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Property and Application of Carbon Fiber Material

-- Manufacturing of High-performance Terminal Products in the Carbon Fiber Industry Chain

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Abstract

The use of materials is always kept in step with the course of human civilization. In the increasing shortage of various resources today, high-performance optimized materials have become an important requirement and development direction of product manufacturing. This paper discusses the performance and application of carbon fiber reinforced materials, first introduces the practical application of carbon fiber in various modern fields, then carefully analyzes the elements of lightweight vehicles, and finally explains the future development direction of carbon fiber composites.

Keywords

Carbon Fiber Material; High Performance; Terminal Products; Lightweight Cars.

1. Introduction

Carbon fiber is mainly composed of carbon element, which is a new type of non-metallic material. Carbon fiber and its composite materials belong to the high-tech products, with high specific strength, high specific modulus, high temperature, corrosion resistance, heat transfer and small thermal expansion coefficient Excellent performance. It can be used both as a structural material and as a functional material. Therefore, in recent years, the application of carbon fiber research has developed very rapidly, in aviation, aerospace, automotive environmental engineering, chemical industry, energy, and communications Communication, architecture, electronics, sports equipment and many other fields have been widely used.

Carbon fiber, like diamonds, is mainly composed of carbon elements, with the following characteristics: lightweight and high strength, its proportion is a quarter of iron, the specific strength is 10 times of iron, especially the high elastic modulus carbon fiber, its tensile strength is 68 times larger than steel, the elastic modulus is 1.8~2. 6 times larger than steel. Very stable chemical performance, high temperature and low temperature and corrosion resistance, its performance remains unchanged at 600℃, still very flexible at-180℃, no corrosive reaction with acid, alkali and salt, for example, carbon fiber cloth is light and bending, can adapt to different component shapes, can paste several layers according to the stress requirements, and no need for large equipment, no need for temporary fixation, no new damage to the original structure. In addition, the other characteristics of the carbon fiber also include the high-intensity X-ray penetration, the high heat resistance, the electrical conductivity, and the abrasion resistance.[1]

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2. Application of Carbon Fiber Materials

2.1 Aerospace Field

Carbon fiber composite material has superior performance, high fatigue fracture resistance and good processing and molding characteristics. At the same time, its electromagnetic performance and wave absorption stealth characteristics, making it more and more used in the aerospace field, as well as military fields, such as aircraft, missiles and rockets.In the early 1980s, carbon fiber began to be used as structural material Applied in passenger aircraft and aviation aircraft, in the mid-1980s, European Airbus began to use carbon fiber reinforced plastic as the primary structural material applied to aircraft. With the launch of the new Airbus A350 and the Boeing 787 Dreamliner , the carbon fiber industry has had a significant boost. The composite material used in the Airbus A350 is already nearly 40 percent of the total mass, and the Boeing 787's wings and fuselage use more than 50 percent. Carbon fiber is also widely used in spacecraft manufacturing materials, such as in artificial satellites, where they are used as components, solar panels, antennas, and other components.

2.2 Sports Field

Carbon fiber in sport for the three main uses of golf bat fishing rod and tennis racquet frame material. It is estimated that the current annual output of golf bats is above 34 million pairs, carbon fiber fishing rods is above 30,000 pairs, and tennis rackets are increasing year by year.At the same time, other sports programs, including ice hockey, skiing, archery, and cycling, as well as a large number of ocean sports programs, are widely used in carbon fiber materials. An important application area of carbon fiber composites, that is Sports and leisure goods account for about 20% of the world's total carbon fiber production. Carbon fiber golf club accounts for about 50% of the total carbon fiber used in sporting goods, and the market prospect is good. As a bicycle enthusiast, I would like to introduce the application of carbon fiber in mountain bikes. Carbon fiber is mainly used to make frames for mountain bikes. The characteristics of carbon fiber frame are: light, steel, good impact absorption is good. However, giving full play to the excellent performance of carbon fiber is not technically so easy, and the quality difference between the carbon fiber material manufacturers is also large. Bicycle manufacturers, considering the cost, are unlikely to use high-grade carbon fiber to make frames. Although the above practical problems exist, but the carbon fiber frame still has the advantages that other materials do not have, you can make about 8,9kg of lightweight bicycle, this carbon fiber lightweight bicycle, the slope can best reflect its advantages, the slope is smooth and refreshing. Instead of being like some light aluminum alloy frames, which feel a direction the power of the rear pull. Carbon fiber is something that solidifies the carbon fiber in resin.Especially very light, but it is a directional material (large rigid but easy to break), so we use the thin material layer by layer overlapping method to solve the disadvantages.[2]

