3D Metal Printing and Materials Overview

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Abstract

This article briefly introduced the principle and development of 3D printing technology, briefly described the research and current status of 3D metal printing technology, laser engineering net shaping technology (LENS), laser selective zone melting technology (SLM) and electron beam selective zone melting technology (EBSM) These three technologies are typical representatives of 3D printing technology for metal parts. Introduced the selection and requirements of metal printing materials. At the end of the article, combined with the research progress of 3D metal printing at home and abroad, it is pointed out that 3D metal printing needs to focus on materials and equipment.

Keywords

3D metal printing; metal materials; additive manufacturing.

1. Introduction

3D printing is an additive manufacturing technology hailed as the core technology of the "third industrial revolution." Compared to traditional processing methods, it uses a computer to cut a 3D model of a formed part into a series of "thin sheets" of a certain thickness. The 3D printing device manufactures each layer of "sheet" from the bottom up to finally form a three-dimensional solid part. It eliminates the need for traditional tools or molds to produce complex components that cannot be completed by conventional machining methods. In the 3D printing industry, successful 3D printing technology can improve product performance and life cycle by changing key components. 3D metal printing technology has attracted more and more attention and has been applied to various important industries.

2. Research Status and Development of 3D Metal Printing Technology

In the past 20 years, 3D printing technology has achieved rapid development. The types of materials used have become more and more complicated. The forming structure has become more and more complex and the precision of parts has become higher and higher. The application of 3D printing technology has been expanding. The huge market makes all countries in the world pay great attention to 3D printing technology. 3D printing of metal materials is one of the most cutting-edge parts of 3D printing technology. Its application in aerospace, medical and other fields is rapidly expanding, and it has great potential for development in the future[1] . Laser Engineered Net Shaping Technology (LENS), Laser Selective Zone Melting (SLM), and Electron Beam Selective Zone Fusion (EBSM) are three typical technologies for 3D printing of metal parts.

2.1 Research Status at Home and Abroad

In the 1990s, the United States and Germany successively proposed and studied the successful laser fused deposition forming technology (LDMD) and laser selective melting (SLM), and then a number

of foreign companies and colleges carried out a lot of research and experiments, and achieved great results. Research results, the United States National Laboratory adopted the technology to carry out a variety of metal materials such as stainless steel, titanium alloys, high temperature alloys and other 3D printing research, and successfully achieved a satellite TC4 titanium alloy parts blank forming. The time required for the forming process is significantly shorter than the conventional method[1-4]. The Fraunhofer Laser Technology Research Institute in Germany has received support from the European Union's 67th Framework Programme, the German Research Fund, and other large aerospace companies such as Boeing, Lockheed Martin and EADS.

Basic researches on material properties, defect control, and stress control have carried out a large number of research[5–10]. In collaboration with Arcam, the Swedish University of Chalmers Industrial University has developed another metal material 3D printing technology - Electron Beam Selective Zone Fusion Molding (EBM) technology. The development of EBM technology in the aerospace field has been rapid, and many airlines have utilized it. EBM technology for the manufacture of aerospace engine complex parts[1].

The time for research and development of 3D printing technology in China is basically synchronized with the world. Universities and research institutes actively participate in the research of such technologies. Northwestern Polytechnical University printed 3D printing technology on the top left edge of aircraft titanium alloys with a maximum size of 3m and weighs 196kg. The Beijing Aviation Manufacturing Engineering Research Institute of China Aviation Industry Corporation carried out research work on electron beam fuse deposition forming. The research and development capabilities of this type of equipment have resulted in the formation of a 2100mm x 450mm x 300mm titanium bearing main bearing structure[11-12].

2.2 Development of 3D Metal Printing Technology

Laser Engineered Net Shaping Technology (LENS), Laser Selective Zone Melting (SLM), and Electron Beam Selective Zone Fusion (EBSM) are three typical technologies for 3D printing of metal parts.

The LENS technology divides the metal powder discharged from the powder feeder into four equal parts through a powder separator and flows into the powder head through a hose. The metal powder is sprayed from the nozzle of the powder head to the position of the laser focus to complete the melting and accumulation process. All powder paths are propelled by a protective gas, which shields the metal powder from the air, thereby preventing oxidation of the metal powder. The advantage is that it directly manufactures metal functional parts or molds with complex shape and structure; a wide range of metal or alloy materials can be processed and can realize the manufacture of heterogeneous material parts; it can easily process materials with high melting point and difficult processing. The disadvantages are: low forming efficiency and slow deposition rate; the surface quality of the formed parts is relatively rough, and post-processing is required to improve the surface quality; the entire process needs inert gas protection and the cost is high.

