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FEATURE

New developments in carbon fiber

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Carbon fiber, or simply carbon for short, goes by many different names and acronyms: carbon fiber reinforced polymer (CFRP), carbon fiber reinforced plastic (CRP) or carbon fiber reinforced thermoplastic (CFRTP). It is a composite material, a type of a fiber-reinforced plastic, and it is used in industries and areas whose products demand high levels of strength-to-weight ratio. This means that carbon fiber is extremely light but at the same time extremely strong, rigid and durable. Some of the areas and industries where those characteristics and features are very needed and sought after are aerospace, civil engineering, automotive, marine, construction, and many others are also starting to discover the good, useful and attractive uses of carbon fiber.

What is carbon fiber?

Carbon fiber is a composite material and a type of fiber-reinforced plastic. To better understand carbon fiber, it should first be clarified what composite material means as well as what fiber-reinforced plastic is, explaining some of their main features, describing some of the most important parts of their formation and production, and giving an overview of the range of their applications.

Composite material

Composite material, or as it is also known, a composition material, or simply a composite, is a material made out of a combination of two or more different materials that form one structure. This new material will have different properties and characteristics than the individual originals that were combined. Interestingly, even though a new and different composite material is formed, the individual components are still visible as they do not blend and mix with each other. The reason that composite material is produced is that it will result in better and superior properties, both physical and chemical, to the properties of the individual components.

The new composite structures are preferred and widely used for many reasons – they are lighter, stronger and significantly less expensive than some traditional materials. Composites can be stronger and bear much more weight than some of the typically strongest metals, such as steel, but at the same time weigh much less, five times less than steel.

Composites have been used since ancient times, for thousands of years. For example some of the first composites were mud bricks, used as building material, or even straw mixed with mud which makes for a very strong material. Concrete is also one of the ancient composites. Historically, it was made out of stones and gravel, mixed with cement and sand, also giving a very strong composite structure. Later, in more modern times, including today, concrete has been upgraded by adding metal rods or wires to it, which in turn increases its ability to bend and stretch when necessary. Today it is called reinforced concrete and it is one of the most commonly and widely used composite materials. The first modern-day composite material used was fiberglass, which is still very familiar and commonly used. Glass is stiff and strong, but due to the fact that it is also very brittle and prone to breakage, it has been slowly replaced with carbon fibers. Other types of modern day composite materials include reinforced plastic, such as fiber-reinforced plastic, metal composites and ceramic composites.

Composites are most commonly made out of two materials, but there can be more. When it comes to the materials, or better yet, the constituents of composite materials, there are two main categories: the matrix or the binder, and the reinforcement. Each category is equally important, so there should be at least one

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0034-3617/ http://dx.doi.org/10.1016/j.repl.2017.07.004

Please cite this article in press as: M. Smith, Reinf. Plast. (2017), http://dx.doi.org/10.1016/j.repl.2017.07.004

Figure 1 Fiberglass (*Source*: https://www.fiberglasswarehouse.com/blog/choosing_which_fiberglass/).

Figure 2 Fiber-reinforced plastic. (*Source*: Pixabay.com).

material functioning as the matrix and one functioning as the reinforcement. The matrix is normally a form of resin, and its role is to protect the reinforcement materials by surrounding them and keeping them in their desired position, bonding them together. The reinforcements, on the other hand, are used to strengthen and stiffen the matrix, using their own unique properties to fortify the matrix and enhance its properties. The unique quality of reinforcements allows them to be shaped, cut and placed in many different ways in order to enhance and produce the desired properties as the end result, in the composite. Since there is an array of possibilities and varieties when it comes to combinations of matrices and reinforcements, the producer or designer can choose any that suits them and their needs and that will produce optimal end results and products.

Matrices can be organic – polymers (fiberglass, carbon fiber, Kevlar), bitumen, mud; or inorganic – concrete, metals, ceramics, glass. Reinforcements are most commonly in the form of fibers, and some of the most common are glass, carbon, cellulose and polymers. Other types of reinforcement include aggregate (for concrete) and steel bars (for reinforced concrete).

Composite materials are usually made by molding, since they have to be formed into a shape, and there is a variety of molding methods, depending on the end-product requirements. During the process of molding, the reinforcement material is placed into the cavity of surface for molding, and the matrix can be introduced either before or after that, depending on the requirements of the end-design.

Fiber-reinforced plastic

Fiber-reinforced plastic (FRP), also called fiber-reinforced polymer, is a type of composite material. The main constituents of FRP are matrix and reinforcements, as with any other composite. Here, the matrix is a polymer which is most commonly an epoxy, vinyl ester or polyester thermosetting plastic, but phenol formaldehyde resins are still being used. When it comes to the reinforcements, their function is carried out by the fibers and they are usually carbon, glass, basalt or aramid, even though other types, such as wood, paper or asbestos, are still being used sometimes.

The main areas of usage of fiber-reinforced plastics are usually aerospace, marine, construction industries and marine, and it can also be found in ballistic armor.

FRPs are very widely used due to their high-quality, useful and advantageous properties, which can be unique and designed according to the desired end-product due to many possible combinations and types of polymers and fibers. Some the most valuable properties of FRPs include their extremely optimal strength-to-weight ratio, which means they are very low in weight and high in strength, and can therefore even be used to replace some metal parts on certain objects. For example in automotive industry they can replace metal parts in cars, since they are as strong as metal but much lighter, decreasing the overall weight of the car and the fuel consumption. They also have significant electrical properties, they are environmentally resistant, resistant to corrosion, provide thermal insulation, and are very stable, resistant, strong and cost-effective when it comes to their production.

Fiber-reinforced polymer is developed through two processes – step-growth polymerization and addition polymerization. Through these processes, the original plastic material, the matrix, is reinforced by strong and stiff fibers, and the end-product is an FRP, higher in both strength and elasticity.

Carbon fiber

Carbon fiber, most commonly referred to as CFRP, is therefore a composite material, a fiber-reinforced polymer, where the reinforcements are carbon fibers. The matrix or the polymer that functions as the binder is most commonly a thermoplastic one, usually an epoxy, but it can also be polyester, nylon and vinyl ester. Carbon fiber reinforced polymers consist of only two elements, so their properties will depend only on those two elements and their type, the matrix and the reinforcement.

Carbon fibers are very stable, stiff and strong, as is the case with other fiber-reinforced polymers, but they are also distinctively very thermally stable and can withstand a wide range of temperature. This is why they are most commonly used FRPs in aerospace and

Please cite this article in press as: M. Smith, Reinf. Plast. (2017), http://dx.doi.org/10.1016/j.repl.2017.07.004