Wool and non-wovens

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In a non-woven process the fibre is converted directly into fabric in one continuous process. The wool inputs are usually similar to those chosen for woollen processing, that is, shorter fibre than for worsted and usually free of vegetable matter, so carbonised wool and broken top is used. Broken top is shorter wool that has been combed to remove vegetable matter (VM), very short fibres and neps and is usually more expensive than carbonised wool of the same micron and length. It is also possible to piece-carbonise the non-woven fabric, having made it with low VM wools, but this is rare and the VM may cause other problems in the non-woven plant if it is not dedicated to wool processing. Blends of wool and synthetic fibres are also possible; a wide range of fibre blends is commonly used in non-woven processing.

Although the significant savings make non-woven fabrics attractive, non-woven fabrics have inherent physical limitations that suggest that weaving and knitting will remain the favoured production processes for most apparel applications for some time. The following is an outline of some of the relative characteristics of woven/knitted and non-woven fabrics:

- wovens/knits
    - within yarns: intimate fibre contact – strength and elasticity
    - between yarns: looser linkages, yarn crimp
    - drape, bulk, good handle, fluidity
- non-wovens
    - intimate fibre contact throughout is required to get strength and fibre security; this leads to –
        - stiffness
        - poorer handle
        - poor drape
        - poor stretch recovery.

The strength and elasticity of woven and knitted fabrics is provided by the yarns, yarn crimp and yarn arrangement, which allow high fabric strength and good fibre security within the yarn, while the fabric's flexibility and fluidity is provided by the looser links between the yarns. Non-wovens cannot easily imitate this effect because the strength and fibre security of the non-woven is derived from fibre entanglement throughout the fabric. These shortcomings currently restrict non-wovens to certain applications; these include industrial fabrics and medical and safety apparel. Some consumer apparel products, however, are well suited to non-wovens and research is continuing to overcome the limitations and widen their applicability.

Production of non-woven fabrics can be broken down into various stages:

- web formation
- web bonding
- finishing
- coloration.

Web formation for staple fibres usually involves a carding process; an alternative is air-laid systems, for example: Fehrer, Danweb. Laroche and Bonino.

