CHEMICAL RECYCLING

Process & Application

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INTRODUCTION

Once textile waste has been sorted, cleaned, cut and shredded, the material moves on to the next stage: recycling. The best-known recycling technologies are chemical and mechanical recycling and extrusion. While the extrusion process can only be used on thermoplastic materials like polyester, chemical and mechanical recycling can be used for most textile materials. In this chapter, we will discuss chemical recycling.

RECYCLING CHEMICAL FIBRES

To understand the chemical recycling process, it is useful to know that textiles are made of long molecules called polymers. Polymers are formed by the reaction of small molecules, called monomers. During the recycling process, these long chain-like polymers are broken down into their constituent monomers, which can then be polymerised to generate new polymers. Thus, no additional fossil resources are needed when using this method.

Unfortunately, chemical recycling currently requires high energy demands and is sensitive to contamination, which results in higher costs compared to plastics derived from fossil resources. However, the general textile industry consensus is that chemical recycling will become the most important recycling technology because its results are just as good as virgin fibres made from oil.

NYLON

Nylon is a synthetic polymer material widely used for various textile applications. In fact, around 5% of textiles are made of nylon. The main commercial applications for nylon include textile fibres for technical applications, for sport and outdoor applications, and for carpet.

Also known as Polyamide (PA), nylon is a polymeric material made up of one or two smaller entities called monomers. We won't delve too deep into the chemistry behind this, but it may be useful to know that nylon 6 is made of one monomer (caprolactam) and nylon 6,6 is made of two monomers (hexamethylenediamine and adipic acid). When nylon is recycled chemically, the long nylon chains are broken down into the monomers and other intermediates. These monomers, or reactive building blocks, can subsequently be re-polymerised into new long chains: new virgin nylon. The closed-loop recovery of Nylon-6 has been widely used in the carpet industry.

However, this method of recycling is both expensive and requires a substantial amount of energy. Current research focuses on making this recycling process more economical and energy efficient. While the chemical recycling of Nylon-6,6 is not yet performed commercially, the recycling of Nylon 6 is. You might have seen recycled Nylon 6 advertised as textiles from old fishing nets (see an example here).

POLYESTER

Polyester (also known as polyethylene terephthalate, or PET) is the most widely used synthetic polymer material. This material is used for a wide variety of textile applications. PET is used in almost every textile application imaginable, from fashion to technical to automotive to building and construction. In fact, around 60% of all textiles are made of polyester!

Because it's a thermoplastic material, polyester melts when heated (for more information, refer to Chapter 9: Recycling by extrusion). Unfortunately, the environmental impact of polyester is significant because the raw materials for PET are usually derived from oil. There are, however, also examples of biobased raw materials.

Polyester is produced by combining two monomers: ethylene glycol and terephthalic acid. Chemical recycling pathways for PET include processes that break down the polymer into its components (monomers and other intermediates). Chemical treatment in the recycling process may also help separate PET from other materials, such as blended fibres (e.g. elastane or cotton), dyes, or chemical finishings. For fibre-to-fibre recycling, we must produce the main monomer constituents of PET (ethylene glycol and purified terephthalic acid) to reproduce virgin quality PET.

Globally, there are many commercial and R&D level activities focusing on polyester recycling. For example, the Dutch start-up company, Ioniqa, currently focuses on recycling PET bottles, but is now also investigating recycling PET from textile waste. Issues hindering chemical PET recycling include: the cost of recycling compared to the cost of producing virgin fibres and the environmental impact of chemical processes involved in recycling PET. Currently, there is no economic benefit and only a small environmental benefit to chemical recycling.

IN SUMMARY

Both nylon and polyester are synthetic textile materials that are broken down into their constituent monomers during chemical recycling. These monomers are then resynthesised into polymers and extruded into filaments, which are subsequently further processed and spun into yarns. In the next section, we will discuss the chemical recycling of cellulose fibres.

CHEMICAL RECYCLING
CELLULOSE FIBRES

COTTON

Cotton represents about 25% of textile materials, totalling an impressive 25 million tons per year. Recycling cotton will help resolve issues around water usage, arable land use, fertiliser use, and pesticide use. Without diving too deep into the chemistry behind the process, it is useful to know that cotton is made of a single large molecule: cellulose. This cellulose is formed by plants and trees and is, consequently, quite different from the synthetic materials described above. For this reason, the recycling process is completely different.

PULP MAKING

To begin the recycling process, cotton textile waste must be separated and shredded as described in the previous chapters. After shredding, the next step is grinding the cotton into a coarse powder. This powder is then chemically treated to remove all the non-cellulosic constituents. Due to the type of chemicals and the conditions of the process, dyes and most of the finishing materials are also removed.

This cotton is often blended with polyester or elastane. If we are dealing with blends, the polyester can be removed by breaking it down and rinsing it away (this polyester may then be recycled as well). Unfortunately, this process does not work for elastane. Therefore, if elastane is present, the cotton cannot be recycled. Solving this issue is the subject of a few research projects.

After removing all these constituents, we must check the length of the cellulose chain. If this cellulose chain is too long, then the recycling process becomes more difficult. For this reason, we also reduce the length of the cellulose chain during this purification step. If everything looks satisfactory, we dry it. The resulting fibrous material is called the **pulp**. Once we have the pulp, we move on to the next step in the process.

WET SPINNING: CELLULOSE FIBRE PRODUCTION

Wet spinning of cellulose fibres is nothing new. The former ENKA used wet spinning to produce rayon fibres in the early 1950s.

To wet spin, the pulp produced during the previous step is dissolved using an appropriate solvent. It is during this step that the length of the cellulose chain becomes very important. If the chain is too long, it will not dissolve. If the cellulose chain is the correct length, then it dissolves and the resulting solution (called "dope") is injected into a spin bath full of water.

Once the solution of dissolved cellulose is exposed to the water, the cellulose solidifies into a gel state first and then into a fibre similar to viscose. This process is similar but not completely analogous to the viscose process. Unfortunately, even low percentages of polyester or elastane block the spinneret and render the wet spinning process unfeasible, which is a real problem.

Once the cellulose fibre has been precipitated in the bath, we can then collect it, rinse it, dry it, and collect it on a bobbin. Now, we have a spool of recycled cellulose filament from cotton.

The next step is chopping this filament into short pieces called staple fibres. These staple fibres are then spun into cellulose yarn, a process that will be described further in the following chapters.

Currently, a number of projects and investment programmes are working to produce chemical recycled cotton on a commercial scale. Fortunately, there is great interest in chemically recycled cotton. Mud Jeans has announced that they will produce jeans made from 100% recycled cotton with the help of chemically recycled cotton. Check out the Mud Jeans website for more information.

WHAT DOES IT LOOK LIKE?

Have we piqued your curiosity? Watch this video to get an idea of what the wet-spinning process looks like.

Above: *SaXcell is an example of a new material made from chemical recycled domestic cotton waste. The fibres are made from 100% cotton, which is a great step towards building a more sustainable apparel industry.*

DO'S AND DON'TS

- Always donate discarded cotton and cotton/polyester blends for recycling.
- Avoid mixing or blending cotton with other fibres, particularly elastane. Until elastane removal is solved, it is better to buy cotton clothes without stretch..
- Support these recycling initiatives where possible.

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90% OF TEXTILES CAN BE CHEMICALLY RECYCLED

NYLON MAKES UP

5% OF TEXTILES

COTTON MAKES UP

25% OF TEXTILES

POLYESTER MAKES UP

60% OF TEXTILES

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