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NATURAL FIBRE REINFORCED POLYMER COMPOSITES FROM TEXTILE WASTES – AN OVERVIEW ON NEW POSSIBILITIES

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Abstract: The current interest for natural fibres from textile wastes as an environmentally correct composite reinforcement has motivated the investigation of new possibilities. For instance, the textile fibres from the textile wastes were recently found to have adequate mechanical properties to reinforce polymer composites. Most natural fibre composites, including the textile waste inserted composites, however, are fabricated with traditional non–degradable polymer matrix but still presenting a recycling advantage over the common glass fibre reinforced polymer composites. Therefore, textile waste inserted composites stand out as a relevant class of engineering materials. The greatest challenge in working with natural fibre reinforced polymer composites is their large variation in properties and characteristics. However, with appropriate attention to fibre and resin design and structural geometry, natural fibre composites may prove a viable alternative to traditional materials in the future. Industrial ecology, eco–efficiency, and green chemistry are guiding the development of the next generation of materials, products, and processes.
Keywords: polymeric composite materials, bio-reinforcement, bast fibers (flax, hemp or jute)

INTRODUCTORY NOTES

The major advantage of composites is the ability to modulate properties and thus obtaining a wide range of materials, the usage of which can be extended to almost all areas of technical activity. Composite materials are the first materials whose internal structural design is conceived by man, not only in their molecular chaining, but by giving them favorable resistances in preferential directions. The initial purpose of composites was to increase the competitiveness of classical materials, whose strength and stiffness properties could no longer be improved by other means. From this point of view, it is understood that the maximum efficiency of the reinforcement of a certain material is obtained by introducing, in its structure, fiber reinforcing elements.

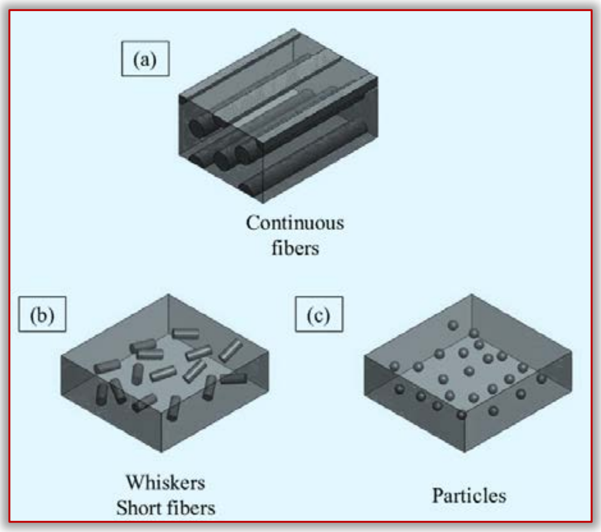

Figure 1. Typical Reinforcement Geometries for Composites: (a) continuous fibers; (b) short fibers or whiskers; (c) particles

Having the background of the need for a sustainable resource of raw materials as well as environmental problems caused by plastics and metallic materials, which are hardly degradable, the leading industries are always looking for new materials, especially those with low impact on the environment, which after end–of–life cycle are easy to recycle and biodegradable to deliver outstanding performance but to be produced as environmentally friendly as possible.

For decades, the development of polymer composites has been driven almost exclusively by performance criteria such as high specific stiffness. It is only in recent years that life cycle considerations have become prominent features in the design of composite-based products, with a gradual increase of recycling efforts, and growing interest for durability analyses. The issues of loop-closing, resource efficiency, waste reduction, and life-extension are to be seen as many facets of the life-cycle engineering concept, developed as an integrated method to design, manufacture, use, and recover materials and products for optimal resources turnover, as presented in Figure 2.

Figure 2. End–of–life cycle – concept

Durability is a key concept for the development of polymer composites, since uncertainties about long-term behavior of these materials often translate into conservative design. There is, however, no general definition of durability, since it obviously depends on the application to be used in an unknown future.

