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Study on three major carbon fiber composites

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Abstract. The rapid development of modern industry has more requirements for materials, and carbon fiber composites have gradually been widely used in various fields as cutting-edge materials. This paper mainly introduces three main manifestations of carbon fiber composites, namely, carbon fiber-resin, carbon fiber-metal and carbon fiber-ceramic. The composition, properties and applications of three carbon fiber composites are discussed. In terms of composition, the chemical composition and manufacturing differences of the three materials are discussed. In terms of performance, the control variable method is used to study the various indicators of the three carbon fiber composites under different temperatures, pressures, etc. The article also discusses the practical role of three carbon fiber composites in different fields, which is not only a breakthrough in materials science, but also an important progress in modern industry. The results show that they all have the characteristics of ultra-high tensile strength and lightweight, and show their excellent properties in other aspects. The results show that carbon fiber plays an important role in cutting-edge fields and under some extreme conditions, but carbon fiber composites have not been widely used due to production cost, time, utilization rate, recovery and environmental protection.

Keywords: Carbon Fiber, Composite Materials, Performance, Process.

1. Introduction

Carbon fiber reinforced composites (CFRP) appeared in the United States in the early 1840s. The composite is composed of carbon fiber (CF) reinforced material and thermosetting resin matrix. Compared with traditional metal structural parts, carbon fiber reinforced composites have excellent specific properties, such as specific strength and modulus, corrosion resistance, wear resistance and longer life, which are widely used in aerospace, wind power, automobile, sporting goods and many other fields. With the popularization and application of carbon fiber reinforced composites, its production scale is expanding continuously.

Carbon fiber refers to the high strength and high modulus fiber with more than 90% carbon content. Carbon fiber can be made with eyes black silk ribbon and viscose fiber raw material, oxidized by high temperature carbonization, and has a high temperature resistant, friction resistance, thermal conductivity and corrosion resistance and other properties. Fiber with high softy can be processed into a variety of fabric, due to the graphite crystallite structure along the fiber axis preferred orientation, so along the fiber axis direction has a high strength and modulus. The density of carbon fiber is small, so the specific strength and modulus are high. The main use of carbon fiber is as a reinforced material and resin, metal, ceramic and carbon composite, manufacturing advanced composite materials. The strength and elastic modulus of CFRP are higher than that of aluminum alloy, and even close to that of high-strength steel, which makes up for the shortcoming of low elastic modulus of FRP. And its specific gravity is smaller than the glass pot, so it becomes one of the highest specific strength and modulus of composite materials. Because of the high elastic modulus of carbon fiber, its composite parts are allowed to be used in the ultimate stress state, which overcomes the disadvantage that glass fiber resin composites are only allowed to be used in the conditions below 60% of the ultimate stress. The strength loss of carbon fiber reinforced plastics in high temperature aging test is also smaller than that of FRP. In addition, in the impact resistance, fatigue resistance, antifriction and wear resistance, self-lubricating, corrosion resistance and heat resistance, have significant advantages. Carbon fiber reinforced metal composites.

Carbon fiber metal composite material is a new advanced composite material in the development stage. Carbon is not easy to be wetted by metal, and it is easy to form metal carbide at high temperature, so it is difficult to make this material. It is mainly used to make metal or alloy carbon fiber composites with low melting point. Carbon fiber aluminum matrix composites were prepared by gilding the surface of carbon fiber. High elastic modulus can be maintained when the temperature is close to the melting point of the metal, and its strength can be maintained at 600℃ and high humidity. The composites composed of carbon fiber and ceramic can greatly improve the fracture work and thermal shock resistance, and improve the brittleness of ceramic. The ceramic in turn protects the carbon fiber from oxidation at high temperatures, resulting in high temperature strength and elastic modulus.

The 2019 Global Carbon Fiber Composites Market report indicates that global demand for carbon fiber composites is as high as 1595 kilotons, with sales revenue of US $17.37 billion. Projected to 2025, the global demand for carbon fiber composites can reach 333 kilotons.

