Advanced textiles - relevance and potentials for consumers and industry

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Are technical textiles able to mitigate and potentially overcome some of the current environmental challenges the various industries in general are currently facing? Even though in many instances the answer might be a profound "no", some major concerns can and already have been addressed by employing intelligent and sustainable textile related solutions. This paper describes some of the windows of opportunities the textile industry has opened to the world over the course of recent years. The focus lays thereby on the use of wood-based cellulosic fibers, enabling various industries to create products that manage to strike the balance between performance and sustainability.

***Key words**: cellulose, technical textiles, plastic pollution, performance, sustainability*

1. Introduction

The use of natural fibers is old as our civilization. One of its initial purposes was to protect the wearer against cold, heat and injury. With mankind evolving, clothing has expanded its role to accommodate ever more functions, such as imparting social status and religious affiliation. Glancing at today's fashion industry, this has not changed ever since.

Along the continuous advancement of cultures, textiles have become more sophisticated and new techniques for coloration, yarn spinning and fabric making have emerged. Since the very beginnings, textiles have also served other purposes than clothing: Bags, sacks and covers are examples of early applications of man-made fabrics. At this day and age, the textile industry is one of the biggest industries worldwide. As with almost any large-scale human activity, the production of textiles has over the years contributed significantly to the myriad of environmental problems we face today, particularly with regard to water pollution to which it has been identified as a major contributor. Much of that is due to the extensive reliance on cotton, which is being used in about half of all textiles manufactured and which requires extremely high quantities of water to grow. Consequentially, addressing the most pressing issues in textile manufacturing such as accelerated environmental problems is one of the key challenges for the industry as a whole.

Thinking only briefly about the most prominent and obvious challenges the global textile industry is facing today, a substantial number of issues arises instantly. The industry is contributing 1.2 bio tons of CO_2 annually to global warming, which is widely regarded as one of the (if not the sin-

*Plenary lecture, 9th INTERNATIONAL TEXTILE, CLOTHING & DESIGN CONFERENCE – Magic World of Textiles, October 7-10th 2018, Dubrovnik, Croatia gle most) pressing threads to life as we know it [1]. Another example of a major issue that is at least to a considerable extend being traced back to textiles is plastic pollution in aquatic and terrestrial ecosystems. Last but not least, we are facing the age-old question of rising and maintaining basic social and health standards of textile workers.

A significant trend of the 21st century is the rising prominence of non-wovens and technical applications within the textile industry. One of the key factors driving this development is the ongoing innovation and R&D in the technical textiles sector, which continues to be as fascinating and versatile as on day one. The fiber industry's leaders have recognized this development and nowadays aim to bring about the most cutting-edge and groundbreaking developments to successfully emerge in this growing field. Adopting the Messe Frankfurt/Techtextil basic outlay of the technical textile industry, a selection of six core application areas in this field can be identified: Mobiltech, Sporttech, Hometech, Clothtech, Medtech and Protech. Each of these application areas generally shows above-average growth rates (6-10 % CAGR) [2].

Despite all, the underlying question still remains: Are technical textiles able to mitigate and potentially overcome some of the current challenges various industries and (on a broader scale) the economy as a whole are facing? In many instances the answer to this question might be a profound "no", but some concerns may indeed be addressed successfully by utilizing intelligent and sustainable textile related solutions.

This papers deals with possibilities the industry has developed over the course of recent years. The focus will be set on wood-based cellulosic fibers, which have proven time and again to bear great potential to offer solutions that manage to strike the balance between performance and sustainability.

2. Cellulose, the most abundant polymer on this planet, plays a key role in the global fiber market

Cellulose is the most abundant organic polymer on Earth with an occurrence of approx. 700 bn tons. The cellulose content of cotton fiber is 90 %, that of wood is 40-50 % and that of year's plants like jute and hemp is approximately 60-70 % [3]. By far the most relevant natural fibre for the textile industry is (without surprise) cotton. It comes in second after Polyester in fiber usage. Cotton is mostly used to produce clothes of various qualities, serving a whole array of purposes. Its annual global industry consumption is around 25 Mio tons. By contrast, the total annual industry consumption of fibers is about 100 Mio tons [4]. In addition to that, cotton cellulose sees limited use in the manufacturing of paper. It has also found use in a variety of other applications.

