

Composites: materials of the future

Part 1: Introduction

Definition

A composite material is a blend of at least two immiscible components, with different structures, whose individual features combine to provide improved overall performance.

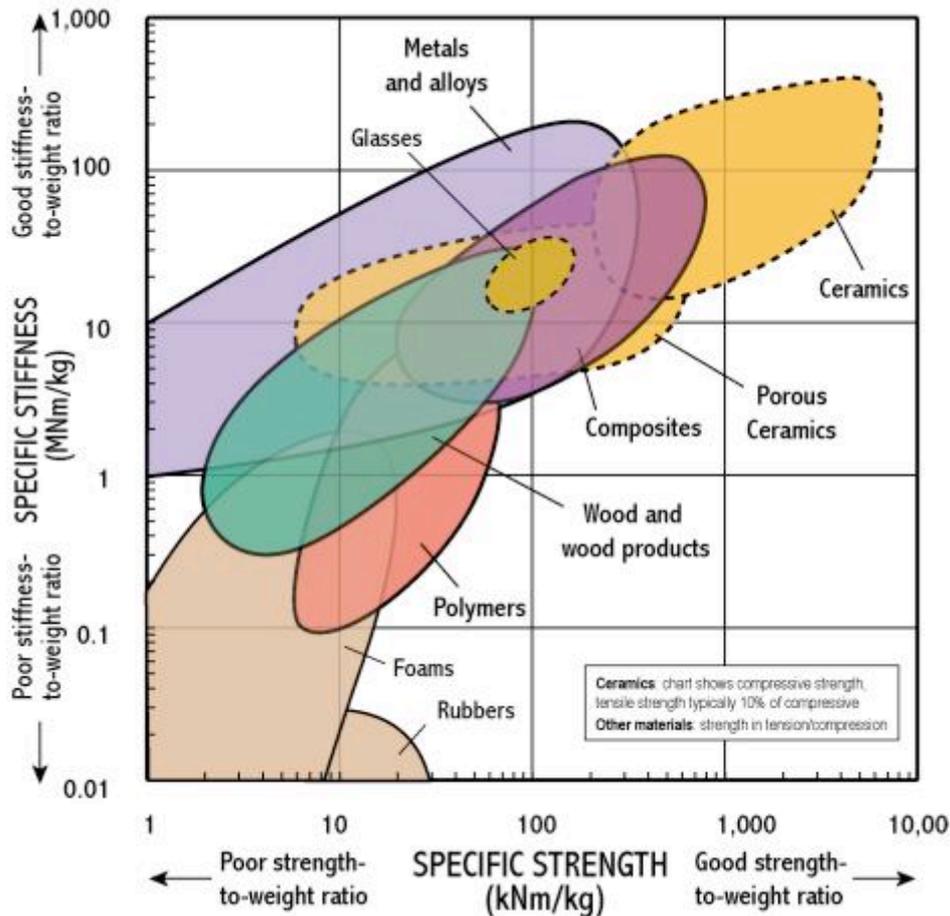
This definition is very general since it includes paper/cardboard, chipboard, coated fabrics, tires, waterproofing membrane, concrete, etc.

In this series of publications, we will highlight composites made of:

- A thermoplastic or thermosetting polymer matrix that gives the material its shape and cohesion, distributes the stresses and protects the fibres from the environment. Reinforcements, mainly in the form of long or continuous fibres, whose function is to provide strength and rigidity
- Other components and additives: compatibilizers, UV stabilizers, conductive fillers, flame retardants, etc.

The matrix of composites can also be metal (Metal Matrix Composite), ceramic (CMC Ceramic Matrix Composite) or carbon (CC Carbon-Carbon). These materials, while serving smaller, niche markets, have interesting properties and also will be featured in an article.

