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Lyocell fibres

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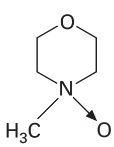
5.1 Introduction

Lyocell is the first in a new generation of cellulosic fibres made by a solvent spinning process. A major driving force to its development was the demand for a process that was environmentally responsible and utilised renewable resources as their raw materials. The first samples were produced in 1984 and commercial production started in 1988. A wide range of attractive textile fabrics can be made from lyocell that are comfortable to wear and have good physical performance. This physical performance combined with its absorbency also make lyocell ideal for nonwoven fabrics and papers.

Lyocell is a cellulosic fibre derived from wood pulp produced from sustainable managed forests. The wood pulp is dissolved in a solution of an 'amine oxide' (usually *N*-methylmorpholine-*N*-oxide (5.1)). The solution is spun into fibres and the solvent extracted as the fibres pass through a washing process. The manufacturing process recovers >99.5% of the solvent. The solvent itself is non-toxic and all the effluent produced is non-hazardous.



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It is the direct dissolution of the cellulose in an organic solvent without the formation of an intermediate compound that generically differentiates lyocell from other cellulosic fibres such as viscose.

Lyocell has all the benefits of being a cellulosic fibre, in that it is fully biodegradable and absorbent. It has high strength in both the wet and dry state. It blends well with fibres such as cotton, linen and wool. In common with other highly oriented cellulosic fibres, lyocell fibrillates when the fibre is abraded in the wet state. Surface fibrils (small fibre-like structures) peel away from the main body of the fibre but remain attached. The fibrillation behaviour of the fibres is exploited to produce a wide range of attractive fabric aesthetics.

This chapter will consider all aspects from the fibre manufacturing methods, the fibre properties including an assessment of its sustainability and biodegradation credentials. It will also consider the key applications of the fibre, concentrating on its application in textile apparel and nonwoven fabrics.

5.1.1 Historical background and production process

1939	Patent appears describing the dissolution of cellulose in amine oxide.
1966–1968	D.L. Johnson, Eastman Kodak Inc., publishes series of papers discussing a range of compounds, including cellulose, which dissolve in amine oxide.
1969–1979	American Enka/Akzona Inc. work on spinning fibre from a solution of cellulose in amine oxide but did not scale up.
1979	Courtaulds start research on the new cellulosic fibre, which was to become Tencel®.
1983	First pilot plant built in Coventry.
1988	Small commercial Tencel® plant at Grimsby, UK.
1989	BISFA agrees to new generic name – lyocell.
1992	Full-scale production Tencel® plant at Mobile, USA.
1997	Lenzing starts a production plant in Austria.
1998	Tencel® plant in Grimsby, UK. First non-fibrillating variant, A100, produced at full commercial scale.
2004	Lenzing AG acquire the Tencel® business.

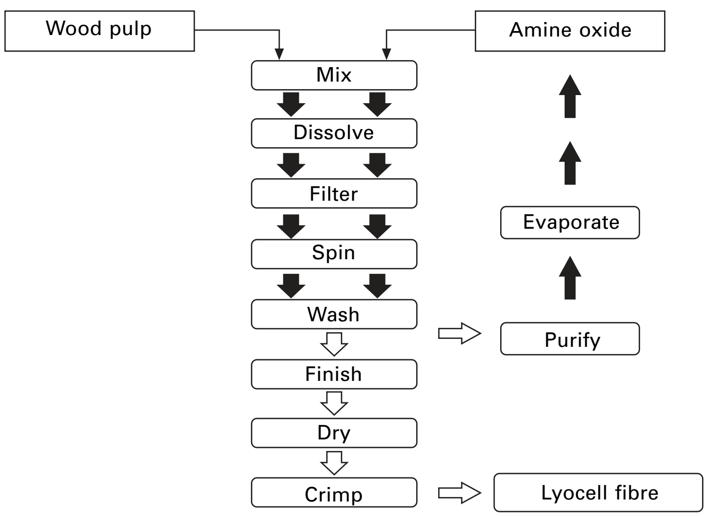
Lyocell was first made in the lab and then in the pilot plant at Coventry during the early 1980s. It used technology that was significantly different to that developed by Enka. Whilst the process appears simple, major technological challenges had to be overcome to achieve an economically viable process – spinning, dissolution and solvent recovery all proved challenging. In 1988 a semi-commercial plant (capacity 30 tonnes/week) was started up at Grimsby, this plant is known as S25 because originally there were 25 spinning ends. The operation at S25 enabled the manufacturing process to be developed and proven and it provided enough staple fibre to initiate full-scale market development. The fibre was branded Tencel®. In May/June 1992 the first full-scale Tencel® factory (SL1) was commissioned in Mobile, Alabama. The £67m investment represented a significant risk to Courtaulds as neither the market nor the technology were proven when the plant design started – it was a three-year project. However, the success of producing and selling fibre from SL1 convinced the board to invest heavily in the future of Tencel®.

The second Tencel® plant, SL2, started up alongside SL1 at Mobile in the summer of 1995 with a capacity of ≈ 20,000 tonnes/year. A third Tencel® plant was installed in UK (Grimsby) in 1998 with 30,000 tonnes/year capacity. Half of this capacity included facility to make a non-fibrillating variant called 'A100'.

Lenzing of Austria commenced production of their lyocell fibre in 1997. This rapid expansion led to a temporary overcapacity and no further production occurred until Lenzing expanded their capacity by 20,000 tonnes per year in 2004. Development of a continuous filament spinning process by AKZO/Tencel® continued throughout the 1990s but has not yet been commercialised because of the decline in the market for filament rayon and the high investment cost required.

5.2 Process description

This section provides a description of the process steps required for making lyocell. A diagram of the process is shown in Fig 5.1. The principles are simple. Firstly, the pulp is wetted out with dilute aqueous amine oxide to fully penetrate the pulp fibres. The subsequent removal of the excess water under heat and vacuum is a very effective way of making a homogenous solution with a minimum of undissolved pulp particles and air bubbles. The solution is highly viscous at its operating temperature (90 to 120°C) and must be processed in similar high pressure equipment to that used in melt



5.1 The lyocell process.

polymer systems. The fibres are formed by spinning into an air gap and then coagulating in a water/amine oxide bath. They are then washed and dried and cut. The wash liquors are recovered, purified, concentrated then recycled. The process description below applies to the two commercial-scale operations of Tencel® and Lenzing. Variations in detail have been cited in patent applications and the literature but these are at a much smaller scale of operation.

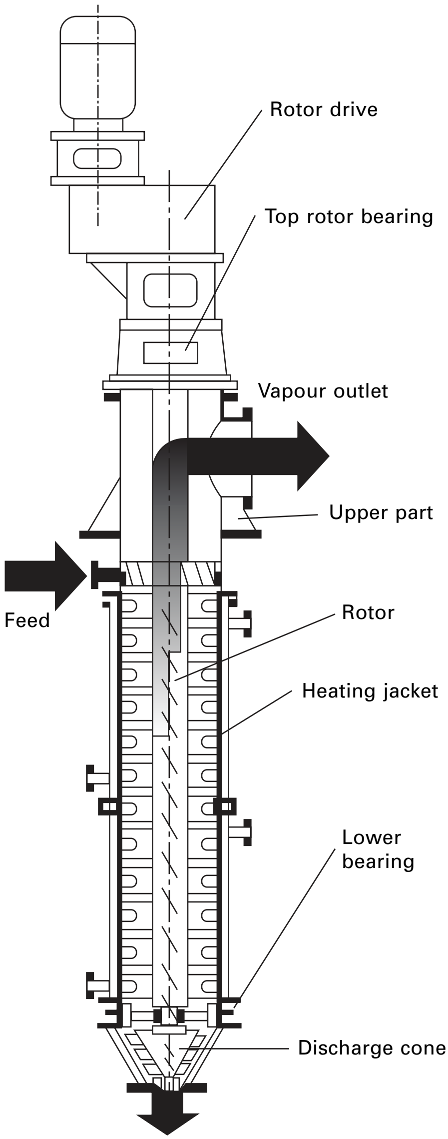
5.2.1 Pulp and premix

Wood pulp is the principal raw material of the lyocell process in terms of cost and volume. The grade used is similar to the dissolving pulp used for viscose rayon but has a slightly lower degree of polymerisation (DP); Tencel® fibres have a DP of 500 to 550. The pulp is pulled from the reels into a shredder, which cuts the pulp into small pieces for mixing with the amine oxide solvent. The amount of pulp fed to the mixer has to be accurately measured so that the cellulose content in solution is closely controlled.

