Research on Mechanical and Control System Design Based on 3D Printing Equipment

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Abstract: Based on the development requirements of printing equipment, the system design, system processing, installation and debugging, performance testing experiments, system trial operation and system improvement of 3D printing equipment are studied in several stages, and the technical standards for the relevant machinery and control systems of the equipment are studied. Design and optimization were carried out, and the development of the equipment was completed.

Keywords: 3D Printing Equipment; Mechanical Design; Control System; Control Software

Introduction

Selective laser melting technology is an advanced manufacturing technology developed on the basis of selective laser sintering technology that uses the superposition principle, that is, the "incremental" manufacturing method of layer-by-layer cladding to directly produce metal products. The process is: In the computer, Use CAD three-dimensional modeling software to establish a three-dimensional digital model of the entity to be processed, and use preprocessing software to perform layered processing on the three-dimensional digital model to obtain the model contour graphics.

1.1 The working principle and composition of SLM 3D printing equipment

The working principle of SLM 3D printing equipment is shown in Figure 1. When f The working principle of SLM 3D printing equipment is shown in Figure 1. During forming, the powder spreading shaft spreads the powder material from the powder feeding cylinder into the working cylinder, and then the laser beam is controlled by the control program according to the profile information of the section of the formed part.[1] The powder material is scanned and sintered, and the scanned powder melts and then falls below the melting point, and is bonded to each other to obtain a sintered surface.

1.2 General requirements for the development and design of SLM 3D printing equipment

The overall requirements for the development and design of SLM 3D printing forming equipment are as follows: The movement accuracy of the powder feeding cylinder is generally controlled to 0.01 mm; the positioning accuracy of the powder spreading roller guide rail is controlled to be 0.0025 mm; etc.; process software and control software can be used alone or together, supporting remote maintenance and remote monitoring Function; Adopt servo closed-loop control; Substrate and fast laser composite preheating technology[2].

2. System Design

Use CAD 3D modeling software to establish a 3D digital model of the entity to be processed, and then perform layering processing. On the laser 3D printer, control the laser point according to the contour graphics of each layer to sinter the powder material on the working platform, layer by layer, and finally A three-dimensional solid prototype consistent with the designed model is obtained, and the process flow is shown in Figure 2.

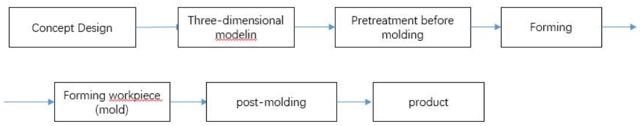

Figure 2 3D printing process diagram

2.1 Mechanical system design

2.1.1 Mechanical design requirements

The weight and volume of the whole machine are as small as possible, it can be handled as a whole, and the transportation is convenient; the operability, maintainability and economy of the system should be taken into account in the structure; The machine works reliably and has a long service life; the appearance design should be beautiful and the assembly is convenient.

2.1.2 Structural design scheme

In order to make the designed product meet the above-mentioned mechanical design requirements, at the same time of structural design, the characteristics of the overall production are considered, and attention should be paid to the structural design: when assembling the position of the design hole, it is generally designed to be matched for processing, Reduce assembly problems caused by inaccurate positioning; in order to ensure the realization of the structural process design, the assembly process and processing technology should be specified in detail.

2.1.3 Overall structure

The overall structure of 3D printing adopts the design scheme of separating the working host unit and the control cabinet unit to reduce the overall size and weight of the host unit and facilitate transportation. The control cabinet unit is separated in layers to improve the space. The utilization rate of the working host is shown in Figure 3.

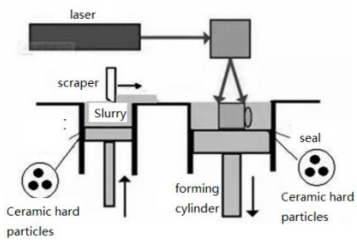

Figure 3 Schematic diagram of the host structure

2.2 Design of Laser Scanning System

2.2.1 The working principle and selection of the dynamic focusing unit

The dynamic focusing unit is introduced to overcome the "arc effect" of the scanning system in the 3D printing system. In an ordinary scanning system without a dynamic focusing unit, the focal spot trajectory formed by the two galvanometers is an arc, as shown in Figure 4, the focal spot scanning trajectory (arc) and the working surface only coincide at the center point C, and the center The two are separated outside the point, and the separation is the largest at the edge A of the workpiece, and the larger the workpiece or the smaller the deflection radius of the beam, the greater the separation. At A', the light beam converges into a point and then diverges, and when it reaches A, a larger-sized light spot is formed, and the power density is reduced, which affects the sintering quality and precision.