2. Carbon fiber resin composite

2.1. General introduction

Carbon fiber resin matrix composites have high tensile strength, and the fatigue strength limit can reach 75% of the tensile strength limit. Therefore, carbon fiber resin matrix composites show good viscoelasticity and fatigue resistance. Carbon fiber reinforced resin matrix composites (CFRP) can be generally divided into two categories: carbon fiber reinforced thermoplastics (CFRTPS) and carbon fiber reinforced thermosetting plastics (CFSTPS). CFSTP has good mechanical properties, reflected in the and high temperature mechanical properties, and good fatigue resistance and corrosion resistance, CFSTPS also have high specific strength and modulus that can be obtained by changing the design and processing measures with several special skills, so as to meet the requirements of different applications. CFRTP has good toughness, large damage tolerance, excellent environmental resistance, good tolerance in the presence of water, light, solvents and chemicals, high temperature resistance, can work at temperatures above 150℃ for a long time [1]. The prepreg has long storage time, simple process and high efficiency. The assembly freedom of the formed product is high, and the waste can be recycled, so it has a wide application prospect in many industrial fields.

Carbon fiber is also recognized as a new material with better specific strength and modulus than traditional steel and aluminum alloy. The prepreg material is impregnated in the plastic matrix with fiber as the reinforcement, that the products can be molded using sheets, felt, clumps and other types under the state of heating or not heating. Due to the high conductivity, high tensile strength and low density of carbon fiber, carbon fiber prepreg has good plasticity, and its applications in aircraft, automobiles, high-speed rail and daily products are gradually expanding.

2.2. Molding process

Liquid forming, molding, vacuum bag/autoclave molding is more classic and common among thermosetting composites molding methods, including vacuum bag/autoclave molding technology has now become a domestic advanced resin matrix composite material is one of the most mature molding technologies, has good product repeat performance, high fiber volume fraction, mechanical properties, low porosity, etc. [2].

Usually in the aerospace field, the main forming process of composite with large structural parts is prepregate-autoclave molding. Composite components using this forming process have the characteristics of high mechanical properties, low porosity and good quality stability. However, due to the use of autoclave, its manufacturing cost is also very high. Resin matrix composite vacuum forming, process using oven (curing furnace)does not need to use the autoclave, but usually uses oven (curing furnace) for the cost of the same size of autoclave cost 10% to 20%, and the manufacturing cost is relatively much lower, so the vacuum forming composite material components have larger cost advantages, to the equipment It has low requirements and is suitable for applications such as unmanned aerial vehicles, airships, aerosols, commercial small and medium-sized rockets, etc. [3]. Of course, compared with the composite material formed by autoclave, due to the low forming pressure, the porosity of the composite material formed by vacuum molding is relatively higher and the mechanical properties are relatively lower. The porosity of aerospace composite structural parts is generally controlled below 2%, and the porosity of composite materials generally formed by vacuum is greater than 2% or even higher than 5%. Therefore, how to reduce the internal porosity and improve the mechanical properties is the main research direction of vacuum forming composites [4]. Domestic and foreign scholars mainly focus on the control of porosity and fiber impregnation in the vacuum molding process, pore formation mechanism, molding technology and mechanical property analysis after forming. Literature proposed a process method of vacuum impregnation and hot pressing curing of carbon fiber composites, combined the advantages of vacuum molding and molding, and studied the influence of resin impregnation on fiber and bubble exclusion on the molding quality of composite materials in the molding process. In the vacuum forming process of composite materials, the internal porosity is reduced mainly by eliminating trace gases encapsulated in the layering process, volatiles of prepreg and other trace gases released in the forming process before resin gel, and improving the impregnability of resin to fiber.

Different molding process parameters (temperature, time of heat preservation, heat preservation platform) and encapsulation mode of medium temperature of carbon fiber/epoxy resin matrix composites (CCF300 / BA9913) are applied to study the influence of porosity and mechanical properties, is proposed to model for the material in the unmanned aerial vehicle (UAV), airship, aerostats, commercialization of small and medium-sized rockets and micro-nano who belong to the application of support.

