

Development and Application of Lightweight High Strength Organic Materials

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Abstract. This paper summarizes the commonly used organic materials with light weight and high strength characteristics, and introduces their types, characteristics, applications and current development status at home and abroad.

Introduction

According to statistics, 60% of automotive fuel is consumed in the vehicle's own weight ^[1], reducing the vehicle's own weight can effectively save energy and reduce emissions. Every 10% reduction in the vehicle's vehicle quality, the fuel consumption will decrease by 3%-7% ^[2]. The realization of lightweight not only is the automotive industry, but all energy-consuming equipment is an important way to save energy and reducing emissions and developing green and environmental protection. With the research and development of high-strength materials, materials that can meet the strength requirements are not limited to metal materials, and plastics gradually step into the stage of the times.

1 High-strength engineering plastics

Engineering plastics, especially high-performance engineering plastics, are widely used because of their good mechanical properties, comprehensive mechanical properties, heat resistance, acid resistance, long life, and good reliability. In order to achieve lightweight of equipment, Wang Tuyuan ^[3] and others put forward the concept of "plastic substitute steel". Polymers have excellent properties such as light weight, corrosion resistance, high strength, and easy processing. At present, high-strength engineering plastics are used in pipelines, automobiles, construction and other fields. Polyethylene chloride, rubber, polyoxymethylene, polyamide, polyurethane, polytetrafluoroethylene, nylon, and synthetic fibers are used for long time ^[4]. In order to ensure a certain degree of strength of the material, Zhang Chao ^[5] and others have proposed steel-plastic composites. The wire-wound mesh skeleton-reinforced plastic composite pipe is reinforced with a high-strength steel wire with a left-right inclination and is formed with a net-

like skeleton reinforced with a thermoplastic plastic matrix. The high-performance adhesive resin is used to tightly connect the steel mesh skeleton with the inner and outer plastics using in the coal mine pipeline. This kind of pipe has the advantages of easy installation, easy maintenance, good corrosion resistance, long service life, no scaling, and good water conservancy performance. The wall climbing robot produced by Li Heng ^[6] chose POM as the body shell in light of the principle of miniaturization. Polyoxymethylene, as an engineering plastic with excellent performance, is known abroad as "steel-reducing" and "ultra-steel". It has similar hardness, strength and steel properties, and it has good performance in a wide range of temperature and humidity. Self-lubrication, good fatigue resistance, and flexibility, and it also has good chemical resistance and low cost. In addition, PET (polyethylene terephthalate) has excellent properties such as high strength, high rigidity, good heat resistance, excellent dimensional stability, outstanding chemical resistance, etc. Machinery, automotive parts and other fields have been widely used ^[7-9].

In the automotive field, the blending of polyethylene (PE) with PP (polypropylene) has high impact resistance. Peugeot bumpers are made from PP/HDPE blends ^[10, 11]. Polyamide (PA) has good mechanical properties and thermal stability, so it is an ideal material for producing high-strength, heat-resistant parts. Plastic accelerators are used on German Volkswagen's "Golf" and "Jetta" cars. The pedal, using DuPont's 180 G 33 PA, has low cost, high strength, and good reliability ^[12].

2 Lightweight high-strength fiber composites

Polymer materials have certain advantages, but their strengths are much different from those of metals. Steel-plastic composite materials do not fundamentally realize

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the lightweight and high-strength characteristics of materials. The resin-based composite material is a kind of fiber-reinforced plastic. The low quality of plastic materials and its high-strength performance are currently the major trends.

2.1 Carbon Fiber Composites

Carbon fiber (CF) is a kind of high-performance fiber. It has excellent properties such as high specific strength, high specific modulus, fatigue and creep resistance, expansion coefficient, and small friction coefficient, becoming the most important enhancement in composite materials, being one of the most important materials^[13]. High-strength carbon fibers such as T800, T1000, and T1100 carbon fibers have tensile strengths of 5.49 GPa, 6.37 GPa, and 6.6 GPa, respectively^[14].

In the 40th and 50th centuries of the 20th century, carbon fiber composite materials (CFRP) were first manufactured in the United States. In 1950, CFRP was first produced by pulling rayon at a temperature of 2000 °C. It has high specific strength, specific modulus, low density, good anti-fatigue properties, good anti-vibration performance, strong designability, and high temperature performance. With good moldability and other advantages, high-performance CFRP strength can reach more than ten times of steel^[15, 16], and is widely used in aerospace and military fields. The specific strength of high modulus carbon fiber/epoxy resin composites is 5 times that of steel and 4 times that of aluminum alloys. Its specific modulus is 4 times that of aluminum and copper. The production of bearing members can exert unique and excellent mechanical properties.^[17]

Bie Mingzhi^[18] prepare carbon fiber/PA6 composites with high strength, high electrical conductivity and flame retardant properties, which can meet the safety and performance requirements of polymer products in coal mines.