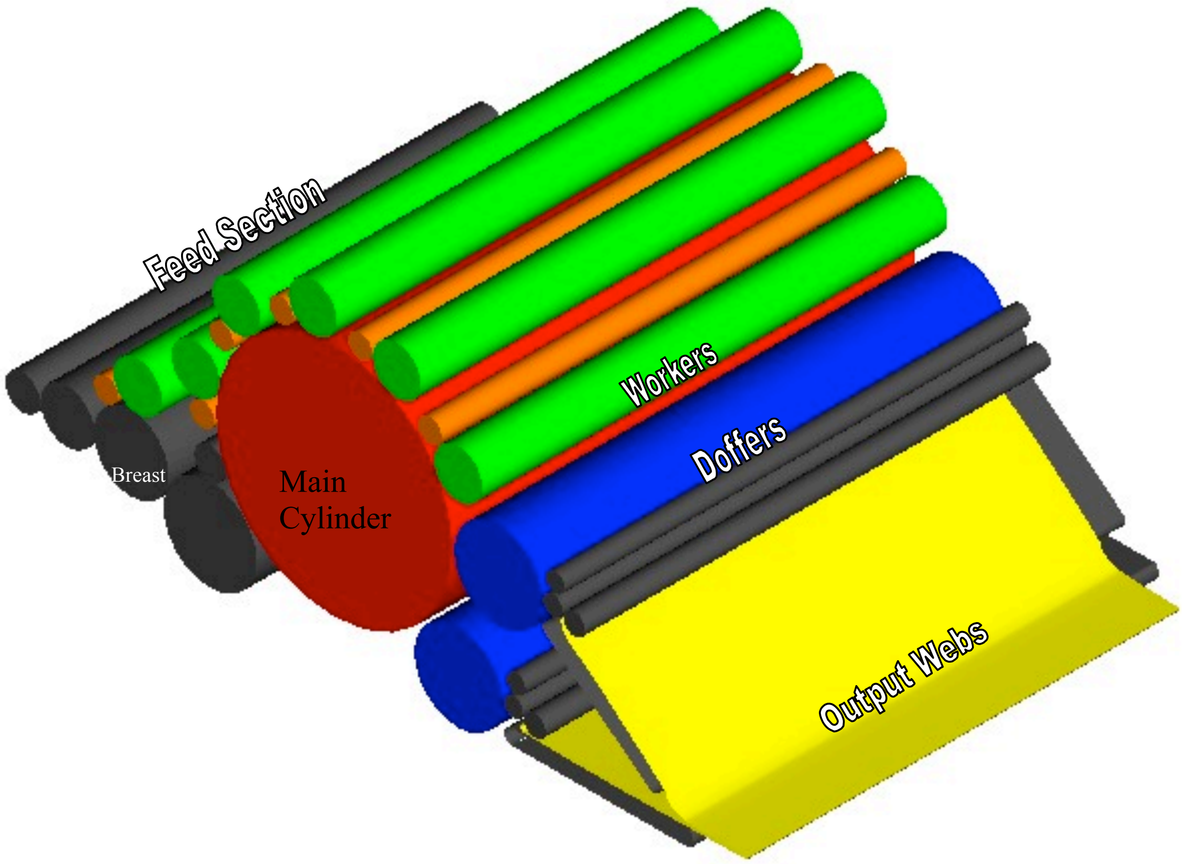

Figure 1: Basic non-woven card. This is the most common means of web formation.

Figure 1 shows carded web formation. One possible bonding route that may follow carding is chemical binder impregnation. The binder is applied as an emulsion or foam and then dried and cured by continuously passing through an oven to glue the fibres together. This process is commonly used for the manufacture of lightweight fabrics for disposable wipes. Another example is the manufacture of wool-blend vertical blinds, usually with stitch bonding. (This will be discussed later.)

For lightweights, the web produced goes directly into the binding process; for heavier fabrics several cards can be positioned in line and their webs combined. The fibre orientation leaving a card is usually predominantly in the machine direction, even though condensing rollers may be used on the outputs. This leads to the strength being greater in the machine direction (MD) and weaker in the cross machine direction (CMD). This leads to a high MD/CMD ratio, which is undesirable for some applications, such as woollen apparel.

Condenser rollers are a pair of rollers positioned after the doffer covered with special wire and that bring the speed down in steps. Each roller is slower than the one before, so the web is crammed into the wire of the following roller changing the fibre orientation. This has the added effect of increasing the doffer speed while keeping the line speed the same, the higher doffer speed takes more fibre from the card per revolution of the main cylinder and so lowers the total fibre load of the card and can allow higher production rates. The desire to increase productivity while maintaining quality has led to the development of non-woven cards with three doffers (FOR, Spinnbau). The three doffers further increase the rate at which fibre can be cleared from the main cylinder, allowing higher throughput, and also lead to further averaging of random web variations to improve quality. Heavier web weights are also then possible.

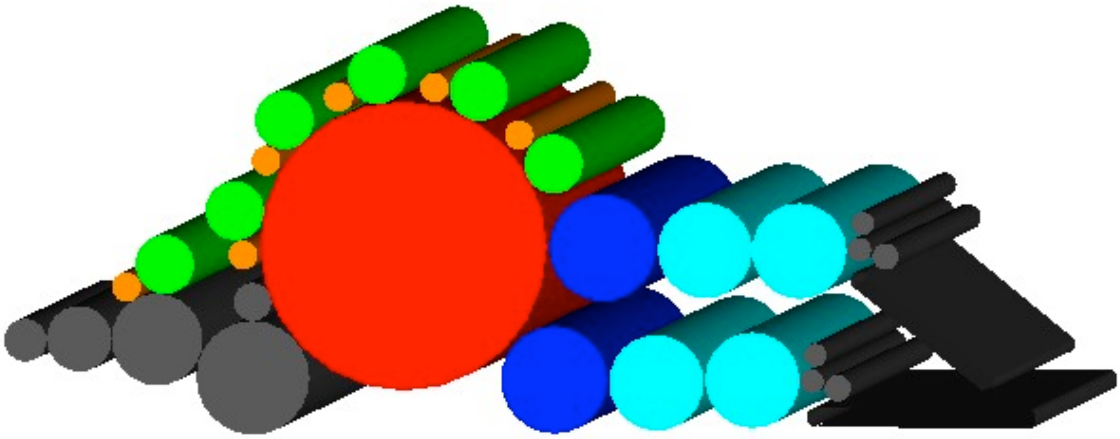

Figure 2: Schematic diagram of a typical non-woven card with condenser rollers (for example, Thibeau, Spinnbau, FOR).