The cut pulp is conveyed to vessels where it is mixed with a 76–78% amine oxide solution in water. A small quantity of a degradation inhibitor is also added to the mixer; other additives such as titanium dioxide (for producing matt fibre) can also be added. The mixing is achieved at 70 to 90°C in a ploughshare mixer that contains a number of high-speed refiners to break the pulp down and aid solvent wetting. The resultant slurry consists of swollen pulp fibres and has the consistency of dough. This premix is dropped into an agitated storage hopper from which it is accurately metered to the next stage of the process.

5.2.2 Solution making

Premix is heated under vacuum to remove sufficient water to give a clear, dark amber-coloured viscous solution of the cellulose. Typically the solutions contain 10 to 18% cellulose. The evaporation of water from premix to make solution is achieved in a wiped thin film evaporator such as a Filmtruder (from Buss-SMS) (see Fig. 5.2). This is a long vertical cylindrical vessel with steam heating in jackets around the vessel. A shaft down the centre of the vessel with blades attached to its circumference is rotated to smear the material around the heated surface to promote the evaporation process and to transport the solution down the vessel. The evaporator vessel is operated under vacuum to reduce the temperature (*circa* 90 to 120°C) at which the water evaporates. This is important because the amine oxide solvent in solution can undergo an exothermic degradation process if it is overheated.



5.2 A Buss-Luwa filmtruder (courtesy Buss-SMS).

5.2.3 Solution transport

The solution leaving the filmtruder is pumped by a number of specialised pumps in series through the transport system. The transport system consists of a solution cooler and a hydraulic ram buffer tank, which feed into the solution primary filters. Due to the viscous nature of solution the pressures involved in pumping solution can be as high as 180 bar. A complication to the process design is caused by the tendency of the amine oxide in solution to exothermically degrade. Exotherms can be caused by maloperation of equipment or chemical contamination of the solution; if an exotherm occurs, the temperature of the solution increases rapidly and it decomposes to volatile amines and water. This causes a very rapid increase in pressure that would be sufficient to rupture the high pressure equipment with very serious safety implications. To allow for this possibility bursting discs are provided at strategic positions throughout the plant to relieve pressure in the event of an exotherm. The bursting discs are of a special design to prevent any flow dead spots. The discs vent into disentrainment pots which separate the solid degradation products and allow the gases to be vented to the atmosphere. The understanding of how and why exotherms occur and the development of a safe way of venting exotherms when they do occur was one of the keys to scaling up the whole process.

5.2.4 Solution filtration

Prior to spinning it is necessary to filter various impurities out of the solution. Most of the impurities are introduced with the pulp feedstock, the principle ones being undissolved pulp fibres or inorganic compounds such as sand and ash. The solution is passed through two stages of filtration. The primary filtration is centrally located and consists of sets of sintered stainless steel media candle filter elements. The secondary stage filtration is achieved by candle filter elements associated with each spinning machine position.

Filters are washed for reuse by an off-line process involving rinsing with hot amine oxide, chemically decomposing the residual compounds and then ultrasonic washing.

5.2.5 Spinning

For spinning, the solution is split into sub-streams, which serve a number of spinning positions. The solution is then supplied to each jet, via a filter, by a metering pump. It is then extruded and spun through an air gap into a spin bath containing dilute amine oxide solution. Each jet consists of thousands of tiny holes through which the solution is extruded into fibres. Just below each jet face is a small air gap across which air is blown by the cross-draught system to condition the fibres. After passing through the air gap the fibres, or tow, are pulled down through the spin bath where the cellulose is regenerated in dilute solvent. The fibres are drawn, or stretched, in the air gap by the pull of traction units, or godets.

The design of the spinning assembly proved critical to successfully scaling up the process and achieving commercially attractive fibre properties and manufacturing costs. Spinning the solution directly into an aqueous bath would necessitate using very dilute cellulose solutions (causing high costs) and generates fibres with properties that are generally inferior to viscose.

Extruding the solution into an air gap enables more economical, higher cellulose solutions to be spun. Furthermore, when the solution is extended or drawn in the air gap it is also orientated so that good strength and elongation properties can be imparted. A draw ratio of between 4 and 20 is typical – within this range fibre properties are similar. At lower ratios fibre tenacities are reduced and at higher ratios spinning stability deteriorates.

When the solution is drawn in the air gap it will readily break unless it is also cooled by means of a gas flow. This tendency to rupture is worse at higher draw ratios and spinning speeds, but is reduced if highly viscous solutions are used. This necessitates the use of relatively small spinneret holes relative to the high polymer viscosity so special jets needed to be designed.

The main limitation of air-gap spinning is the tendency of neighbouring filaments to touch and stick together. This limits the packing density of the spinneret and hence the productivity of the spinning machines. This is compounded by the need to adequately cool all the filaments using an air flow velocity sufficiently low that it does not disrupt the stable flow of the filaments.

The two commercial processes overcame these constraints in different ways. Tencel® arranges the spinnerets into rectangular strips whereas Lenzing uses a circular array. Both processes use a controlled flow of gas across the filament arrays to stabilise and control the process.

5.2.6 Fibre washing

The fibre tows from each end are brought together into one large tow band for processing down the fibre line. The first process on the fibre line is washing; the solvent is washed from the fibre with hot demineralised water in a series of wash baths. In the Tencel® process the fibre is washed as a single large continuous tow through a series of wash troughs, each of which consists of a wide, shallow bath containing a number of wedges. These wedges deflect the tow band alternately up and down as it is pulled along the trough. This serves to allow dilute solvent into the tow band and then squeeze it out. Wash liquor leaving the wash line goes into the spin bath system. The washing water is fed counter-current to the tow band at a rate to keep the spin bath liquor concentration at the required level. In the Lenzing lyocell process the fibres are cut before washing – as in the viscose process.

5.2.7 Fibre treatments

After washing the fibre is treated in a number of ways:

- The fibre could be bleached if required.
- Soft finish is always applied to make further processing easier.
- Antistatic agent is applied.
- Other treatments to give specific fibre properties can also be performed – in particular various chemical treatments are used to control fibre fibrillation (e.g. as for the Tencel A100 and Lenzing lyocell LF grades).

5.2.8 Fibre drying

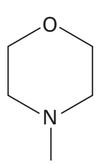
After washing and finishing the fibre is dried in a fibre drum dryer. These consist of a series of perforated drums that the fibres pass over. Steam heated air is sucked through the fibres as they pass over the drums.

5.2.9 Crimping, cutting and baling

In the Tencel® process, dry fibre is crimped before being fed to a radial blade cutter for cutting into staple. In the Lenzing process, the fibres emerge from the driers with a crimp imparted during the washing stage. The fibres are then baled and dispatched in the normal manner.

5.2.10 Solvent recovery

Diluted amine oxide solvent from the spin baths on the spinning machine and various other process sections is collected to recover the relatively expensive solvent. Over 99.5% of the solvent used is recycled and recovered by the process. The amine oxide will slowly oxidise the cellulose during the process – particularly at the elevated temperatures used. The reaction will reduce the DP of the cellulose (giving poorer fibre properties) as well as generating coloured compounds that would detract from the whiteness of the fibres. The amine oxide degrades to *N*-methylmorpholine (5.2) plus other amines. The reaction is strongly catalysed by transition metals such as copper and iron. To control this it is essential that a stabiliser such as propyl gallate (5.3) is incorporated – this acts both as an antioxidant and a chelating agent.



