip and the fiber temperature is raised to the point at which tackiness and melting cause fiber segments caught between the tips of engraved points and the smooth roll to adhere together. The heating time is typically of the order of milliseconds. The fabric properties are dependent on the process temperature and pressure and other parameters like the contact time, quench rate and calendar pattern. Experimental results show that for a given nip line pressure and calendaring speed, the breaking strength reaches a maximum at a critical bonding temperature on keeping the nip line pressure constant.

The maximum strength achieved is influenced by the nip line pressure. This influence depends on the melting behavior of the fiber. If the maximum occurs in the softening region, higher pressure yields higher strength. On the other hand, if maximum occurs in the early melting region, a low calendaring pressure is desirable. The degree of product bonding depends on the pattern of bond points on the roll surface. Bonded areas are compressed and densely compacted. Unbonded area is very open, breathable and porous. The products formed range from thin, closed, inelastic, strong, and stiff to open, bulky, weak, flexible and elastic depending on the number density, the size and the pattern of the bond points.
(6.3.2) BELT CALENDERING

Belt calendaring is a modified form of hot roll calendaring. The two main differences are the time in the nip and the degree of pressure applied. In belt calendaring, time in the nip is 1-10 seconds. The pressure applied is about 1/10th of the pressure applied in the hot calendaring process. The belt bonder consists of a heated roll and a rubber blanket. The nonwoven fabric is heat bonded by running it between the roll and the blanket. Pressure is applied by varying:

a. The tension on the blanket against the heated roll
b. The pressure on the exit guide rolls inside the rubber blanket.

Belt calendred products are much less dense and papery compared to hot roll calendaring. The belt bonder facilitates the use of binders with sharp melting and flow properties. Such binders can present difficulties in a hot roll calendaring process.

(6.3.3.) THROUGH-AIR BONDING

Through-air thermal bonding involves the application of hot air to the surface of the nonwoven fabric. The hot air flows through holes in a plenum positioned just above the nonwoven. However, the air is not pushed through the nonwoven, as in common hot air ovens. Negative pressure or suction, pulls the air through the open conveyor apron that supports the nonwoven as it passes thorough the oven. Pulling the air through the nonwoven fabric allows much more rapid and even transmission of heat and minimizes fabric distortion.

![Figure 19 through-air bonding](image)
Binders used in through-air thermal bonding include crystalline binder fibers, bi-component binder fibers, and powders. When using crystalline binder fibers or powders, the binder melts entirely and forms molten droplets throughout the nonwovens cross-section. Bonding occurs at these points upon cooling. In the case of sheath/core binder fibers, the sheath is the binder and the core is the carrier fiber. Products manufactured using through-air ovens tend to be bulky, open, soft, strong, extensible, breathable and absorbent. Through-air bonding followed by immediate cold calendaring results in thicknesses between a hot roll calendared product and one that has been though-air bonded without compression. Even after cold calendaring, this product is softer, more flexible and more extensible than area-bond hot-calendared material.

(6.3.4.) ULTRASONIC BONDING

This process involves the application of rapidly alternating compressive forces to localized areas of fibers in the web. The stress created by these compressive forces is converted to thermal energy, which softens the fibers as they are pressed against each other. Upon removal from the source of ultrasonic vibration, the softened fibers cool, solidifying the bond points. This method is frequently used for spot or patterned bonding of mechanically bonded materials.

No binder is necessary when synthetic fibers are used since these are self-bonding. To bond natural fibers, some amount of synthetic fiber must be blended with the natural fiber. Fabrics produced by this technique are soft, breathable, absorbent, and strong. This bonding method is used to make patterned composites and laminates, such as quilts and outdoor jackets.

