Unit 5.1 Yarn and Non-Woven Fabric Production in Circular Economy

Content

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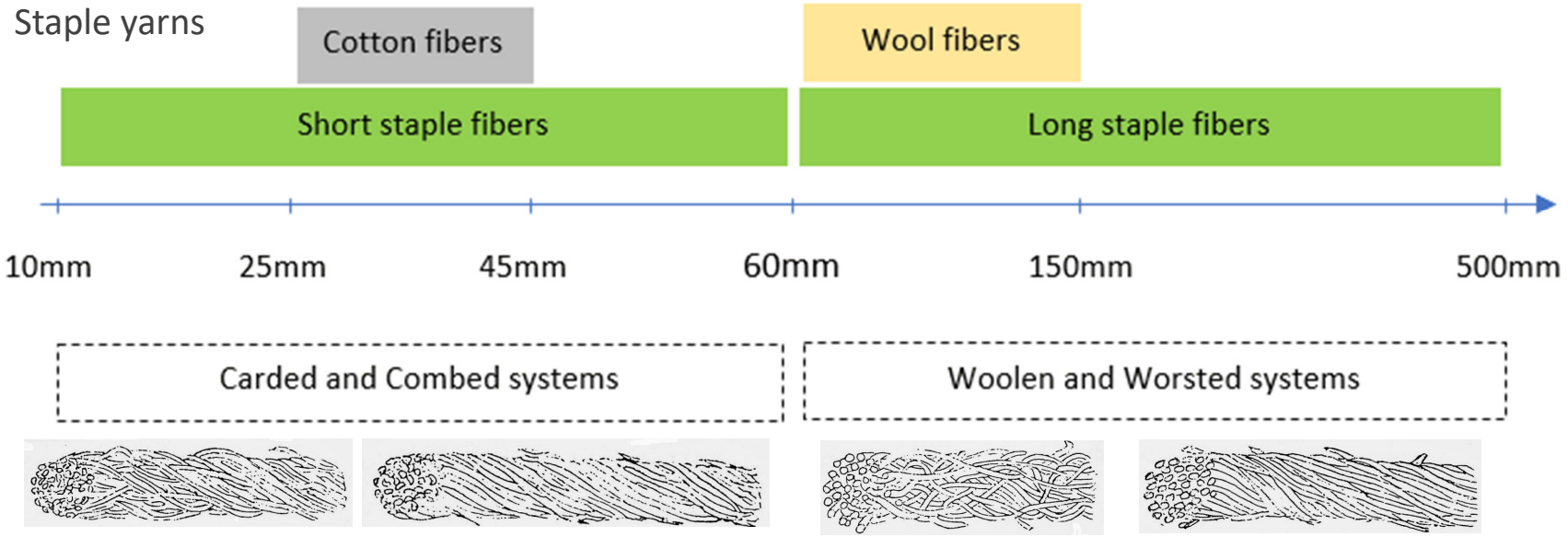
5.1.1 Yarn Spinning Processes

- Staple yarns



- Continuous – filament yarns

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Filament yarn spinning : from polymers to multifilaments (and to yarn)

Operations:

Spinning methods :

- Dry spinning
- Wet spinning
- Melt spinning
- Gel spinning

Examples of polymers :

- Polyester
- Viscose
- Polyamide

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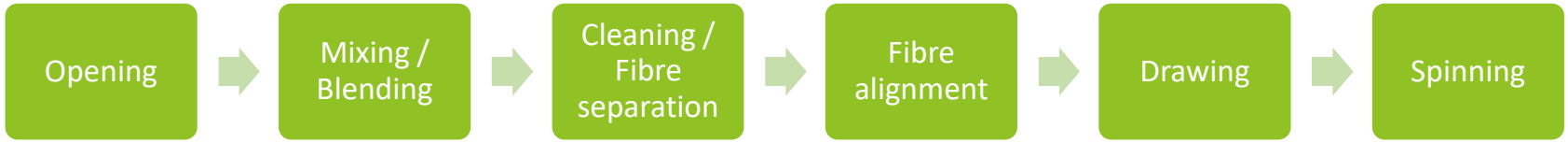
Staple-fibre spinning : from fibre to yarn

Operations :



Spinning methods :

- Ring-spun yarns — Conventionnal spinning methods
- Rotor-spun yarns — Non-conventionnal spinning methods
- Twistless yarns
- Wrap-spun yarns
- Friction-spun yarns

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5.1.2 Fibre Blends

- Synthetic fibre / Synthetic fibre :

  Possible to cut the filaments to obtain staple fibers and spin them, but not mandatory.

