6. Textile products – composites

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6.1. The use of composites and the currently amount of production

The world is currently facing the risk of a climate catastrophe. The constantly growing amount of waste force companies to look for a new production solutions that allows to minimize post-production waste. World economies are increasingly turning to the idea of sustainable development.

Textile product means any raw, semi-manufactured or manufactured product, either factory or handmade, which is composed of textile fibres, regardless of the manufacturing process employed, any of the products, materials or items: woven textiles, non-woven textiles, knitted textiles, pre-formed loose fibers, filaments or yarns and textile reinforcement composites.

In 2021 the size of the global composite market was estimated at USD 88 billion. It is forecasted that this value will increase by 7.5% annually, reaching USD 126.3 billion in 2026. On the other hand, the value of the European composite market in 2018 was USD 16.6 billion. It is predicted to grow at a pace equal to the world value. The main sectors driving growth are the automotive and aviation industries which were hit by a temporary stagnation in the second half of 2020, caused by the Covid-19 pandemic. Demand for composites will also increase in the wind energy and defense sectors [1].

The type and constituents of the composites, i.e. the proportions of resin, reinforcement and filler, are tailored to the specific end use of the composites which means that there are many types of composites. Composites can, therefore, be classified based on structure or application. Carbon and glass fibers account for the main share in the production of composites. It is predicted that the share of carbon fibers in the production of composites will continue to increase.

The properties of these fibers, such as high temperature resistance, high stiffness, low thermal expansion, low weight and high chemical resistance, make them very popular in industrial applications [2]. Glass fibers had the largest share in the production of composites in 2018. They are light and durable. However, they have lower stiffness compared to carbon fiber. Their properties, on the other hand, are extremely favorable compared to metals. The development of the automotive and wind energy industries in Germany is expected to drive the entire European composite production market [3].

Composite materials are widely used in the automotive, aerospace and renewable energy industries because they are characterized by high strength, low weight and low maintenance. A car made of composites is lighter than that made of metals which translates into lower fuel consumption while driving and this, in turn, has a smaller impact on environmental pollution by exhaust fumes.

Technological innovations aimed at minimizing production cycle times are expected to stimulate demand for composites in the automotive sector. The presence of strict environmental regulations in Europe has forced car manufacturers to include composites in car production. All over the world, especially in Europe, regulations are forcing OEMs (Original Equipment Manufacture) to significantly reduce the carbon dioxide emissions of vehicles. The proposed regulations in the countries are expected to further fuel demand for products from this sector.

The same is true of aeronautics. It is one of the fastest growing sectors on the European market. The consumption of products in this industry is increasing due to their lightness and high stiffness. The primary purpose of using composite materials in these solutions is to reduce the weight of the aircraft and introduce machines with improved performance. Europe is one of the key markets in the aviation and defense sector and demand is driven by aircraft manufacturers such as Airbus and Dassault Aviation. Composites are also used in the production of sports articles and in the marine and oil industry.

6.2. Recycled composites

A very important aspect of the economy based on the idea of Sustainable Development is the principle of reduce – reuse – recycle, i.e. limiting production and waste generation, using already manufactured goods for as long as possible and recycling those items that are no longer usable. It is important to take into account the principles of Sustainable Development already at the product design stage, i.e. designing recycling-oriented products. The preferred form of waste management is material recycling, which reduces the demand for the production of new raw materials through the re-circulation of recycled materials.

There are solutions for recycling composites containing carbon fibers in order to use them for further production of composites that can be used in the automotive and aviation industries. Carbon fiber regeneration initially involves cleaning the composite from metals and cutting large composite structures to a size suitable for further processing. The capacity of this process is 4 tons per hour. The recovery of the carbon fibers takes place by a pyrolysis process in which the resin is burnt off. The furnace is capable of producing 1500 tons per year.

The carbon fiber is then further processed to form a non-woven mat or pellet. The use of recycled carbon fiber can reduce the cost of fiber reinforcement by about 40%. Another advantage is that recycled carbon has over 10% less global warming potential than virgin fiber. The recycled composite has the same production capacity as the 6 mm long virgin fiber composite. Moreover, the recycled composite retains 90% of its original tensile strength without changing its Young's modulus [4].

In the case of construction and demolition waste, wood, paper and plastics, these raw materials are mainly used to obtain energy through incineration. The use of them in a closed loop for the production of recycled composites is still rare. Mixing and possible contamination of materials are challenges that limit recycling. The recycling of metals, glass, paper, cardboard and plaster requires specialized technologies.

The degradation and contamination of materials often affect the properties of composites made of recycled materials. Processed materials often cause discontinuities in the composite if not processed properly. The possible use of such materials should be considered individually. Also, the environmental benefits that can be obtained depend on the composition of the composite material. Estimating the true potential of recycled composites remains difficult as studies on processing quality, economics, carbon footprint, health and safety are scarce and composition specific [5].

