Research on the Application of 3D Printing in the Structural Manufacturing of Intelligent Robots

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Abstract. This article focuses on the study and discussion of the use of 3D printing technology in the manufacture of intelligent robotic structures, as well as the associated innovation points and rational directions of innovation. First, from the direction of development of 3D printing technology and intelligent robots and the degree of existing development, find the research junction point of the two, analyze and study their past cases and development trend, identify the part that needs to be improved and innovative. The hypotheses and analysis of the innovation part and the identification of research axes on the problems to be solved are followed by the analysis and discussion of the success cases linked to this innovation study. Clarify the direction of improvement and expansion area of innovation, then according to the point of innovation and direction of innovation for the future of 3D printing technology and intelligent robot structure combined with the application appearance, reasonable perspective and analysis.

Keywords: 3D printing; intelligent robot; lightweight design.

1. Introduction

Since the 21st century, the world has paid more and more attention to the development of robotics. With the progress of science and technology, the scope of robotics has expanded further. Robotic technology is considered one of the high technologies that is important for the future development of the emerging industry. In addition, the manufacturing industry has adopted new intellectual equipment, represented by machines, to gradually transform itself into a flexible intellectual industry [1].

And with the rapid development of technology, 3D printing technology has gradually moved from laboratory to practical application, especially in the manufacturing field. Its unique advantage makes its application in the manufacture of intelligent robots increasingly promising[2]. 3D printing is an extremely innovative rapid prototyping technique. Based on digital mock-up files, it ultimately transforms virtual digital mock-ups into three-dimensional entities through layered fabrication, superimposed layer by layer. This technology has broken the many limitations of traditional manufacturing processes and has shown unique benefits and potential. It has made major changes in many areas and played an important role in the manufacturing journey. Traditional manufacturing techniques are limited by tools and product shapes are limited. While 3D printing technology breaks down objects into two dimensions, it is theoretically possible to process objects of any shape, with unlimited design space. The accuracy of processing depends on the minimum size of the material particles in the output of the printer[3].

With the continuous development of technology, 3D printing technology is gradually realizing applications in various fields. In the aerospace sector as well as in the construction of rail transport, 3D printing technology can be used to produce rocket parts, automotive parts, etc. 3D printing has cost advantages when used to produce small quantities of components. It can improve productivity and enable accurate production in large quantities[4]. And can be used to manufacture parts of complex structure, fully support topology optimization, but also can integrate several parts into a whole, and finally realize the lightness of the parts. The main direction of this research is to combine all aspects of 3D printing and intelligent robots, using 3D printing to complete the improvement of all aspects of intelligent robots.

2. Intelligent Robot

2.1. Characteristics and application scenarios of intelligent robots

With the growing problem of society's aging, there will be massive shortages in the supply of labor, the need for social services and security will become more urgent, and intelligent robots will more widely replace labor in the various operations of productive life. The three characteristics of intelligent robots are autonomy, automation and movement. In terms of autonomy and automaticity, while traditional industrial robots essentially perform actions according to pre-established instructions, intelligent robots must add more autonomy in decision making and automation. According to the application scenario and application content, smart robots can be divided into three categories: domestic smart robots, medical smart robots and public smart robots.

The intelligent home robot is a robot capable of replacing a person to accomplish the work of home service. It comprises a walking device, a perception device, a receiving device, a transmitting device, a testing device, an implementing device, a storage and assembly device, an interactive device, etc[5-6]. With the robotic butler as representative, the robotic man butler technology is still in development. It can fully plan and manage the domestic environment in controlling the temperature and humidity of life, cleaning the environment and so on. It belongs to the intelligent life system and can provide great motivation to improve the individual quality of life.

Intelligent robots in the medical scene are increasingly widely used and are the hot direction of attention in the medical industry. It is mainly divided into two main categories: surgical robots and nursing robots. It can effectively help doctors and nurses to perform surgery and care, which brings great convenience to the medical industry.

Public are already putting on the market intelligent robots extension, shopping malls, Banks, restaurants, museums, even often seen the administration hall of these "machine friendly services, to provide services and information such as intelligent robots in terms of reception, robotics, guided Tours, etc[7].

2.2. The direction of lightweight development for intelligent robots

The current design of robot manufacturing is usually to do a simple job, so it fails to solve many things and jobs that need to be solved by man, but that need to be performed by robots. And the light weight design is one of the main ways to solve the above problems, after the light weight can improve the robot's motion ability and work efficiency and improve the speed and precision of operation, reduce the inertia of movement, increase the safety of the robot[8]. The choice of lightweight materials and the optimal design of the structure are key elements to achieve the lightness of the robot.