- Synthetic fibre / Natural fibre :
  - Conventionnal methods : Materials are intimately blended. It is not possible to mix fibers of such different lengths in conventional processes. Therefore, synthetic fibers must be cut to the same order of length as the fibers with which they are blended.
  - Non-conventional methods : Materials are not intimately blended. Filaments are used as core in the yarn, or as binding, so no need to cut it.

- Natural fibre / Natural fibre :

  Natural fibers have lengths that can be very different, so we can recut the longest fibers (linen for example) to mix them with the shortest fibers.

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5.1.3 Environmental Impacts

Spinning can represent up to 1/5 of a cotton garment global environmental burden. [11]

More than 75% of the greenhouse gas production of spinning processes comes from energy comsuption. [1,2] Energy consumption is directly related to the thickness of the yarn: the thinner the yarn the more energy it consumes.

Sources of environmental impacts for yarn production that must be considered [1] :

- Energy use (processes and requirement for humidification systems)
- Consumables used, such as chemicals (lubricants), packaging materials (cone inserts, plastic ring cops, roving bobbins, card and draw frame cans) and their disposal
- Amount of fibre waste created and its disposal

  Very short fibers, which cannot be re-inserted into a spinning process. Use as flock, or as padding/insulation material.
- Amount of dust and noise created

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5.1.4 Use of recycled fibers

Recycled polymers :

- Can be spun as virgin ones, through dry, wet or melt spinning. However, the output material may have lost mechanical properties, depending on the process used.

Recycled fibres :

- Shorter than virgin fibers. Therefore, it must be mixed with virgin fibers to ensure the mechanical properties of the yarn.
- Can be spun into yarns through Rotor spinning, Friction spinning or Ring spinning.
- Non-uniformity of fiber lengths, unopened fibers, small yarn pieces, and other imperfections make the spinning process difficult for thin and middle count yarns. Most recycled yarns are coarse count.

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Ring Spinning

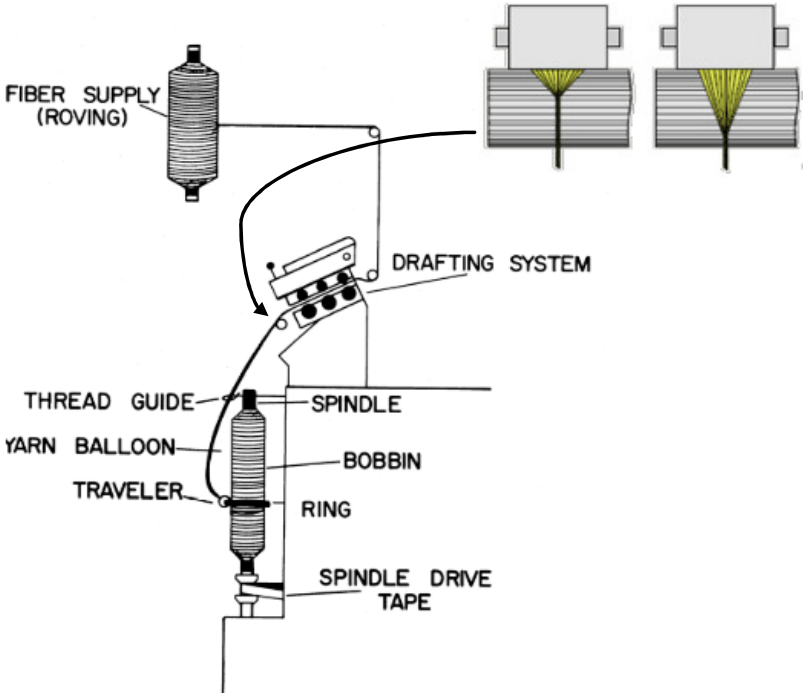

Figure 1. Diagram of ring spinning [3,5]

The drawing is carried out on a rolling mill system.

The twisting is conferred to the yarn by the traveler which moves on the ring. The winding is done thanks to the delay that the traveler takes in relation to the spindle speed and the rise and fall of the carriage on which the ring is placed. [3]

Ring spinning contribute to a stronger yarn and is the most often used method for cotton yarn spinning. The fiber orientation of ring spun yarns is good, which helps with the spinning of short recycled fibers.