(6.3.5.) RADIANT HEAT BONDING

Radiant heat bonding takes place by exposing the web or mat to a source of radiant energy in the infrared range. The electromagnetic energy radiated from the source is absorbed by the web, increasing its temperature. The application of radiant heat is controlled so that it melts the binder without affecting the carrier fiber. Bonding occurs when the binder resolidifies upon removal of the source of radiant heat. Lower energy and equipment costs make this a favored method for processing powder-bonded nonwovens. Versatility and lower shipping costs are also factors. Post-calendared rolls can be shipped in thin, compacted form and rebulked by reapplication of heat, without pressure or restraints, to the desired state at the time of use. Powder bonded products made in this manner are soft, open, and absorbent with low-to-medium strength. They also can be reactivated by heat for use in the manufacture of laminated composites.
(6.4.) BONDING OF SPUN-LAID WEBS

There are several possibilities for bonding spun-laid webs. The filaments may be self-bonded (fibers which bond together when heated under pressure); subjected to heat, a bonding agent (usually in powder form) and pressure; interlaced by needle punching; or sprayed with adhesive to make the filament bond.

Bicomponent filaments can be used to produce a bonded fabric with one of the components being thermoplastic to facilitate heat bonding and the other component having property that will enhance the quality of the final fabric area density in this processes is controlled by the speed of lay down belt.

Tyvek is an example of self bonded fabric, in which extremely fine polyethylene fibers from a continuous network. Considerable variation in the fabric characteristics can be obtained by varying the bonding pattern. A dense, smooth and relatively stiff product is created if the sheets are bonded over their entire area, while bonding at discrete points gives a high mobility softer and more flexible product. End products include medical and surgical gowns and protective clothing for use in the handling of harmful chemicals substances.

Tyvek is a self bonded spun-laid polypropylene made from coarse fibers originally developed for carpet backing. It is widely used in geotextiles, for drainage, erosion deterrent, the separation of layers or segment of soil construction system and reinforcement of load bearing structures.
(7.) FINISHING OF NONWOVEN FABRICS

(7.1.) INTRODUCTION

Nonwoven fabrics are finished in exactly the same way as other textiles such as wovens and knitted fabrics. This is certainly true in many cases and there is no storage of examples of particular methods or types of machine being used for both kinds of textile fabrics. There are, however, many instances in which nonwoven fabrics require different treatment to obtain the desired results.

(7.2.) CLASSIFICATION OF FINISH APPLIED TO NONWOVEN FABRICS
(7.3.) SHRINKAGE

Nonwoven fabrics are subjected to tensile strain, predominantly in a longitudinal direction, during the manufacturing process, which means the strain is not the seldom occurrence.

In adhesive bonding the web always has to be dried and so if the drying process is carried out correctly with suitable machinery, it is relatively easy to remove any signs of strain by appropriate relaxation.

If bonding takes place purely in dry state (stitched bonding) a special shrinkage process may be required to ensure dimensional stability afterwards.

(7.4.) WRENCHING AND CREPING

Some nonwoven fabrics do not satisfy the wishes of manufacturer and customer alike with regard to their feel and draping quality. They resemble paper. Every efforts has, therefore being made to find a solution and to provide a fuller, softer fabric. Mechanical treatment, wreching and creping, being the most important methods and the most from the technical point of view.

(7.4.1.) WRENCHING

The Clupak process, invented by Sanford Cluett, is similar to the sanforising process first used in the paper industry in 1957. It was later adopted to wet-laid nonwoven bonded fabrics.

The machinery consists of a continuous rubber belt, about 25 mm thick, with an intermediate woven layer lying on a heated, chromium-plated and polished drying cylinder. The web is pressed against the cylinder at the first point of contact by a non-rotating clamping bar. The rubber cloth is compacted lengthwise, which affects the web between it and the cylinder in the same way thus causing compacting and crimping of the fibers in the web longitudinally. The web is fed moist, through the gap between the belt and the cylinder. The compacting is fixed by drying.
The outcome of the Clupak method depends on a number of factors. Hydrophilic fibers are more suitable than hydrophobic ones. Polyolefin fibers are not suitable due to their lower moisture absorption and sensitivity to heat. Webs in which the fibers are oriented lengthwise give a more pronounced effect than cross-laid or random-laid webs. The degree of wrenching is increased if the moisture content is high - about 20% - but if the bonding agent is more than 50% such increases are unattainable. Thermoplastic bonding agents assist wrenching but the web tends to adhere to the cylinder. Elastomer bonding agents due to their elastic nature almost cancel the wrenching effect.

(7.4.2.) CREEPING: THE MICREX-MICROCREEPE PROCESS

In the Micrex process, compaction of the web is so strong that the creeping effect is visible and the increase in extension and basis weight can easily be measured. The surface per unit area is larger and the flexibility is improved even further than by the Clupak method.

