

Progress of Large-size Part Manufacturing Based on 3D Printing

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Abstract. 3D printing is a fast-developing field at present, and it has been widely used in daily life. With the wide application of large-size parts in aviation, ships, machinery, construction, and other aspects, 3D printing gradually develops to large-scale and integration. However, the printing of large-size parts is still a huge challenge due to its performance, materials, and production technology. Therefore, this paper summarizes the relevant research progress of 3D printing large-size parts in the world, including equipment design and manufacturing, robot collaboration, and multi-degree of freedom printing, and finds that there is still a certain distance to meet the needs of high precision, high efficiency and performance integration of large and complex parts. The subsequent research work can be developed to improve manufacturing technology, optimize mechanical properties, optimize algorithm structure, multi-robot collaborative manufacturing, and research and development of new materials to support the high-quality manufacturing of a new generation of large-size parts. At the same time, attention should be paid to the thermodynamic performance and environmental protection of materials. This study can summarize the printing method of large-size parts, to provide reference and guidance for future research work in this field.

Keywords: 3D printing, Large-size parts.

1. Introduction

3D printing is currently a very rapid development in the field, of medicine, machinery, urban planning, daily life, and other aspects are involved [1]. Its cost is relatively lower, can achieve a high degree of precision and complexity, can produce the traditional technology that cannot produce the shape, while not producing unnecessary connection surface, will make the product more stable, rigidity and strength will be significantly higher than traditional products [2]. Secondly, 3D products do not need to open molds, rapid prototyping, and fast production speed, which can significantly improve production efficiency. However, at the same time, it is also facing corresponding difficulties, and most 3D printers still stay at the desktop level and cannot promote the large-scale industrialization of manufacturing [3]. Including the printing of large-size parts, due to its printing process parts are easy to produce deformation, cracking, collision, and other risks, but also produce more production waste pollution to the environment. Therefore, how to print larger-sized parts, how to achieve accurate control, how to stabilize molding, and how to better control costs and reduce environmental pollution is a problem in front of many people. This paper summarizes the printing methods of large-size parts. First, optimize the structural design of the wind farm to reduce the impact of production waste on the printing process to improve printing efficiency and printing accuracy, or produce a large printer that takes into account printing accuracy and heating uniformity; Secondly, the use of robot technology for printing, including single robot multi-degree of freedom printing and multi-robot collaborative printing; Third, by increasing the degree of freedom of the print nozzle to broaden the printing space to achieve the purpose of printing large-size parts. This paper summarizes the above methods of printing large-size parts, and then it should continue to study the optimization of mechanical properties, optimization algorithms, exploration of multi-robot collaborative methods, and research and development of new materials.

2. Large-size Parts for Additive Manufacturing

3D printing (also known as additive manufacturing) is a digital model to prints physical objects layer by layer to quickly manufacture the model, which is very different from traditional manufacturing methods. Large-size 3D printing, also known as large-size additive manufacturing, refers to the use of 3D printing equipment to manufacture large-size parts technology, which is generally used in aerospace, automotive manufacturing, construction and industrial design, and other fields. Compared with traditional 3D printing, large-size 3D printing can produce length, width, and height of several meters or even dozens of meters of large components, without open mold, stronger forming ability, shorter production cycle, and higher efficiency, but because of its high material cost, few species, algorithm design, and optimization difficulties, large size additive manufacturing industrialization still faces many challenges. With the development of the industry, the application of 3D printing technology has become an unstoppable trend. But at present, most 3D printers are still stuck at the desktop level, and cannot really promote the large-scale industrialization of the manufacturing industry.

At present, there are generally the following ways to solve the problem of 3D printing of large size parts: design larger size 3D printing equipment, use robots to minimize the hidden danger of instability of large size components; increase the freedom of nozzle, etc.

2.1. Large-size 3D Printer

2.1.1 Large metal additive manufacturing equipment

At present, 3D printing of large-size parts in technology and market development has made rapid progress [1]. Manufacturers around the world, including Platinum, EOS, SLM solutions, Concept Laser, and other world-famous enterprises, are also launching more and more equipment, gradually solving the problem of large-size parts being difficult to produce [2].