- Clothing / Towels …

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Rotor (or Open-End) Spinning

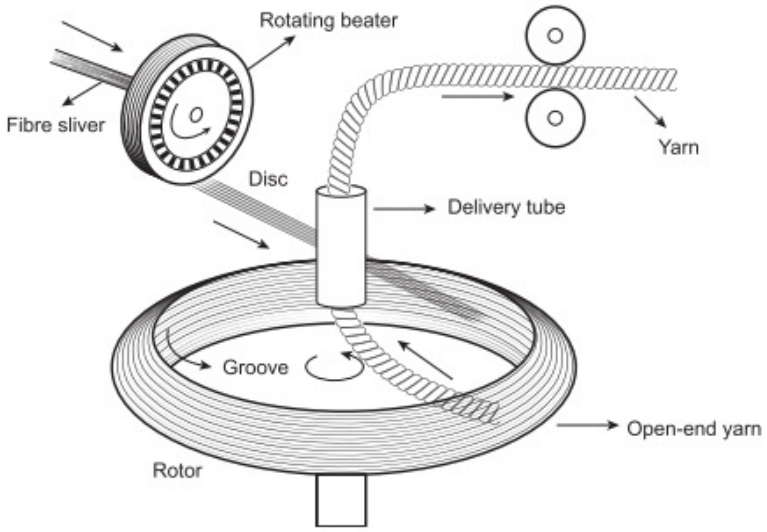

Figure 2. Diagram of rotor spinning [6]

Principle similar to the production of cotton candy.

A sliver of fibres is fed into the spinner by a stream of air. The fibres then come into contact with a rotating comber roll, which creates a thin stream of fibres.

These fibres are then deposited in the v-shaped groove on the outside edge of the rotor. The rotor spins rapidly, imparting twist to the fibres.

Fibres fed to the rotor are incorporated into the rapidly rotating 'open-end' of a previously formed yarn that extends out of the delivery tube.[5,6]

Rotor spinning is cheaper than ring spinning, even though the strength of rotor spun yarn is lower than ring spun yarns.

- Carpets / Towels / Sheeting / Furnishing / Clothing

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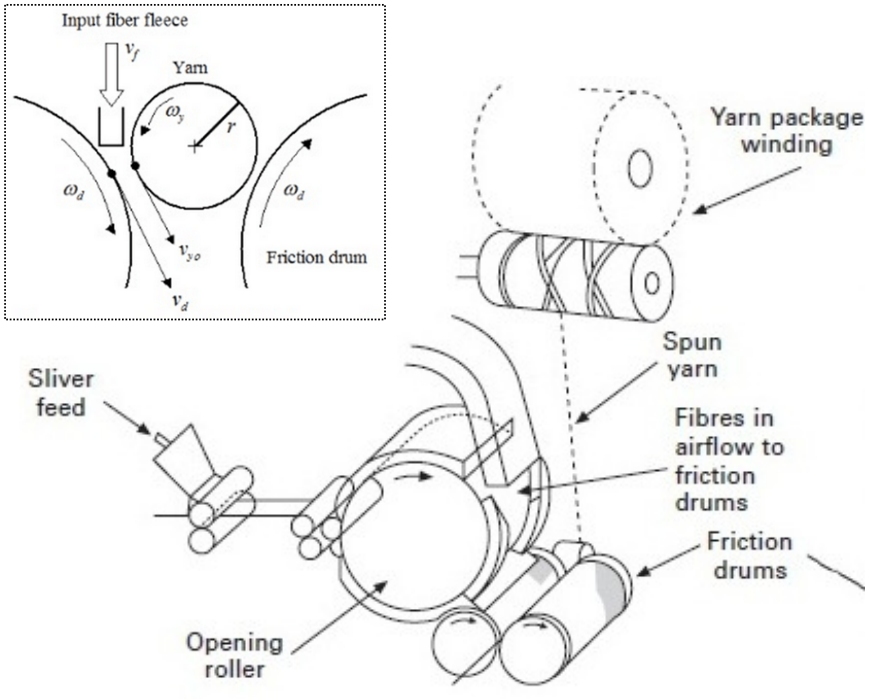
Friction Spinning



A sliver is fed to an opening roller, where the fibers are individualized. Thanks to an air flow, these fibers are brought between two drums which rotate in the same direction (to bring torsion).