2.3. Properties and technology of carbon fiber prepreg

The curing process of carbon fiber presolvent leaching can be divided into four main stages: (1) softening of layering; (2) resin gelation in the paving layer; (3) resin curing; (4) product cooling. In the purification room, the semi-solid prepreg material spreads and is pasted to the required thickness in a predetermined way. Then, it is heated to a certain temperature in the hot press, autoclave or oven and other equipment to hold heat. The resin solidifies and gels. If the curing temperature is directly increased without the use of stage heating, the reaction activity will be too high, and a large amount of polymerization heat is generated in a short time, so that the finished product will produce warping, bulging, porosity and other defects, so the prepreg usually will use stepped heating and solidification process. After the curing time is over, next step is the cooling stage [5].

3. Carbon fiber metal composite

3.1. General introduction

Carbon fiber and copper, aluminum, brocade, or at least one of these metals as the main components of metal alloy matrix composite and carbon fiber reinforced metal composite materials with high strength and electrical conductivity, thermal conductivity and friction resistance and other advantages,

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as a kind of new material brought to the attention of the people in all fields. On the other hand, due to the excellent mechanical properties of carbon fiber, such as high specific strength, high specific modulus, and excellent fatigue resistance and corrosion resistance, using carbon fiber to strengthen lightweight metals, such as aluminum and magnesium alloys, can effectively improve the comprehensive strength properties of these metals to meet the increasingly stringent industrial production requirements.

With the development of modern industry, higher and higher requirements are put forward for materials. In addition to high strength, lighter quality, higher corrosion resistance and better friction and wear resistance are also required for materials. As a result, the traditional metal materials showed obvious limitations, such as traditional metal spring steel have been the bottleneck of development to performance, although in recent years and the methods of the permeability at low temperature ammonia further enhance the fatigue resistance of the spring steel, but these methods in material performance of ascension must invest more costs at the same time [6].

3.2. Preparation methods

For carbon fiber reinforced metal matrix composites, the preparation methods can be divided into liquid phase method and solid phase method according to the states of matrix and carbon fiber during preparation. Solid phase method mainly refers to powder metallurgy method, using powder sintering technology, and are mainly used to prepare short fiber reinforced metal matrix composites. The fiber reinforced composites are prepared by forming and sintering the short-cut fiber and metal matrix powder evenly mixed under certain conditions. The biggest disadvantage of this method is that there are many gaps and looseness between powder and powder and between powder and fiber, which affect the densification and performance of the whole finished product. Therefore, it is often the first to use cold pressing molding to make a certain density of prefabricated body, reaction sintering after hot extrusion. Through the action of extrusion and friction in all directions to improve the porosity and uniformity of the product, the performance of the finished product is improved. Luo Xiaoping et al., after cold-pressing magnesium and short-cut carbon fiber, sintered them at different temperatures and then carried out hot extrusion. Through the observation of microstructure, the microstructure after hot extrusion has higher density and better performance. The tensile strength, hardness and yield strength of the composite are 1.85, 4 and 5 times higher than those of the matrix, respectively [7]. Liquid phase method refers to the method that the matrix material exists in the form of liquid phase. The carbon fiber is woven into porous prefabricated parts, and the liquid phase matrix material is soaked into the carbon fiber and then solidified to make the composite material. According to the presence or absence of pressure and vacuum conditions during preparation, it can be divided into pressure infiltration, non-pressure infiltration, vacuum pressure infiltration and vacuum infiltration, etc. Through this method, continuous fiber or short cut paper reinforced metal matrix composites can be prepared simultaneously. Since the matrix material of this preparation method exists in the form of liquid phase, it can effectively impregnate the fiber. Especially when the impregnation pressure exists, it can better infiltrate the fiber and also have a good infiltration rate, so as to improve the efficiency of production. However, when the substrate material is liquid phase, its high temperature will cause damage to the fiber. At the same time, the material will oxidize or even react with the liquid phase at high temperature, which will reduce the performance of the composite. Therefore, when fiber reinforced metal matrix composites are prepared by liquid phase method, emotional gas protection or preparation under vacuum is often used to reduce the damage of fiber and the reaction with liquid phase. Therefore, the preparation of composite materials by liquid phase method is often complicated with high cost and high requirements for equipment.

