Carbon fiber composites. types, applications and limitations

Abstract

The discovery of Carbon fiber composites has been a major step in the technology industry. These materials have ranging suitability and superior physical and chemical properties and thus play a major role in the aerospace industry by making light but stiff materials that are desired. Additionally, they are used in transportation and other fields of engineering. Due vast usefulness of Carbon composite fibers, this paper explores their synthesis, technique characterization and their properties.

Introduction

Carbon fibers are also known as carbon fiber reinforced polymer (CFRP) is a fiber reinforced material with superior properties in comparison with individual materials making the composite. They are chemically insensitive to many chemical species except in altered chemical environment like in introduction of a flame. The matrix of the composite is a Thermoplastic in many cases epoxy. Vinyl, polyester and nylon can also be used as the matrix. It is reinforcements are Carbon fibers which are synthesized from polyacrylonitrile or rayon. The CFRP is very strong and stable with high thermal stability over a range of temperatures. This material is also light in comparison to metals and alloying elements such as Zinc, that is used in alloying elements such as magnesium and Aluminium. This is the basic advantage of using carbon reinforced-fibers in development of lightweight composite materials for structural applications especially in space and aircraft industry. Even though it is lighter than steel, it is tougher than steel according to Liu et al. 1   Joseph Swan produced carbon fibers in 1860 for use in bulbs as well as Thomas Edison in 1879. Rolls-Royce company was the first to make carbon fibers.

Carbon fiber processing and Advancements

The processing of carbon fibers from different precursors may differ, but the thermal conversion process is similar. First precursor fibers are stabilized by oxidation in air at a temperature of 200-400 degrees Celsius. This process increases the thermal stability of the fibers. The stabilized Carbon fibers are placed in an inert atmosphere of high temperatures of about 2000 degrees. This process is called Carbonization process, where non-carbon elements such as nitrogen and oxygen are removed hence the formation of Carbon fibers as reported by Khayyam et al. 9

New advancements have led to the introduction of polymer nanocomposites which have carbon nanotube (CNT) as a filler embedded in polypropylene, epoxy or cotton fabrics bulky polymer composites according to J. Chen. 3 The CNTs are widely applied in nanotechnology, electronics and many other fields of science and technology. CNTs can be single-walled carbon nanotubes (SWCNT) or multi-walled carbon nanotubes (MWCNT) with different structures, thickness and length suitable for the required purpose. CNTs are flexible and so can be added to some materials. Depending on the rolling angle, CNTs can be semiconductors or conductors of electricity hence their potential use to replace metal wires and use in the production of computer microchips respectively.

Types of Carbon fiber composites

There are various Carbon fibers composites with different properties due to differences in constituent materials:

Silica particle coating of Carbon fiber-reinforced polymer (CFRP) composites produces a high strength and light type of CFRP composite making it desirable in many industries. It is made by joining CFRP with silica and thus increasing their structural integrity as stated by. However, according to Malinowski et al., four bolts and nuts are not used in the joining CFRP as they compromise the structural integrity. Instead, adhesive bonding is used. On observations of the dispersion, size and shape of silica particles on CFRP, they are seen to be spherically shaped particles with a diameter of about 320 nm, non-aggregating on CFRP surface. The silica particles adsorb strongly such that they do not easily fall when the material is subjected to ultrasonication due to the strength yield that is increased by about 20%

To make up for the strength deficiencies of Silicon Carbide ceramics, reinforcement with Carbon nanotube (CNT) results in a stronger composite, overcoming its intrinsic brittleness according to Xu et al. 5 CNTs was discovered by Iijims. 6 They are tube-like and, measure a few nanometers. The hollow tube is made by a number of graphite sheet hence can be single-walled carbon nanotube (SWCNT) with one graphite sheet and multi-walled carbon nanotube (MWCNT) with many graphite sheets. The Bonding occurring in these nanotubes is essentially sp2 with out of plane bonds. Due to these features, nanotube has superior and extraordinary electronic, magnetic, thermal, mechanical, chemical, and optical properties. The experimental measurement revealed by Moniruzzaman et al., 7 show that CNTs are as stiffer and stronger than diamond. Therefore, rendering CNTs the ultimate reinforcement materials. They have thus have been incorporated into polymer, ceramic and cement matrix to improve the composite's mechanical strength.