Between these 2 rollers is a core filament. The fibers are wrapped around the filament to form a yarn.

Friction spun yarns have a poor orientation. They are generally not as strong as ring spun yarns, but the yarn appearance of friction yarns is very good.

- Softening filter / Mop / Carpet underlay / Terry towels …

Figure 3. Diagram of friction spinning [7,8]

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Percentage of recycled fibers

Not all blends are possible with recycled fibers. When there are too many short fibers the yarn doesn't have good mechanical properties and is unusable.

The machine provider Rieter produces recycling systems for rotor and ring spinning. [9]

Table 1. Possible blends on Rieter systems [9]

Recycling system	Yarn count	% recycled material	% virgin material
Rotor spinning	Ne 20	75% post-consumer	25% virgin cotton
	Ne 30	87,5% pre-consumer	12,5% polyester
Ring spinning	Ne 20	60% post-consumer	40% virgin cotton
	Ne 30	60% pre-consumer	40% polyester

CLASSIFICATION	SHORT-FIBER CONTENT	MEAN FIBER LENGTH
Very good	45%	17 mm
Good	55%	14 mm
Medium	60%	13 mm
Poor	78%	10 mm
Cotton as reference	24%	21 mm

Table 2. Rieter's quality classification [9]

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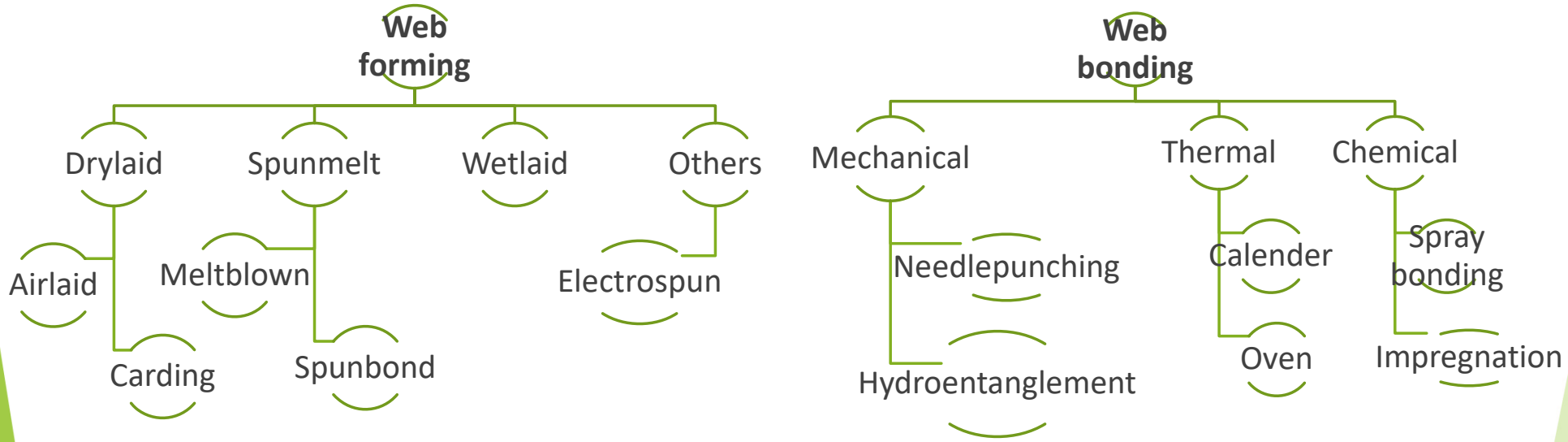
5.1.5 Non-Woven Production Processes

The 2 main steps are :



The choice of process is determined by the fibre used and the final application of the product.