A recent development has been the random card. This card has an extra roller between the doffers and the main cylinder with special wire (see Figure 3). This roller turns counter to the main cylinder and partially strips it. The transfer is said to be mostly via air-flows and a more random orientation is produced. MD/CMD is claimed to come down to 3:1 and, with condenser rollers, down to 1.5:1.

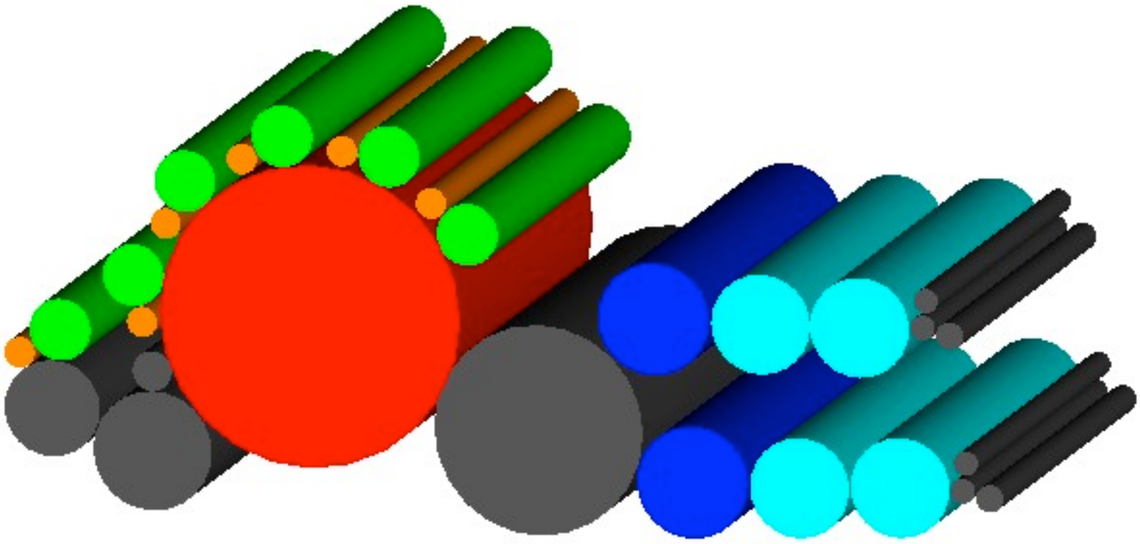

Figure 3: A random card, has extra counter-rotating roller between cylinder and doffers.

Many new high-speed, non-woven cards from, for instance, Spinnbau or Thibeau, have suction systems to control the web as it is doffed at high speed. This has led to improvements in web quality and production rate. The Turbo card from FOR uses aerodynamic stripping of the workers instead of stripper rollers. The FOR cards now also have a high speed doffing system that does not use suction and is claimed to allow heavier webs to be produced from the card. Another interesting development in carding is the Sirolock card wire invented by CSIRO and available from ECC. This has steps in the teeth profile to increase fibre retention. It has been used successfully on workers and doffers. On a worker, the increased retention would improve blending power and on a doffer it would increase the fibre transfer rates, reducing card loading at high production rates.

Cross lapping

To produce heavier weight fabrics from a single card, a cross-lapper is used. This device over-lays the light-weight web leaving the card onto itself with the layered web leaving the cross-lapper at 90^{o} to the card direction. The ratio of the card speed to the cross-lapper output speed determines the number of layers and the weight of the cross-lapped web. In this case the predominant fibre direction has become across the fabric; the MD/CMD ratio is then less than 1. The heavy cross-lapped web can be drafted, or stretched, to pull the fibre orientation towards the machine direction. In this way MD/CMD ratios closer to 1 can be achieved. Cross-lapping and needle punching can produce variations in the density of the fabric across its width. The latest non-woven card cross-lapper systems are computer control programmed such that the card speed and cross-lapper speed can be varied to change the web weight as it traverses the fabric, giving a predetermined profile in density leaving the cross-lapper such that when the fabric is needle-punched it provides a very flat density profile.