However, it is accompanied by various technical problems, such as the huge pressure brought by the increase of the wind field, the precision of multiple lasers working at the same time, and the technical problems caused by the larger size of the printer. It often takes several days or even months for large-size equipment to complete the printing task of a large-size part. By stacking tens of thousands of slice data through layers of slices, each layer is 30~100 μ m thick, and the error almost cannot exist. Therefore, there are extremely high requirements for the stability of the equipment and the control of miscellaneous materials. Therefore, in the study of Wang et al. [2], by redesigning and improving the wind field, they removed as much as possible the pollutants generated in the printing process that is not conducive to metal forming, and formed a protective layer for protecting the fiberscope area and components, so as to ensure the quality of 3D printing. Tao [3] found some deficiencies in existing hotbeds, especially for large hot melt 3D printer hot beds some problems with, the design made fast heating, heating uniform, and temperature stability of high power hot bed system, at the same time design and assemble a hot melt 3D printer, found in the printing experiment test, the hotbed to improve the hot melt 3D printer printing accuracy and printing quality. Based on the preliminary research of the melt differential 3D printer, under the design and research including pressure, screw speed, printing speed, height, printing spacing, and other parameters, Liu et al. [4] successfully made a large FDM 3D printer for printing molds, and verified the printing feasibility of the printer, as shown in Fig. 1.

Since 2000, relevant scientific research units in China have carried out research on laser additive manufacturing technology of large components. Wang et al. successfully developed a new system of multi-channel deposition "bridge" large laser additive manufacturing equipment, as shown in Fig. 2. A series of achievements have been made in the integration of "material-structure-manufacturing" for laser additive manufacturing of large key load-bearing components of high-performance metals, and the development and production tasks of major national equipment such as large transport aircraft, carrier-borne aircraft, and large carrier rockets have been successfully guaranteed [5].

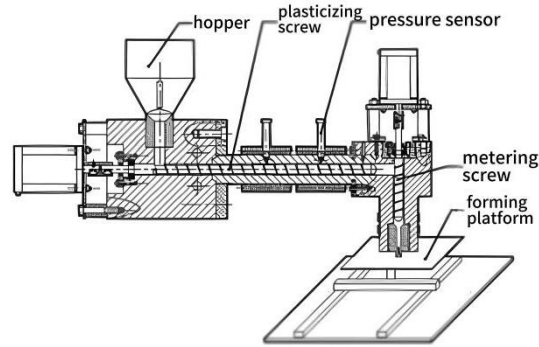


Figure 1. Melting extrusion system [4]



Figure 2. Multi-channel deposition of "bridge-type" additive manufacturing equipment [5]

2.1.2 New large-size 3D printing system

So far, most of the current 3D printers use steel axes and mobile platforms as structures that produce relative displacement between the printing nozzle and the product. Due to the nature of the steel shaft itself, the movement range of the nozzle is limited during the printing process, which then affects the printing range. If the size of the printer, the strength of the steel shaft and body structure will become a difficult factor affecting the success of printing.

In the design study of Fang et al., based on FDM printing, by changing the material forming mode, the printing head movement mode, innovating the innovative printing platform, through the connection of multiple independent steel cables, the sling instead of a steel shaft, avoid the size and stiffness limit of the steel shaft and the body itself, to achieve the printing goal. As shown in Fig. 3, the structure enables the printing nozzle to move freely, change the spatial position arbitrarily, and theoretically allow the printing range of infinite [6]. To solve the problem of nozzle shaking and the error caused by acceleration and deceleration, the path segmentation is increased as far as possible in the program, so that each step is finer and the interval between steps is smaller so that the movement process tends to be more uniform.

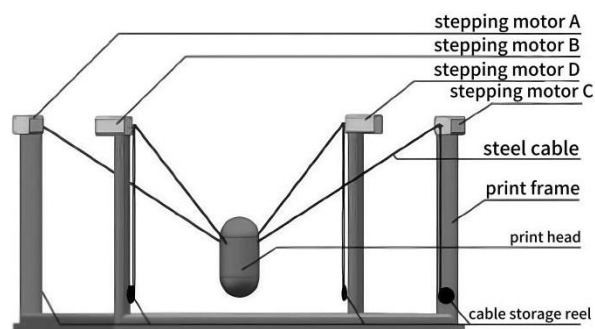


Figure 3. A Schematic diagram of the printer structure [6]

2.1.2 Disadvantages of large-size printers

Large-size 3D printers are difficult to design and manufacture, with high equipment costs and maintenance costs. At the same time, the performance of the parts cannot be guaranteed after printing, and it has high requirements for the use environment, such as temperature, humidity, etc. In addition, large-size 3D printers have a higher waste material rate, which may affect the manufacturing cost of products and may cause more environmental pollution. At the same time, the stability and accuracy of large-size printers is also a big problem. Therefore, a more refined algorithm structure, more suitable for large-size printing nozzle, as well as the treatment and recycling of material waste, and reasonable materials with less impact on the environment are all challenges for the development of large-size printers in the future.

