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Overview of aerospace materials and their applications

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Abstract. Aerospace materials play a crucial role in modern aerospace technology. This paper is mainly a comprehensive overview of aerospace materials, including their classification, properties and applications. Aerospace materials are used in a wide range of applications, including aircraft and spacecraft, propulsion systems, and electronics. The paper also summarizes the importance and diversity of aerospace materials in various applications. The classification of aerospace materials includes metal materials, composite materials, ceramic materials and nanomaterials. Each material has unique properties that make it suitable for different applications. Aerospace materials are used in a wide range of applications, including aircraft and spacecraft, propulsion systems, and electronic devices. Materials for aircraft and spacecraft are particularly demanding because they are subjected to extreme temperatures, pressures and vibrations. Materials for propulsion systems and electronics require properties such as high strength, high electrical conductivity and high corrosion resistance. This paper also summarizes the importance and diversity of aerospace materials in various applications. Through the reading of this article, readers will understand the key role of aerospace materials in modern aerospace technology.

Keywords: Aerospace Materials, Classification, Application.

1. Introduction

In recent years, with the rapid development of aerospace, aerospace materials have been rapidly developed, and aerospace materials have an important position and role in the development of aerospace products. Aerospace materials include metal materials, inorganic non-metallic materials, polymer materials and composite materials four categories, each material has unique properties, make it suitable for different occasions. With the continuous improvement of science and technology, aerospace materials will have broader prospects for development. The properties of different aerospace materials and their applications are reviewed in this overview. This paper mainly discusses the relevant aspects of aerospace and its applications: firstly, the classification and properties of different aerospace materials are introduced, and secondly, the application of aerospace materials in different application fields is discussed, including the application of aircraft and spacecraft, engines and propulsion systems, instruments and electronic equipment. This paper provides an important reference for an understanding of the properties and applications of aeronautical materials, and helps to promote technological innovation and performance improvement in the field of aeronautical engineering.

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2. Classification and properties of aviation materials

Aviation materials are the material basis for the development and production of engines, and are an important guarantee for the realization of lightweight, precise, high reliability, long life and low-cost of aero-engine equipment [1]. And aviation materials can be mainly divided into four categories, metal materials, composite materials, ceramic materials and nanomaterials.

2.1. Metallic material in aviation

Mouritz revealed that metal materials in aviation materials have a series of key properties that make them widely used in aeronautical engineering [2]. First, the metal material needs excellent strength and should be able to withstand stress under air load and flight conditions, which is essential to ensure the structural stability of the aircraft. Secondly, metal materials are relatively lightweight, especially aluminum alloys, which helps to reduce the overall weight of the aircraft and improve fuel efficiency. Metal materials are generally good corrosion resistance, they can resist corrosion factors such as atmospheric and chemicals, and ensure the long-term service life of the aircraft [3]. Metals also have high thermal conductivity and are suitable for radiators and other high temperature environments. In addition, metal materials are easy to process and form, and they can manufacture various complex-shaped parts, which improves the design flexibility of the aircraft. The magnetic and high conductivity of metals also play an important role in some avionics equipment. Dursun & Soutis found that the machinability of the metal material makes it easier to process, weld and connect, which is essential for the manufacture of aircraft and maintenance [4]. It is obvious that different types of metal materials have different properties, so choosing the right metal material is one of the key decisions of aircraft design and manufacturing to ensure the performance, safety and reliability of the aircraft.

2.2. Composite materials in aviation

The wide application of composite materials in aeronautical engineering has attracted much attention. First of all, the composite material is known for its light weight, and is composed of a combination of various lightweight components, such as carbon fiber, glass fiber, etc. This allows the composite to perform well in reducing the overall weight of the aircraft, thereby improving fuel efficiency and flight performance. This feature has been widely explored in many studies to promote the lightweight trend in the field of aeronautical engineering. Dursun & Soutis claimed that composites exhibit excellent high strength and high stiffness, which is critical to the properties of aviation materials. The research in the literature shows that composite materials can provide excellent performance when withstand external stress and air load, thereby ensuring the structural stability and safety of the aircraft. This characteristic plays a key role in the design of aircraft structure and strength analysis. In addition, it generally has good corrosion resistance, can resist atmospheric, moisture and chemical corrosion factors, and prolong the service life of aircraft components [5]. The study of this property in the literature also covers the corrosion resistance of composite materials and related surface coating technologies. Composite materials have also attracted much attention in terms of high-temperature resistance, electrical insulation and moldability. These properties give composites multiple advantages in the application of engine parts, electronic devices and structural parts.