Carbon fiber reinforced metal matrix composites, metal as matrix and carbon fiber as reinforcement, its performance enhancements come mainly from the following several aspects: when metal matrix composites by external effect, dislocation due to movement and entanglement between each other, and the intensity of carbon fiber is high, easy to cause dislocation around the fiber product increase the dislocation density. Similar to the effect of dislocation strengthening, the properties of composites are improved. There are residual stresses in metal matrix composites due to the difference of thermal expansion coefficient in the preparation process. The appropriate residual stress will have a favorable effect on the behavior of the composite interface, thus improving the performance of the composite. When the metal matrix composite fails under force, some energy will be taken away due to fiber pulling out, fracture and interface destruction, so as to strengthen the composite.

4. Carbon fiber ceramic composite

4.1. Ultra-high temperature (UHT) ceramics

Ultra-high temperature ceramics are refractory metals such as Ta, Zr, Hf carbide. As the representative of ultra-high temperature (UTH) resistant materials, these materials can maintain good physical and chemical properties and mechanical properties in aerobic environment above 2000 ℃. Possesses rare characteristics such as high melting point, high thermal conductivity and high Young's modulus, and can maintain good structural strength under ultra-high temperature conditions of 2000℃ [8]. However, as a ceramic material, it still has the common shortcomings of low fracture toughness and poor thermal shock resistance, which are closely related to the composition and preparation process of ceramic materials themselves, leading to obvious constraints in the application of the material in the scene of shock and vibration. In order to make up for the poor toughness and shock resistance of UHT ceramics, many researchers and scholars try to use UHT ceramics as matrix and continuous fiber reinforced UHT ceramic matrix structure to get UHT ceramic matrix composites with improved properties. Among them, carbon fiber reinforced UHT ceramic matrix composites have been studied and most commonly applied. So far, this material has become the most widely used UHT ablative material in the field of aerospace thermal protection. Carbon fiber reinforced ultra-high temperature ceramic and carbon fiber reinforced composite material with ultra-high temperature ceramic matrix body. The advantages of the ultra-high temperature ceramic substrate with high melting point, high thermal conductivity, high young's modulus, under the condition of ultra-high temperature to maintain solid no phase change and can maintain many characteristics, such as high strength fiber reinforced body has greatly improved the matrix thermal shock resistance is poorer, the fracture toughness is low Got stuck. In addition, carbon fiber reinforcement also has excellent mechanical properties at high temperature, which can maintain excellent mechanical properties at a temperature higher than 2000℃, which is extremely rare in fiber materials. The soft texture of carbon fiber can be changed by winding and weaving, which can help to shape ultra-high temperature ceramics quickly in the preparation process.