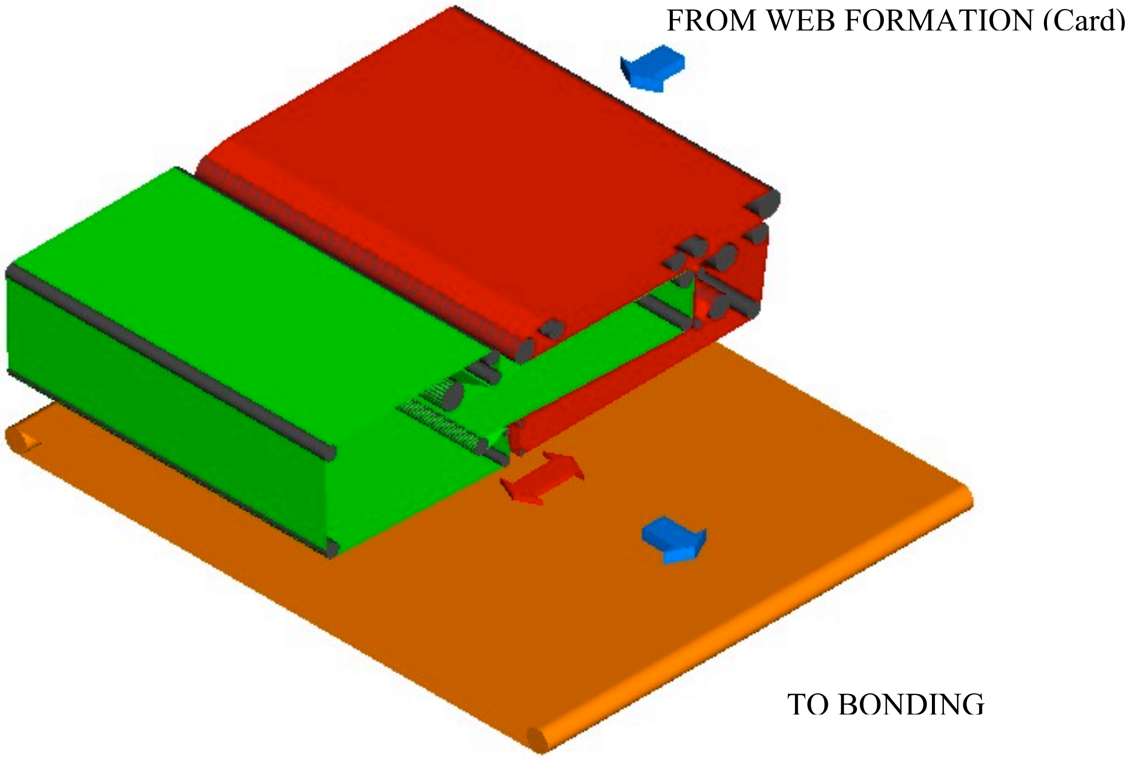

Figure 4: *Cross-lapper.*

An alternative to cross lapping is to use the recently developed Turbo and Airweb doffing systems from Thibeau or Spinnbau. These use a conventional card followed by a new system that throws the fibres into an air-stream to be collected suction onto a drum or belt to give a randomised pattern of orientation. These devices are claimed to produce MD/CMD ratios down to 1.2 directly. The output speed can be reduced to produce quite heavy webs without cross-lapping and high bulk is also possible with some fibre orientation in the vertical direction.