It was already in the late 19th century that scientists and entrepreneurs started looking for alternative "man-made" fibers, in order to make the early textile industry less dependent on a fluctuating cotton availability. Viscose Rayon proved to be the very first viable manufactured fiber and artificial silk fiber.

In 1891, English chemists Charles F. Cross and Edward J. Bevan discovered the "Viscose Process". They filed a British Patent called "Improvements in Dissolving Cellulose and Allied Compounds" for Viscose, which laid the foundation for the viscose and rayon industries as we know them today.

The duo went on to create the "Viscose Syndicate" with the purpose of granting licenses for the "Viscose Process". In 1905, Courtaulds Ltd. produced the first commercial Viscose Rayon, being the very first economically viable "Artificial Silk". As they say, the rest is 'history'. In 2018 the global annual production of viscose fibers is expected to be in the range of 6.3 to 6.6 Mio tons [5].

3. About Lenzing Group

Lenzing Group is an international corporation that produces high-quality fibers from the renewable raw material wood utilizing environmentally friendly and innovative technologies. These fibers form the foundation for a wide range of textile and nonwoven applications, and are also being used in work and protective wear, as well as in various industrial applications.

Lenzing fiber products are part of the natural cellulose cycle. Thanks to its ongoing technological advances, Lenzing is the only producer in the world today offering all three generations of man-made cellulose fibers: Viscose, TENCEL™ Modal and TENCEL™ Lyocell. TENCEL™ Lyocell is the newest generation of man-made cellulose fibers. Lenzing's products are marketed under the following brands: TENCEL™ for textile applications, VEOCEL™ for non-woven, and LENZING™ for special fiber applications in areas separate from the more traditional textile and non-woven businesses.

The environmental friendliness and biodegradability of TENCEL™ Lyocell fibers are essential market criteria for sensitive segments such as cosmetics and hygiene. Moreover, TENCEL™ Lyocell fibers have optimum moisture management properties that make them appealing for the use in high-grade home textiles such as bedspreads, sheets and pillow cases, but also in sportswear, and women's outer garments.

In some cases, innovations in applications help opening up new market segments with already existing Lenzing products, and in other cases they help to transfer existing technologies to new markets. The use of fibers from Lenzing has expanded over the years to encompass a wide range of applications. Along with classic uses in the textile industry, Lenzing fibers are also convincing choices for products in various technical textiles.

4. Problem Statement – It's about plastic

Taking a closer look on how we live our life today, it is not very difficult to discover that most packaging around us is mostly made of plastic, ranging from beverage bottles to plastic wraps and shopping bags. It is nearly impossible for us to escape plastic, as it has become a seemingly irreplaceable material option thanks to its cost effectiveness, durability and unrivalled functionality.

Since the 1960s, the global production of plastics has increased twenty-fold, reaching 322 million tons in 2015 with the number being expected to double again over the next 20 years [6]. In particular, 146 million metric tons of polymer plastics were put into packaging applications in 2015, and 141 million metric tons were in turn being discarded [7]. Given such massively high numbers, how has the environment been affected?

According to a study conducted by Roland Geyer, an industrial ecologist at the University of California Santa Barbara, an overwhelming majority of packaging plastics are acquired and discarded within the same year. Since most plastics are utilized only a short period of time and discarded of after only a single use, more than three-quarters of plastic waste lands in landfills or the environment, causing potential soil and water contamination. Annually, about 8 million metric tons of plastics end up in the ocean, resulting in an estimated 165 million tons of plastic debris currently floating in the marine environment, threatening the health and safety of marine life. If the current trend continues, the share of coral catching diseases after coming in contact with plastics will increase from 4% to 89%, and it expected that the amount of plastic will surpass that of fish (by weight) in our oceans by 2050 [8].