Song Yanjiang^[19] added carbon fiber to the thermoplastic polyimide resin for composite reinforcement. The effect of carbon fiber addition and molding method on the mechanical properties of the composite material was experimentally studied. The addition of carbon fiber can significantly improve the room temperature and high temperature mechanical properties of the material, and carbon fiber different types, the degree of improvement is also different; the tensile strength and bending strength of the composite material increase with the increase of the amount of carbon fiber; J. Karger-Kocsis^[20], who used carbon fiber reinforced thermoplastic polymethyl methacrylate Ethyl acrylate composites and carbon fiber-reinforced thermoplastic polyetheretherketone composites, and their mechanical properties were studied. The results show that the mechanical properties of the composites are determined by the bonding of the resin matrix and the carbon fibers, the toughness of the resin, and the arrangement of the carbon fibers in the resin.

2.2 Fiberglass

FRP is a high-strength engineering plastics, its full name is - glass fiber reinforced plastic, which has the characteristics of corrosion resistance, good insulation, high specific strength, low cost, simple process, short production cycle, etc.^[21], FRP the traditional products of composite materials are made by the glass fiber winding forming process, such as internal pressure vessels, pipes and tanks, which mainly utilize the properties of fibers with high tensile strength. The advantage of the filament winding method is that the fibers can be arranged according to the stress conditions, thereby improving the mechanical structural efficiency of the product^[22-24].

FRP is often used in industrial pipes. The quality of FRP pipes is light. The same size is only 1/4 of the quality of steel pipes and 2/25 of concrete pipes. The pipes contain rich resin layers and the surface is extremely smooth, small resistance, no scaling. When the flow is the same, the pressure loss caused by the FRP pipe conveying medium is about 3/5 of the same inner diameter carbon steel pipe, the conveying capacity can be increased by more than 20%, and the power and energy of the pump can be saved by 30% to 40%. The resin-based composite material itself has good corrosion resistance. Unlike metal pipes, which require regular anti-corrosion and other maintenance, the service life is much higher than that of steel pipes. Especially in coal mine drainage systems with acidic water quality, corrosion resistance can be achieved, long-term safe and reliable operation, and comprehensive benefits are good. The use situation abroad and the research results of Henan Polytechnic University show that the high-strength double-resistant coal mine FRP pipe does not require maintenance within 30 years, even if it needs repairs, it is very convenient. If the pipe is damaged, it only needs to prepare the raw material with the prepared double-resistant glass steel. System can be repaired^[25]. Zeng Xiantao^[26] and other research and development of a new type of glass fiber reinforced plastic composite material tank, the tank path consists of two parts of rectangular steel core and glass fiber coating, this modified pipe has anti-static, flame retardant, wear resistance The performance partially replaces the steel, the quality is reduced, the surface corrosion resistance is far superior to steel, and the service life can reach 30 years.

2.3 Kevlar

“Kevlar” is an aramid composite material with dark yellow fibers, with a diameter of 0.01-0.02mm and a density of 1.43-1.44g/cm³. Its greatest feature is its high mechanical properties and good stability. Its strength is 3.6Gp, its modulus reaches 131GPa, and its elongation at break is only 2.8% and it is insensitive to temperature^[27, 28]. It was made by DuPont in the 1960s. This new type of material has low density, high strength, good toughness, high temperature resistance, easy processing and molding and is widely used in military and other fields of defense. Compared with FRP, Kevlar bears the same pressure. The material weight of Kevlar can be reduced by half, and the toughness of Kevlar-laminated sheet is 3 times that of steel, which can withstand repeated impacts, including para-aramid. The specific strength is 6 times that of steel

Table 1 The main performance of Para aramid with the same brand number ^[29]

Product brand	Density/ (g/cm ³)	Tensile strengt/ (cN/dtex)	Tensile modulus/ (cNdtex)	Elongation/%	LOI/%	Decomposition temperature/ °C	Moisture absorption rate/%
Kevlar29	1.44	20.3	490	3.6	29	500	7.0
Kevlar49	1.45	20.8	780	2.4	29	500	3.5
Kevlar119	1.44	21.2	380	4.4	29	500	7.0
Kevlar129	1.44	23.4	670	3.3	29	500	7.0
Kevlar149	1.47	16.8	1150	1.3	29	500	1.2
Twaron Reg	1.44	21	500	4.4	29	500	6.5
Twaron HM	1.45	21	750	2.5	29	500	3.5
Technora	1.39	24.7	520	4.6	25	500	2.0
Armos	1.43	35.0-39.0	1050	3.5-4.0	39-42	575	2.0-3.5
Rusar C	1.46	36.3	1074	2.6	35	575	2.25
Rusar HT	1.47	34.7	1200	2.6	45	575	1.35

wire, 3 times that of glass fiber, and 2 times that of high-strength nylon industrial yarn. After 100 hours at 200 °C, it can still maintain 75% of its original strength. After 500 hours at 160 °C, it can still To maintain the original strength of 95% ^[29], the main types and performance of the world para-aramid are shown in Table 1.

Summary

Lightweight is the eternal theme of material development, and it is an important way to realize green environmental protection. The quality of organic materials can be reduced to a certain extent compared to that of metal materials. What we need to do now is to increase the strength of organic materials. The effective method to increase material strength is using fiber to strengthen materials.

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