3. 3D Printing

3.1. Overview of 3D Printing Technology

The development of science and technology has laid a solid foundation for the development of 3D printing technology. The emergence of the 3D printing process is a subversion of traditional material processing technology. This technology, called additive manufacturing technology, can be based on the data of the three - dimensional mathematical model and complete the manufacturing and processing of materials through the superposition of physical layers, enabling the transformation of the virtual model into a three - dimensional entity[9]. Its characteristics and advantages are very distinct, and it is an important means to achieve the goal of digital manufacturing.

3.2. The application of 3D printing technology in intelligent robots

3.2.1 Complex exoskeletons and framework structures

3D printing technology can be used for the bone structure of the robot housing and main frame, such as biomimetic structures, lightweight frames, etc. An example is Boston Dynamics' Atlas robot, which uses 3D printed parts to create lightweight and resistant parts for legs and torso. Its lower limbs of the 3D printing robot currently being designed not only the structure is very simple, and many important parts of the interior is similar to the hollowed structure in the shape of a mesh, will greatly reduce its own quality, but the effect of specific lightness is unknown. Robots Imitations of the lightening of internal structures aimed at increasing the weight of holes to reduce the means of manufacturing, not too long to the manufacturing method, of transforming the lightening of composite materials, as to invent composite materials based on fiber from the academy of sciences of industrial robots boom arm 16. 2 kg, greatly mitigating deadweight must be integrated into the agreement [10].

3.2.2 Common 3D printing technologies and materials

Based on the current status of 3D printing materials and printing forming methods, printing technologies can be classified into the following types: Fused Deposition Modeling (FDM), Stereolithography (SLA), Selective Laser Sintering (SLS), Multi Jet Fusion (MJF), Metal Printing (SLM), etc[6]. The table 1 give some information about comparison of major 3D printing technologies.

Table 1. Performance comparison of major 3D printing technologies

Printing technology	FDM	SLA	SLS	MJF	SLM
Characteristic	Low cost, simple operation, and multiple material options	Ultra-high precision, smooth surface, but brittle	High strength, no need for support	Fast speed, high precision and strong strength are comparable to SLS	Extremely high strength, high temperature resistance, lightweight
Applicable to robot components	Non-load-bearing shell, tooling fixtures	High-detail prototype, precise sensor support structure	Complex parts, joints, shells	Small-batch structural components	High-performance joints, load-bearing frames, and lightweight metal components
Conventional materials	PLA, ABS, PETG, PA, Carbon fibre composite	Various photosensitive resins	PA11/PA12, Carbon fiber reinforced nylon	Nylon powder	TC4, aluminium alloy, stainless steel

To achieve lightness, first of all, lightweight materials can be used at macro level, such as titanium alloys, aluminum alloys, magnesium alloys, earthenware Porcelain, plastic, fiberglass or carbon fiber composite, etc. Secondly, 3D printing, as an advanced manufacturing process, offers the possibility of achieving light weight through optimized structural design. The main methods are hollow sandwich construction and thin wall reinforced structure, hollow mesh structure construction, integrated structure design and atypical topology optimization design.

3.2.3 Case studies of 3D printing technology applied to lightweight applications

The faculty of mechanics of dalian Jiaotong university discussed the lightweight design and manufacture of the thigh structure of a humanoid robot. Therefore, when building the thigh of the

robot, the upper and lower extremities and the outside of the thigh are transformed into a solid body, the middle generates a grid structure. Miniature reconstructions of models in Creo, a 3d modeling software, are called inlays. Its use to remove the thigh of a humanoid robot makes it possible to form hollow structures entirely chimerical of the external surfaces. With respect to materials, the excellent materials available for humanoid robots are primarily titanium or aluminum alloy aluminum alloys in the strength bearing components, and carbon fiber composites for non-bearing mechanisms[11]. In materials, excellence existing ChengLi robots imitations of components of non-chengli materials of titanium or aluminum alloys daca using carbon fiber Dimensional composite materials. The alloy and annual report for this report Ti6Al4 e-v, lightness for intensity, hardness, difficult to adopt laser technology molded riding good to bypass its difficult transformation. After the material is determined, static mechanical analysis under different working conditions will be conducted for light weighting.
(1)As shown in Fig. 1, the humanoid robot, the force acting on the thigh is directed vertically towards the two hinge connection circular surfaces of the component. It is set at the upper hinge connection point, and the force area is 3,405.5 mm². The components are in force balance, and the overall torque is also in balance.