In response to the growing concerns around the negative impact of plastic pollution, more and more countries and regions are launching anti-plastic initiatives. Under the G7 Ocean Plastic Charter, the United Kingdom, Canada, France, Germany and Italy have all agreed to ramp up plastic recycling by 50%, along with other measures aimed at reducing the impact of plastic on the environment. While plastic-free initiatives can help combating plastic pollution, it is hard to imagine that they alone can ever be a cure-all. So what other innovative solutions are out there?

4.1. Sustainable Packaging - Smart solutions from botanic origins

Just a few years ago, leading global cellulose fiber producer Lenzing embarked on a journey to revolutionize the way retailers pack fresh fruits and vegetables, Fig.1. Since then, packaging nets made of Lenzing beech wood fibers have become an eco-favorite with many leading Central European retail chains.

Fig.1 Botanic Nets for packaging fruits and vegetables made from Lenzing fibers

A major reason for packers and retailers to switch to this new alternative packaging material is their taking up the fight against the sheer endless influx of plastic in everyday life. While the commonly used Polyethylene (PE) netting can usually not be recycled but has to be burned or otherwise will end up in landfills, beech wood fibers offer an alternative way of waste reduction: composting. By having microorganisms thriving in earth and soil eat the cellulose, no remaining material will be left after just a few weeks' time – no micro-particles, and consequentially no harm to the environment, Fig.2. The nets need not necessarily be processed in industrial composting facilities, but can instead be disposed of in compost heaps at home, thereby helping taking pressure off local waste management systems.

On the other side of the equation – raw material production – things look equally bright. Here, cellulose fibers shine with an astonishingly low eco footprint, especially in comparison to PE, the most common plastic used for fruit and vegetable packaging: According to HIGG MSI, Lenzing's fibers for F&V nets are particularly advantageous when it comes to glob-

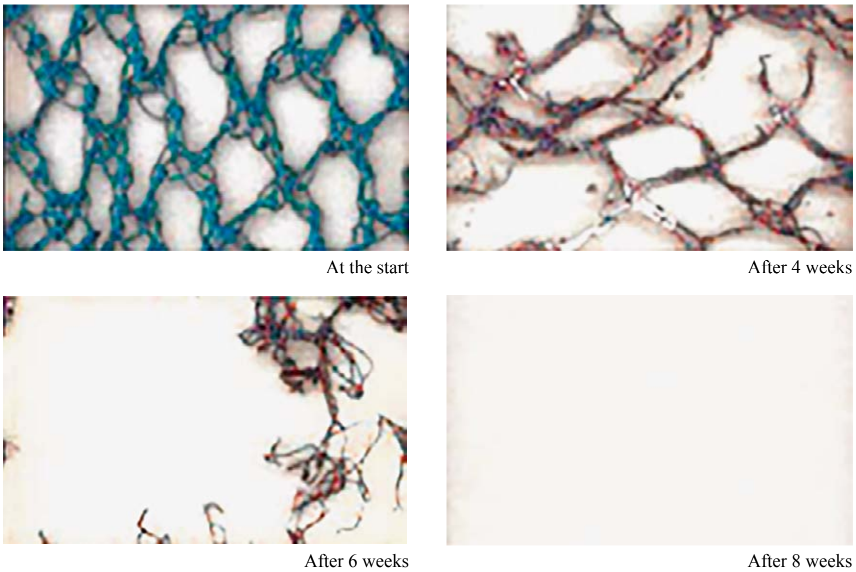

Fig.2 Breakdown of fibers during composting

Forest Wood Pulp Fiber Yarn End product

Fig.3 Production steps - from forest to botanic nets

al warming, where they produce less than half the CO_2 equivalents of PE granulate [9]. All in all, their footprint in relation to PE is almost halved, making them a clearly favorable eco solution.

What is particularly special about Lenzing's approach to sustainable packaging is the fact that the fibers are spun-dyed, meaning that the color pigments are already incorporated in the fiber itself, Fig.3. This eliminates the need for conventional energy- and chemical-intense dyeing processes, and consequentially allows for a highly sustainable production. As a result, colorful packaging and eco-conscience need not be polar opposites anymore, but instead go together exceptionally well.