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Drylaid web forming

Natural or synthetic polymer composition, processed alone or in blends. [4]

- Carded webs : produced from short staple fibres (20–60 mm) or long staple fibres (50–150 mm).
  - Geotextiles / Building and Roofing
- Airlaid webs: produced by suspending relatively short fibres in air and then transporting this air–fibre mixture to a continuous air permeable conveyor, where the air is removed and the fibres are deposited to form a web.
  - Automotive (soundproofing) / Thermal insulation

Figure 4. Diagram of carded process[10]

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Spunmelt web forming

Formed from continuous filaments that are produced by extrusion process. The production process is fully integrated, enabling polymer chip to be made into fabric in one continuous operation. [4]

- Spunbond fabrics contain coarser fibres and have a great tensile strength.
  - Filtration / Medical gowns/ Geotextiles / Durable wipes …

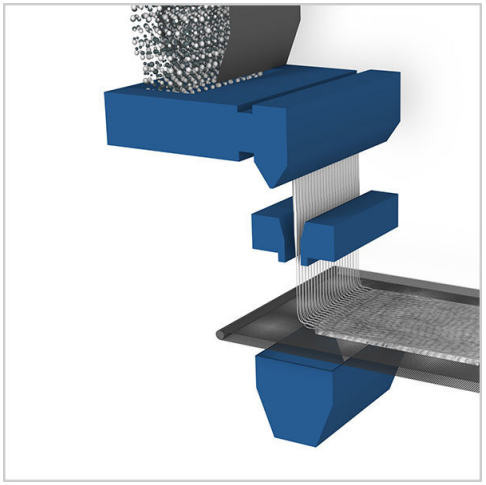

Figure 5. Diagram of spunbond process[10]

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Spunmelt web forming

- Meltblown process uses high-velocity hot air streams that impinge on the filaments as they are extruded, involving attenuation of the filaments. Meltblown fabrics have smaller diameter filaments and superior filtration properties.
  - Filtration / Oil absorbents / Protective mask / Blood filters …

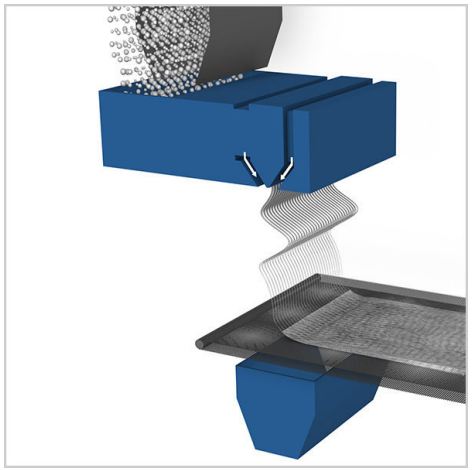

Figure 6. Diagram of meltblown process[10]

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Wetlaid web forming

Produced using technology that originated from the papermaking process, in which fibres are first suspended in water. [4]

Whereas paper is normally produced from short, fine fibres of cellulosic composition, the fibres in wetlaid nonwovens can be substantially longer and can be composed of many different natural, high-performance synthetic or inorganic materials.

- Tea bags / Air and liquid filters / Surgical clothing and drapes / Insulation …

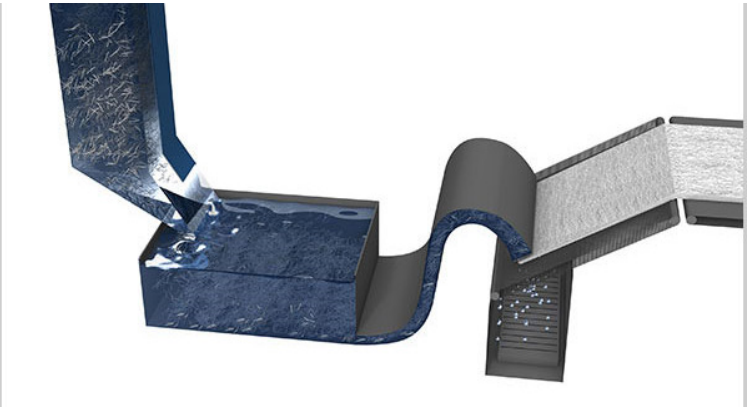

Figure 7. Diagram of wetlaid process [10]

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Mechanical bonding / Needle Punching

The fibres in most nonwoven webs are arranged in a planar fashion within the structure – very few are oriented in the thickness direction. In the needling process, barbed needles are repeatedly oscillated through the web to reorient groups of fibre into the interior of the structure.

The degree of bonding is strongly affected by the number of needles that penetrate the web per unit area.