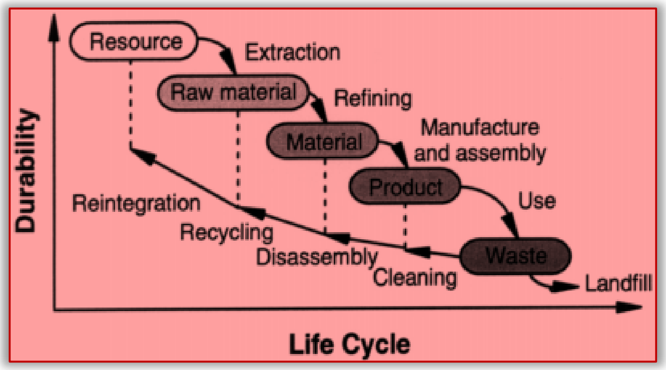

Figure 3. Durability – a key concept

With this approach in mind, the objective of life cycle engineering may be seen as maintaining the durability of the constituent materials shown in Figure 3 to the highest possible level during the whole life cycle.

MARKET TRENDS OF COMPOSITES

Increasing market demand for end products made of lightweight composites ranging from aircraft structures, automotive parts, pressure vessels, constructions, sport products and wind turbine blades, leads to a fast-growing composite materials market. The top business objectives, common to all composites manufacturers, are:

- exploring new materials for new composite solutions,
- exploring new manufacturing processes,
- automating manufacturing processes for faster and more predictable production,
- improving process and quality control of composites,
- cost reduction in various composite parts
- reduce raw materials and waste reuse possibilities, and
- increase ecological sustainability of composites, consist in environmentally friendly resin and fiber systems.

In response to the growing market demand, and in search of a competitive advantage, leading companies significantly invest in technology, research of new materials and innovative manufacturing processes to increase throughput and profitability while improving process and quality control.

Over the past few years there has been a significant developments and innovations in the composites industry across various industries. Market trends of composites are:

- Trends in new and innovative technologies. Composite play a crucial role in the innovative industries and the recent move of aircraft structures or automotive parts manufacturing towards automated tape laying (ATL) and automated fiber placement (AFP) is expected to drive the market during the forecast period.
- Trends in fibers destined to advanced composites. Companies are continuously investing in innovating and developing high strength natural fibers to improve both mechanical and chemical requirements. Additionally, the recent trend on developing green materials would give momentum to development of high strength natural fiber to increase penetration in automotive, construction, and various other industries;
- Trends in new resin systems destined to advanced composites. Companies are launching new resin types that focus short cycle times, especially on shorter cure time in the range of 1–2 minutes for mass volume applications, adapted for new and innovative forming technologies like High Pressure Resin Transfer Molding (HP-RTM) or Compression Molding.

Such objectives indicate that companies dealing with composites invest in the areas of new materials research, process innovation and look for ways to increase production throughput while investing in improvement of process and quality control. Also, the focus on green materials would give momentum to development of natural reinforcements to increase penetration in various advanced industries.

Therefore, the latest trends in composites technology:

- The lightweight characteristics and cost reduction factor of composites will continue to fuel innovations in the airplane, automotive and wind energy industries. Automobiles in particular are feeling the pressure to reduce fuel consumption so expect to see more manufacturers utilizing new composite solutions.
- Expect the advanced and innovative industries to use new reinforced composites to replace parts currently made with other materials or other types of composites.
- The increased focus on green technology will result in high strength fibers to increase penetration in manufacturing. Resins, together with natural fibers, have sustainability. They can create lightweight components for interior/exterior structural parts. Moreover, in the future, natural-inspired materials may replace traditional composites and come to dominate the industry.
- The transport industry has for some time been engaged in the application of new lightweight materials for structural design, with advanced lightweight composites replacing traditional metal materials more and more in both structural and non-structural parts. The rail industry could also benefit from the use of structural new materials.
- A class of biological materials found within numerous natural systems, most notably trees, cellulose materials have captured researchers' attention for their extreme strength, toughness, lightweight and elasticity. Cellulose materials are an attractive alternative because they are naturally available, relatively inexpensive, renewable and nontoxic, and can be easily extracted from wood and plant pulp by-products.

Therefore, continuous innovation is expected in development of higher performance fibers and core materials to meet higher mechanical and chemical requirements.

APPLICABILITY OF TECHNICAL TEXTILES IN COMPOSITES

The applicability of technical textiles in engineering has experienced an exponential growth over the last decades, although in the technical fields requiring mechanical stress is still limited. However, textile materials have particular advantages in terms of formability and dynamic impact properties, and thus composite materials with textile reinforcement are one of the main areas of application of technical textiles.