One of the great strengths of composites is that the properties are adjustable according to design parameters such as the nature, rate, orientation and fibre architecture, arrangement of folds and the nature of the matrix. The composite material may be insulating or electrically and/or thermally conductive, have a coefficient of thermal expansion that is specific to the intended application, be optimised for energy absorption (impact, sound). It can have complex geometries and/or large dimensions and can incorporate many features (inserts, decorative elements, protection, etc.). It finds applications in "low cost" as well as "high tech" sectors.



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Matrices

Matrix composites are typically thermosetting: They are liquid resins of low viscosity, which cure in an irreversible polymerization cycle and, thus, are not recyclable by fusion: especially polyester, vinyl ester, epoxy, phenolic, cyanate ester, etc.

Thermoplastic matrices are becoming increasingly important. They have a high viscosity and are implemented by fusion in a reversible cycle. These are PPs, PAs, PBTs, PEIs, PPSs, PEEKs, etc.

Thermosetting

Conventional thermoset composites have several drawbacks:

- Their implementation releases volatile substances such as styrene;
- The production cycles are long since they have a polymerization phase.
- The material is not recyclable by re-fusion.

In recent years, many efforts have been made to solve these problems. Low-styrene resins, fast curing materials that are compatible with mass production, effective

All these systems are marketed in different reinforcement/resin combinations (PA12, PBT, PPS, LCP, PEEK + carbon, glass, para-aramids).

The choice of thermoplastic materials is vast: convenience plastics, engineering plastics, high-performance plastics, etc. The choice is made based on criteria such as density, operating temperature, chemical resistance, etc. and, of course, cost.

High-performance matrices are increasingly required because demanding applications are also increasing.

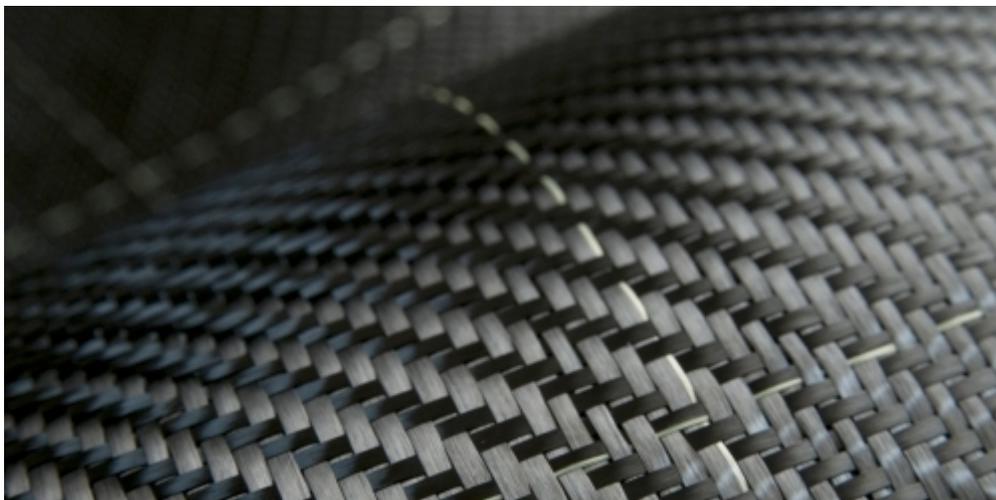
Biodegradable and/or bio-based materials are the subjects of much interest, whether they are matrices from renewable resources or natural fibres. So far, organic matrices occur mainly in composites with short vegetable fibres, but applications are evolving towards more technical products.

Reinforcements

Glass fibres represent 95% of the composites market. Their production for composites is estimated at 250,000 t/year. That of carbon fibres reached 30,000 t and that of natural fibres reached 40,000 t.

The main characteristics of glass fibres are the low cost, mechanical strength and the thermal and electrical insulation properties.

Carbon fibres are used in high-performance structural composites. They are thermal and electrical conductors.



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Aramid fibres (Kevlar, for example) are used for their good damping performance. They have high specific resistance, low compressive strength, excellent impact and cutting resistance.