Bonding systems – needle punch

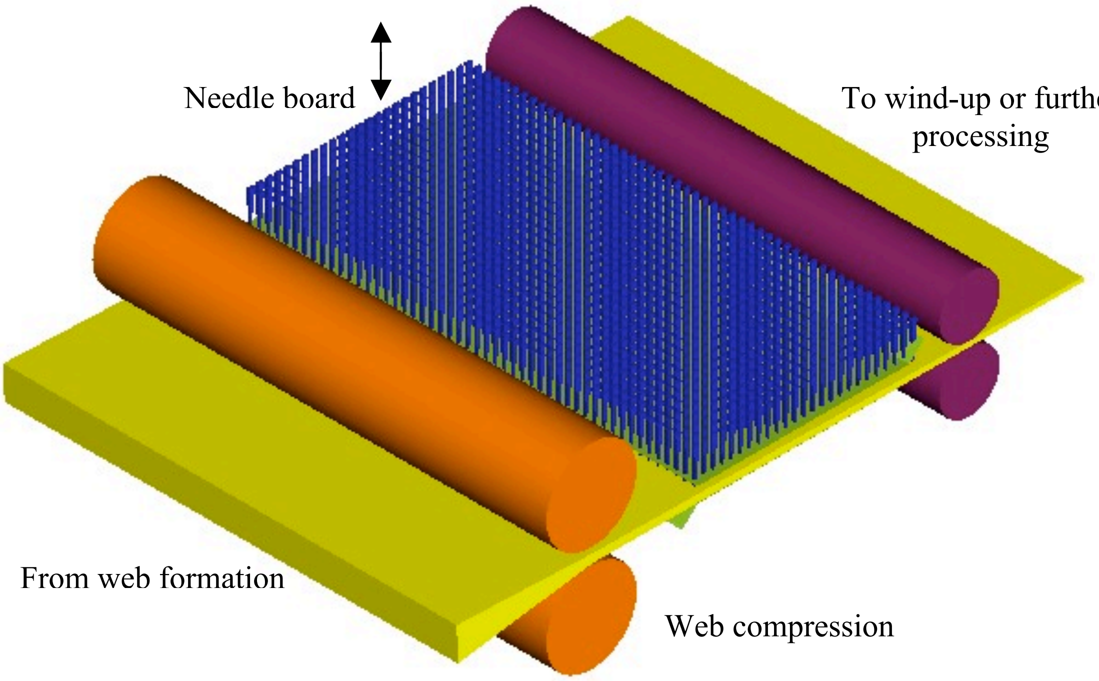

Figure 5: The needle punch process.

Figure 5 shows the needle-punching process, which is commonly used to manufacture medium to heavyweight fabrics. The needles are used at a density of several thousand per square metre and reciprocate through the fabrics. The barbs on the needles catch the fibres and entangle them to form a felted fabric. Often, several stages of needling from each side of the fabrics are required to give the fabric sufficient strength. Because of the reciprocating motion the speed is limited by the ‘advance per stroke’ the fabric cannot be pulled forward while the needles are in the fabric without damaging either the fabric or the needles. A fairly recent development is the Hyperpunch system, where the needles follow an elliptical path rather than straight up and down, so they partially follow the fabric as it advances through the needle-loom. Over-needling can lead to excessive fibre breakage and so there is an optimum level of needling with respect to fabric strength.

For wool non-woven textiles, an attractive needling process is the velour needle punch. This machine needles the fabric into a brush underneath rather than into a steel stripper-plate with a hole for each needle to strip the fibres from it. The velour needle punch pushes the fibres through the fabric to the opposite surface in a controlled way and produces a velour or velvet-like finish to the fabric. The fabric can also be patterned in this way by using special arrangements of needles and brushes.

Stitch bonding

Because non-woven fabrics need to derive their strength from the intimate entanglement of the fibres, and this leads to their stiffness relative to wovens and knits, a compromise is reached in pure-fibre non-wovens between handle and performance. However, non-wovens can be reinforced so the fibres can be more loosely entangled, but the strength is provided by the reinforcement. One means to do this is called stitch-bonding. One example is the Meyer Maliwatt. In stitch bonding, sewing threads are inserted by sewing needles aligned across a cross-lapped web. The threads provide mostly machine direction strength while the natural fibre orientation of the cross-lapped web provides the CMD strength. The sewing threads, constituting only about five per cent of the fabric weight, are buried into the fabric in finishing where a pile may be raised or the fabric lightly wet-felted, so that they are not visible in the final garment. Such wool and wool-blend fabrics can be used in outerwear and are limited to heavier than around 250 gsm. A fleece-like fabric can also be produced in this way.

An alternative to stitch bonding to give extra strength is the use of a scrim. These are woven fabrics that are incorporated into the non-woven, usually by insertion between two webs before bonding. Needle punching the webs through the woven fabric can produce a strong fabric with a lower degree of entanglement and so give a softer fabric. However, the fibre security can then be low and pilling and fibre shedding can become a problem. The cost of the woven fabric often has to be low, so synthetic fibres are used and for disposables, often welded nets are favoured. However, for highly specified technical fabrics, such as some wool-containing paper-making felts, the scrim is a carefully designed key component rather than a cheap reinforcement.

