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Analysis of the role of products made from carbon fibre and C/C composites: Opportunities and challenges

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Abstract

Carbon fibre is a very lightweight and very strong material showing wide range of properties. It can be used to make carbon/ carbon (C/C) composites. C/C composites are capable of finding applications in all fields of life due to its versatile nature of properties. At the time of selection of material for the manufacturing of product, so many properties are required to be considered keeping in mind the use of the product. Dimensional stability, heat resistance, chemical resistance, high thermal conductivity, high rigidity are the properties observed in carbon fibre reinforced plastic molded products. This paper gives note of some important products made from C/C composites and carbon fibre. Brake disc pad, high temperature furnace shielding, illizarov external fixator rings, pipes and tubes made from this material is used showing variety of applications. Opportunities and challenges for C/C composite material are also analyzed briefly.

Keywords: Carbon fibre, C/C composites, high and normal temperature range products.

1. Introduction

Common materials used for man- made structures like concrete, glass, plywood and metal alloys etc are composite materials which are widely used to fulfill our needs. However due to changing scenario of demand, designing of composite material for specific purpose is realized. To fulfill this requirement, steel and other metal alloy are used for the application where products are required to bear high strength. But use of these metals and alloy increases the weight of the products made from these metals and alloy. Recently lots of efforts have been made to develop high strength and low-density materials. For which more than one material in specific proportion is combined to make composite material having required properties. At present, carbon fibre is preferred as structural engineering material because carbon fibre is found five times stronger than steel. It is also two times stiffer than steel. Simultaneously it is much lighter than steel. Due to this carbon fibre composites are replacing products made from steel and alloys. Carbon/Carbon (C/C) composites^[1-3] are made using carbon fibre as reinforcing material and high carbon content material as matrix. The structure and mechanical performance of a composite depends on so many factors like volume fraction, orientation of carbon fibre, diameter, density and other properties of fibres used. Carbon fibre and its composites are preferred in several application in aerospace, automotive, medical, military, recreation and information communication.

2. Methodology and discussion

This review paper gives knowledge about products made from carbon fibre composite material. In this paper carbon fibre composite products made using PAN and Pitch based carbon fibre as reinforcing material have been discussed. Carbon fibres are impregnated with thermoplastic/ thermoset matrix to form prepregs which are molded in the shape of actual products as per requirement.

3. Applications of carbon fibre and composites

United States, France, Germany and Japan are using carbon fibres and C/C composites for

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the production of so many components simultaneously India is also using C/C composites in large number of applications because Indian market demand has increased. There are two broad categories of applications of carbon fibres and C/C composites as discussed below.

3.1 High temperature range products

Sublimation temperature of carbon is found as 3727 degrees Celsius which is higher than other structural material. Carbon can retain its strength up to 2200 degree Celsius^[4]. Due to this superior property, the fins of first missile were made from graphite which were used during World war-II. But it is realized that graphite is very brittle material in nature and cannot retain strength at elevated temperature. Therefore, graphite was replaced by C/C composites which is able to retain its strength and dimensional stability at the time of elevation of temperature. Since then, it is used in large scale in missiles. In Washington M14/ M1-A Rifles are also made using carbon fibre and resin composites.

Temperature of rocket nozzles increases very high during operation. Therefore, Rocket nozzles are made using the carbon material which can retain its strength at very high temperature and in highly corrosive atmosphere. C/C composites are used in making furnace fixturing, heat shields, load plates, heating elements and x-ray targets. Bullet proof helmets and jackets are made using C/C composites. Aerospace industry is using C/C composites at large scale in making several components to save it from fire hazards.

Carbon fibre fuselage can be made as per dimensional requirement which are heat resistant and is safe material. C/C composite brakes are used in Formula 1 and other high speed racing cars. Clutch is also made using C/C composites.

3.1.1 Friction based applications

Due to suitable properties required for brake pads such as high thermal conductivity, low coefficient of thermal expansion and light weight C/C composites are considered as best material for their smoother braking performance. These can take extreme rejected take offs without brake failure. C/C composites are used in large scale in the soviet space program. These possess comparable properties to western composites, although production methods were lower^[5-6]. At the time of landing of commercial and fighter aircrafts, temperature of brake pad increases very high i.e. approx.700 degree Celsius. Sometimes it reaches up to 1000 degree Celsius. Therefore, high temperature resistant material is required. This property is exhibited by the C/C composites. The supersonic commercial plane, the mirage F-16, F-18, A-6, A-310, A-320, A-300, A-747 etc are using C/C brake linings. Data shows that the brake temperature of A-320 increases up to 300 degree Celsius, if the brake fans are off. But if the brake fans are running prior to takeoff then the brake temperature will be below 150 degree Celsius.