The apparatus for the Micrex process consists of a rotating conveyor roller, the surface of which has screw-shaped grooves in it, and two guide plates - one fixed and one elastic - forming a knee lying against the cylinder. Between these is fed the web and nearby is a scrapper-like compressing device inclined at an acute angle to the surface of the roller.

The web is compacted in the first gap, and then raises itself from the cylinder in the relaxation zone to be compacted by the scrapper again. The process can be adjusted to produce a fine or coarse crepe without significant impairment of the mechanical properties despite production speeds of 150-200 m/min since the web is handled dry and at much lower temperatures as compared to the Clupak method. This method is suitable to creeping longitudinally oriented carded webs, wet or dry-laid random structured webs, spun-bonded and spunlaced products.
(7.5.) PROCESSCRABBING, CALENDERING AND PRESSING

These methods are used to improve the surface characteristics of the fabrics, the most important features being smoothing and patterning. The processes used are continuous and usually involve one or several pairs of rollers operating under pressure.

(7.5.1.) GLAZING OR ROLLER CALANDERING

This method is not particularly important for nonwoven fabrics, with occasional exceptions. Calendering has not met with much success since it is often accompanied by undesirable compression. The only time a rolling calender is used is when two steel rollers are paired to break the so-called 'blotches' in spun-bonded fabrics.

(7.5.2.) MOIRE OR GOFFERING CALENDER

The calenders are common in nonwoven finishing and are used in the compacting of the webs made of natural and synthetic fibers. This type of calendering can be considered to be both a bonding and finishing process.

Hot embossing of synthetic fiber webs, even when the fibers are longitudinally oriented, produces a product remarkably strong due to the fibers melting at the embossed areas. The patterns can be of grid, webbed or point type.

The embossing effect is used to obtain special effects such as leather graining, simulated weave, plaster, brush strokes, cord and mock tiling. Another area in which heated calenders are used is in the manufacture of laminates. Here thermoplastic fibers, layers of thread or film are placed between two layers of non-plastic web and are fused together by heat and pressure. Such laminates are used as tablecloths, seat and cushion covers. Calenders are also used in the transfer printing of the bonded webs.

(7.5.3.) ROLLER PRESSES

The oldest form of improving the surface of nonwoven bonded fabrics is the pressing of wool felts, especially felts for collar linings. This gives a smoother surface finish and also improves strength and luster.

(7.6.) PERFORATING AND SLITTING

The nonwoven bonded fabrics produced are too stiff and are, therefore, unsuitable for clothing. This is because the individual fibers are not free to move in relation to one another, as are threads in woven or knitted fabrics. Perforating and slitting are two methods practiced to improve the fall or drape of nonwoven bonded fabrics.
(7.6.1.) PERFORATING

The Artos method is a method of perforating in which the web, which has been bonded by using chemicals, is perforated with hot needles. This process not only punches holes but also reinforces as a result of cross-linking and condensation of the bonding agent. The Hungarian firm Temaforg uses a similar method to perforate webs made of synthetic fibers to produce nonwoven bonded fabrics which are strong and yet supple enough for use as building and insulation materials.

(7.6.2.) SLITTING

Slitting, originally developed to improve the softness and drape of films was used by the Breveteam company for interlinings, in particular for adhesive fixable interlinings. The optimum cut length and distance between the slits to get maximum softness and fall without serious reduction of strength can be calculated. The effect of slitting allows greatest flexibility at right angles to the direction of the slit.

The slitting is accomplished by a roller with small blades mounted on it, for example, in an off-set arrangement 1.7 mm apart, making slits of a maximum length of 6.5mm. Rotary knives with spreaders can be fitted to the roller, thus making an interrupted cutting edge. Polyethylene or polyamide film shaped by splitting or embossing and stretching by the Xironet and Smith-Nephew methods make good air permeable bonding layers for laminating nonwoven bonded fabrics.