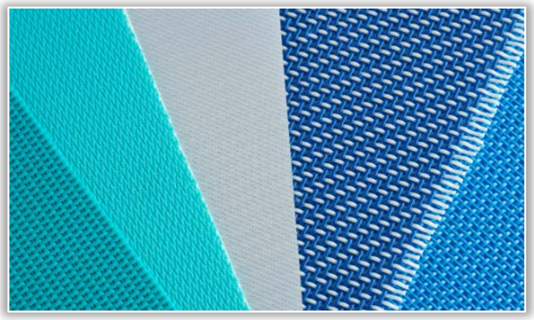

Figure 4. Typical technical textiles

Technical textiles are fabrics and textiles designed and made primarily for their technical and performance properties, rather than for aesthetic and decorative features. Textiles or composites based on technical textiles are intended to replace many of the current metal or plastic materials used in the leading or consumer industries.

Figure 5. Composites based on technical textiles

Imposing these composite materials in the cutting–edge areas of the technique is also due to their technological features:

- easy machinability, with the possibility of obtaining finite pieces in a single operation or by not very difficult operations,
- operations in many cases possible mechanized and automated, which determines the location of costs at relatively low, competitive levels. These advantages are an important economic parameter that reduces the direct cost of making parts, structural elements, or building elements.

The very diverse manufacturing technologies of these materials involve processes for:

- obtaining the polymer matrix,
- preparing the textile reinforcement components,
- impregnating or treating the textile reinforcement,
- making the textile reinforcement (in the form of knit, fabric, and braiding),
- making the composite itself and so on.

THE POTENTIAL USES OF RECOVERED TECHNICAL WASTE

In a circular economy resources are kept in a circulatory system over the longest possible use phase. In this sense, circularity means reusing and recycling materials and products, to keep them at their highest value - in order to turn discarded resources valuable resources. The idea is to develop methods or technologies to repair, reuse and recycle goods according to the hierarchy of waste striving always to reach the highest effectiveness of a raw material by choosing the next step of a product which is most valuable and needs the least new input: reuse before recycling. The materials are often used for several purposes and returned again and again in the recycling cycle. The ecological advantage of the circular economy is that it produces less waste and minimizes the extraction of resources. In fact, the aim of a circular economy is the resource-efficient and sustainable use of natural resources, their reuse and recycling within a circulatory system and the prevention of waste.

For economic and environmental reasons it is necessary that as much of this waste as possible is recycled instead of being disposed of in landfill sites. In reality the rate of textile recycling is still relatively low. Considering the diversity of fibrous waste and structures, many technologies must work in concert in an integrated industry in order to increase the rate of recycling. In this sense, recycling in textiles presents several promising technologies and ideas for recycling systems.

The textile recycling, on the other hand, most often refers to the reprocessing of pre- or post-consumer textile waste for use in new textile or non-textile products. Moreover, if the fabric of a product is recovered and reused in new products, it is considered as fabric recycling, albeit sometimes this is referred to as material reuse. If a product from recycled material is of higher value (or quality) than the original product, it is termed upcycling. The term upcycling is also often used when materials or parts of an old product are rearranged and reutilized to create a new product. Such new combinations might preserve the textile value.

Concluding the concerns in the field of textile waste, we can mention, according to technical, economic, social, ecological criteria, the following directions of action:

- establishing modalities for waste disposal at the end of life–cycle losing production cycles, using and recycling waste;
- designing and launching new products by improving the quality of materials to extend the life of products made from these materials;
- identification of the various internal and external organizations necessary for practice recovery

By processing on classic traditional / nonconventional traditional technologies, the potential uses of recovered technical fiber can be:

- phono– and thermo–insulating materials / building materials (which are used in the textile branch by the production of non–woven textiles, upholstery wadding for furniture and cars, insulating materials, geotextiles, and representing about 60% of the recovered waste: yarn waste knitted fabrics, knitted fabrics, knitted fabrics, knitted fabrics and strips);
- textile composites (which are used in the automotive, naval, construction, military technique, and so on) industries;