6.3. Eco products used in the production of composites

Natural fibers play an important role in the development of high-performance, fully biodegradable 'green' composites that will be key materials in solving current environmental problems. Compared to 2012, in 2017, three times more composites containing natural fibers were produced and used. This shows that the demand for composites reinforced with natural resources is growing. According to Nova Institute and FNR, since 2012 there has been a sharp increase in the use of flax as a reinforcement of composites in technical applications, furniture, automotive, construction, aviation, car parts, fire extinguishers, ballistic laminates, or biomedical applications. Composites containing natural fibers are lighter, and therefore a car made of such material consumes less energy while driving, while emitting less pollutants [6].

Moreover, natural fibers are preferred over synthetic fibers because they are renewable and biodegradable, which cannot be said about synthetic fibers. Natural fibers can be used as green substitutes due to their advantages such as light weight, good mechanical properties and low density with good strength.

Other natural fibers used in the production of composites are, among others jute, kapok, cotton, coconut, kenaf, kudzu, linden, sisal, hemp, alpaca, wool, angora. The term ‘green composites’ can be defined as those composites in which both the resin and the reinforcement are fully biodegradable and made of renewable raw materials. Biodegradable resins are obtained from plants, animals or bacteria. These are i.e. natural rubbers, soy protein, chitin and chitosan, starch, gelatin, PLA, PHBV, PCL, PVA, PBAT, PHB.

6.4. Waste composites and recycled composites

The vast majority of the market are composites made of glass and carbon fibers. Due to their properties, such as high strength in relation to low weight, high stiffness, high damping capacity, long service life, high resistance to wear, corrosion and fire, they are used in aviation, wind turbines or the automotive industry [7, 8]. The constant demand for green energy sources increases the production of composites used in the construction of wind turbines. Along with the increase in this demand, the turbines themselves are also constantly improved and expanded, increasing their weight and size.

Current wind turbines will last approximately 20–25 years. It is predicted that in the years 2020–34, over 200,000 tons of waste from used wind turbines will be generated [9]. Environmental legislation (including the Circular Economy Package of the European Commission) obliges to increase the recycling of waste. While composite products are typically strong and can be used for a long time, the first generation of composite products, such as windmills, is nearing the end of the product life cycle. This creates a new problem, namely the need to recycle the composites. This material is constructed to be strong and durable, and despite being firmly bonded, it is still heterogeneous, making recycling very difficult. Additionally, composites are often used in combination with other materials, such as foam fillings, for example, leading to mixed waste streams.

The largest part of the market are thermosetting polymer composites, reinforced with glass fibers. In Europe alone, over a million tons of such composites are placed on the market each year. Due to the construction of the composite itself, i.e. its heterogeneous structure, recycling is very complicated. Such composites cannot be remelted to obtain a new element. These materials are recycled in two ways:

– mechanical recycling, which is relatively simple, inexpensive and the most common. Used materials are subjected to comminution, grinding and classification. As a result of these processes, a recyclate is obtained that can be reused;

– thermal recycling – use of high temperature (300-1000°C) for resin pyrolysis and separation of fibers and fillers. Pure fibers can then be used for further production (however, they have worse properties than virgin fibers), while the remaining material is used as fuel.

When it comes to carbon fiber reinforced composites, depending on the composite production technology, the amount of carbon fiber waste is 30-40%, globally it is currently about 24 kt and it is forecast that in 2021 the amount of carbon fiber waste will be 32 kt. Currently, less than 1 kt is recycled. About 2/3 of all fiber waste is production waste and 1/3 is fiber from used parts fiber-reinforced composite (FRC) materials account for a significant proportion of plastic waste because they have a wide range of applications, including in construction, aeronautics, aerospace, sporting goods, renewable energy industry.

FRC materials are characterized by high strength, high durability, low weight and high flexibility of shapes which makes them a good alternative to steel and other materials. The development of the FRC industry has not only increased production and consumption, but also leads to the creation of a large amount of End of Life Products (EOL). The maintenance and recycling of used FRC scrap has become an important challenge for a sustainable and circular economy.

In 2015, almost 300,000 tons of composites waste were produced in the European Union alone of which 250,000 tons were EOL products.

Currently, the majority of composite waste (almost 98 %) is landfilled, and those that undergo further processing are most often used as fuel. As the use of composite materials continues to increase, it is essential to develop solutions to reduce the waste generated [10].

Check *GreenTEX Handout: Waste generated during the production of textiles (https://greentex.p.lodz.pl/)*

Extra readings

1. Grand View Research, Epoxy Composite Market Size, Share & Trends Analysis Report By Fiber Type (Glass, Carbon), By End-use (Automotive & Transportation, Wind Energy), By Region (APAC, North America), And Segment Forecasts, 2021 – 2028, online https://www.grandviewresearch.com/industry-analysis/epoxy-composites-market (access: 15.08.2022).
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