(7.7.) SPLITTING, GRINDING, VELOURING AND SINGEING

(7.7.1.) SPLITTING

When nonwovens are substituted for leather, the thick layer of needled fabric is split similar to the splitting of leather to make thinner fabrics. The fabrics used are thick, high strength, firmly bonded, closely needled and usually shrunk. The product is thin, supple and like leather is used for slip belts, shoe interlinings, backing material for shoe uppers and leather bags.
Splitting is done by machines in which a continuous rotation hoop knife is guided with great precision in the gap between two conveyor rollers, the distance between them depending on the thickness and type of fabric required.

(7.7.2.) GRINDING AND VELOURING

Splitting is followed by either ironing and friction calendering or moire calendering and possibly also grinding and polishing to make the surface even, giving the fabric the appearance of velour or suede. The process is known as velouring. First there are several machines or consecutive passages to coarsely roughen the surface and then polish it increasingly fine. After grinding, the dust is removed by brushing or beating the fabric or by suction. The distinctive features of such products are their soft feel, elegant draping qualities and velvet-like surface.

(7.7.3.) SINGING

It belongs to the category of a dry finishing process. It is essentially the burning off of protruding fibers from nonwoven fabrics, particularly needled fabrics. The process is exactly the same as traditional singeing and is carried out on gassing frames where the fabric is passed over an open gas flame. The surface is made smoother, which simplifies the dusting of filter fabrics.

(7.8.) WASHING

- The purpose of washing is to remove unwanted substances from the fabric. In a wet process a suitable washing machine, using water as the washing medium and occasionally a detergent, intensifies the effects required.
- Some anionic washing agents also have the effect of softening the fabric; nonionic agents have the advantage of being universally compatible but are more efficient at specific temperatures. As in all wet and dry processes the fabric should be subjected to as little tension as possible when being washed and, lengthwise, stretching is undesirable.
(7.9.) DYEING

It is not easy to estimate the ratio of colored nonwoven fabrics to crude white or natural colored ones. The fabric will be colored, either plain or patterned, where it is used for decorative purposes, for example in wallpapers or floor coverings, table or bed linen or as furnishing fabric. Interlining for shirts and blouses is also dyed to match.

(7.10.) PRINTING

Due to the increasingly popular use of nonwovens in the home furnishing sector there has been a great expansion of the color range and printing methods. The most commonly employed methods are screen and rotary screen-printing.

(7.11.) CHEMICAL FINISHES

Nonwovens are finished with various chemicals in order to obtain the specific property depending on end-use. Different chemical finishes are discussed below

(7.11.1.) ANTISTATIC FINISH

Static electricity tends to build up in nonwovens made of synthetic fibers due to their lack of moisture regain and conductivity. This can cause problems such as clinging and dragging during processing, apparel that clings and crackles, dangerous discharge of static electricity in explosive atmospheres and tendency to attract airborne dirt and soil in processing and use. The antistats work in three basic ways. They improve the conductivity of the fibers, coat the fiber with a thin layer of material that will attract a thin layer of moisture, and finish the fabric such that it holds a charge opposite to that normally accumulated on the fiber to neutralize the static charge. Antistats can be either durable or non-durable. Examples of durable antistats include vapor deposited metals, conductive carbon or metallic particles applied by binders, polyamines, polyethoxylated amine and ammonium salts and carboxylic salts. Non-durable antistats usually consist of inorganic or organic salts or hygroscopic organic materials. Examples are quaternary ammonium salts, imidazoles and fatty amides which are cationic. Anionic antistats include phosphates, phosphate esters, sulfonates, sulfates and phosphonates. Examples of nonionic antistats include glycols, ethoxylated fatty acids, ethoxylated fatty alcohols and sorbitan fatty acid esters.
(7.11.2.) ANT MICRO BIALS

These are used to control populations of bacteria, fungi, algae and viruses on the substrate. The treatment usually prevents the biological degradation of the product or prevents the growth of undesirable organisms. Broadly classed, the antimicrobials are either fixed or leachable. The fixed treatments are durable, but the leachable treatments may transfer to the surrounding environment through migration, solubility or abrasion. A generic list of the treatments include alcohols such as isopropanol or propylene glycol, halogens such as chlorine, hypochlorite, iodine, N-chloramine and hexachlorophene, metals such as silver nitrate, mercuric chloride and tin chloride, various peroxides, phenols quaternary ammonium compounds, pine oil derivatives, aldehydes and phosphoric acid esters. Care should be taken in the application of these compounds to prevent inactivation, loss of durability or masking of the active ingredient with other finishes.