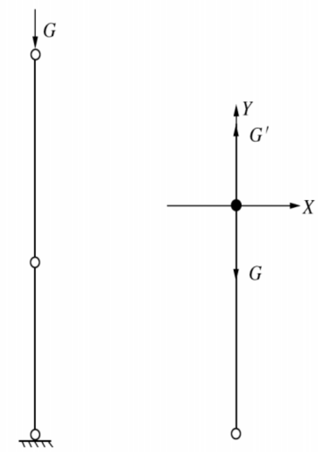

Fig. 1 Schematic diagram of posture and analysis of thigh forces

(2) When the right foot touches the ground to when the left heel is off the ground), and the swing phase (from when the left heel leaves the ground to when the left foot touches the ground again). According to previous studies, the force is the greatest when the human body reaches the contralateral weight-bearing stage with full weight-bearing on one leg[12-13].

On the basis of imitating the design of human walking and bipedal robots.The offset angle between the Y axis and the plumb force is set to B=28°, the support direction of the upper end of the hydraulic rod and the angle of the Y axis are set to a=13°, and the angle between the force acting on the hinge at the bottom of the component and the Y axis is set to 0, as shown in Fig. 2. The force set P at the connection of the upper hydraulic rod, and the force area force is 1374.6 mm'; the force at the lower end hinge is F, and the force area force is 6927 mm'. Ignoring the walking acceleration, this situation simplifies the force equilibrium state, AB=600 mm, AC=500 mm.

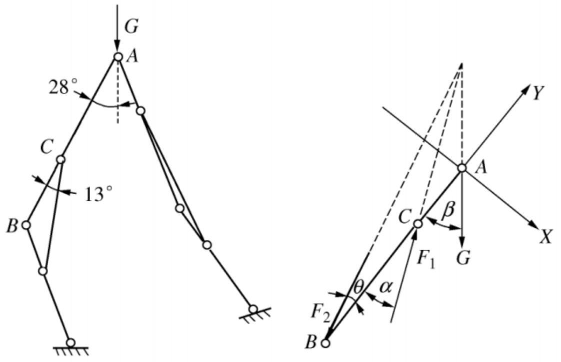

Fig. 2 Diagram of walking posture and analysis of thigh force distribution

(3)Squatting posture. Referring to the previous research on the force of the lower limbs of the human body when squatting with weight, it can be concluded that the force is at the lowest level of squatting 21 is the largest, so the thighs of the humanoid robot are set to be 80° in the vertical direction, and the hydraulic rod support angle is 20° with the Y-axis direction. The working conditions and forces are shown in Fig. 3, at this time, the force is balanced and the torque is balanced.

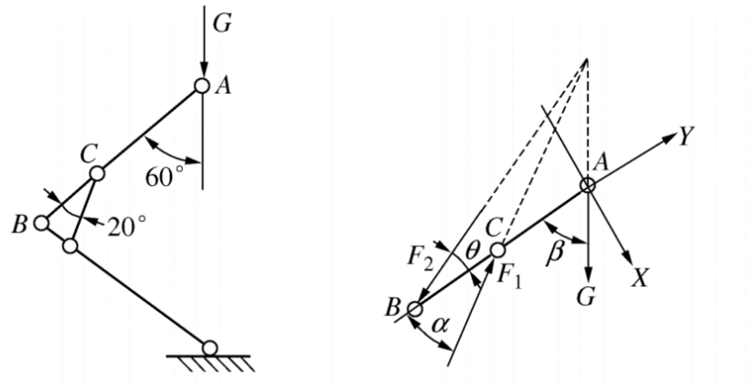

Fig. 3 Diagram of squatting and standing up posture and analysis of thigh force distribution

Their experiment, through the simulation analysis of the legs of the humanoid robot under three different working conditions, can conclude that the humanoid robot's thigh can perform the basic functions such as basic walking, standing and squatting of the robot, and the strength is completely within the allowable limit of the yield strength of the TC4 titanium alloy components prepared by SLM[14]. This also further confirms the feasibility of the selected materials and methods for 3D printing.

4. Expansion of Lightweight Design for 3D Printing Materials

The above case shows that 3D printing technology in light design is designed and implemented with great success, and also confirms the feasibility of light 3D printing design for smart robots. Then in this case of feasibility, lightweight materials can be developed and studied. Not only limited to a single material, but also the composite processing of materials.