4.2. Wood-based cellulose fibers for Agriculture - Driver of Sustainable Innovation in Agriculture

Agro twines made of the cellulose fiber Lyocell, having been developed with green-house applications in mind, can be tailored to keep the required strength during the growth period of a particular type of plant, while still being fully compostable after harvesting. This unique trait makes the substitution of plastic and wire twines a real possibility for the agricultural industry. After harvesting, the twines do not need to be separated from the remaining organic waste. The biomass as a whole can instead be directly transferred to a composting site, offering both time and cost savings for the grower.

The Lyocell fibers used in this application are being produced in an environmentally friendly process, and are 100 % compostable and biodegradable, even under marine conditions. With reference to the natural cellulose cycle, the utilization of this fiber for applications like these falls under the circular economy umbrella.

Fig.4 Agro ropes - twines made of the cellulose fiber Lyocell

The benefits of botanic fibers for agriculture on land are evident and the aquatic applications are equally impressive. Its inherent strength for example makes Lyocell an ideal fiber for net structures for shellfish farming. The fiber is strong enough to withstand the long mussel growth season and provides a reliable structure on which the shellfish can thrive.

Fig.5 Mussel nets

Sustainability advantages in aquatic farming are particularly evident given the fact that the material is being used directly in the oceanic ecosystem. If pieces of the nets break off, they will harmlessly decompose rather than pile up in the ocean. In order to close the sustainability loop, the nets can be composted after harvesting and processing.

4.3. New sustainable solutions for the footwear industry

The demand for sustainable materials certainly did not stop short of the footwear industry. With a global production of more than 23 billion pairs of shoes per annum, shoes represent an enormous burden for the environment both, in terms of their production process, and in terms of end-of-life since, as a rule, shoes are not being recycled [10]. In their search for sustainable and innovative materials, an increasing number of reputable brands and shoe manufacturers are becoming aware of Lyocell fibers. The possibilities range from textile fibers in the upper material, as a filling material, a non-wovens fleece in the inner sole, through to Lyocell powder in the outer sole and in the padding. Likewise, shoe laces and the supporting material for zippers are possible. The more shoe components are made of Lyocell fibers, the closer we are getting to the vision of a biodegradable shoe.

Due to their eco-friendly production and bio-degradability (two criteria which are increasingly significant in the shoe sector) cellulose Lyocell fibers are an ideal alternative to conventional materials. Lyocell fibers naturally have good breathing properties, ensure an efficient moisture management in the shoe and offer excellent color fastness. Moreover, they can be easily combined with all other materials commonly used in shoe production. Currently, more innovative footwear components are under development: lining, inner lining, thermo-adhesive lining, paddings, and insoles - all focused on

Fig.6 Moisture absorption of LENZING™ Lyocell fibers compared to PES and Cotton

improved moisture management and required to deliver a defined technical performance.

Summarizing, the recently introduced Lyocell fibers in footwear offer three remarkable benefits in comparison to traditional materials:

- moisture management (performance e.g. enhanced breathability)
- performance improvement (comfort e.g. gentleness on skin)
- sustainability

5. Problem Statement – It is about performance

The growing segment of technical textiles encompasses textile products developed for functional purposes as opposed to aesthetic and apparel-related ones. Technical textiles are used in a variety of industries, amongst others.including packaging (Packtech), Filtration (Indutech), and Energy & Mobility (Indutech & Mobiltech).

Irrespective of the area of application, users expect technical textiles to exhibit high performance levels with respect to adequate lifetime, durability, strength and weight. Fiber based industrial performance materials must as well fulfil stringent standards when it comes to resistance to heat, chemical stability, abrasion, wear and colour fading.

5.1. Filtration solutions based on cellulose fibres

The market for fibers in filtration applications is increasing on a global basis, with a CAGR of 7 % [11]. The highest growth rate is observed in air filtration, particularly in HVAC (Heating-Ventilation-Air Conditioning). Filter solutions are, amongst many other places, being employed in offices, industry, residential buildings, shopping centers, hospitals, and other public buildings.