2.2. Robot Printing

2.2.1 Robot-based 3D printing technology

With the development of science and technology, robots have gradually stepped into People's Daily life, so the use of robots for 3D printing has become an indispensable part of the development of 3D printing technology. In the existing traditional 3D printing device, to print large parts, the device needs to do a large part, which will undoubtedly increase the printing cost. The robot has a large range of motion and good axis expansion ability. Therefore, in the study of Xiao [7], prints for the robot to expand an outer axis while moving together with the rotating table. Among them, a method of composite processing of robot 3D printing and reducing material based on visual detection and turntable control is proposed, as shown in Fig. 4 and the corresponding research.

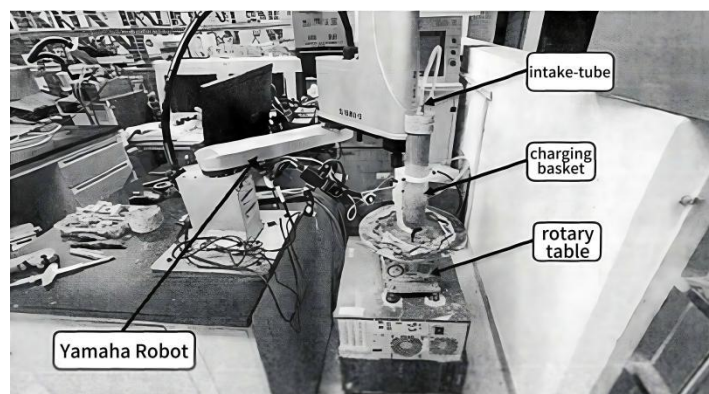


Figure 4. Overall structure of the robot 3D printing equipment [7]

2.2.2 Multi-machine collaborative additive manufacturing

At present, multi-machine and multi-nozzle cooperation to complete large-size parts operation is the current mainstream direction. The mobile robot is a kind of highly intelligent robot. By integrating various disciplines, it can complete the 3D printing work with the help of robots and improve the scalability of the printing system. The advantages of mobile robots can make up for the problem of limited printing area and provide a good foundation for printing large-size parts. Based on the principle of AM, Qian et al. [8] proposed a mobile stitching 3D printing technology scheme based on machine vision.

The essence of compound additive is milling on the basis of additive manufacturing to reduce the surface roughness of parts, reduce the "step effect" caused by additive, and provide a smooth surface for the subsequent additive processing. At present, China has also successfully developed commercial composite processing centers and the processing accuracy and efficiency are constantly improving [9].

The 3D Printing Center in Singapore has developed a mass robot additive system, as shown in Fig. 5, but to avoid interference between robots, it can only complete loose tasks [9].

To meet the additive requirements of large-size components, Shen et al. [9] constructed a two-parallel four-robot collaboration system, as shown in Fig. 6. In order to solve the problem of

interference and optimization failure caused by the emergency coupling additive task, researchers from Southeast University built a multi-twin driven online multi-machine collaborative additive system, which can improve the accumulation efficiency and accumulation forming quality, and reduce the residual stress and deformation of the forming parts [10].

However, at the present stage, the relevant research of multi-machine collaborative additive manufacturing is still at the synchronous composite level, and there is still a certain distance between "intelligent collaboration" and "mutual coupling association" [8].



Figure 5. Movable MCAM system [9]

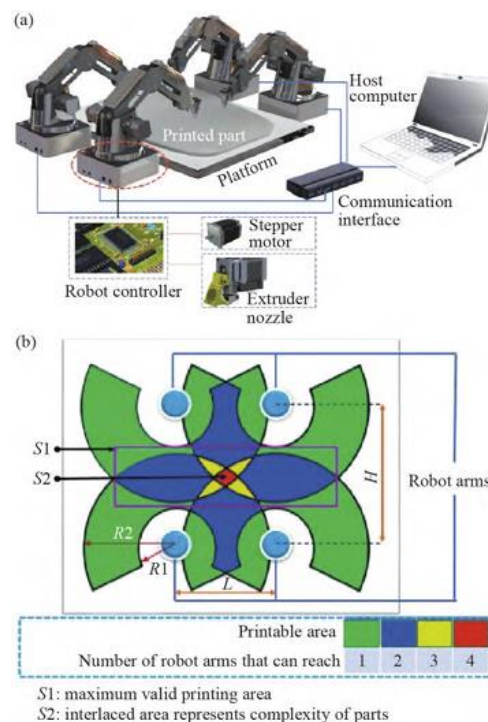


Figure 6. 4 Robotic additive manufacturing system [9]

2.2.3 Disadvantages of robot printing

Robots themselves are more complex, more expensive to manufacture, and with more freedom require more complex algorithms. At present, there is no universal algorithm applicable to most robots. At the same time, the robot itself and its parts are prone to interference.