Hydroentanglement

Also known as Spunlace or Jetlace, hydroentanlement uses rows of fine high pressure water jets to entangle the fibres of the web into non-woven fabrics. The water from the jets is removed by suction slots behind each injector. Because there are no reciprocating parts, the production speed is not limited as needle-punching is by 'advance per stroke'. The speed can be very high and is limited only by the energy that can be injected by the water jets into the entanglement process. Speeds of hundreds of metres per minute are used on lightweight synthetic fabrics for disposables, but lower speeds are often used for heavier or more durable fabrics. Power consumption is relatively high, but the energy cost per kilogram remains low because of the high production rates possible. Only two companies supply large-scale Spunlace lines, Rieter Perfojet and Fleissner.

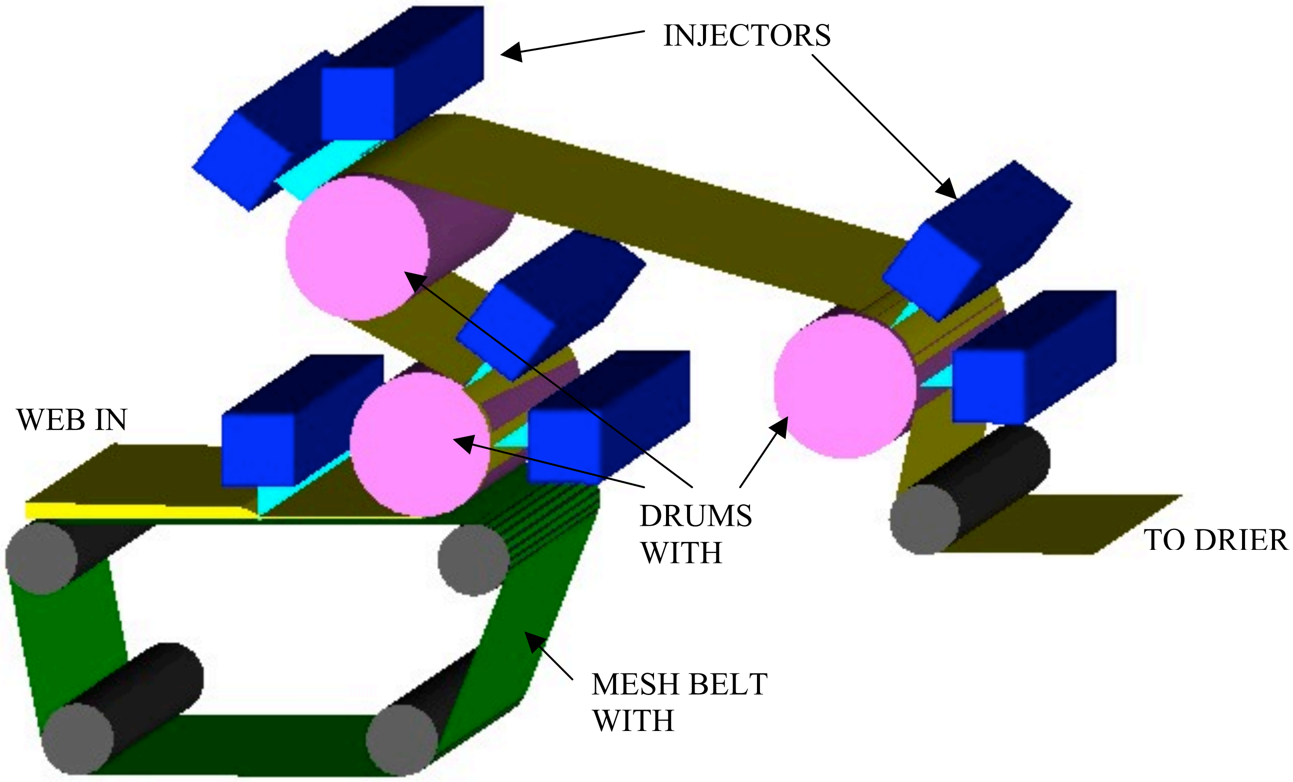

Figure 6: Hydroentanglement or Spunlace.

The fine, high pressure water jets are applied against the fabric backed by either a mesh belt or drum. The drums have mesh shells or, in the case of Rieter-Perfojet, may have random perforated shells designed to improve entanglement and reduce striping by the jets.

Spunlace process speeds may exceed 300 m/min but are usually much lower, especially for wool, which is harder to entangle than finer synthetic fibres.

Common Spunlace products are:

- wipes, towels and tissues
- filters
- protective apparel
- surgical gowns and covers
- synthetic leather
- sanitary products
- home furnishings
- interlinings (some wool).