2.3. Ceramic materials in aviation

Ceramic materials in aviation materials have unique properties that make them popular in specific aviation applications. First of all, ceramic materials are famous for their excellent high temperature resistance. Ceramic materials such as silicon carbide and alumina can maintain their physical and mechanical properties under extreme high-temperature conditions, which makes them an ideal choice for high-temperature engine components [6]. Ceramic materials generally exhibit good corrosion resistance. This property enables ceramic materials to withstand the erosion of chemicals, moisture and other corrosion factors, and ensure the long-term stability of aircraft components in harsh environments. The corrosion resistance of alumina ceramics has been widely studied in the literature to meet the different application needs of the aircraft inside and outside [7]. Ceramic materials also

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play an important role in avionics and sensors, as they are generally electrically insulating. This means that they are not conductive, which is very important to protect electronic devices from electromagnetic interference and damage [8]. This property helps to optimize the design and performance of avionics systems.

2.4. Nanomaterials in aviation

Nanomaterials have aroused a wide range of interest in the field of aviation materials, and their unique properties provide new opportunities and challenges for aviation engineering [7]. First, nanomaterials are known for their very small size and large specific surface area. This makes them exhibit superior potential in dispersibility and enhanced performance in composites. By introducing nanoparticles into the traditional material matrix, the strength, stiffness and abrasion resistance of the material can be significantly improved, and at the same time, the weight of the material can be reduced, thereby improving the performance and efficiency of the aircraft. Nanomaterials have excellent conductivity and thermal conductivity, which is of great significance in applications such as avionics and heat sinks [9]. The high conductivity of nanomaterials makes them ideal for electronic wires and connectors, and their high thermal conductivity helps to effectively dissipate heat and maintain the stability of avionics equipment. The nanomaterials also exhibit superior high-temperature resistance. For example, Cao finds that nanomaterials such as carbon nanotubes can maintain stable properties in extreme high-temperature environments, so they are widely studied for the manufacture of engine parts and thermal insulation materials. These properties are essential to improve the engine efficiency and performance of the aircraft. Nanomaterials also have potential applications in the corrosion resistance and fatigue resistance of aviation materials. Zhuk also discovered that extend the service life of aircraft parts by improving the nanostructure of the material, which can enhance its ability to resist corrosion and reduce fatigue damage [10].

3. The application of aviation materials

3.1. Applications of materials in aircraft and spacecraft

Metal materials play a vital role in the field of aeronautical engineering, and their wide application covers many key aspects. Due to its series of excellent properties, aluminum alloy has always been the preferred material for aircraft structure and shell [11]. Its lightness reduces the overall weight of the aircraft, which improves fuel efficiency and flight performance. At the same time, the high strength of aluminum alloys enables them to withstand the air load under various flight conditions, ensuring the structural stability of the aircraft. In addition, the aluminum alloy also shows good corrosion resistance, which can cope with the erosion of materials by atmospheric, moisture and chemical substances, and prolong the service life of the aircraft. Magnesium alloy also plays an important role in aircraft manufacturing with its lightweight properties and high specific strength. Magnesium alloys are often used in aircraft interiors and components, providing additional lightweight advantages for aircraft [9]. In addition, some special steels are also used in aircraft manufacturing, especially some components and structural components to meet specific engineering requirements. The application of composites in the aviation field cannot be underestimated, and its diversity and excellent performance make it a key material. First of all, carbon fiber composites occupy an important position in aircraft manufacturing with their excellent light weight, high strength and high stiffness properties [12]. These materials are composed of carbon fiber and matrix materials, and their light properties help to reduce the overall weight of the aircraft, improve fuel efficiency, and maintain sufficient strength and stiffness. Therefore, Soutis thinks carbon fiber composite materials have become the preferred material for key components of aircraft such as wings and fuselage. Its excellent performance in tensile strength, flexural stiffness and fatigue resistance enables the aircraft to operate safely under various flight conditions. Secondly, glass fiber composite materials are also widely used in the aviation field, especially in the manufacture of bulkheads, interiors and structural parts. These materials are composed of glass fibers and matrix materials, with certain strength and durability, while the price is relatively low. Therefore, they are

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suitable for interior construction of aircraft, such as seats, compartments and interior panels, providing lightweight solutions. In addition, various polymer matrix composites have been widely used in aeronautical engineering because of their diversity and adaptability. Polymer-based composites are commonly used in a variety of aircraft components, including hatches, avionics system housings, flight control surfaces, and other structural components. Their preparation process is relatively easy to master and can meet different engineering requirements.

