The Application of 3D Printing in the Manufacture of Composite Materials

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Abstract: Composite materials are a new generation of structural materials, which are widely used in aerospace rocker structures, such as bearing frames. Low-cost and high-efficiency manufacturing technology is an important way for composite applications. 3D printing technology offers the possibility of low-cost and rapid manufacturing of composite materials. 3D printing technology of composite materials is gradually becoming an emerging field. This paper introduces the research situation of 3D printing technology of fiber reinforced resin matrix composites as printing materials, and analyzes the application of 3D printing technology in aerospace composite materials manufacturing.

1. Introduction

Spacecraft launch costs are high, and payloads focus on structural efficiency in structural design. Carbon fiber composites have the characteristics of high specific strength and good stability, and the excellent comprehensive performance is the demand of aerospace products. The carbon fiber composite products currently used in aerospace optical remote sensors cover various parts, such as camera holders, and the reinforcing materials used are mainly continuous carbon fibers. According to the process characteristics and product performance requirements, the prepreg is stacked on the mold in a certain auxiliary layer sequence to form a blank body, which is placed in a pressure tank for high temperature and high pressure curing for several hours. The aerospace remote sensor composite uses continuous fibers to ensure the mechanical properties of the product. The resin matrix epoxy resin needs to be cured at a specific curing temperature for several hours. The interior of the prepreg laminate is loose, and air is not excluded. When the body is heated, high pressure is required to ensure the mechanical properties of the product. The pre-dip layup design of complex structure products requires multiple planes. For example, the thin-walled reinforced mirror tube needs to protect the flange ring continuously, and the reinforcing ribs and the barrel of the lens barrel are continuous. Ensure that the ends are axially continuous. The demand for composite materials is growing rapidly, and its high cost has become an important bottleneck restricting the application of materials. Low-cost composite manufacturing technology is a core issue in composite research. In this paper, we will improve the cost performance, assembly and maintenance of composite materials, and reduce the manufacturing cost of composite materials. The emergence of 3D printing technology has opened up new ideas for the manufacturing industry. Unlike traditional manufacturing methods, 3D printing technology rapidly shapes complex shape products by adding materials. Studying the applicability of this technology in the manufacture of aerospace composite products is of great significance for promoting low-cost manufacturing of products.

2. Introduction

2.1 Introduction to 3D Printing Technology

3D printing is different from the traditional method of manufacturing materials, which uses physical layer-by-layer accumulation methods to manufacture solid parts.3D printing is developed on the basis of modern laser technology, information technology and physical chemistry of new materials. The working principle is to discretely form a three-dimensional model of the physical

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entity to form a two-dimensional layer, and to form a three-dimensional solid product by superimposing the molten molding material through a continuous physical layer according to the layer information.

3D printing technology was born in the late 1980s, and is a systematic new technology combined with computer software and other fields. The basic principle of this technique is to perform layered slicing on the 3D solid model of the part. The 3D printer generates two-dimensional data according to the section layer, and the different materials are heated and melted to form an entity by superposition construction. The technology is based on design, and the automated superimposed connection becomes a solid object. Compared with the traditional material reduction manufacturing, the product can be directly molded once, and the manufacturing speed of the complex structure is obvious.3D printing technology has great potential for development due to manufacturing advantages.

The 3D printing technology process mainly includes stereo lithography apparatus technology and selective laser sintering technology. The stereo lithography apparatus technology divides the three-dimensional digital model into planes by slicing, and has a lifting platform when working. The surrounding liquid tank is filled with ultraviolet light to irradiate the solid liquid printing ink, and the solidified formation liquid is finally formed. The stereo lithography apparatus process is widely used, and has the characteristics of high degree of automation in the molding process and high dimensional accuracy. The shortcoming is that it can adapt to a limited variety of inks. The fused deposition modeling is a process of 3D printing technology in which a filament material such as a thermoplastic material is extruded from a heating nozzle, and melt deposition is performed on a predetermined trajectory of the two-dimensional data after slicing. FDM is a well-established 3D printing process. Its system construction principle is simple, and its molding materials are wide. It is suitable for small and medium-sized model manufacturing. However, the process printing accuracy is not high and requires post processing. Selective laser sintering technology was successfully developed in 1989 by the University of Texas. This technique is formed using a powdered material. The powder material is spread on the workbench, and the cross section of the part is scanned with a high-intensity carbon dioxide laser. The powder material is sintered, and the new powder material is laid after the cross-section powder is sintered. This technology typically produces structural features.