3. Manufacturing of Lightweight Cars in the Two-carbon Fiber Industry Chain

3.1 The Lightness and Hardness of Carbon Fiber

The world's first production car to use carbon fiber was the McLaren F1, born in 1992. It was once the fastest production car in the world, and the fastest reason was because it was made of carbon fiber. But the carbon fiber area feels like hard plastic, so what's good about him? The first is that carbon fiber of the same size weighs less than a quarter of the weight of steel. The Bugatti Chiron, a top-of-the-line sports car, has a giant 8.0-liter, 16-cylinder, 4-turbine engine, but weighs less than 2 tons because of carbon fiber, which can greatly reduce the weight of the body.And the recent carbon fiber wheels, each spoke is centrally controlled, 40% lighter than aluminum forged wheels. The advantage of full-carbon lightweight is that it brings more power and saves fuel consumption, and another great thing about carbon fiber is its hardness. Carbon fiber is 10 times harder than steel.The general family car is made of a variety of materials and splicing, but the supercar can not drive the rate of so much, often is the whole car carbon fiber. Such a car body runs fast and strong, but the harm is natural, that is, broken a little repair can not be repaired, can only be the whole vehicle replacement. Carbon fiber

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in addition to their own strong, but also can be mixed with other materials, such as carbon fiber and ceramic carbon ceramic brake disc, this brake disc weighs less than half of ordinary steel brake disc, but more resistant to high temperature, long time violent brake will not appear thermal attenuation, super wear-resistant, the car is scrapped also do not need to change. Although carbon fiber is carbon, its manufacturing process is complex and its production yield is low, so carbon fiber is so far a relatively luxury material, only the top sports car can be used.

3.2 Weak Impact Resistance of Carbon Fiber

Carbon fiber is very hard, but the collision will greatly damage, because the components are one, so the seam streamlined shape looks good.And carbon fiber can not be distorted, while iron or aluminum can bend. It is because of the material characteristics of carbon fiber that luxury cars are easy to be broken.In order to improve the performance, the car has to reduce its own weight, so it usually uses a lot of carbon fiber material, but to ensure enough safety, the supercar cockpit is still a metal frame. When an accident occurs, the carbon fiber car will break, reducing the inertia force of the car body. The metal car can absorb the impact force through deformation and protect the driver to the maximum extent. During high-speed collisions, the carbon fiber cockpit breaks into as much debris as tempered glass to absorb shock energy to avoid injuries when the vehicle deform. For example, at a high-speed collision, the tire is easy to fall off, or directly decomposed into two parts, with nothing in the cab, which is the buffer effect. The carbon fiber car protected the people at the expense of the shell, and the sports car was badly damaged in the crash. In addition to the collision angle and strength, the vehicle itself material should be considered. Of course, carbon fiber, as a material containing more than 95% carbon, has understandably caught fire in a major accident.[3]

3.3 Application in Racing Car Field

Carbon fiber is currently the most suitable material for a racing cars.Compared with traditional metal materials, carbon fiber strength, stiffness and impact resistance performance generally have advantages, especially per unit weight performance is significantly better than metal materials. Looking back on the history of F1, it is also clear that carbon fiber racing has great advantages in performance and safety.

Silverstone Raikkonin 2014 accident, when the Raikkonin Ferrari car after getting out of control eventually crashed into the parapet, with about 240 km / h straight hit the parapet, collision instant impact as high as 47g, then the car was bounced back to the track, on the track through the dense F1 car traffic, and then hit the opposite guardrail, during this period also hit the Massa car. After such an impact, Raikkonen only slightly bruised his ankle and knee and was able to climb out of the car himself. What would happen to such a collision if it were a thick door-closing car?