3.2. Application of aerospace materials in engines and propulsion systems

Titanium alloys are more common metal materials used in engine components. Its main application areas include engine parts and structural parts [13]. Titanium alloys are known for their excellent high-temperature resistance, which makes them ideal for high-temperature environments. In engine components, such as turbine blades and combustion chambers, the high-temperature stability of the titanium alloy is essential to ensure the reliability and performance of the engine. In addition, titanium alloys also have good strength and corrosion resistance, which further strengthens their application in the aviation field. In addition, ceramic materials have a special position in the field of aviation, and their application focus is mainly on the manufacture of high-temperature engine components. In this field, ceramic materials such as silicon carbide and alumina are famous for their outstanding high temperature resistance. The silicon carbide material plays an important role in the manufacture of high-temperature engine components [14]. Silicon carbide is a kind of high-temperature ceramic material that maintains its physical and mechanical properties in extreme thermal environments. This makes silicon carbide an ideal material for manufacturing high-temperature components, such as jet engine turbine blades and nozzles. Its high-temperature resistance helps ensure that the engine maintains stable performance during high temperature, high pressure and high-speed operation while extending the maintenance cycle. Alumina ceramic materials are also widely used in the aviation field. Alumina ceramics are known for their excellent high-temperature resistance and insulation properties, and are often used to make insulating layers of combustion chambers, jet engines and other high-temperature components [15]. The high thermal stability of alumina ceramics enables it to withstand extreme thermal shock and high-temperature airflow, thereby improving engine reliability and performance.

3.3. Applications of aeronautical materials in instruments and electronics

Nano-materials are more commonly used in instruments and electronic equipment. One of the most significant advantages of nanomaterials is their application in lightweighting [3]. By introducing nanoparticles in the nanostructure of the material, the weight of the aircraft structure can be significantly reduced. This is essential for reducing fuel consumption, reducing carbon emissions and improving the overall efficiency of the aircraft. The high strength and high stiffness properties of nanomaterials have a profound impact on improving the properties of aviation materials. The addition of nanoparticles can strengthen metals and composites, making them more resistant to various external stresses and environmental factors, which has the potential to improve the structural stability and fatigue resistance of the aircraft [16]. Nanomaterials also play an important role in the wear and corrosion resistance of aviation materials. Nano coatings and nanocomposites can enhance the wear resistance of the material surface and reduce the wear of mechanical parts, thereby prolonging the maintenance cycle. In addition, the corrosion resistance of nanomaterials contributes to the long-term stability of the material when exposed to corrosive factors such as atmosphere and moisture during flight. The thermal conductivity and electrical conductivity of nanomaterials also bring new possibilities to the field of avionics and sensors. By designing a material with nanostructures, the performance of the sensor can be improved, the size of the electronic components can be reduced, and the reliability of avionics equipment can be enhanced.

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4. Conclusion

Now the aerospace industry is a highly developed and competitive field. As the foundation of the aerospace sector, materials are critical to the design, performance and safety of aircraft and spacecraft. In this paper, the aerospace materials are classified and summarized, and their applications in different fields are introduced. From metal materials, composite materials, ceramic materials to nanomaterials, these materials have a wide range of applications in aircraft and spacecraft, engines and propulsion systems, instruments and electronic equipment. By summarizing the application of these materials, it can be seen that the diversity and importance of aerospace materials are constantly increasing. This paper can also introduce and explain the characteristics and properties of aerospace materials in more detail, and introduce more new research results and technologies to show the latest developments and trends in the field of aerospace materials. This paper can also strengthen the research on environmental protection and sustainability of aerospace materials, so as to reflect the social concern for sustainable development. With the continuous progress of science and technology, there will be a variety of aerospace materials, which will make greater contributions to human exploration of the universe and improve the quality of life.

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