2.2 Classification of composite 3D printing technology

Among the 3D printing technologies, composite 3D manufacturing is mainly composed of fused deposition molding, layered solid manufacturing and stereo lithography apparatus technology. The primary method by which SLS manufactures composites is the hybrid powder process. The laser heats the specific area powder according to the cross-sectional shape of the design drawing, and bonds the matrix and the reinforcement to the composite component. The problem is that the difference in material density in the mixed powder tends to result in uneven product composition. By improving the synthesis of a single composite powder, it is possible to overcome the problems of easy settlement of the mixed powder and obtain a high quality product.

The FDM process for manufacturing composite materials requires the fibers to be prepreg tow, which is heated and melted at the nozzle, and stacked on the platform according to the design trajectory, and the layered material is partially melted by the resin to form a joint. The composite prepreg used in FDM technology must meet the requirements of strength and the like, and a plastic agent is added to increase the fluidity.

LOM technology needs to prepare unidirectional fibers and prepreg tows in advance and arrange them into prepreg strips, which are sent to the workbench through the conveyor belt, and then the prepreg strips are cut by laser to form a three-dimensional product. The use of SL composite materials requires rapid scanning of the photopolymer with a UV laser in a liquid bath mixture, which rapidly polymerizes, and the working table lowers the height of the sheet, and the second layer laser scans repeatedly to form a product. The composite material produced by SL has pores in the solution after the foam is solidified, and the laser absorption energy becomes low and requires

long-time irradiation.

2.3 Research on 3D printed polymer materials for FDM

The FDM forming technology divides the 3D CAD solid model graphic data into continuous 2D cross-section data through the slicing software, and uses different algorithms to produce the cross-sectional shape according to the cross-section information, and each cross-section layer is superimposed to form a three-dimensional entity. The printer nozzle is heated and the thermoplastic material is sent to the nozzle, and the wire is extruded and bonded to the work surface to cool and solidify. The nozzle moves in the horizontal direction according to the slice information, and the cross-section printing completes the lowering of the background surface. The extrusion melt is bonded to the front section layer through the nozzle, the worktable is lowered, and the solid shape is repeatedly superposed and formed. The key to the FDM process is to keep the melt material in the nozzle at the melting point. The 3D printer nozzle has a close relationship with the wire feeder, so that the plastic wire enters the nozzle to be heated and melted. At present, the commonly used polymer fuse wires are mainly thermoplastics such as ABS and nylon. The FDM process is an important process for the manufacture of composite materials.

The fused deposition modeling process 3D printing-dedicated polymer material is the thermoplastic material such as PC or the like. Filament supply is cleaner than other powder-based processes and does not cause powder contamination. The distance between the gear and the fixed wheel is constant. If the wire is too thick, the wire cannot be fed. If the wire is too fine, it will not be detected. This requires the wire to meet the specified specifications. FDM adopts the thermoplastic molding method, which has specific requirements on the properties of the material and the shrinkage of the molding, and the different materials have different performances of the forming thermometer.

ABS is an acrylonitrile-butadiene copolymer with anti-shock, low temperature resistance, easy processing and good surface finish. It can be used for secondary processing such as surface metallization and welding. It is widely used in industrial fields such as automobiles, instrumentation, etc. It is a thermoplastic engineering plastic with a wide range of uses. ABS is the first polymer consumable used in FDM printing, but its material products are easy to shrink and deform. PLC materials are environmentally friendly and degradable materials with good mechanical properties and fiber-forming properties and are widely used in FDM printing consumables. PLA can be processed in a variety of ways, such as spinning and injection blow molding. It has certain bacterial and UV resistance. It can be used as packaging materials, etc. Currently, it is mainly used in clothing and other fields.

PCA is a polymer having a carbonate group in a molecular chain and can be classified into various types such as aliphatic. It has many excellent properties of engineering plastics, including high strength, low odor and low shrinkage. The strength of 3D printing wire made of PC is high. The residual bisphenol A in the PC material is usually a potential carcinogen. The PP material is a thermoplastic resin made of a propylene polymer, which is superior in rigidity and heat resistance to low-pressure polyethylene, has good dielectric properties, and becomes brittle at low temperatures. It is suitable for general mechanical parts and is not affected by common organic solvents such as acids.

3. Application of composite 3D printing technology

Thermoplastic resins have the characteristics of heating and softening. In the 3D printing market, thermoplastic materials are the main materials, and thermoplastic resin-based composite materials are the main research objects.3D printing technology from Germany and other countries and short-cut fiber composite powder developed by China Department of Science and Technology.

In early 2014, Mark Company of the United States developed a composite 3D printing device to print nylon composite materials. The printer uses a nozzle to transport thermoplastic resin. The prepreg carbon fiber is coated with a thermoplastic resin specially developed for the printer. The FDM process lays the resin along the X/Y plane to achieve fiber-to-resin compounding. It can be

oriented as needed, and the device can only achieve fiber orientation in the X/Y direction. American Stratasys develops FDM manufacturing technology for mass-produced carbon fiber composites. The first phase of the study examined how to place broken fibers. The second and third phase studies focused on the construction of continuous carbon fiber composites at the centerline.