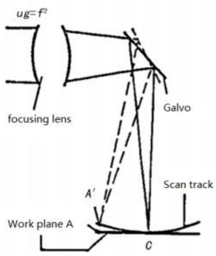

Figure 4 Schematic diagram of arc effect

The double galvanometer scanning head controls the light spot to scan in the x-y plane, and the focusing error ΔS of the double galvanometer system is:

$$\Delta S = S_2 - S_1 = \sqrt{\left(\sqrt{a^2 + y^2} + b\right)^2 + x^2} - (a + b)\#(1)$$

In practical engineering, in order to ensure the reliable response of the linear displacement of the negative lens to the scanning speed of the galvanometer, the axial displacement of the negative lens is controlled within ±5 mm. Assuming that the maximum scanning angle of the galvanometer is ±20°, and the distance from the galvanometer to the working surface is 465 mm, the focusing error of 60 mm can be obtained, and the change of the system focus position is ±ΔS /2 = ±30 mm. The HLP-350I molding machine adopts the varioSCAN 40 dynamic focusing unit of SCANLAB Company, and its focal length variation is ±38.5 mm.

2.2.2 Galvanometer mirror

The HLP-350I molding machine is a low-power laser system, and the mirror does not need to be cooled and dissipated. Therefore, the mirror substrate is made of ordinary optical glass, and then coated with a multi-layer dielectric film, with a reflectivity of more than 99%. The size of the mirror must be large enough to not cut the beam during deflection. For any laser system, the focal spot size is determined by diffraction and spherical aberration, where the focal spot diameter affected by diffraction is:

$$\mathrm{d}_1 = \frac{4M^2 f\lambda}{\pi D} \#(2)$$

The diameter of the focal spot affected by spherical aberration is:

$$\mathrm{d}_2 = \frac{kD^3}{f^2} \#(3)$$

In the formula: :$\mathrm{M}^2$is the quality factor of the laser mode (:M^2=1.4 in HLP-350I); f is the focal length of the focusing element, f = 630 mm; λ is the laser wavelength, λ=10.6 μm; D is the aperture diaphragm Diameter, D = 40 mm; k is a factor related to the focusing element material.

d1 and d2 are 0.298 mm and 0.005 mm, respectively. Focal spot diameter, i.e. d = d1 = 0.298mm.

2.2.3 Demonstration of laser power and laser selection

The parameters of PS powder and wax powder are listed in Table 1. When the laser power is P = 20 W, δ= 0.2 mm, d = 0.3 mm, it can be seen that when the laser power is 20 W, the PS is completely melted The scanning speeds of powder and wax powder are 2.12 m/s and 1.96 m/s, respectively, so the scanning speed of the universal extraction system is 2 m/s. The actual scanning speed after process optimization is about

1.3m/s, so the laser power can be appropriately reduced.

parameter / Material	C(J/g•°C)	ρ(g/cm^3)	T°C	T_0°C	D mm	δ mm	ν (mm/s)
PS	1.25	1.05	185	65	0.3	0.2	2116.4
Wax powder	2.9	0.9	90	25	0.3	0.2	1964.8

2.3 Control system design

2.3.1 Hardware Design of Control System

In the 3D printing system, the control system controls the coordination of each component in the entire system according to a predetermined program. The laser 3D printing system is composed according to the structure, mainly including: scanning system control[3]; working cylinder and feeding cylinder motion control; powder spreading mechanism motion control; power distribution control; lighting control; preheating system control; cooling induced draft motor control; exhaust air Filtration system control.

2.3.2 Software design of molding system

In the laser 3D printing system, the software system is mainly composed of three parts: three-dimensional graphics software, processing software and control system software[4].

2.3.3 3D graphics software

3D CAD graphics software is a key component of 3D printing forming technology, and its main functions are 3D model design of parts and surface triangulation of 3D models.

Summary

According to the requirements of the development task of HLP-350 3D printer, the system design, system processing, installation and debugging, performance testing experiment, Several stages such as system trial operation and system improvement were studied, [5]the technical standards of the relevant machinery and control systems of the equipment were designed and optimized, and the development of the equipment was completed.

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