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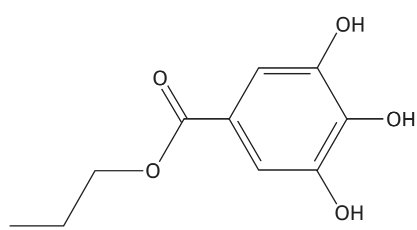

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Solvent recovery consists of two main processes, ion exchange of the dilute solvent then evaporation of the excess water to a concentration required in premixing. The ion exchange process consists of cation and anion beds which remove various ions that would destabilise the solution and the colour contaminants that would otherwise build up in the solvent. The ion exchange resins and regeneration procedures have been developed especially for amine oxide.

The amine oxide is re-concentrated in a steam heated multiple effect falling thin film evaporator. The tendency of the solvent to exothermically degrade means the process control of the operation has to be such that the amine oxide can never be overheated. The water overheads can be reused to wash the fibres so minimising the environmental impact of the process.

5.3 Lyocell sustainability

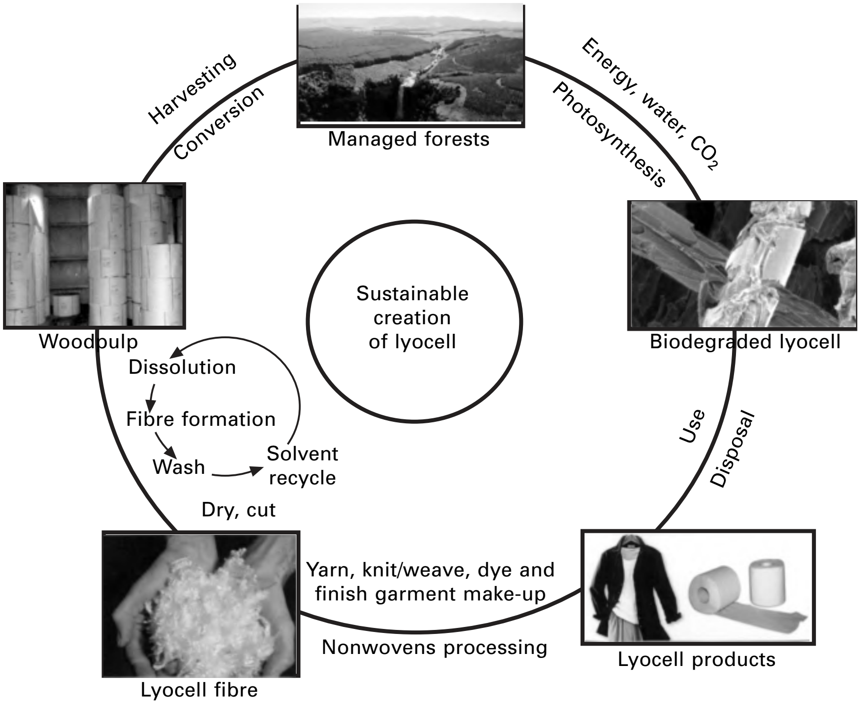
In addition to their well-documented consumer comfort, aesthetic and performance benefits, cellulosic fibres also offer the potential for very attractive environmental characteristics. Lyocell is the youngest member of the cellulosic fibre family. It was first commercialised, under the brand name Tencel®, in the early 1990s. One of the key development targets was to deliver a product offering significant benefits in terms of low environmental impact and sustainability.

Lyocell is an excellent example of a 'sustainable fibre' because:

- The forests that provide the raw material for lyocell are always being replenished.
- Other materials used in the fibre production process are re-cycled with very little loss.
- The fibre is biodegradable.

The following is a simplified representation of the life cycle of lyocell fibres, from creation through to ultimate disposal and biodegradation (see also Fig. 5.3).

- Lyocell fibre is manufactured from cellulose wood pulp, which is produced from trees grown in managed forests.
- The fibre production route is, chemically, very simple. The wood pulp is dissolved directly in a solvent and formed into fibres. There are no chemical by-products and the solvent is recycled at high levels of efficiency.
- Lyocell fibres are converted to a very wide range of textile and industrial products. In many areas, the particular properties of lyocell lead to environmental benefits for customers during product manufacture and use.
- At the end of their useful life, lyocell products are biodegradable. The



5.3 Lyocell sustainability.

products of this biodegradation can be considered as contributing to photosynthesis, and hence the growth of new trees for future lyocell production.

Each component of the lyocell life cycle is considered in more detail in the following sections.

5.3.1 Raw material

Lyocell cellulosic fibre is produced from special grades of wood pulp, a natural and sustainable resource that is derived from trees. By contrast, synthetic fibres such as polyester and nylon are oil-based. A very wide range of tree types, both softwood and hardwood, are suitable for conversion to wood pulp for lyocell (Fig. 5.4). The main species currently chosen as feedstock for commercial lyocell production is eucalyptus.

Provided the forests are managed and harvested in a responsible manner, trees are an excellent source of renewable raw material. Lyocell manufacturers have paid particular attention to forestry management practices when developing partnerships with wood-pulp suppliers. Independent accreditation

5.4 The trees used for Tencel® production (courtesy of Sappi Saiccor).

schemes, which have the support of environmental organisations such as Friends of the Earth, are now being adopted. A leading example is that offered by the Forestry Stewardship Council (FSC).

The Forestry Stewardship Council aims to support ‘environmentally appropriate, socially beneficial and economically viable management of the world’s forests’. It offers a labelling scheme for forest products (including wood pulp) that provides ‘a credible guarantee that the product comes from a well managed forest’. The Principles and Criteria of FSC cover issues such as protecting water quality, managing the effects on threatened or endangered species and monitoring the effects of harvesting techniques. The primary supplier of wood pulp to Tencel has recently demonstrated compliance with all the requirements for FSC ‘Chain of Custody’ accreditation.

Trees as a source of cellulose offer a number of potential advantages over most of the world's cotton production. The cellulose yield per acre of land is much higher (up to 10 times more, dependent on conditions). They do not require 'high grade' agricultural land that could be used for food crops and require much less irrigation and pesticides. The trees are converted to wood pulp in pulp mills. Environmental performance of the pulp mill is an important consideration in the overall Life Cycle Analysis for lyocell. It is vital that by-products from the pulping process are used in a sustainable manner and effluent is minimised. The class-leading mills which supply lyocell manufacturers adopt a number of strategies to achieve this: for example, by-products are converted to specialist chemicals for sale and to produce energy. Bleaching is via either Elemental or Totally Chlorine Free processes (ECF, TCF).

5.3.2 Lyocell fibre

Details of the lyocell production process have been described earlier. This section will focus on the environmental attributes of the technology. Overall, current lyocell factories are designed and operated to achieve world-class low levels of emissions and minimise energy consumption.

The solvent used to dissolve cellulose wood pulp, N-methylmorpholine-N-oxide ('amine oxide'), is not classified as corrosive or toxic and is biodegradable. The cellulose dissolves directly in the amine oxide. There is no 'chemical conversion', so no requirement for the complex emissions treatment associated with the release of by-products. After fibre formation, solvent is recovered from the fibre via multiple washing steps. It is then purified and returned to the concentration required to dissolve cellulose, for reuse at the beginning of the process. This is the so-called 'closed-loop' technology. By careful attention to detail at each stage of recycling, solvent recovery rates in excess of 99.5% are achieved.

A range of design and operational features minimise the production of solid waste. Any fibrous waste produced is processed and used in non-textile applications. Lyocell has been awarded the right to use the Oeko-Tex 100 'Confidence in Textiles' label, issued by the International Association for Researching and Testing in the field of Textile Technology. This independent testing confirms the purity of lyocell fibre. In addition, in December 2000, Lenzing Lyocell was awarded the 'European Environment Award for Sustainable Development' and in 2002 received the European Eco-label. The Eco-label is a voluntary scheme, sponsored by the European Union, designed to encourage and highlight examples of sustainable development.