Use of C/C composites are preferred in space craft because due to heat resistant property which secures the spacecraft from heat produced by the air friction while passing with very high speed through the earth's atmosphere. Carbon fibre composite Profile having flawless finish are used in aerospace industry.

3.2. Normal atmospheric temperature range products

High quality carbon fibre tube is durable and light weight product which is used in multi purposes such as making gutter cleaning system and carbon fibre tubes for drones. It is useful for offices, restaurants, hospitals, houses and shopping areas. Carbon fibre composite tie rod is also multipurpose product. Carbon fibre seat, carbon fibre fabric, carbon fibre shafts, aircraft wings, car components, propeller blades etc are giving best performance comparing to other materials. Now a days carbon fibre composites are used in producing bike frames and car bodies because of high strength and stiffness.

Luxury carbon fibre jewellery such as rings for men and women is made from aerospace grade carbon fibre. Carbon fibre is molded into a ring like shape by special techniques. Carbon fibre molded bathtubs are very light in comparison to other bathtubs. Carbon fibre laminated sheets are multipurpose material. It is used for making picture frames and light fixtures due to high strength and stiffness. It is also used for kitchen utensils and furniture items. C/C composites are also used in wind energy mills.

Carbon fibre tripod assembly is also useful carbon product. Carbon fibre toys, carbon fibre guitars and violins are light weight and high-performance items. Carbon fibre sandle base is lightweight product. Carbon fibre helmets and shoes are also light weight preferred items. Carbon fibre composite material is used in making sports equipment^[7]. Carbon fibre is used to make hockey sticks. Carbon fibre composites are used to make archery bows and golf clubs.

3.2.1 For medical applications

Carbon is main constituent element in the human body. Due to this, carbon fibre is considered as a biocompatible material and have no toxic effect^[8-9]. Therefore, carbon fibre products are considered as highly suitable for medical field. Carbon fibre laminated sheets are used in various medical applications. Carbon fibre half ring of various sizes for external fixator made of carbon fibre composites are available which are used for the treatment of correcting the bone disorder. These carbon fibre composite rings are used in place of stainless-steel rings because total weight of complete system made using C/C composites is very less comparing to stainless steel. This is considered as very useful product in medical science. Carbon fibre table top for operation theatre (OT) table is useful product. Carbon fibre medical table is finding applications in operation theatre and other treatment purposes. Polymer based composites are used in biomedicine for dental resin composites, drug release, tissue engineering, surgical operations and regenerative medicine.

Carbon fibres are used in scanner devices, medical imaging devices and various parts used in x-ray in medical field because Carbon fibre and its products are not affected on the exposure of radiation. Carbon fibre products are completely safe for the use in the form of components for implants. Hence carbon fibre implants are used in large scale for orthopedic surgery such as in arthroplasty, oncology, spin and trauma.

Carbon fibres are used in various industries like electronics, telecommunication and entertainments. Industrial applications have increased with the use of so many products such as Nut, bolt, diverter armor, hot press mold, crucible for semiconductor etc.

4. Opportunities and challenges

Carbon fibre, C/C composites and its products are extensively used in various fields due to its wide range of attractive properties. As per requirement of products used in specific atmospheric conditions, its properties can be customized. It shows high thermo-shock resistance and chemical resistance especially at high temperatures. The production of carbon fibre has started in India and is increasing day by day. Therefore, the price of carbon fibre is decreasing continuously which is making it popular for the purpose of developing new products. These products are replacing large proportion of products made of metals and alloys used in manufacturing of spacecraft and aircrafts.

New startups are required to be started to increase the production of these products in large scale. For high temperature applications, products are required to be heat treated at high temperature during production process which makes it brittle in nature. Hence it is required to handle it with care. Simultaneously awareness among the mass community is required about its fantastic properties to increase its uses. Technological expertise and skilled laborer is required to increase the production of useful products. Carbon fibre composites cannot be recycled.

5. Conclusions

Carbon fibre composite products show variable nature of properties. Changing processing conditions results in change of the properties of the yield products. Carbon fibre composite provides a variety of products which are useful in all fields of human life. Most important properties are light weight, high strength, heat resistance and chemical inertness.

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