4.2. Preparation methods of CF/ceramic composite

At present, carbon fiber reinforced ultra-high temperature ceramic matrix composites can be prepared by many methods, and the materials obtained by different methods are usually different. Among them, the volume proportion, strength, homogeneity of carbon fiber, density and uniformity of matrix, volume fraction and state of pores will be more or less different, which also leads to different properties of composites prepared by different methods. At present, there are several commonly used methods for the preparation of CFRP, including reactive melt infiltration method, precursor transformation method, chemical vapor deposition method and slurry infiltration cracking method. Based on the research situation of ultra-high temperature resistant ceramic matrix composites at home and abroad, the above methods are also the main methods for material development and preparation. Reactive melt infiltration method is a rapid preparation technology with low preparation cost. It is also one of the most studied and applied methods for the preparation of ultra-high temperature ceramic matrix composites. The method is usually divided into three steps. Firstly, the surface of the fiber preform is modified by coating, and then carbon is added to make the fiber preform part dense. Finally, the molten metal is used to impregnate the preform, so that the molten metal can infiltrate through the holes of the preform, and the molten metal will skin with the ceramic matrix, so as to obtain the ultra-high temperature ceramic matrix composite with high density. At present, a variety of composites have been prepared by this method. Precursor transformation method, also known as precursor impregnation cleavage method, usually requires the fabrication of fiber preforms as the skeleton of the prepared material, and then impregnation of ultra-high temperature ceramic precursor. The precursor can be prepared by metal-organic method, and the preform and precursor can be cross-linked and cured under ambient environment, and then the cross-linked material can be cracked under high temperature condition, so as to prepare ultra-high temperature ceramic matrix composite. On the basis of this method, the formed composites can be further densified by cyclic impregnation and cross-linking cracking. Chemical vapor deposition (CVD) refers to the deposition of a layer of solid material on the surface of a heated material through chemical reactions. There is also a modified process called chemical vapor infiltration. The main difference between the two methods is that the permeable material of the former is mainly deposited on the outer surface, while the permeable material of the latter will penetrate the material through pores. At present, the materials prepared by this method and related researches are few. Slurry infiltration and cracking method is also known as slurry method. In this method, the ceramic powder is first made into slurry, then the ceramic slurry is filled into the fiber preform, and then the mixture of ceramic slurry and preform is sintered through high temperature, and finally the fiber reinforced ultra-high temperature ceramic matrix composite is obtained. The above four methods have been applied in the preparation of ultra-high temperature ceramic matrix composites at present. For other UHT ceramic matrix composites except carbon fiber reinforced, the preparation process is similar to the above method. Sometimes, in order to further improve the density and related properties of materials, a combination of various preparation processes, such as slurry impregnation and reaction infiltration method, will be selected [9]. Excellent multi-process hybrid preparation methods can usually make up for the shortcomings of single process preparation, and combine the characteristics of each process, so that ultra-high temperature ceramic matrix composites with better performance can be prepared.

5. Discussion

Aimed at the status quo of the domestic carbon fiber reinforced resin matrix composites technology and innovation to carry out research and development is the development of high performance carbon fiber, high-performance carbon fiber technology and product system, break through the low cost carbon fiber preparation of key equipment and technology, improve the low cost production of carbon fiber production line, product performance, product prices have a competitive advantage. Application of strategic emerging industries such as technology and new energy has expanded to rail transportation and aerospace technology [10]. Based on the difficult problem of waste recycling of carbon fiber reinforced resin matrix composite products, the development of efficient recycling and reuse technology, the establishment of special recycling and reuse equipment, to achieve large-scale recycling and utilization, to achieve the purpose of large-scale application and green development in new energy and transportation and other fields. Only advanced and complete composite material industry technology system and process equipment can support the rapid and large-scale development of carbon fiber composite material industry.

Carbon fiber composites also have limitations and face many challenges, mainly reflected in the following aspects :(1) The cost of carbon fiber raw materials is too high; (2) The production cycle is too long and the processing cost is high; (3) Excessive R&D investment and complex product design; It is necessary to fully consider the interlayer bonding, the number of layers, the angle, the integration mode of parts, and the mechanical distribution, the connection position and the strength of the material connection parts need complex design to ensure the comprehensive consideration; (4) It is difficult to recover the product waste [11]. Only through the breakthrough of carbon fiber performance improvement and cost control, to achieve large-scale production, can meet the domestic demand of carbon fiber.

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6. Conclusion

This article introduces carbon fiber prepreg, carbon fiber metal composite and carbon fiber ceramic composite from the current situation of composition, performance, application and development. Due to the high modulus and tensile strength of carbon fiber, these carbon fiber composites have higher strength, heat resistance, electrical conductivity, etc. than ordinary materials. Nowadays, carbon fiber composites play an irreplaceable role in aerospace, racing, medical devices, sports equipment and other fields. Carbon fiber reinforced resin matrix composite scale low-cost application technology as a breakthrough focus, to achieve its scale application in a number of emerging industries and high-end civilian fields, to make the industry stronger and bigger.

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