5.3.3 Fibre processing

There are many process steps involved in the conversion of fibres to finished articles. The particular properties of lyocell can assist customers in reducing environmental impacts of some of these steps, particularly in textile manufacture. Because lyocell is very clean, with virtually no impurities, bleaching for textile applications is not normally required. (Most of the cotton used for apparel application is bleached). Lyocell is also extremely efficient in terms of dye usage, allowing reduced dye-house effluent. Dyeing and finishing technology for lyocell is the subject of continuing intensive research and development. Recent technical breakthroughs in this area are expected to allow customers to further reduce chemical consumption, water consumption and energy usage. In nonwoven applications, the openness of Tencel® fibre in the bale makes it easier to process, giving lower energy consumption

5.3.4 Product use

The impact on overall life cycle of product use is often underestimated. For example, life cycle analyses of textiles have shown that most of the energy consumed during the life of a garment occurs during domestic laundering. This is accompanied by significant discharges of detergents to effluent.

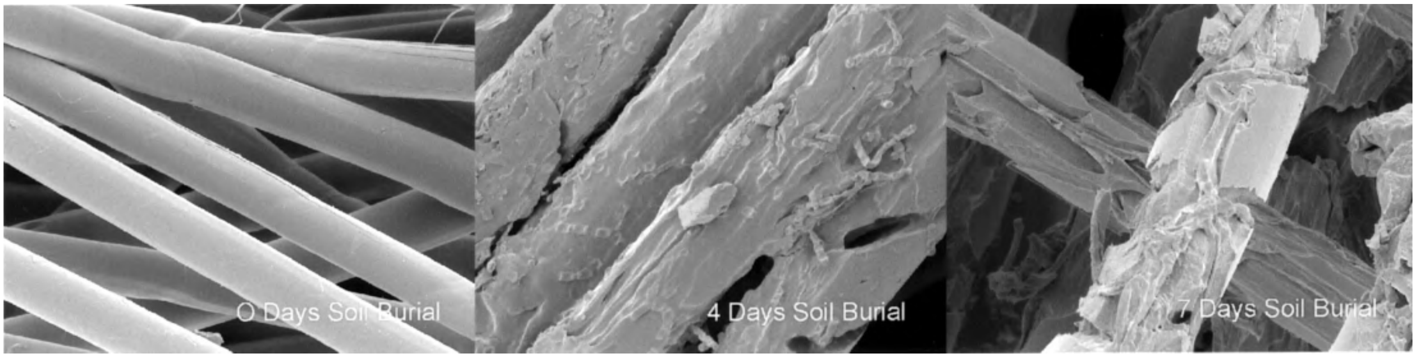
This is an area of the life cycle where fibre producers have relatively little direct influence. However, major retailers are now launching initiatives to reduce the environmental impact of laundering. For example, Marks & Spencer, the major UK retailer, has implemented a programme to encourage lower temperature laundering. They commissioned independent life cycle assessments of cotton and polyester garments which showed over 75% of the 'life cycle extracted energy consumption' is associated with consumer care. Further, the assessment concluded that a move from washing at 50°C to 40°C would reduce life cycle energy burden by ~10%.

The inherent properties of lyocell fibres make them particularly suitable for less intensive laundering.

5.3.5 Product disposal

At the end of their useful lives, lyocell products are biodegradable. Biodegradation occurs through the action of enzymes created by living organisms, breaking a product down to carbon dioxide and water. Cellulosic fibres are known to be biodegradable, whereas synthetic fibres are not. There are a number of accepted techniques to quantify biodegradation (Fig. 5.5):

- *Composting*. Lyocell fibres have been found to degrade completely after six weeks in a static aerated compost pile. Synthetic fibres tested



5.5 Biodegradability of lyocell fibre.

(polyester, polypropylene, polyethylene) showed very little sign of degradation.

- *Sewage treatment*. Lyocell fibres degrade completely within 8 days in a typical sewage farm anaerobic digester, where the residence cycle is about 20 days. Synthetic fibres showed slight reductions in strength after 12 weeks.
- *Landfill*. Organic matter buried in the ground rots over a period of time by the bacterial process of anaerobic digestion. A landfill site is not easy to define or simulate, as it is somewhat heterogeneous. Soil burial tests (BS 6085/AATCC 30) are accepted methods of assessing the biodegradability of a product. Lyocell degrades completely within 12 weeks. Synthetic fibres gain weight initially and only show slight strength and weight loss after 24 weeks' burial.

Alternatively, if lyocell fibre were destroyed by incineration, it would burn readily, to carbon dioxide and water, with a heat of combustion of 15 kJ g^{-1}. In a commercial incineration plant, this 'waste energy' can be put to good use.

5.3.6 The future

Lyocell is an excellent example of a sustainable fibre today. Building on this, lyocell manufacturers operate a policy of continuous improvement in partnership with key raw material suppliers, customers and retailers. Future developments are likely to further minimise the environmental impact of lyocell fibres in areas such as:

- Energy efficiency. Tencel® are working in partnership with the Carbon Trust to explore new energy-saving opportunities for lyocell production.
- The development of new fibre processing routes that require less energy and chemicals and consumer education to minimise environmental impact of consumer care.

5.4 Lyocell fibre properties

Tencel® fibre is characterised by its high strength both dry and wet as can be seen from Table 5.1.

Tencel® shows a dry tenacity significantly higher than other cellulosics and approaching that of polyester. In the wet state, Tencel® retains 85% of its dry strength and is the only man-made cellulosic fibre to be stronger than cotton when wet. The high strength of the fibre translates into strong yarns and fabrics, and plays an important role in subsequent processing. In addition, Tencel® has a high modulus that leads to low shrinkage in water. Thus fabrics and garments demonstrate good stability when washed. Tencel® fibre

Table 5.1 Lyocell fibre properties

Property	Tencel®	Viscose	Cotton	Polyester
Titre (dtex)	1.7	1.7	–	1.7
Dry tenacity (cN/tex)	38–42	22–26	20–24	55–60
Dry elongation (%)	14–16	20–25	7–9	25–30
Wet tenacity (cN/tex)	34–38	10–15	26–30	54–58
Wet elongation (%)	16–18	25–30	12–14	25–30

fibrillates under certain conditions: in the wet state, through abrasive action, micro-fibrils develop on the surface of the fibre but, critically, remain attached to the main body of the fibre. The development of these micro-fibrils occurs mainly on the surface of a fabric and can be used to engineer a range of interesting fabric aesthetics.

5.5 Lyocell in textiles

5.5.1 Lyocell yarn conversion

Once lyocell fibre has been produced, either as cut staple fibre or continuous tow, it will be converted to yarns and fabrics by a range of conventional textile processes. The most common way of using lyocell fibre is as cut staple, with 1.4 and 1.7 dtex fibres cut to 38 mm and converted into a spun yarn using machinery developed over many years for handling cotton fibres that are similar in dtex and length to lyocell. The following comments apply to the processing of Tencel® fibres. Lenzing lyocell is made by a wet-cut route and has different processing characteristics.

Yarn manufacture

Lyocell can be processed via established yarn manufacturing routes, using, for example, 1.7 dtex 38 mm, 1.4 dtex 38 mm and 1.25 dtex 38 mm fibre for short staple routes. The fibre can be processed on conventional machinery, usually requiring a few setting changes in order to optimise processing performance.

Lyocell's processing performance is mostly influenced by the following properties:

- it is a cellulosic fibre and absorbs moisture readily;
- it has a smooth surface with a round cross-section;
- it possesses a non-durable crimp;
- it has a high modulus;
- it has a high tensile strength;
- the fibre is very open and there is little fibre entanglement;

- the fibre supplied is usually lower in moisture content than cotton or viscose.

Thus lyocell will open very easily with little nep formation. In sliver and roving, the fibres pack together, giving high cohesion and therefore requiring high drafting forces. Lyocell yields very regular yarns with high tensile strength and few imperfections. Lyocell blends well with other fibres, including cotton, viscose, linen, wool, silk, nylon and polyester. Lyocell adds strength to the yarn as well as enhancing the performance and aesthetic properties of the final fabrics.

