CLEANTEX

Clean and Innovative Textiles Strategy for Circular Economy

MODULE 5

Sustainable Yarn, Fabric and Garment/Assembly Production

Unit 5.1

Yarn and Non-Woven Fabric Production in Circular Economy

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Yarn Production

There are two kinds of yarns: the staple yarns, which are made of shorts fibers, and the continuous (also called filaments) yarns which are of infinite length.
Staple yarns can be divided into two categories: the yarns made of short staple fibers (between 10 and 60mm long) and those made of long staple fibers (from 60 to 500mm long). For example, cotton fibers are short stable fibers and wool fibers are long stable fibers.
Filaments are of infinite length. This means that the length is much more important than the diameter of the yarn. The only natural filament is silk. All the other filaments are chemical.

Most of the clothes are made of blends (cotton /polyester/elastane e.g.). In order to intimately blend different materials (fibers and/or filaments), they must be of the same length and similar fiber count. A fortiori, a polyester filament cannot be intimately mixed with cotton fibers. It is then necessary to convert the filaments into fibers, and to convert the longest fibers (linen e.g.) when necessary. On the other hand, when the materials are not intimately mixed, it is not necessary to convert them (core filament e.g.). When using recycled fibers, since they are shorter and weaker than virgin fibers, this can be a problem when blending.

Not all the blends are possible with recycled fibers. When there are too many short fibers in a yarn it doesn't have good mechanical properties and will be unusable, because it causes higher losses and poorer efficiency. A yarn made of 100% recycled fibers is really rare. The machine manufacturer RIETER, which produces recycling systems for rotor and ring spinning, proposes on its website a table with possible blends that are feasible on its recycling systems [1]. With rotor spinning, it is possible to use up to 87.5% recycled fiber from a pre-consumer deposit. With ring spinning it is possible to use up to 60% recycled fiber from a pre-consumer deposit. If the recycled fibers come from a post-consumer source, it is possible to use up to 75% with rotor spinning, and up to 60% with ring spinning. However, the yarn will be coarser with post-consumer recycled fibers, as they are already damaged by usage and more fragile. It is thus more difficult to realize a thin yarn.
RIETER also propose a quality classification. To get a really good yarn there must be a maximum of 45% of short fibers. Beyond that the quality decreases, and if the percentage of short fibers exceeds 78%, then the yarn will be of poor quality.

Yarn spinning can represent up to 1/5 of a cotton garment global environmental burden.[2] More than 75% of the greenhouse gas production of spinning processes comes from energy consumption, and the energy conception is directly related to the thickness of the yarn: the thinner the yarn the more energy it consumes. During yarn production, the different sources of environmental impacts that must be considered are [3], [4]:

- the energy use (processes, humidification systems),
- the process unit efficiency
- the consumables used (chemicals, packaging materials) and how they are disposed,
- the amount of fiber waste created and how it is disposed (some fibers can be re-inserted in a spinning process however some very short fibers cannot and will be used as flock or as padding insulation materials)
- the amount of dust and of noise created.

Production of filaments

To produce a chemical filament granulates of polymers are firstly converted from solid to fluid state (through melting or dissolving e.g.). The fluid is extruded through a die to get a monofilament or a multifilaments, depending on the number of holes in the die. The filaments are drawn to align the polymer chains in the filament direction and if needed the filaments are converted which means they are cut to a shorter length. The conversion from solid to fluid state and extrusion steps can be done through dry, wet, melt or gel spinning.

It is possible to use recycled polymers in the production of filaments. They 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. You can find information on polymers recycling in the unit 4.3.

Production of staple yarns

Staple fiber spinning is a process in which fibers are processed into a yarn. First of all, bales of fibers are opened. The fibers can then be mixed or blend with other fibers or colors. After this comes multi-steps of cleaning in which impurities are first removed, then too short fibers are eliminated through carding process, and usually for yarn count below 25 Tex combing is also used. The fibers are then aligned in the direction of the yarn, drawn and spun. The different spinning methods are ring spinning (regular method), rotor spinning, twistless spinning, wrap spinning and friction spinning (non-regular methods).

Recycled fibers can be used in staple yarn production. However, the recycled fibers are shorter than virgin one and therefore, in case of short spinning process, they must be mixed with virgin fibers to ensure the mechanical properties of the yarn. Recycled fibers can be spun through rotor spinning, friction spinning or ring spinning. Depending on how the fibers have been recycled, there are a non-uniformity of fiber length, some unopened fibers, some small yarn pieces and it is really difficult to spin thin and middle count yarns. Most of recycled yarns are coarse count.

The first process to spin recycled fibers is ring spinning. The particularity of this process lies in the presence of a ring, on which there is a traveler. The traveler moves on the ring, and gives a rotation to the yarn [5]. Yarns spun with the ring spinning process are stronger than with other processes (all parameters equal). The fiber orientation of ring spun yarns is good, which helps with the spinning of short recycled fibers.