Harvard University has developed epoxy resin for 3D printing. It has added nano-clay, silicon carbide crystal and imidazole-based ion as curing agent to improve the resin viscosity, which expands the resin printing window. The viscosity of the resin printing window is not increased. By controlling the diameter of the nozzle, the filler is oriented under the action of the extrusion flow, the printing member is pre-cured at a low temperature, and the high temperature curing is removed from the substrate.

Composite materials are often formed by assembling a single simple part in a conventional process, resulting in early structural failure of the material joint. The 3D printing manufacturing technology is based on a computer model and can directly manufacture complex shaped objects without the need to combine multiple single parts into complex parts. It changes the material composition at specific parts of the product. The 3D printing manufacturing process enables accurate placement of materials and recycling of residual materials.3D printing technology has become a new choice in the development of composite materials, but the use of incremental manufacturing technology faces new challenges, such as process monitoring difficulties, printing accuracy and surface finish. Researchers use incremental manufacturing techniques to create fiber-reinforced preforms and are ideal for composites for aerospace applications.

At present, the total cost of composite manufacturing is mostly composed of tooling, which requires skilled workers to meet design requirements. Tooling can be manufactured in CAD files used in automated processes. In advanced 3D technology, fused deposition can quickly produce molds that conform to materials. Suitable for FDM thermoplastics for composites, such as ULTEM9085 is a high performance thermoplastic that, combined with a 3D production system, allows designers to produce fully functional parts without the cost of traditional molds. The thermal expansion coefficient of thermoplastic materials is higher than that of traditional aluminum molds. Computer-aided software should be used to analyze the thermal properties of finished molds. 3D printing can be used to make prototype molds.

4. Development of the 3D printing industry

In 2013, the annual report of the American Additive Manufacturing Technology Service Association analyzed the development of the industry. The global direct production value of manufacturing equipment and services was 2.2 billion dollars, the equipment materials were 1 billion dollars, and the service output value was 1.2 billion. Its development characteristics are that the service is relatively fast with respect to equipment materials, the motor vehicle field is reduced to 18%, and the medical field is increased to 16%. Aircraft manufacturing applications are the fastest growing application areas.

At present, China ranks fourth in the world with about 9%, and the highest output of 3D printing equipment in the United States, and Europe ranks second in the world with 12%.China's equipment products account for 4%, manufacturing companies have Strasys, Delcam and other well-known companies.

In the early 1990s, with the support of the Ministry of Science and Technology and other departments, Tsinghua University and other major research progress in the field of typical molding equipment. Many universities in China have carried out related research, such as Beihang University, Shanghai Jiaotong University, China Academy of Engineering Physics and other units to do exploratory research work. China's research on software and other aspects has made significant progress. In 2000, equipment industrialization was initially realized, which changed the dependence of equipment on imports. More than 20 service centers have been established nationwide, with equipment users in aerospace, electronics and other industries.

The domestic 3D printing market has not developed much, mainly in the industrial field for model making, insufficient investment in research and development, and industrial technology is

lagging behind the United States. The key technologies of China's 3D printing process lag behind the advanced level of foreign countries. There is a big gap in the preparation of materials compared with foreign countries. Some of the technological equipments have gaps with the advanced level of foreign countries.

At present, composite 3D printing technology is mainly composed of short fiber composite materials, and thermosetting composite materials realize 3D printing of chopped fiber composite materials. Continuous fiber reinforced solid composite printing technology needs to be broken in multidimensional continuous printing.

Composite 3D printing technology requires proper fluidity of the printed material, and the adaptability of the existing aerospace composite system needs to be developed. Composite printing equipment needs to break through multiple layers of continuous accumulation, such as setting up a six-axis printing platform to meet the requirements of continuous lamination of multiple parts of complex structures. The thermosetting resin-based composite material needs to be cured at a high temperature. After printing a certain number of layers, the device pre-compacts the blank, and after completion, the blank is moved to the curing device for curing.

5. Conclusion

In recent years, 3D printing technology has attracted the attention of academic circles and society, but it has not yet formed an economic growth point in China, and the industrial volume is not large. In the process of comprehensively advancing China's manufacturing 2025, 3D printing technology has become a clear new information technology and new material strategy key potential technology. How to obtain technological breakthroughs with industrialized value under the fierce competition of powerful countries has important practical significance for planning and developing 3D printing technology related industries. The use of low cost technology is an effective way to reduce composite products.3D printing technology can maximize the material utilization rate, and it can reduce the dependence on tooling for complex structural materials and achieve overall molding. It is of great significance to study the application of 3D printing technology in aerospace composite materials. 3D printing needs to solve the problem of multi-dimensional continuous printing of fibers.

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