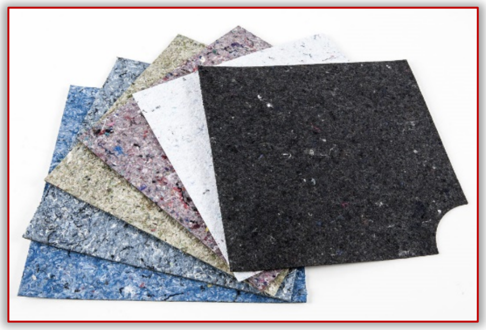

Figure 6. Insulating materials from recovered technical textiles

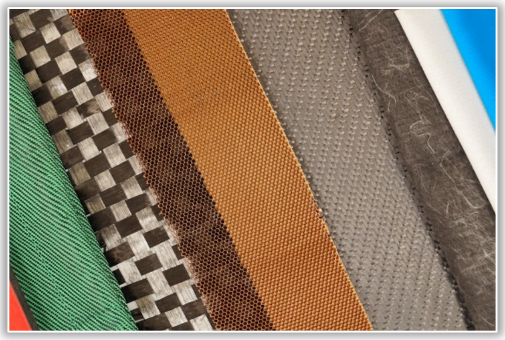

Figure 7. Textile destined to composites

CONCLUDING REMARKS

The rise of composites have already transformed most of the world's industries and will continue to grow in the years to come. The researches in this area of composite materials will focus on:

- making advanced composites less expensive and energy-intensive to manufacture.
- making composites easier to recycle, and
- develop new fibers and resins to open up even more applications for composite materials.

In the future, the composites industry will continue growing into more applications and markets. Environmentally friendly composites will incorporate recycled plastic and bio-based polymers to feed the growing demand for stronger, lighter, and more environmentally friendly materials. Within the field of composite materials, we find a wide range of processing techniques based on the use of reinforcing materials mainly focused on textile structures and matrices of polymeric materials.

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Note

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References

[1] Saxena M, Pappu A, Sharma A, Haque R and Wankhede S (2011), Composite materials from natural resources: Recent trends and future potentials, advances in composite materials – Analysis of natural and man–made materials, InTech, http://www.intechopen.com/
[2] Pickering KL, Efendy MGA and Le TM (2016), A review of recent developments in natural fiber composites and their mechanical performance, Composites Part A, 83, 98–112
[3] Faruk O, Bledzki A, Fink H and Sain M (2014), Progress report on natural fiber reinforced composites, Macromolecular Materials and Engineering, 299(1), 9–26
[4] Faruk O, Bledzki A, Fink H and Sain M (2012), Biocomposites reinforced with natural fibers: 2000 – 2010, Progress in Polymeric Science, 37, 1552–1596
[5] Bledzki A K and Gassan J (1999), Composites reinforced with cellulose based fibres, Progress in Polymer Science, 24, 221– 274
[6] Summerscales J, Dissanayake NPJ, Virk AS and Hall W (2010), A review of bast fibers and their composites. Part 1 – Fibers as Reinforcements Composites, Part A, 41, 1329–1335
[7] Summerscales J, Dissanayake NPJ, Virk AS and Hall W (2010), A review of bast fibers and their composites. Part 2 – Composites, Composites Part A, 41, 1336–1344
[8] Dicker M, Duckworth P, Baker A, Francois G and Hazzard M (2014), Green composites: a review of material attributes and complementary applications, Composites Part A 56 280–289
[9] Sen T and Reddy HN (2011), Various industrial applications of hemp, kenaf, flax and ramie natural fibers International Journal of Innovation, Management and Technology, 2, 192–198
[10] Chokri Cherif (2016), Textile materials for lightweight constructions: Technologies – Methods – Materials – Properties, Chapter: Introduction, 1–7
[11] Jan Hausding and Olaf Diestel (2016), Textile materials for lightweight constructions: Technologies – Methods – Materials – Properties, Chapter: Pre–impregnated Textile Semi–finished Products (Prepregs), 361–379
[12] Malgorzata Zimniewska, Jerzy Myalski, Mateusz Koziol, Jerzy Mankowski and Edyta Bogacz (2012) Natural Fiber Textile Structures Suitable for Composite Materials, Journal of Natural Fibers, 9(4)
[13] Todor M–P, Bulei C, Heput T and Kiss I (2018), Researches on the development of new composite materials complete / partially biodegradable using natural textile fibers of new vegetable origin and those recovered from textile waste, IOP Conference Series: Materials Science and Engineering, 294, 1–9
[14] Todor M–P, Bulei C and Kiss I (2018), Composite materials manufacturing using textile inserts with natural origins fibres, IOP Conference Series: Materials Science and Engineering, 393, 1–6
[15] Todor M–P, Bulei C and Kiss I (2018), An overview on key trends in composite materials continuous innovation and improvements with focus on composites based on cellulose fibers, Acta Technica Corviniensis – Bulletin of Engineering, XI, 4, 107-112

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