Hybrid reinforcements, such as carbon/aramid, carbon/glass in the same layer or in different folds of the same structure, are used to combine the properties of each.

Natural fibres, which are not new in composites, are currently making a breakthrough.

Among the less common reinforcing fibres are:

- UHMWPE fibres, with ultra high molecular weight (such as Dyneema by DSM), which are particularly resistant to impacts. They have a low coefficient of friction but the operating temperature is limited.
- Metal fibres, used for electromagnetic shielding and electrostatic discharge. Their density is high.
- Basalt fibre, characterised by excellent high temperature behaviour, good thermal and acoustic insulation properties, good mechanical, strength, etc. It is more ductile than fibreglass and cheaper than carbon reinforcement.

Markets

In the last thirty years, the composite industry has experienced good growth at the same time as general economic development thanks to greater penetration of this material in key markets such as the construction, wind, aeronautics and automotive industries. Currently, we have achieved a global market of €68 billion for 7.9 Mt.

Since the economic crisis, however, as the composite market is strongly linked to those of the user sectors, production has experienced an overall drop of -3%/year. Nonetheless, some recovery has been noted, at least in some regions of the world.

In spite of it all, composites display great vitality and innovations follow one after the other. The main trends, which will be developed in a series of other articles, are summarised here:

1. The market's growth is due to the development of emerging countries, particularly in Asia. It is directly related to the health of the economy. These countries are in the equipping phase and the demand for a variety of goods is high there.
2. Thermoplastic composites are growing faster than thermosets.
3. According to some experts, carbon composite would be ready to be introduced into the mass applications, via automobiles in particular. But the current uncertainty on the user markets leaves the question open.
4. "Eco" or "organic" composites are receiving interest and the use of natural fibres is becoming more professional. Few "fully organic" products, however, are reinforced with long, natural fibres. This market is expected to grow significantly in the next decade.
5. Reinforcement architectures are increasingly complex and "intelligent": 2.5D or 3D, triaxial or multiaxial. Solutions are proposed to obtain structural reinforcements that are much more deformable. 3D preforms are needed.

6. Carbon nanotubes are spreading. They are added to epoxy prepregs or laminating resins to improve the ultimate strength and dimensional stability or change conductivities.
7. Production is becoming highly automated. The composites industry is moving towards low volume mass applications; automation is essential and is accompanied by an acceleration in cycle time.
8. Out-of-autoclave (OOA) systems are taking off. They make it possible to produce composite parts faster, more efficiently and with an excellent surface finish in a non-autoclave environment. The technique is more flexible, requires less expensive tools, much less investment and is more energy efficient. Resin injection techniques (RTM and others) are growing.
9. The need to solve the problems of recycling composites is increasingly urgent with the advent of mass applications. Little progress has been made in recent years, but the issue remains on the agenda.
10. Integrated composite structures, designed and manufactured in a single step, are one of the strong trends at the moment. The combination of multiple processes allows manufacturing with low power consumption and advanced automation. An interesting implementation technique involves thermoforming reinforced sheets of continuous fibres and moulding them from a casting by conventional injection with a short fibre reinforced polymer.
11. The aeronautical, automotive and wind industries are innovative sectors. Composites in the first niche are growing (11%/year) thanks to on-going efforts to produce lighter aircraft. The automotive industry remains creative and is investing in carbon composite, but this sector is very sensitive to the economic situation. The wind power industry is using an increasing amount of composites (16% growth/year), but its future is linked to politics, which are rather uncertain today, and the authorities.

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Conclusions

Composite materials, after having raised hopes in the 80s and 90s, were a little "out of fashion". Many companies in the sector could not move from the craft and manual implementation stage to the professionalization made necessary by new safety, health and environment requirements.

Today, composites once again appear as materials of the future and R&D is instilling them with a new dynamic.

This article forms part of a series of technical articles aimed at industrial manufacturers wishing to increase their knowledge of the field of composite materials. It was produced within the +Composites project (www.pluscomposites.eu).

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