SLM technology is developed on the basis of SLS. The basic principles of the two are similar. The SLM technology needs to completely melt the metal powder and form the metal parts directly. Therefore, before the laser beam of the high power density laser beam is required to be scanned, the horizontal powder spreading roller first spreads the metal powder onto the substrate of the processing chamber, and then the laser beam will press the current layer. The profile information selectively melts the powder on the substrate, processes the outline of the current layer, then lifts the system down a distance from the thickness of the layer, rolls the powder coating roller, and then spreads the metal powder on the already processed current layer. Into the next layer for processing, so layer processing until the entire part is processed. The manufacturing process is simple and the materials are widely selected. The flexibility and toughness of the molded products are very strong and can be comparable to industrial forging/casting products. However, the equipment costs are high, toxic gases are

generated during the molding process, and the surface roughness as in the LENS technology requires secondary treatment.

The process of EBSM technology is: first spread a layer of powder on the plane of powder spreading; then, the electron beam is selectively melted under the control of the computer according to the profile information of the cross section, and the metal powder is melted together under the bombardment of the electron beam. , and with the following part of the formation of bonding, stacked layers, until the entire part of the complete melting; Finally, remove the excess powder to get the desired three-dimensional products. Formed in a vacuum, the protective gas is not consumed in the molding process, and there is no need to worry about the oxidation problem; the molded part has good mechanical properties, no impurities, and there are generally no internal pores. However, due to the reason of the electron beam, the forming accuracy still needs to be improved, the forming efficiency is low, and the machine is bulky.

3. Metal Printing Material Powder

3.1 3D Printing Metal Powder

3D printing metal powder is the most important part of the 3D printing industry chain of metal parts, and it is also the greatest value. At the 2013 World 3D Printing Technology Industry Conference, authoritative experts in the 3D printing industry in the world gave a clear definition to 3D printed metal powders: that is, groups of metal particles smaller than 1 mm in size, including pure metal powders, alloy powders, and certain metals. Some refractory compound powders[13-14]. In addition to the good plasticity of 3D printing metal powder, it must also meet the requirements of high purity of the powder, fine powder particle size, narrow particle size distribution, high sphericity, good fluidity, and high bulk density. Taken together, the 3D printing metal powder has several basic requirements on the powder properties, including: powder purity, powder particle shape, particle size and distribution, and powder recycling[14].

3.2 Commonly Used Metal Materials

Titanium alloys have the advantages of high temperature resistance, high corrosion resistance, high strength, low density and biocompatibility, and have been widely used in aerospace, chemical, nuclear industry, sports equipment and medical devices and other fields[15]. TC4 alloy is one of the earliest alloys used in SLM technology. Its usage has reached more than 50% of the world's titanium consumer products. TC4 parts produced by 3D printing are used in aircraft and aviation and have achieved excellent results.

3D printed stainless steel parts have excellent corrosion resistance, high temperature resistance, wear resistance, creep resistance and good appearance glossiness, and the strength of molded parts is high. At the same time, they can meet the processing requirements of large-size prints, Aerospace, medical device manufacturing, automotive manufacturing, daily life and other fields have been widely used. 316L stainless steel powder is an earlier stainless steel material developed for 3D printing, and has now become a typical processing material in the 3D printing market. Wu Wenheng[16] et al. obtained experimental results that the mass fraction of oxygen in 316L stainless steel powders used for 3D printing is less than 0.08%.

Superalloy refers to a type of metal material that can work long-term under high temperature of 600°C and certain stress environment based on iron, nickel and cobalt. It has high temperature strength, good resistance to thermal corrosion and oxidation resistance. And good plasticity and toughness. According to the type of alloy matrix can be roughly divided into iron-based, nickel-based and cobalt-based alloys 3[15,17].

4. Conclusion

Since the advent of 3D printing technology, it has begun to subvert certain areas of the traditional processing industry. With the continuous improvement and development of technology, it has become a pivotal technology in today's manufacturing industry. With the development plan of "Industry 4.0" proposed by Germany, the development of the future manufacturing industry will tend to be more intelligent, automated, and have higher flexible manufacturing companies. 3D printing is bound to be a powerful driving force for the advancement of industrial intelligence automation. However, any kind of technology has its limitations. Only by combining 3D printing with existing traditional technologies can we break the limitations and conduct more in-depth research. The inadequacy of 3D printing can make it a truly revolutionary technology in the future.

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