- Velours / Automotive / Furnishing / Synthetic leathers / Geotextiles / Building…

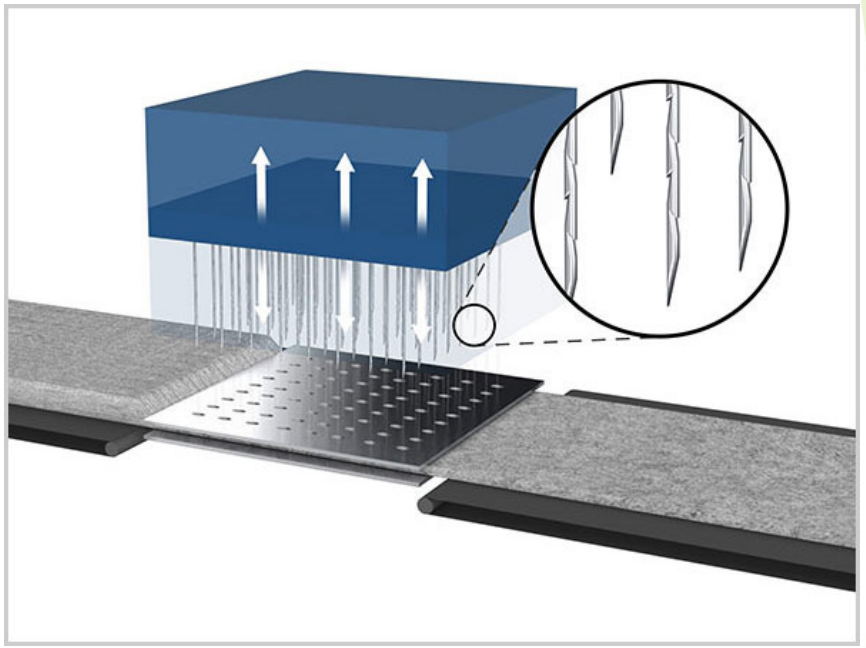

Figure 8. Diagram of needle punching [10]

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Mechanical bonding / Hydroentanglement and stitch bonding

Hydroentanglement : Entangling fibres using high-velocity water jets. Fibres in the web are entwined with others, displaced and reoriented to increase frictional resistance to slippage and strength of the fabric. Hydroentangling can provide a convenient means of joining one or more webs without the need for thermal or chemical bonding.

- Synthetic leathers / Wipes / Automotive / Furnishing / Thermal protection / Geotextiles / Coating substrate …

Stitchbonding : Stitching or knitting the fibres in fibrous webs together.

- Wipes / Carpet backing / Thermal insulation / Geotextiles / Filtration / Automotive interior / Absorption …

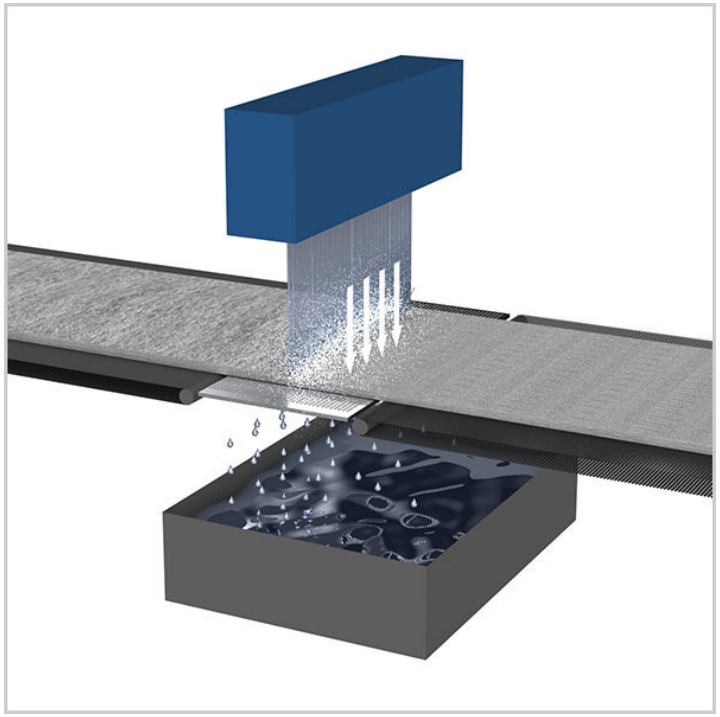

Figure 9. Diagram of hydroentanglement [10]

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Thermal bonding

Suitable for fibrous webs containing fibres (or particles) made from thermoplastic polymers. Web is bonded by thermally fusing the thermoplastic components to the surrounding fibrous material.