4.1. Overview of Composite Materials

A composite material is a polyphasic material, usually composed of two or more components with different properties and morphologies. Not only does it maintain the characteristics of the original component material, but also extends the superior properties that the original component material does not have. Carbon fiber composite is one of the most used and important composite materials. Carbon fiber composites are made from carbon fibers with a carbon content greater than 95% as reinforcement material, with a mixture of resins, metals and ceramic materials. They are characterized by low overall density and high specific strength/rigidity, while being more resistant to corrosion and fatigue than commonly used metallic materials[15]. Mainly in aerospace, automotive industry, wind power and medical aspects and other application fields. In the field of carbon fiber composites, the use of resin-based composite materials (CFRP) can account for about 80%. Epoxy, phenolic resin, ptfe are currently the most used resin materials in the matrix. The density of CFRP is lighter than aluminum, the strength is also very high, its modulus of elasticity is larger than aluminum alloy and steel, and it has the advantages of high job resistance, good impact toughness, water and moisture resistance, stable chemical properties, strong design, etc., in short, in existing structural materials in optimal overall performance and is widely used in aerospace, railway traffic, Wind power, sports and recreation, medical care and other areas. Now the stage segment process is mature, less expensive and the temperature resistance ability is improving. But in its manufacturing parts of surface treatment, machining and other aspects of post-treatment problems still need more research and exploration, and the need to focus on molding technology and equipment localization, the development of resin matrix technology, adjusting the structure of industrial demand towards the high-end development [16].

4.2. Forming Process of Carbon Fiber Composite Materials

4.2.1 Traditional Molding Process

Most traditional carbon fiber composite parts are manufactured by molding processes such as pultrusion, molding and winding. Pultrusion molding is a continuous bundle of fibers impregnated with resin glue that, under the influence of tensile force, is formed and solidified by an extrusion mold to produce profiles of unlimited length continuously and without breaking. Molding involves first putting the fibrous plastic into the mold cavity at the molding temperature, then closing the mold and pressing it to mold and harden it. Winding moulding is the continuous fibre soaked with resin glue according to a certain regularity wound to the core on the mold, then by solidification and release to obtain the product [17].

4.2.2 New Forming Process

The in-situ molding technology for the automatic laying of thermoplastic composite materials reinforced with continuous fibers is an additive manufacturing technology for composite materials based on automatic laying equipment of fiber yarns, which means that the manufacturing of the parts is completed at the same time as the laying. This technology significantly reduces the manufacturing process of composite materials. The technical requirements on the molds are reduced. It is capable of forming parts with complex geometry and large size. It is characterized by high molding efficiency and high quality. Thermoplastic prepreg materials can be used for storage at normal temperature, reducing composite manufacturing costs by more than 50% [18].

Compared with traditional molding process, there is high production efficiency, the cost is lower, but it is more difficult in the opposite side of the process. Both have their advantages and disadvantages, but overall, the new molding process is more composite than current production methods.

4.3. Application of Carbon Fiber Composite Materials in 3D Printing

3D printing of continuous carbon fiber composites, mainly commercial thermoplastics. Carbon fiber (or impregnated carbon fiber) and plastic bundles are printed by FDM (single or double head). From the equipment point of view, FDM equipment must be capable of co-extruding and cutting. 3D printing of carbon fiber reinforced continuous thermoplastics has promising development potential due to its efficiency and low cost. The key to molding lies in the right interface between carbon fiber and thermoplastic, the orientation of carbon fiber, the structural design of parts and the control of the printing process (nozzles and knives design, raw material pretreatment and post-treatment of parts).

3D printing on short carbon fiber composites is relatively well established. For short carbon fibre composites, the theoretical fibre lengths are 0.2 to 0.4 mm and the fibre lengths are 5 to 10 μm printed by FDM (modeling by fusion deposition) and SLS (selective laser sintering). The addition of short carbon fibers can obviously increase the mechanical properties of the material, especially tensile and flexural strength and modulus. Short carbon fiber composites, especially polyamides (PA) and polyether etherketone (PEEK) based materials, have high mechanical properties and can be applied to the strength and lightness requirements of industrial parts such as automotive, drones, robotics, aviation, etc [19].

In summary, the use of carbon fiber composite materials for 3D printing is very wide and applicable, so the use in all types of robotic industrial meetings isa good choice.

5. Conclusion

Combining 3D printing technology and intelligent robot structural manufacturing, we address the light weight of the robot structure, the robot usage scenario and material selection and expansion of

3D printing technology. Realize the light weight of the robot, reduce production cost, reduce energy consumption, can realize mass production and usage.

If the future wants to realize the use of carbon fiber composites on intelligent robots, to realize the further research and development on 3D printing materials and carbon fiber composites. Test the materials in all aspects, such as high temperature resistance, high strength, high toughness, etc, reduce the cost of materials, shorten the printing time, develop 3D printing carbon fiber composite suitable for intelligent robot.

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