(7.11.3.) WATER REPALENT FINISH

Water repellent finishes are a type of barrier, which function to lower the critical surface tension of the fiber surface. To be most effective it is important that the fibers are treated evenly on all surfaces to give the lowest critical surface tension possible. Water repellency can be achieved with a variety of chemical finishes such as waxes, wax dispersions, melamine wax extenders, chrome complexes, silicones, and fluourochemicals. The finishes require curing to develop the best repellency and are also prone to destabilizing with shear, heat or changes of pH or ionic strength.

(7.11.4.) LUBRICANTS

Lubricants or slip agents are generally applied as processing aids to help in stretching or to improve the processability of nonwovens. They are also applied to aid in sewing, quilting, tufting or other processes where needles penetrate the fabric. Lubricants impart the same properties as softeners but specifically reduce fiber friction. Common chemicals include sulphonated oils, oil emulsions, silicones, esters, polyethylene dispersions and fatty acid soaps. Many surfactants may also be used. Care should be taken to avoid excessive strength loss.

(7.11.5.) UV ABSORBERS AND POLYMER STABILIZERS

Ultraviolet light can do great damage to the polymers causing photo-degradation, yellowing, loss in strength and fading of the colors. The damage is generally due to the formation of destructive free radicals in the polymer. The finish can protect the fabric by shielding the fiber or absorbing the light or by chemically quenching the free radicals. The three main classes of products used are, substituted benzotriazoles, benzophenones which are uv absorbers, and hindered amines.
which are free radical reactants. They are applied from a bath or added to the polymer.

(7.11.6.) FLAME RETARDENTS

The finishing of fabrics with flame retardants can reduce the tendency to burn or reduce the tendency to propagate the flame. The flame retardants may char the fuel, quench the reaction of combustion, absorb heat or emit cooling gases or replace oxygen. Flame retardants are durable or nondurable. Durable retardants include decabromodiphenyl oxide, antimony oxide, phosphates, brominated esters, PVC and other chlorinated binders. Nondurables include borates, boric acids, zinc borate, sulfamic acid sulfamates, ammonium phosphates, urea, etc. Hydrated alumina and zinc borate act as smoke suppressants. Problems in the application include odor, yellowing, loss of tensile strength, stiffening, skin irritation and color change or loss.

(7.11.7.) SOFTNERS

Softeners are applied to improve the aesthetic and functional characteristics of a fabric. The hand, drape, abrasion resistance, sewability and tear strength can be improved with the addition of a softener. It works by reducing the coefficient of friction between the fibers. There are different types of softeners such as anionic (sulfates or sulfonates), cationic (amines and quaternary amines) and nonionic (silicones, ethylene oxide derivatives and hydrocarbon waxes.)

(7.11.8.) ABSORBENCY ANDREWETTERS

Chemicals used to impart hydrophilicity to a nonwoven are referred to as rewetters. These treatments increase the critical surface tension of the fiber making it more wettable. This property is desirable in end-uses such as wipes, hygiene, medical absorbent pads and garments. For hydrophobic fibers the treatment facilitates the movement and penetration of the liquid in the capillary channels. Many anionic and nonionic surfactants, antistats, flame retardants and softeners impart hydrophilicity.

(7.11.9.) THERMOPLASTIC BINDERS, RESINS AND EMULSION POLYMERS

Binders and resins are widely used in the finishing of nonwovens to add strength, control stiffness, add moldability or pleatability, provide durable flame retardants, color, reduce linting and control shrinkage. They soften when exposed to heat and return to their original state when cooled and, hence, can be set. Emulsion polymers are also called latexes. The common binders, resins and polymers include acrylics, PVC, polyacrylic acid, urethanes, starch, vinyl acetate etc.
(7.11.10.) THERMOSETTING RESINS AND CROSSLINKING AGENTS

These are used to produce wrinkle resistant or permanent-press textiles. They are used to crosslink cellulose for wrinkle resistance, crosslink binders for wash durability and solvent resistance. The technology is based on the ability of formaldehyde to react with cellulose and nitrogen containing resins. The important resin types are melamine-formaldehyde, urea formaldehyde and dimethyloethylene urea. The reaction is usually catalyzed by acids, such as Lowry-Bronsted or Lewis acids. Problems encountered include formaldehyde generation, tensile loss, discoloration and amine odor.