Incorporating CNTs into Silicon Carbide (SiC) matrix improves the fracture profile and mechanical strength. The process involves homogeneous mixing of CNTs in SiC ceramic matrix, in disperse-mix-densification process. According to Cho et al. 8, in this process, a homogenous mixture must be obtained in order to avoid agglomeration that may initiate stress and internal cracking. This is followed by dispersion of CNT intensifying material in the SiC matrix.

Dispersion of CNT in SiC matrix is achieved by either conventional powder processing where CNTs and SiC particles are mixed in a solution, especially organic alcohol such as isopropyl alcohol, followed by ultrasonic shaking. The ultrasonic process is determined by the amplitude and cycles of ultrasonic waves. For proper quantification of dispersion, Particle size analysis carried out through dynamic light scattering technique and UV-Vis studies using a UV-Vis spectrophotometer characterization technique is applied.

Another incorporation method is colloidal processing where two suspensions are heterocoagulated by mixing. The final adhesion is provided by the opposites charges on each suspension. The techniques used in densification as reported by Hajiaboutalebi et al. 9 include liquid phase sintering, rapid microwave processes are involved, hot pressing, spark plasma sintering and pulsed electric current sintering.

In the fabrication process, as reported by Thostenson et al. 10, polymer impregnation is carried out, which involves thermal decomposition of preceramic polymers and mixing with CNTs resulting in thermoset matrix that is then subjected to heat treatment in a non-oxidative environment to produce a ceramic matrix. Fabrication of SiC matrix can also be done by reaction of Silicon with Carbon in a process known as Liquid silicon infiltration (LSI) A good microstructure of the formed composite, its density and porosity indicate successful synthesis. As reported by Margiotta et al., 11 in order to fabricate a dense SiC ceramic by the LSI method, the ideal open porosity of the carbon preform should range within 31. 1% and 57. 3%. The degree of densification increases as laser power increases, thus increasing the density.

More mechanical strength is imparted to a Carbon fiber reinforced ceramic matrix composites by adding a Boron Nitride coating interface. The coating also protects the carbon from unwanted oxidation. In this coating process, carbon fiber is subjected to heat treatment prior to the deposition of a boron nitride, a process which impacts further on the strength of the composite. A silicon carbide matrix obtained from methyl trichlorosilane is applied by chemical vapor infiltration (CVI) and Boron nitride by chemical vapor deposition (CVD), according to Shieh et al. 12

As reported by Sasmal et al., 13 CNT are used in the development of cement materials. Due to its smaller size, it can seal tiny cracks hence delaying the propagation of the crack hence useful in cementitious composites. CNT reinforced cement composites can be fabricated by sheer compression method where CNTs are dispersed in cement powder with no need of dispersants, hence obtaining low porosity. This increases the Seebeck coefficient and electrical conductivity but low thermal conductivity as reported by Meng et al. 14

The present work deals with the fabrication of Glass and flax fiber hybrid which is reinforced by MWCNT produces a composite which is reusable, eco-friendly, which can be recycled. On the study of the adhesion and tensile strength by Scanning Electron Microscope (SEM) using Energy Dispersive X-rays (EDS) technique, Ramakrishna et al., 15 explain that addition of MWCNT to the hybrid composite increases the tensile strength hence improved mechanical properties.

Limitations of Carbon fibers

Proper dispersion of CNTs into the matrix is quite challenging due to strong self-attraction by Vander Waals forces alongside their hydrophilic nature. This can result in agglomeration which is undesirable which can cause crack initiation hence reducing the beneficial reinforcement effect Hence, a need to separate CNTs into individual fibers before incorporation into the matrix.

Due to high internal bonding poor interfacial bonding between the nanotubes and the polymer matrix occurs, setting challenge information of the composite, according to Hou et al. 16 Additionally, exposure of carbon fibers may lead to chemical reactions that make the composites weak and brittle hence a need for a coating to minimize such reactions

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