Spunlace fabric weights have an upper limit, if the fabric is to be entangled throughout its thickness, of around 400 gsm. The main advantage of the Spunlace process for wool is that lighter-weight fabrics can be produced compared to needle-punch non-wovens. Also, a higher degree of entanglement can be achieved with less fibre damage compared to needle-punching. Reinforcing scrims can also be used in Spunlace fabrics to add strength. While there is currently very little commercial production of Spunlace wool fabrics, research and development is ongoing and is expected to provide commercial outcomes in the near future.

Air-laid

Air-laid non-wovens are becoming increasingly popular for producing thick batts, particularly for thermal or sound insulation, from waste fibres. The machines are usually very simple with a feed system and a single high-speed roller clothed with card wire and no doffer. It is stripped of its fibre by a high-speed air stream. A corresponding suction zone on an output conveyor collects the fibres in a fairly random manner to produce a batt. Often, thermal bonding fibres are included and the batt is bonded directly after the air-lay machine in a through-air bonding oven. Chemical bonding is also sometimes used.

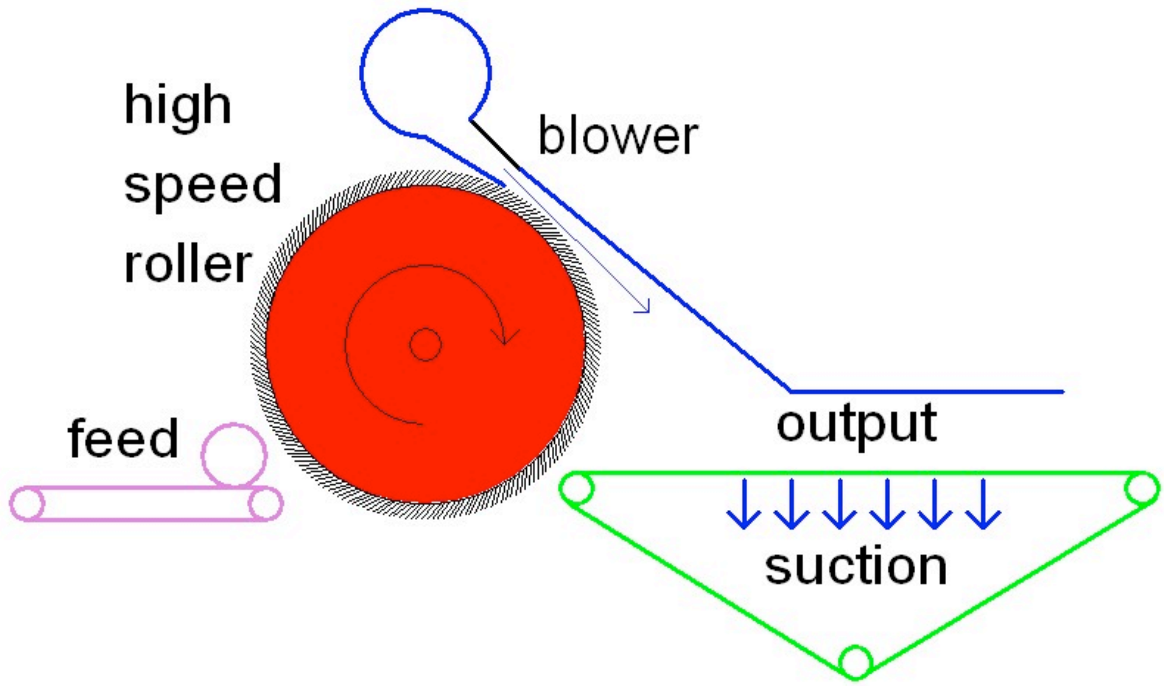

Figure 7: Schematic of an air-lay machine.

Readings

www.fincarde.com

www.karlmayer.de

www.nsc.com

www.spinnbau.de

Questions

1. What are the four main stages of non-woven production?
2. What is the main purpose of the card?
3. What does a cross-lapper do and when is it used?
4. How does the speed of the cross-lapped web compare with the single input web?
5. How does the predominant fibre orientation differ between the card web and the cross-lapped web?
6. Why do some cards have double doffers?
7. Why is a non-woven fabric likely to be stiffer than a knitted or woven fabric of the same real density?