Important differences between the processing of viscose and lyocell are summarised as follows. The fibre is very open and it is important to minimise the number of opening points to avoid too much fibre breakage. Lyocell tends to dye slightly darker than viscose and cotton, hence it is important to take effective measures to guard against cross-contamination and airborne fly contamination during processing. Minimal carding power is required, as the fibre is very open. In drawing, sliver detectors may need to be re-set to adjust for the low bulk of the lyocell. In roving, the twist should be low to avoid too high a cohesion. Optimisation is very important at this stage of the process. Yarn steaming should be avoided wherever possible. Steaming cellulosic fibres, amongst other things affects fibre dye affinity, twist liveliness and splice strength. The dye affinity for cellulosic fibres reduces with increasing steam temperature and the influence on lyocell fibre is greater than for other cellulosics, such as cotton and viscose. Therefore steaming should be avoided unless this can be extremely well controlled. Twist liveliness can be reduced in other ways, such as by storing yarn on ringtube for 16–24 hours in a high humidity environment prior to winding.

5.5.2 Fabric manufacture

Weaving of lyocell fabrics can be successfully carried out on most conventional looms and in a wide range of constructions. The construction needs to be carefully engineered with the dyeing/finishing route to develop the best performance and aesthetics. Very tight constructions can give problems in dyeing and tend to give fabrics with poorer easy-care performance.

Woven fabric structure

The effects of fabric structure on fabric properties such as weight, bulk, warmth, flexibility, smoothness, cost, etc. are generally well appreciated in the trade. However, the fundamental influence of fabric structure on other important factors such as stability and susceptibility to creasing are often ignored or poorly understood.

Fabric structure is particularly relevant for lyocell because of its high water absorption characteristics. Good absorption is, of course, highly desirable for comfort but the consequence of high absorption in lyocell is the development of powerful swelling forces. Swelling easily causes fibres and yarns to move. Such movement can cause creasing unless the fabric and finishing are designed with swelling in mind. Cotton, viscose and other cellulosic fabrics also swell and give similar effects but cotton swelling is smaller and viscose swelling is less powerful.

Swelling and yarn crimp

It should be appreciated that lyocell fibres are stable in length when wetted and dried (i.e. they do not shrink). Fabric shrinkage arises only from the fact that the fibres and yarns swell in diameter; swelling in diameter forces yarn crimp to increase so that the fabric will contract (shrink) and become thicker. Thickness is due to an increase in the yarn crimp amplitude.

This, together with more 'space' within the fabric, creates useful fabric bulk. Contraction can be altered to some degree by dimensional control during finishing. However, it is the fabric structure and not finishing that largely determines the dimensions at which the fabric will be stable. Structure (ends/cm, picks/cm and yarn tex) can be adjusted to tailor fabrics to meet specific shrinkages.

Contraction and shrinkage

The total amount of wet fabric contraction depends directly on the number of yarns in warp and weft and the size of those yarns. For a fabric with similar warp and weft yarns, the distribution of the wet contraction between length and width depends on the relative numbers of warp yarns compared to weft. A predominance of warp yarn means that fabric length contraction will tend to be greater than that in the width. The greater the difference, the more the length will tend to contract compared to the width. Fabrics with equal numbers of yarns and similar counts in warp and weft will have more or less equal potential for warp and weft contraction. In practice, actual contraction may differ due to dimensional constraints such as warp tensions during processing. Residual shrinkages in such fabrics tend to differ correspondingly.

Fabric contraction and 'jamming'

Fabric shrinkage and contraction effects occur as a consequence of swelling in fibre diameter and the resulting increases in yarn crimp. There are three particular factors that affect the amount of yarn crimp development:

- *Processing tensions*. For example, greater warp tensions will give either (a) more weft yarn crimp or (b) greater residual warp shrinkage (or both!).
- *Frequency and diameter of yarns 'yarn density*'. Where yarns are more numerous and/or larger in diameter then yarn crimp will develop only to the point at which adjacent yarns just touch. When such yarns touch one another the fabric becomes 'jammed' or locked so that no more yarn crimp can develop without disrupting the alignment of yarns in that plane. 'Jamming' prevents further contraction in that plane but can readily force increased contraction (shrinkage) or fabric movement (creasing) elsewhere.
- *Fibre and yarn swelling in diameter.* Swelling adds to the 'jamming' effect by thickening the yarns. Fabrics that are apparently quite loosely woven when dry can become stiff and firm when wet. Again, this limits the amount of yarn crimp that can develop within the plane of the fabric (i.e. without buckling).

Causes of fabric displacement and creasing

Fabrics only exhibit creasing when one or more groups of yarns are displaced with respect to their neighbours. Yarns may become displaced to form creases either through handling or because of structural movements that are driven by swelling. Such movements already referred to above of course are contraction, shrinkage and yarn crimp development. However, such swelling-induced movements will only lead to creasing if wet yarns are unable to return to their original positions when dry.

Minimising fabric movement and creasing

There are several areas to consider in order to minimise wet fabric creasing:

- *Limiting the scope for yarn movements by 'setting' the fabric*. Unlike synthetics, lyocell fabrics are not thermoplastic and so cannot be 'set' with heat. However, there are wet finishing treatments that can fix yarns so that they will retain a memory of their crease-free state. Resin treatments help in this respect but caustic 'setting' is particularly relevant for lyocell.
- *Limiting the effects of fibre/yarn swelling by creating 'space' inside the fabric*. Fabric movement, and potential for creasing, is reduced if the finished fabric has sufficient room ('space') within the structure to accommodate yarn swelling without causing yarn displacement. Fabric construction is important. Generally fabrics should not be too tightly woven (to allow room for swelling). For tighter woven fabrics, caustic treatment is recommended. Caustic soda promotes increased lyocell swelling that causes additional useful 'space' to develop within the woven structure.

- *Adjusting the 'balance' between warp and weft yarn components*. As mentioned earlier, the amount of fabric contraction is dependent on the numbers (and sizes) of the yarns in the structure. Where one set of yarns (say the warp) predominates over the other then this promotes greater contraction in that direction. Some inequality between proportions of warp and weft is acceptable but where differences are great then excessive contraction can develop in one direction, say the warp, together with negligible weft contraction. Imbalance can lead to excessive fabric movements in one direction and correspondingly greater tendency for creasing. Relatively well-balanced constructions are preferred.

Although the foregoing is presented primarily with wet creasing in mind, these recommendations generally apply also to dry creasing. In this case the wet swelling issues are less relevant but fabric setting and the need for balance in the construction remain important.

More detailed explanations of the interrelationships between these factors are beyond the scope of this chapter. However, on request Lenzing can provide its customers with more detailed and specific advice in respect of fabric constructions on a case-by-case basis.

Knitting

Lyocell fabrics are readily made on most commercially available knitting machines. The best quality fabrics are made with high quality yarns and slightly shorter stitch lengths to minimise the risk of work up and pilling during dyeing and subsequent use.

5.5.3 Dyeing and finishing of lyocell

Over the last twelve years since the commercial introduction of lyocell into the global marketplace, great progress has been made in dyeing and finishing technology. We should not forget that at that time lyocell fabrics could not be piece dyed on jet machinery at all, because of uncontrolled fibrillation leading to damage marks on the fabrics. The garment processing system has always been central to lyocell processing, because the effective re-orientation of the garment during the process allows fibrillation to be generated evenly throughout the piece.

Conventional liquor jet machines will always be problematical because the fabric rope does not move sufficiently in running on the machine and uncontrolled localised fibrillation can develop. We have seen the introduction of air jet technology to help in rope re-orientation and hence with fibrillation control, together with the introduction of new processing routes to reduce the high cost of lyocell piece finishing. Fabric behaviour understanding has seen the development of new possibilities for lyocell with the importance of causticisation now being fully characterised. This has led to the development of Tencel® Natural Stretch, TOP+C and MAGIC processing which will be discussed later.

Studies of lyocell fabrics processed with conventional open width techniques demonstrate the virtues of lyocell with low-cost production techniques and have shown the excellent easy care performance that lyocell can deliver in combination with resin finishing. The softness, fluidity and drape characteristics shine through even without fibrillation.

The introduction of Tencel® A100 and Lenzing lyocell LF have further demonstrated that lyocell can offer positive performance attributes without fibrillation. Tencel® A100 also has a powerful colour story, with its reactive dye yield being higher than any other cellulosic fibre in the market, which has advantages in dye and chemical cost reductions as well as positive environmental messages from reducing colour in effluent.