3.4 Misunderstanding of Carbon Fiber Composite Material

What we call "carbon fiber", is actually the "carbon fiber reinforced composite material" for short and commonly known, and the real "carbon fiber" is different. The real "carbon fiber" is like a single wool thread, and what we usually call "carbon fiber" is a variety of sweaters, scarves, gloves, etc. The so-called carbon fiber reinforced composite material, is actually with a lot of carbon fiber, arranged in a certain direction, and then with resin or other adhesive materials closely connected into one. As shown in the picture below, these individual cylinders are carbon fibers, and the cylinders are filled together with resin filled in the middle.The distribution density of these fibers directly affects the final material properties. Because of this, the final performance of the carbon fiber material is controlled by adjusting the fiber volume ratio [fiber volume fraction]. The greater the density, the more fibers per unit volume, the stronger the strength along the direction; the contrary, the less fibers per unit volume, the lower the strength of the carbon fiber material.[4]

Take carbon fiber and our common steel for example, compare these two pictures, carbon fiber strength is around 400 to 800 Mpa, while ordinary steel strength is 200 to 500 Mpa, which is not several or even ten times. Looking at the toughness, carbon fiber and steel are basically similar, there is no obvious difference.

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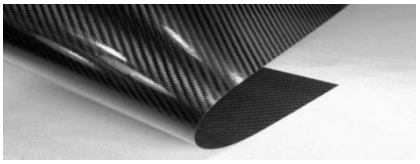

Figure 1. Multi-direction crossover carbon fiber

Figure 2. Comparison between steel and carbon fiber

Of course, the evaluation of impact resistance is very complex, and there are many testing methods, such as traditional fracture toughness measurement, low-speed charpy or Izod impact test, high-speed bullet impact test, or plate drop weight impact specifically for FRP materials. The impact properties of carbon fiber materials are also greatly affected by the temperature and loading speed. Different application fields also care about different test conditions, and the corresponding damage patterns are also different. Here we just use the general concept of toughness, just to show that the toughness of the carbon fiber is basically in the same order of magnitude as the steel.

There's no carbon fiber, why if there's no obvious difference? Because we have not yet considered another important parameter, which is the density. The density of carbon fiber is much less than that of steel and aluminum alloy, that is, making the same part is about in size, meeting similar mechanical properties, and carbon fiber parts are much lighter than metal parts, which is crucial for motorsports.

As we all know, the concept of a push to weight ratio is very important for racing cars. For example, the famous civilian performance car Subaru WRX STI, although has 310 horsepower, but as a four-door car, weighs nearly 1.5 tons, so 0.2 horsepower per kg; and Kawasaki ninja H2R also has 310 horsepower, but as a motorcycle, weighs only 215 kg, an average of nearly 1.5 horsepower per kilogram. This is especially true of F1 cars, slower since the major straight.With the minimum weight and the highest strength and stiffness, carbon fiber is almost the only option under such design requirements.

This has led to another misunderstanding of many people about carbon fiber, which is thinking that carbon fiber is a super material, so the things made of carbon fiber must be far better than the things made of metal in all aspects.In fact, engineering is a combination of materials and dimensions, not just solely on the material. Just like saying, as we all know, steel is obviously stronger than wood, and simply, steel is stronger, but must something made of steel be stronger than something made of wood? For example, a 1 cm diameter steel bar and a 10 cm diameter wood, which is more load-bearing?

The simplest example is like a part on the F1 car that needs to meet certain stress requirements during the race, such as 100 thousand cattle, if I use the strength of 400 k pa steel, then the section area needs 2.5 square centimeters, if I use 800 k pa carbon fiber, then the section area of this part only needs 1.25 square centimeters. In other words, because the carbon fiber is twice as strong as the steel, the parts can be half the size of the steel. And the carbon fiber is only a fifth the density of steel, so this carbon fiber part weighs only one tenth of the weight of steel parts, but has the same force, which can carry 100 kilo newton.[5]

But, as we see above, carbon fiber and steel per unit area have similar toughness, like 20-kilojouels per square meter. For these two parts, to meet the same strength requirements, the area of the carbon

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fiber parts only needs half of the area of the steel parts, so the toughness is naturally only half that of the steel parts. That is, the same design meets the same stress performance requirements, and if no additional remedies are done, then the impact resistance to fracture energy of the carbon fiber parts is only half that of the steel parts. Obviously, in bearing the impact load, the lower the fracture toughness, the more adverse to the safety performance.