3. Multidegree of Freedom Printing

To improve 3D printing technology and optimize possible interference in robot printing, researchers began to study multi-degree of freedom 3D printing technology.

3.1. Multi-degree of Freedom 3D Printing System

From the current development, the movement of traditional 3D printing is usually a three-axis movement and is faced with the problem of many supporting materials and difficult secondary

processing. Fig. 7 is a comparison of different printing methods [11]. Therefore, more and more researchers are starting to study multiple degrees of freedom [12].

Ordinary 3D printing equipment usually uses the series and parallel mechanism as the actuator, which can meet daily needs to a certain extent. However, when printing large-size parts, the printing accuracy is often not satisfactory and cannot achieve the desired effect. Moreover, large 3D printers are relatively expensive to build. The multi-degree-of-freedom 3D printing system optimizes the "ladder effect" by increasing the degree of freedom of the printing system to improve the printing accuracy.

Su et al. [12] use the motion platform based on Stewart-type six-degree-of-freedom parallel mechanism as the bearing platform for 3D printers, as shown in Fig. 8. The platform consists of two platforms, 6 telescopic rods in the middle and 6 hinges composed of 6-6 shapes, making the printing workpiece have a multi-directional motion mode. Through this platform, prints have multiple degrees of freedom, improving their size and accuracy. In the design study of Fang et al., the above-mentioned steel cable-type printing structure, its nozzle also has multiple degrees of freedom. By combining the parallel mechanism with the melt deposition mechanism, Qu [13] deformed the 3-PRRR parallel mechanism and added the series guide rail to increase the movement space of the parallel mechanism, so as to meet the space demand of printing large-size parts, as shown in Fig. 9.

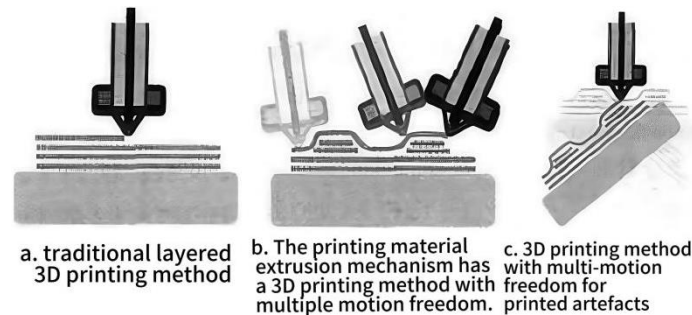


Figure 7. Comparison of different printing methods [11]

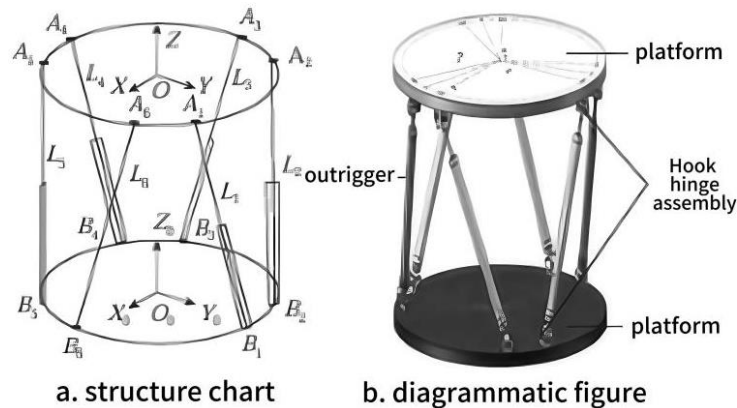


Figure 8. A Schematic diagram of the printer platform [11]

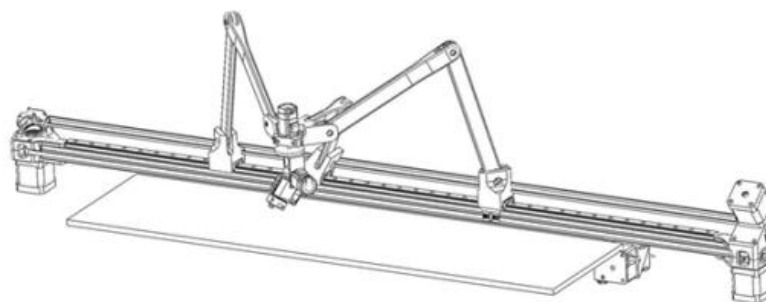


Figure 9. The 3D printing system main body [12]

3.2. The 3D Printing of The Multiaxial Robotic Arms

The mechanical arm has strong joint flexibility, a large working range, high accuracy, and can carry out complex operations. The mechanical arm has strong joint flexibility, a large working range, high accuracy, and can carry out complex operations [11].