Fundamental fibre properties and their influence on dyeing and finishing

The key fibre properties are swelling and fibrillation. The high lateral swelling in water causes fabrics to stiffen appreciably in cold water, giving difficulties in crease avoidance. The creases formed also are more susceptible to abrasion and hence fibrillation. Localised fibrillation on the creases gives rise to white lines and damage marks in the finished goods. Correct machinery selection and the use of fabric causticisation help to minimise these effects.

Pre-treatment of the fabric in caustic soda can be very effective in improving both fabric performance and aesthetic. It is very widely used in commercial lyocell fabrics. In caustic soda, lyocell swells very significantly in its diameter but very little in length. The maximum effect is at 10% to 12% concentration, but mercerisation conditions can also be used. The swelling of the fibres will increase the diameter of the yarns in the fabric and this will cause the fabric to shrink. This step needs to be carried out with the fabric in open width form and if the fabric is allowed to shrink during caustic treatment its bulk will be significantly enhanced.

Furthermore, the fibres become set into this new configuration when the fabric is subsequently washed. The fabric then has a greater bulk and flexibility – in particular the wet stiffness of the fabric is much reduced. The latter is important for further processing since it is less prone to crease damage marks during the dyeing processing. The caustic treatment also gives more rapid fibrillation removal in processing and a reduced tendency to fibrillation in domestic use.

The fibrillation on the fabric surface changes the light reflectance behaviour. This gives rise to the ‘bloom’ or ‘frosted’ look on a peach-touch lyocell fabric. The degree of fibrillation will influence the apparent colour.

Basic process for standard lyocell

The conventional process is a three-stage system. Fibrillation is deliberately induced and then removed by a treatment in a cellulase enzyme. Secondary fibrillation is then created by further mechanical action, which can be simultaneous with dyeing if the fabric is not already pre-dyed. This three-stage process is time consuming and a great deal of effort has been directed at new process development to reduce the time of or eliminate these steps. Final finishing on a rope tumbling machine is required to fully generate the fibrillated effect.

Processing in garment form

By its nature this technique will deliver a casual peach-touch result. Lyocell can be successfully processed in garment dye or garment wash systems (including indigo). The high level of garment movement and mechanical aggression in the machine make for rapid processing through the fibrillation and enzyme processing steps and even surface effects.

The acceptance of lyocell by the garment processing industry was relatively straightforward as they were already used to enzyme systems for indigo denim. (It is also interesting to note that cellulase enzymes were only introduced for textiles in the mid-1980s so prior to that lyocell would have been impossible to process to a controlled fibrillated finish.)

The Nidom development

The early–mid-1990s saw a hybrid machine development in Japan. The Nidom is a garment type processing machine designed to process fabrics in piece form, rather than in made-up garments. It allows a garment-processed aesthetic to be generated on fabrics prior to garment construction. The aesthetic quality is exceptional, but the processing of short lengths in multiple chambers gives an extremely labour-intensive and hence expensive system.

Piece processing on jet machines

As has been mentioned previously conventional liquor jets do not have sufficient action to re-orientate the fabric rope. The result is damaged second quality fabric. Air jets are a relatively new development from the supply industry (again coming in the 1980s) that cause the fabric to ‘explode’ from the jet, giving excellent re-orientation and high first quality results. The three-stage process can be followed to give a peach-touch result, or the step order can be changed to give a clear fabric surface, but in this instance resin finishing needs to be applied to prevent secondary fibrillation being generated in domestic washing.

Pre-causticisation of the fabric can help as it imparts wet softness to the fabric, which allows better running on the machine and decreases the risk of creasing and damage. Recent developments have seen the extension of garment process technology in combination with optional processing on the air jet, to knitted fabric constructions, to create a so-called ‘angelskin’ aesthetic.

TOP+C processing

Tencel® Oxidative Preparation plus Caustic is a technique that incorporates a peroxide bleach (preferably pad steam) prior to causticisation. The result is that the fabric requires much less mechanical action to generate the peach touch and the three-stage process is no longer required. In jet processing the action on the fabric of a reactive dyeing process followed by rope tumbling is sufficient. This can halve the time needed on the jet and eliminate the cost of the enzymes. It is also applicable for garment processing, again showing significant time-savings and chemical cost reductions, although enzymes can still have positive effects on finished fabric hand.

MAGIC processing

Not every finisher has the right sort of equipment for TOP+C. MAGIC only needs a pad mangle and stenter, possessed by 99% of fabric dyers. The pre-treatment means that pre-fibrillation and enzyme can be omitted from the jet process delivering shorter, less complex processes such as TOP+C.

Open width processing – processing without fibrillation

Lyocell can be processed in conventional open width systems. Because the mechanical action on the fabric is virtually eliminated the result is a flat classical fabric. Aesthetical differentiation is reduced against cotton, but the lyocell (or blend) will still be softer and more fluid than a cotton comparison. No fibrillation occurs on lyocell fabrics that have been open width processed, but they still retain a soft handle with an underlying bounce and resilience.

The high strength of lyocell means that aggressive surface treatments such as wet and dry emerising can be successfully used which enhances the aesthetical difference. Resin finishing on fabrics processed by this route is imperative to maintain appearance in washing. In fact, wash performance of lyocell is excellent with hand and appearance being retained exceptionally well on multiple washing. Open width processing enables cost-effective routes to production of lyocell fabrics for a wide range of garment types without the need for specialist processing equipment. This enables the production of garments with the touch and drape of lyocell extracting both performance and value from the fibre, which until now has needed special treatment.

Tencel® natural stretch

This is an extension of the open width processing principles in combination with causticisation. The fabric construction should be devised so that there is space to allow yarn crimp to develop. Causticisation will cause the crimp development and impart a memory which together with the fibre's high modulus and resilience will allow stretch with high degrees of recovery, equal to that achievable with elastane containing fabrics. It should be borne in mind though, that this is a 'comfort' stretch rather than the 'power' stretch associated with elastomerics.

Easy-care lyocell

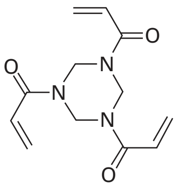
As with any fabric, chemical finishing is an important aspect of the process and this is especially true when considering the finishing of open-width processed lyocell fabrics. In such processing, resination is the method of controlling fibrillation. If too little resin is fixed then fabrics will fibrillate on subsequent washing, too much and physical performance deteriorates. It is also important to include appropriate softeners and auxiliary products into the chemical finish so that performance and handle are appropriate to the customer's requirements.

The application of ~2–3% omf (on mass of fibre) fixed resin appears to be optimal for easy-care properties, dependant on the fabric construction and weight. Application levels of 2% omf are needed to stop fibrillation on domestic washing. In addition to the resin, the choice of softener can have a large effect on the easy-care performance of fabrics, and it is important to consider the whole formulation and build it up to give the required performance. Silicone micro-emulsions penetrate yarns more than the macro-emulsions. Polyethylene dispersions aid sewing and build the handle of the fabric, whilst some soft acrylic-based chemicals can increase the abrasion resistance. It is also worth remembering that caustic soda or liquid ammonia treatment in preparation will help to increase the easy-care rating of lyocell fabrics.

Tencel® A100

The normal glyoxal-based easy-care resins significantly impair the dyeability of cellulosic fibres so they cannot be used as a treatment prior to dyeing. To prevent a lyocell fabric from fibrillating during jet dyeing for example, other types of cross-link chemicals had to be considered to modify the fibre's behaviour.

TAHT (Triacroyl hexahydrotriazine (5.4)) will cross-link lyocell under alkaline conditions. Pre-treatment of the fibre using this chemical during the manufacturing process has proved successful. In the A100 process developed



5.4

by Tencel®, the TAHT chemical is applied to the washed tow in the fibre production line. It is then dried, crimped, cut and baled in the normal way. The A100 fibre has similar strength, elongation and modulus properties to the standard fibre and has an enhanced dye uptake that gives more economical dyestuff costs and strong, deep colouration. Its resistance to fibrillation means it can be processed on most dyeing machines and the fabrics produced have a good performance in subsequent washing.