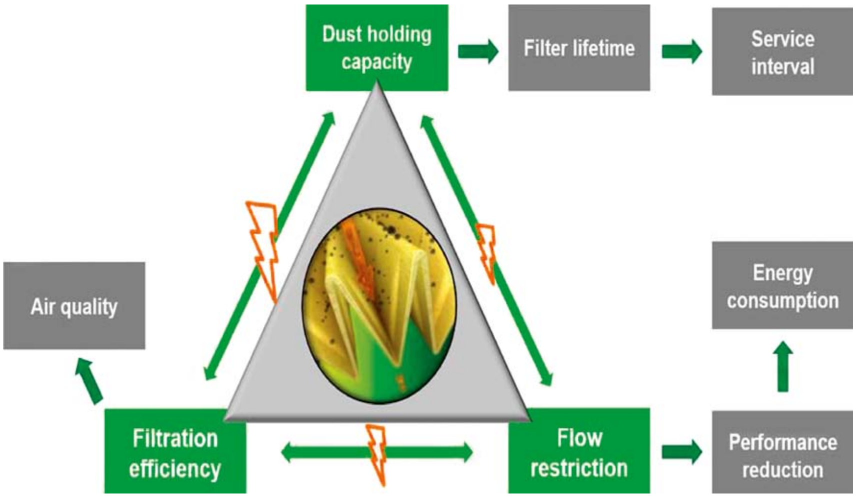

Fig.7 Key parameters relevant for air filtration [12]

Taking a rather simplified approach, the main areas of concern within air filtration are particle holding capacity, filtration efficiency, and air flow restriction.

The requirements for fibers used in air-filtration (cellulose, glass, synthetic) are stringent and ever increasing. Man-made fibers for filter media require a defined fineness and porosity (sometimes as multi-layer hybrid), material and process safety, as well as water and rot resistance.

Typical particle sizes that need to be filtered are strongly dependent on the application. For example, ultra-low penetration air filters are effectively removing particle <0.1 μm with a collection efficiency of 99.99 %. When treated wet-mechanically, Lyocell fibers tend to fibrillate, which means that μ-scale fine fibers separate from the core fiber, but remain connected to the stem. An aggregate of fibrillated fibers forms a three dimensional network that effectively functions as a filter layer. In this respect, Lenzing™ Lyocell fibers are unparalleled and well-balanced in terms of cost and filtration performance.

5.2. Electrical separators

Electric energy storage devices like batteries and capacitors are multicomponent structures with built-in separating layers that effectively prevent electrodes from touching, thus avoiding electrical short-cuts. From a structural perspective, this needs to be a thermally stable layer. Furthermore, there needs to be a well-defined material porosity of the separating layer to allow for migration of ions. Typically those separating layers are made of stretched synthetic films or very thin cellulosic fiber material. Consequently, this chapter focuses on fibrous separator media. A most advanced technical offering consists of Lyocell-based paper separators that have been showing proven reliability and performance in the market for

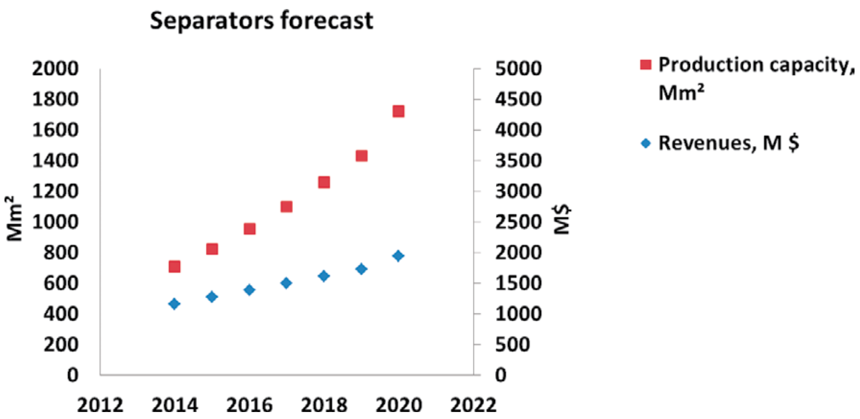

Fig.8 Global market growth for electrical separators [13]