The second process is rotor spinning, also called open end spinning. The principle is similar to the production of cotton candy. Fibers fed to the rotor are incorporated into the rapidly rotating 'open-end' of a previously formed yarn that extends out of the delivery tube [6], [7]. Rotor spinning process is cheaper and faster than ring spinning.

The third process to spin recycled fibers is friction spinning. In this process, fibers are wrapped around a core filament to form a yarn. Friction spun yarns have a poor orientation but their appearance is very good.

Nonwoven production

The two main steps to produce nonwovens are web forming and web bonding. There are several ways to achieve these steps. The choice of process is determined by the fiber used and the final application of the product.

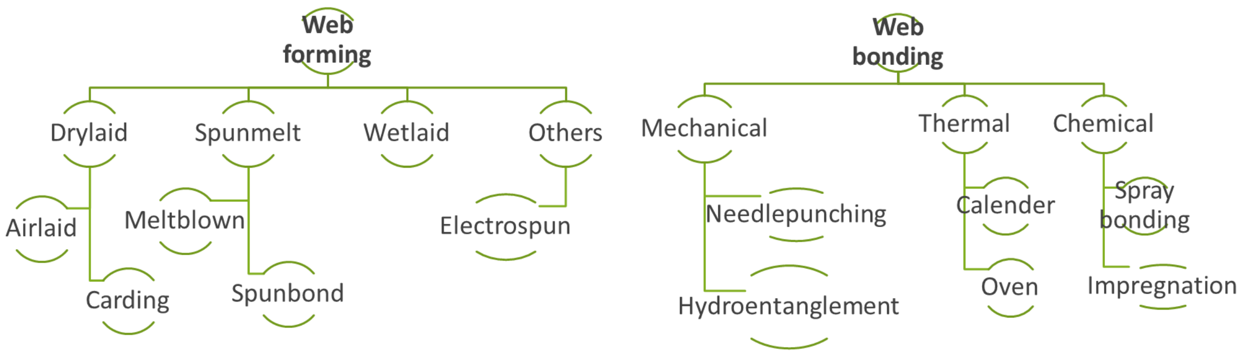

Figure 1 Web forming and web bonding processes

Web forming processes

The first processes are part of the Drylaid group. They can handle natural and synthetic fibers, alone or in blends [8]. When the carded process is used, the web is produced on a carding machine, from short or long staple fibers and can be used in geotextiles or building roofing. When the airlaid technology is used the web is produced by suspending relatively short fibers in air and then transporting this air/fiber mixture to a continuous air permeable conveyor, where the air is removed and the fibers are deposited on to form a web. Airlaid webs can be used as automotive soundproofing or thermal insulation.

The second processes are part of the Spunmelt group. The web is formed from continuous filaments that are produced by extrusion process. The production process is fully integrated enabling polymer chips to be made into fabric in one continuous operation [8]. Spunbond webs contain coarser fibers, have great tensile strength and can be used in filtration, medical gowns, geotextiles, durable wipes… Meltblown process uses high velocity hot air streams that impinge on the filaments as they are extruded, involving attenuation of the filaments. Meltblown webs have smaller diameter filaments, superior filtration properties, and can be used as filtration, oil absorbent, protective masks, blood filters...

The third process is Wetlaid process, which uses technology that originated from the papermaking process [8]. Fibers are suspended in water. Whereas paper is normally produced from short, fine fibers of cellulosic composition, the fibers in Wetlaid nonwovens can be substantially longer and can be composed of many different natural, high- performance synthetic or inorganic materials. This web can be used in tea bags, air and liquid filters, surgical clothing and drapes, insulation...

Web bonding processes

The first process is needle punching. The fibers 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 fiber 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. This process is used for velour, automotive furnishing, synthetic leathers, geotextiles, building…

There are also the hydroentanglement and stitch bonding which are mechanical bonding processes. Hydroentanglement consists in entangling fibers using high-velocity water jets. Fibers 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 and can be used in synthetic leathers, wipes, automotive, thermal protection… Stitch bonding consist in stitching or knitting the fibers together and can be used in wipes, carpet backing, thermal insulation, geotextiles, filtration...

Then there is thermal bonding which is suitable for fibrous webs containing fibers (or particles) made from thermoplastic polymers. Web is bonded by thermally fusing the thermoplastic components to the surrounding fibrous material. It can be done by through-air bonding, calendar bonding, ultrasonic bonding, microwave etc. This process can be used in wipes, automotive textiles, filtration, geotextiles, teabags...

Lastly there is chemical bonding, in which binders consisting of polymer latex adhesives in the form of emulsions, dispersions or solutions are deposited on to fiber surfaces in the web and then dried and cured to form a cross-linked film that bonds adjacent fibers together. Additionally, some nonwovens are solvent bonded, wherein fibers are treated with a solvent specific for the constituent polymer to produce bonding in the web. This is mostly used for wipes and sponges...

Using recycled materials in nonwovens is really easy because they accept really short fibers which is an advantage for fiber recycling. It's also 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 followed by needle punching. Spunmelt and Meltblown processes are currently not used with recycled fibres. However, the choice of processes will depend on the application and the desired properties of the final material.

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