Tencel® A100 was launched in 1998 and has proved to be very popular and effective at extending the range of applications for Tencel® fibres. It is particularly beneficial for jersey knit applications because of its excellent colouration, attractive aesthetics and good wash/wear performance. The warm touch of jersey fabrics made from A100 complement the cooler touch of 'peach skin' fabrics made from standard lyocell.

Wet processing of tencel® A100

The non-fibrillating nature makes dyeing on conventional liquor jets feasible. The drape and fluidity will generate more effectively than standard lyocell processed in an open width system and resination is an option rather than a necessity. The colour properties of Tencel® A100 are exceptional. Its uptake of reactive dyes is higher than any other cellulosic fibre. This means that either the same shade can be obtained more cost effectively (typically 40% less dye than modal or cotton), or unique deep shades can be obtained that are not possible on other fibres. The high efficiency of dyeing with Tencel® A100 (dye exhaustion and fixation) means that less unfixed colour remains to be removed, both reducing the water consumption in washing off and reducing the colour loading in the dyehouse effluent.

5.6 Lyocell – a versatile, high performance fibre for nonwovens

The early stages of the commercialisation of lyocell were focused towards the fashion textile apparel sector. However, this has changed during the first years of the twenty-first century so that lyocell is now targeted equally into the industrial sector, with particular emphasis on the key nonwovens markets of wipes, filters and feminine hygiene products. The key difference between traditional textile production and nonwovens production is the omission of the yarn stage from the production process. In nonwovens manufacture, the fibres are formed into a web and a fibre bonding or entangling process is used to impart integrity and control the function, hand and appearance of the resulting nonwovens' substrate.

Staple fibre grades are produced to suit carded dry laid, air laid and wet laid processes. The attributes of lyocell fibre are discussed with reference to each of these conversion technologies below.

5.6.1 Lyocell in carded processing

Staple fibres provide the starting point for many nonwoven processes. Because the staple-based technologies are so diverse in terms of machinery design and fibre processing requirements, a range of fibre types have been developed to suit individual needs and to ensure optimum conversion efficiencies and fabric properties.

For carding-based technologies, Tencel® fibres have been designed to open easily and fully prior to the carding step. This gives uniform and nep-free webs. To ensure adequate web cohesion and high running speeds, high cohesion fibre surface finishes and high crimp fibre variants have been introduced, to provide for efficient web transfer and to minimise fibre fly. Fully optimised lyocell variants have been shown to run at greater than 250 m min^{-1} on commercial nonwoven carding lines. This is significantly faster than the speeds at which traditional cellulosic fibres can be run, and with greater web quality and control.

The benefits in terms of maximum card speed achieved with Tencel® HS260, for instance, on the new generation of Thibeau cards are outlined below (Table 5.2). The webs formed in the trials were set at 30g m^{-2} weight.

Table 5.2 Comparative carding speeds of different fibre types

Fibre type	Maximum carding speed (m min^{-1})
Tencel® HS260	250+
Polypropylene	250+
Polyester	200–250
Viscose	~150

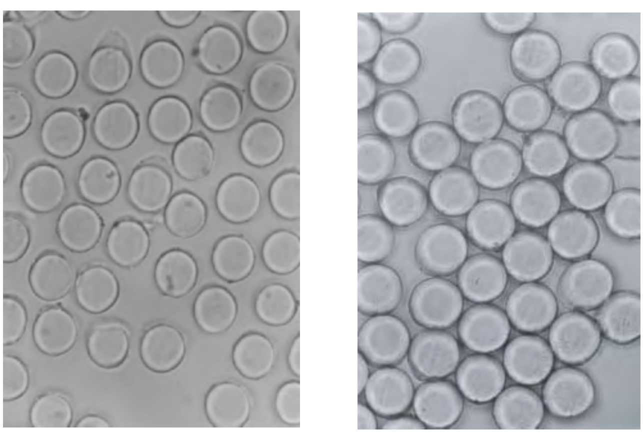
The high crimp Tencel® HS260 grades are supplied in a form that is very similar to that of polyester or polypropylene staple, so blending with these fibre types is very efficient. However, lyocell is also available in a natural crimp variant, giving it similar processing characteristics to that of a standard viscose whilst maintaining the superior fibre strength of lyocell. This variant is selected for processing lines that have been designed from the outset to process viscose fibres.

5.6.2 Fabric properties

A large amount of work has been carried out over the last five years to understand and enhance the attributes of lyocell in nonwoven structures. These basic attributes are now being exploited to significant commercial advantage by an increasing range of nonwoven producers.

Spunlacing

The basic properties of lyocell fibre are particularly well-suited to the spunlacing (hydroentanglement) method of bonding. The fibre strength is very high, particularly in the wet state, being at least twice as strong as regular viscose. Lyocell also entangles efficiently, because of its smooth surface and because its fibrillar cellulose structure plasticises when wet. This results in very strong and stable spunlaced nonwovens, but it is still entirely possible to preserve the drape and softness of the final fabric through appropriate choice of bonding pressure profile, belt design and fabric basis weight. Fabric wet strengths can sometimes be higher than the dry values because the lyocell filaments swell predominantly in the diameter (Fig. 5.6). This causes the entangled fibres to lock together even more efficiently. Consequently very soft fabrics with adequate strength can be produced, by using relatively low water pressures. Also significant basis weight reductions can be achieved,



Dry state   Wet state

5.6 Radial swelling of lyocell fibres in water.

either to generate cost savings, or to reach new markets such as thin, highly permeable coverstocks with basis weights below 20 g m^{-2} (10 g m^{-2} for some latex bonded structures). When using apertured entangling belts, fabric hole clarity is the best of any fibre, leading to a superior wiping action and an improved appearance. The combination of a strong fibre and efficient entanglement also results in exceptionally low lint levels, a key requirement for many nonwoven wipers in critical task situations. High fibre modulus and relatively low fibre elongation gives superior fabric stability, which improves the efficiency of conversion from fabric to finished product and acts as an excellent base material for many coating processes. The flexibility in the possible basis weights and bonding levels possible with lyocell permits an expanded range of absorbent fabric properties to be achieved. The working range of water pressure for lyocell is about 40 to 100 bar (compared to viscose rayon at 55 to 70 bar). The range of consolidation is therefore greater, and capacity, wicking, bulk and softness can be engineered within a much larger envelope.

Needlepunching

In needlepunching applications where bonding is achieved through the use of mechanical needling of the fibre web, very efficient bonding is seen with lyocell, even with what for this market sector is traditionally perceived as a low decitex product. For example, 1.7 decitex lyocell is now used routinely in needlepunched nonwovens, whereas the lowest practical decitex limit for traditional fibres is about 3.0 or above. This is achieved without significant fibre breakage and leads to softer, more absorbent structures, which have a unique ability to retain and release fluid. The high wet resiliency of the fibre allows the fabrics to retain bulk in the wet state, leading to superior handling aesthetics and wiping action. Where greater resilience or firmer fabric hand are required, 2.4 dtex and 3.3 dtex lyocell grades are available.

Latex bonding

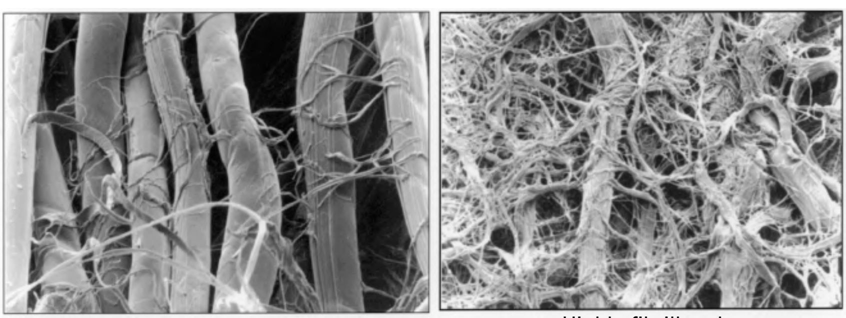
In latex bonding, fabrics are created by bonding the webs with latex emulsions, starch sizes, or other adhesives. This is usually followed by a curing step. For this technology, which is still used extensively to produce dry wipes, the high fabric strength produced from lyocell enables binder levels to be reduced by as much as 50%. This enhances both fabric absorbency and softness. Binder levels can be reduced to such an extent that the flushability and biodegradability of the final fabric can be significantly enhanced. These are useful features in today's environmentally aware marketplace. If binder levels are maintained, then very strong and stable fabrics can be obtained with good abrasion resistance and hence increased product lifetime.