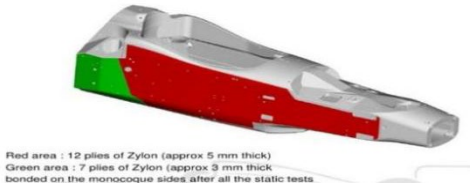

Figure 3. Side zylon panel

Stress concentration is a problem with carbon fiber materials, for example, the F1 racing lines are so smooth, without any sharp edges, with both aerodynamic considerations and also trying to avoid any possible stress concentration. Carbon fiber is actually like knitting a sweater, knitting one piece of fiber into a whole piece of material, does the different weaving affect?Actually, there is something. Pull a rope hard, if it is tight at the beginning, with not tense at the beginning, the effect is different. And different weaving methods, some are easy to let these fibers do not tighten, which will affect the final stiffness. At the same time, different weaving methods may also cause local stress concentration, and then break as a weak point on the whole carbon fiber parts. There are similar examples in our daily life, like once a sweater or a cotton garment is broken, the hole will easily get bigger and bigger, because the small crack has become a stress concentration point.

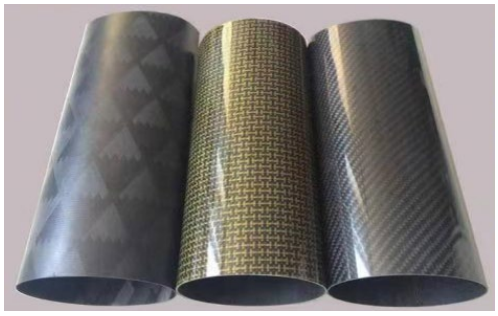

Figure 4. Knitting ways of fiber

Maybe some people think that the F1 is just drag racing.In fact, F1 is against the technical strength of the team, and behind the scenes.Fifty years ago, no F1 team had its own materials laboratory, but today every F1 team has dozens or even hundreds of scientists and engineers with its own laboratory, starting with the question of how to weave carbon fiber better. All this is not only for the performance, but also for the safety of the driver.Looking back at the whole history of F1, since McLaren first introduced carbon fiber in 1980, we can also see the huge changes that carbon fiber has brought to the F1 movement. With the technological development, carbon fiber is not limited to F1, but has begun to appear in many civil performance cars.Carbon fiber brings not only improvements in sports performance, but also improvements in safety performance.[6]

4. Prospect Outlook

At present, China's carbon fiber industry is in a period of explosive growth, the future carbon fiber demand market growth remains at around 17%, with carbon fiber with many capitals into the carbon fiber industry, carbon fiber technology is constantly breakthrough, the demand field will further expand, it is expected that China's carbon fiber market demand will exceed 110,000 tons in 2026.[7]

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Table 1. Future research area

categories	application fields
Mature market	aerospace and national defense industry:plane satellite rocket missile radar
	Sports equipment:golf pole fishing gear volleyball pats bike arrow shaft
late-model market	Pressure vessel construction reinforcing materials wind turbine blade fiction Drilling platform
to be developed market	Auto parts medical instrument

5. Conclusion

Carbon fiber is mainly composed of carbon elements, with a series of light quality, high strength, high modulus, electrical conductivity, thermal conductivity, corrosion resistance, fatigue resistance, high temperature resistance, small expansion coefficient and other irreplaceable excellent performance of other materials. Carbon fiber is widely used in aerospace, wind power blades, sports and leisure, pressure vessel, transportation construction and other fields and is an indispensable strategic material for national economic development. Domestic PAN based carbon fiber material processing industry has begun to take shape, has a certain technical basis and market development capacity, but the production of carbon fiber is far from reaching the market demand, need a large number of imports.

References

[1] Xiong Fei. (2021) Breaking the shackles of the automotive industry with carbon fiber materials.Industry and Information technology in China, 5: 92-96.

[2] Zhang Jian, Chuai Xuebing. (2017) The development and application status of carbon fiber. Chemical Industry Management, 23: 60.

[3] Zheng LinRui. (2015) Ford worked with Dow to develop carbon fiber materials for vehicles. High-tech fiber and Application, 40: 72.

[4] Shi Jian. (2015) Carbon fiber composites will become the mainstream of the automotive market in 2025. High-tech fiber and applications, 40: 74.

[5] Ma Xiaokun, Wang Rui, Hou Jianfeng, et al. (2020) Application analysis of carbon fiber composite materials based on automobile lightweight. New Chemical Materials, 11.

[6] Wang Junzhao, Ding Cunguang, Xiao Jianyun, et al. (2020) Research on the application of carbon fiber composite materials for vehicles. China's New Technology and New Products, 18.

[7] Lu Jiahai, Wang Xia, Kou Hongbin. (2021) Multi-scale optimization design of strength performance of carbon fiber composite shock tower. Automotive Technology, 1.