The key to 3D printing of the robotic arm is to convert the spatial position of the printed piece into the joint angle value corresponding to the joint space of the robotic arm, which belongs to the inverse kinematics category of the robotic arm. The correctness of the transformation is directly related to the success of the printing, and its accuracy is related to the molding quality of the final print piece. Based on the research of 3D printing-related methods, Li [14] realized the STL model from slicing to path planning to the robotic arm according to the planned path. Will affect the mechanical arm 3D printing model forming quality and efficiency of printing, the mechanical arm 3D printing layered algorithm, filling path planning algorithm, and mechanical arm inverse kinematics are studied, and the different mechanical arm using different methods of inverse kinematics of difficulty are analyzed, successful build simulation experiment platform for printing, as shown in Fig. 10. Wang et al. [15] built a multi-direction additive manufacturing electromechanical system based on a vertical 6-axis manipulator, optimized the structure for 3D printing, and verified the technical route and feasibility of the manipulator for multi-direction printing, as shown in Fig. 11.

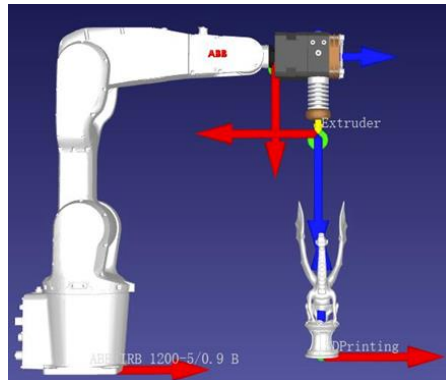


Figure 10. Mechanical arm 3D print simulation [14]

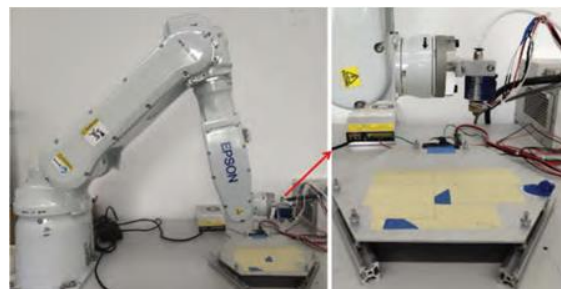


Figure 11. Mechanical arm additive manufacturing platform [15]

3.3. Lack of Multiple Degrees of Freedom to Print

The multi-degree-of-freedom printing process is not yet mature, the printing model has many limitations, and the algorithm is difficult to implement. When the arm performs 3D printing tasks, the arm has joint structure limitations, so it cannot reach some positions, and will also produce the interference between the arm and interference between the arm and the parts. Co-printing with multiple robotic arms can significantly improve the flexibility and freedom of the entire 3D printing system, allowing it to reach the same location in space in more ways. However, algorithm optimization and production technology are currently facing a new bottleneck, optimization and production, and manufacturing difficulties.

4. Conclusion

In the future, 3D printing will enter industrialization and large-scale industrialization, and it is urgent to solve the problem of how to produce large parts more efficiently. With the progress of industrial technology and the development of computer technology, more efficient 3D printing technology similar to robot printing will gradually be on the production line. Therefore, whether it is to improve production technology, produce large 3D printers to ensure the performance of parts, improve the level of computer technology, bring artificial intelligence and robots into the production line, optimize algorithms, improve production efficiency, reduce costs, and reduce environmental pollution, will be the direction of 3D technology progress in the future, at the same time, the deformation of materials caused by temperature changes is also a difficult problem to be overcome in the future.

This study summarizes the way of large-size parts 3D printing and analyzes the advantages and disadvantages of different ways, clarifies the research after from the mechanical performance optimization, multiple robot control and cooperation, large size parts stress deformation evolution mechanism and explores new materials, reduce temperature influence, reduce waste ratio, reduce environmental pollution, to realize the industrialization and universality of large parts 3D printing.

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