Lyocell in air-laying

Air laying technology requires very different fibres to those used for the main staple processing routes described above. Here fibre webs are created using air dispersion, usually followed by deposition on a suction belt. For optimum air laying, low cohesion and static free fibre surfaces are advisable, combined with a short fibre cut length. The inherently open nature of a tow washed and mechanically crimped fibre like Tencel® makes it more suitable for web formation in an air stream than many other cellulosic fibres. Tailored fibre crimp can also be employed to enhance this performance and improve filament dispersion within a matrix of other fibre types. Substituting for modest percentages of normal fluff pulp with lyocell can significantly increase the softness, strength, bulk and absorbency of air laid fabrics. The longer lyocell fibres support the pulp matrix leading to higher tear and burst resistance, and better fluid transport because pores in the structure collapse less easily.

Lyocell in wet-laying

An alternative method of dispersing short fibres to form a fabric is to use water. This is the basis for wet laid nonwoven manufacture or traditional papermaking. When wet laying to form a fabric the high modulus of lyocell fibres allows relatively long length filaments to be processed without dispersion problems. This results in low defect webs with excellent tear and burst strength and good dimensional stability. In addition, the unique fibrillar, crystalline structure of lyocell can be broken down through mechanical wet abrasion, for example at the beating stage of a traditional papermaking process. This can be very readily achieved because the fibre swells so much radially when wet. The wet abrasion generates submicron diameter fibrils, which are retained within the fibre matrix, creating a micro-porous network, which is ideal for fine filtration (Fig. 5.7.).



Lightly fibrillated — Highly fibrillated

5.7 Fibrillated lyocell used in special paper applications.

5.6.3 Finished product benefits

Much of the impressive growth in the use of lyocell in nonwovens has coincided with the substantial growth in, and segmentation of the consumer and industrial wipes sectors. Lyocell is the ideal fibre for many categories of wiping. It is free of chemical odours because the manufacturing process is effectively a simple dissolution and regeneration process. This permits the production of fragrance-free wet wiping products, where the liberation of unpleasant odours have been a perennial problem when using other fibre types. Also for many wet-wiping applications, the use of lyocell means the absorbent properties of the wipe can be engineered to ensure that gravitational drainage in tubs and canisters can be reduced to a minimum and yet all the wiping layers are equally wetted out. Because relatively little liquid is trapped within the fibre structure, the volume of expensive lotion required for an effective wiping performance can be significantly reduced.

Lyocell produces low lint fabrics because of its strength and durability as a fibre and the efficiency with which it can be bonded. This low linting feature is mandatory for many critical-task wiping applications. This includes clean-room use, surface preparation in the automotive, aerospace and printing industries and many medical wipes, gauzes and swabs.

Chemical purity and a good regulatory history and compliance record commend the fibre's use in personal hygiene and hospital products. Lyocell has excellent wet resilience, giving improved aesthetics and efficient skin exfoliation in cosmetic wipes.

High fabric strength can extend the life of many wiping products. In particular, lyocell wipes stand up well to overnight bleaching, which is common in the food service industry. Also, as bonding levels can sometimes be reduced to take advantage of the filament strength, fabric flushability and biodegradability can be enhanced making disposal cheaper and easier.

In non-wiping applications, lyocell fibres impart strength, stability and uniformity to synthetic leather substrates. Lyocell is ideal for food contact use in hot oil and beverage filtration, as a result of very uniform fabrics and good regulatory clearance. Papers containing fibrillated lyocell are an economic alternative to other sources of nanofibres in high efficiency air and liquid filtration.

5.6.4 Conclusion

The case for specifying lyocell fibres in nonwoven products is compelling. Priced cost effectively, with unique attributes and excellent environmental credentials, their future in absorbent nonwoven products is assured.

5.7 Marketing

It's a long run through the supply chain from a fibre to the consumer. The consumer either automatically chooses a fibre, such as cotton, because they always have or thinks again when they see a new fibre name on a label. But what comes to mind when they see a fibre name such as lyocell? Research tells us that the consumer thinks the fibre is man-made, or synthetic – the two terms being synonymous in their minds. The fact that lyocell is a cellulosic fibre and was invented to be environmentally sound is not something that easily comes into the consumer's mind. So what does a fibre company do about this?

In the case of Tencel®, the company has had a long and consistent approach to marketing its fibres and getting the natural/nature message across. The Tencel® brand has associated itself with all forms of 'nature' in developing communications platforms to and through the trade. More recently, the focus has been closer to the end consumer with a higher level of involvement with brands and retailers. The success of this increased focus is measured by the uptake of the Tencel® Branding Programme.

Through direct research, consumers also tell us that they find on-garment labels helpful in quickly identifying a brand, a type of garment, a type of fit or a type of fibre – all important to the busy shopper who shops less frequently and with less time to spare.

Marketing vehicles such as the Tencel® Branding Programme are extremely supportive for brands and retailers who understand the importance of making shopping easier. Tencel® provides, free of charge, a contemporary branded swing ticket, printed on recycled paper stock reflecting the consumer's concern for the environment.

With increasing recognition of the Tencel® brand comes an association and understanding that the garment will be several things: soft to the touch; comfortable to wear; easy to care for and easy to wear. The loyal Tencel® purchaser is an avid one and ultimately looks for the brand when shopping.

Tencel® is a market-led company with a market-facing brand and prides itself on its understanding of customers through the supply chain. The company partners with key consumer brands and labels to reinforce a brand's commitment to its own ultimate consumer. The company reinforces its supply chain partners by paralleling their marketing efforts to optimum effect.

Business and brand growth for the future will come from increasing Tencel®s menswear market share and also in further developments within home textiles. In addition, special finishes and processing routes will enable Tencel® to work with a broader supply chain and expand its own capabilities into new sectors. Strategically, the company believes that Tencel® will be one of the most trusted fibres of the future as it continually reinforces the importance of sustainability and its natural roots. Link these benefits to the ultimate needs of the primary consumer's modern lifestyle: versatility, ease, comfort, style and value and you have the perfect solution to today's modern wardrobe! Tencel® lyocell!

5.8 Future trends

The speed at which lyocell fibres have been accepted by both the textile apparel and the nonwoven markets has been a remarkable success story. In textile apparel, the ability of the fibre to fibrillate and create new and novel fabric appearances and handles, has allowed innovative textile mills to launch completely new and differentiated fabric types.

In textiles, the newly developed processing systems, becoming ever less complex and cost effective is likely to see a continued market penetration of this fibre type into a widening range of fabric and product types. The use of lyocell fibres in the home textile market is expected to see significant growth, where the comfort properties can deliver tangible consumer benefits.

The last few years have seen a huge growth of lyocell in nonwoven applications. The fibrillation property can deliver significant performance benefits and sustained growth is expected in the key areas of wet wipes and filtration.

New fibre types are currently in development and the future will see significant launches of new fibre variants into the market. The introduction of the new non-fibrillating fibre types of Tencel® A100 and Lenzing lyocell LF have seen impressive growth since their introduction, and we can expect to see fibres with new and innovative functional properties being introduced over the next few years.

The environmentally benign production process sets lyocell apart from other man-made cellulosic fibre types, and this will gain in importance over the coming years providing impetus for fibre production growth.

Already Hanil of Korea have been producing fibre from a large pilot plant, and talk is of a significant investment in China to construct a large-scale manufacturing facility. It is clear that great opportunities exist, and the life cycle of lyocell fibre has only just begun.

5.9 Sources of further information

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