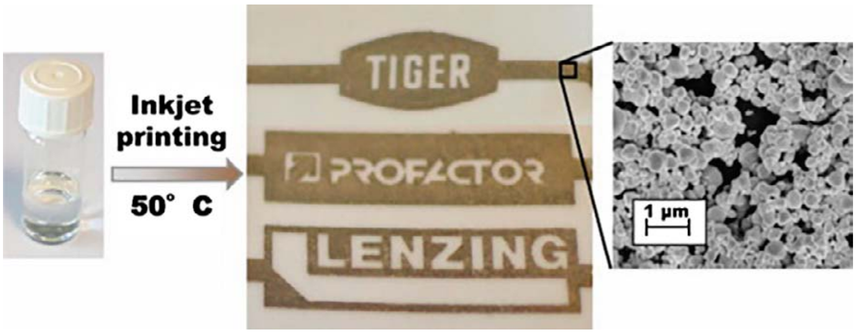

Fig.9 Partner Model for iTextiles project [15]

many years. The separator market itself is highly dynamic and characterized by impressive growth rates as well as rapid innovation cycles, Fig.8.
The reason for this sharp increase in demand for separators is easily explained by the massive progress in electric mobility as well as the exponential growth in the use of electrical devices at home, as well as in leisure, industry, and transportation.
Fiber based electric separator media are in competition with synthetic film based products, which are dominating some market segments, like the one for batteries. Re-chargeable devices (2ndary batteries), especially high energy density batteries, are easily reach temperatures up to around 100 °C. Synthetic battery separators soften under such conditions, leading to electric shut-downs. In this case, Lyocell fiber-based solutions are favorable due to thermo-stability, resulting in increased longevity and safe operating conditions. This is an important feature because in secondary batteries, separators are high cost elements that define the technical performance characteristics of the devices. Consequently, it is expected that Lyocell-based electrical separator media will increase their share in a soaring future market for electrical devices, especially in the area of electrical mobility.

6. Summary conclusion

Advanced textiles such as described in this paper can be defined as textiles that have a performance value beyond and in addition to an initially textile related value proposition, for example *information, protection, reinforcement, sustainability* etc.
There are numerous initiatives, research and product developments based on fibers and textiles that provide solutions for current challenges in the industries and the environment. One of those developments is based on cellulose fibers.
Cellulose fibers manufactured according to the Lyocell process have a great potential to substitute standard plastics and oil-based synthetic fibers. Coming from renewable origins, LENZING™ Lyocell can be returned to the natural cellulose cycle without restrictions. The claim 'from nature' to 'usage' and 'back to nature' is truly fulfilled.
Fortunately, botanic fibers can offer a much more sustainable choice without sacrificing technical performance in many applications.

7. Outlook

A key element of future R&D activities in application development is the combination of textile performance characteristics and the use of textiles as substrate materials for additive manufacturing processes.
Currently, we are evaluating additional promising applications where sustainability will meet demanding technical performance criteria like carrier bags, filters and even thermoplastic reinforcement, as well as composite materials and smart textiles, Fig.9.
An example of a smart textile development may be given by an Austrian project on the construction of stretchable conductive textiles combined with the integration of miniaturized (e.g. nano-sized) sensors e.g. for humidity, temperature, pressure, gas etc., as well as for connection concepts of individual sensors in large area textiles to form networks. Despite a big number of research activities, available technologies are still not powerful enough to deliver a conductive network in textiles that allows sufficient conductivity by stretching while offering high fiber flexibility. (Project "Nanostretch") [14].
A new and exciting technology appears to be the combination of textiles and printing substrate for electronic devices, conductive layers, and printed sensors. LENZING™ Lyocell-based textile substrate structures are used for printing electric conductive layers. In cooperation with Upper Austrian Research company Profactor and industry partner TIGER Lacke, the foundation for a

new opportunity in wearable multifunctional fabrics has been laid (Project Itextiles) [15].

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