- Through-air bonding : Hot air delivered via an oven system
- Calender bonding : direct contact via heated rollers.
- Ultrasonic bonding
- Microwave, infrared or laser heating

- Wipes / Automotive / Filtration / Geotextiles / Insulations / Tea bags

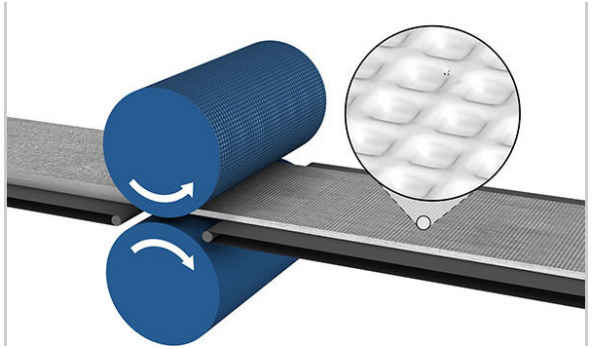

Figure 10. Diagram of calender bonding [10]

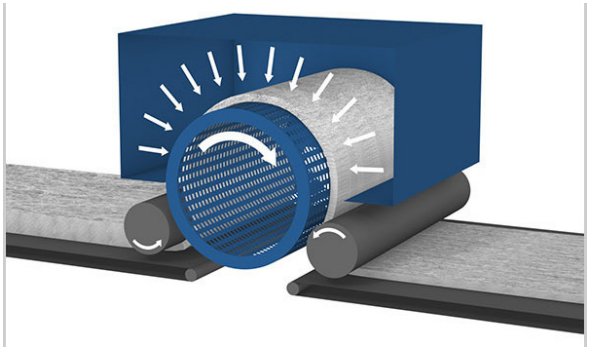

Figure 11. Diagram of through-air-bonding[10]

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Chemical bonding

Binders consisting of polymer latex adhesives in the form of emulsions, dispersions or solutions are deposited on to fibre surfaces in the web and then dried and cured to form a cross-linked film that bonds adjacent fibres together.

Additionally, some nonwovens are solvent bonded, wherein fibres are treated with a solvent specific for the constituent polymer to produce bonding in the web.

- Wipes / Sponges

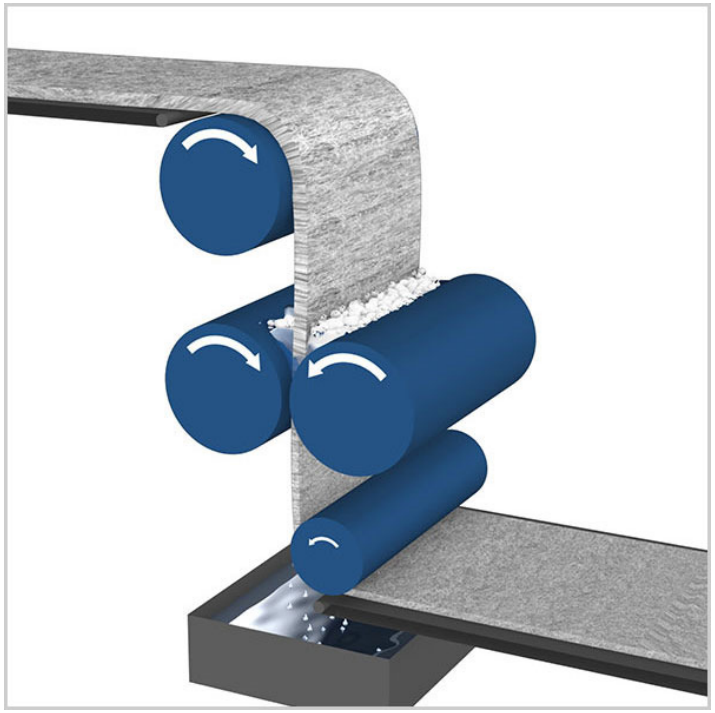

Figure 12. Diagram of chemical bonding [10]

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5.1.5 Use of recycled material

- Nonwovens accept very short fibers, which is an advantage for fiber recycling.
- It is possible to recycle fiber blends and non-textile materials into nonwovens. Natural/synthetic fiber blends can even be an advantage for thermal bonding.
- The easiest recycling method is Drylaid (very short fibers accepted, no water, no need for polymers), followed by needle punching (no heat, no water, no chemicals) but the choice of processes will depend on the application and the desired properties of the final material.

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