(7.11.11.) SOIL RELEASE

The soil release chemicals reduce the problem of soiling in two ways: repel the stains and soil using repellants such as flourochemicals or create a surface that aids the removal of soils when cleaning or laundering using chemicals based on polyacrylic acid.

(7.11.12.) OPTICAL BRIGHTENERS

Optical brighteners or fluorescent whitening agents are organic chemicals that are used like dyes or pigments to add brightness to fabrics. These chemicals are colorless but can absorb UV light and reemit it to the visible range usually as a blue or blue-green. These products produce very white fabrics or brighten colored fabrics.

(7.12.) COATING

Coating is a basic and exceptionally important form of finishing for non-woven bonded fabrics. The way in which the coating is carried out depends on the substrate, the machinery available, the substance that is to be applied and, also on the effect desired.

Slop padding: It is one of the best known methods of direct coating. The coating is put on with a rotary roller, the surface of which is covered in the substance to be applied. The slop padding roller is fed directly with the laminating float by being dipped into it or using special feed rollers.

(7.13.) LAMINATING

Laminating is the permanent jointing of two or more prefabricated fabrics. Unless one or other of the fabrics develops adhesive properties in certain conditions, an additional medium is necessary to secure bonding.
(7.13.1.) WET LAMINATING

Adhesives used in the wet process are dissolved or dispersed in a suitable solvent. The simplest form of wet laminating consists of applying the adhesive to one of the lengths of material that is to be joined, and to put the second length on it with the required amount of pressure. Then drying, hardening or condensing the material that has been joined together is carried out. The solvents can be macromolecular natural or synthetic substances and water.

(7.13.2.) DRY LAMINATING

All Kinds of thermoplastics are used for dry laminating. These include powders, plastisols, or melt adhesives, and are applied to the substrates that are to be joined together using suitable machinery. Dry laminated non-woven fabrics have a soft feel.

(7.14.) FLOCKING

Flocking is the application of short fibers, natural or synthetic, to a base fabric coated with adhesive. The fibers are usually perpendicular to the fabric which produces a velvet-like effect. There are two main methods of flocking, (1) Mechanical (2) Electrostatic.

The principal fibers being used are cotton, rayon and nylon, although it is possible to use other fibers. Flock is available as either precision or random cut. The average length of fiber in the flock normally varies between 0.015" and 0.200". The short flock usually has finer denier and is used for suedes. The long flock which is much coarser is mainly used for carpets. Besides the difference in length and denier, flock is available in its natural color or dyed. There are many types of adhesives available, such as acrylic emulsions. In flocking applications it is necessary to thicken the emulsion polymer to avoid excessive penetration of the adhesive into the fabric substrate. The adhesive should for the most part be on the surface so as to be available to anchor the flock. There are three methods generally used for the application of the flocking adhesive:

(1) Knife coating resulting in a continuous overall coating.
(2) Print roll application which results in the application of stripe, blotch or similar pattern.
(3) Screen printing which is used for applying decorative patterns.
(8.) TESTING AND EVALUATION OF NONWOVEN FABRICS

The development of testing techniques for nonwovens has to be treated in conjunction with the testing of textile in general. Nonwoven fabrics make a third category of textile a fabric alongside woven’s and knitted.

Since nonwoven fabrics produced for specific end use, appropriate methods are required to test them and these are very often not applicable to textiles. The methods of testing nonwoven fabrics can, therefore, be divided into two groups:

1. Test specifically for nonwovens derived from general or textile material testing technique.
2. Product oriented test

The economic importance and verity in manufacturing of nonwovens means that testing procedure have been standardized for a long time. There are:

1. EDANA recommendations (European disposables and nonwoven association)
2. DIN standards (Deutsches Institute fur Normings)
3. ASTM standards (American Society for Testing Material)

REFERENCES

4. Book- “nonwoven fabrics”, by Francis M. Buresh