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Design and analysis of 3D printing system in parallel structure

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Abstract. A 3D printing system with parallel transmission mechanism is designed. The motion principle of the system is analyzed, and the length of the inclined rod and the angle of the inclined rod are expounded.And the reason of horizontal deviation is the extrusion ratio, nozzle diameter, lamination thickness, nozzle temperature and hot bed temperature related to the accuracy of parts processed by 3D printing system. The analysis and optimization of the working parameters so as to ensure the precision of the parts. PLA plastic is used as a processing material, and the processing of bipolar plate with fuel cell is completed. The performance test of parallel channel and snake like fuel cell proves that the operation of 3D printing system is effective, and is applied to fuel cell for subsequent 3D printing system.

Key words. 3D printing, deviation analysis, parallel mechanism, fabrication parameter.

1. Introduction

3D printing technology generates products of any shape directly from computer graphics data without accumulating machining mode or machining mode. It can greatly shorten product development cycle, increase productivity and reduce production cost. 3D printing technology covers all the printing processes, technologies, equipment categories and applications related to the "rapid prototyping" at the front-end of the product life cycle and the "rapid manufacturing" in the whole production cycle. 3D printing technology can be the traditional method of processing is difficult to manufacture parts, and realize the near net shape first, avoid outsourcing data leaks and shorten the processing cycle time, greatly reduce the manufacturing preparation and data conversion time, high speed, high usability and other advantages, is of great significance for key parts of power equipment manufacturing aerospace, automotive and other high-end products. 3D printing technology from the aspect of technology can be divided into melt accumulation manufacturing, selective laser sintering, selective light curing type forms, the accumulation of melting fabrication technology of thermoplastic filamentary material by wire feeding

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mechanism to melt nozzle, and heating in the nozzle and melt into a semi liquid, selectively deposited on the work on the stage, and ultimately the formation of three-dimensional parts[1].

2. Design of 3D printing system with parallel mechanism

As shown in Figure 1, the frame is made of aluminum profile, and three torchers which can move in a straight line in the vertical direction are installed on the frame column, and the stepping motor drives the pulley to move up and down[2−3]. The slider is connected to the printer nozzle through the fixed length inclined rod, and the three small torchers cooperate to move the movement of the trochlear into the horizontal plane of the nozzle. The printer nozzle is the key part of the 3D printing system. It is mainly composed of three parts: the guide part, the heating part and the heat dissipation part. The feeding part is composed of core inserted Teflon (PTFE) pipe and nozzle, the nozzle aperture size directly affects the thickness of silk[4−7].

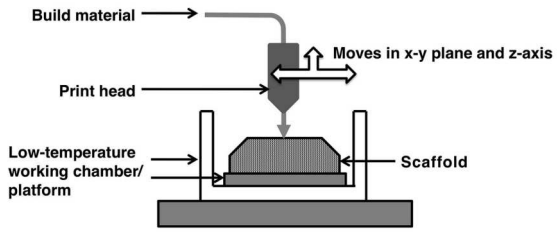

Fig. 1. Scheme of 3D printer

We have a structural design for the mechanical structure[8]:
Pre-tightening force of each bolt:

$$F_0 > \frac{K_s F_\Sigma}{fiz} \tag{1}$$

The pre-tightening force of each bolt[9]:

$$F_0 \geq \frac{K_s T}{f \sum_{i=1}^{n} r_i} \tag{2}$$

The position of the 3D printer's nozzle in space is obtained by the distance of the three torchers to coordinate the moving distance. Loose bolt connection[10]:

$$\sigma = \frac{F}{\pi d_1^2/4} \leq [\sigma] \tag{3}$$

In a triangle composed of three dimensions, which are projected in a horizontal and vertical direction, the length of the inclined rod is unchanged. Tight bolt

connection[11]:

$$\sigma = \frac{1.3F_0}{\pi d_1^2/4} \leq [\sigma] \tag{4}$$

Suppose the nozzle moves only on the X axis and does not move on the Y axis and the Z axis. Axial static load[12]:

$$\sigma = \frac{1.3F_2}{\pi d_1^2/4} \leq [\sigma] \tag{5}$$

Axial dynamic load[13−14]:

$$\sigma_a = \frac{C_b}{C_b + C_m} \bullet \frac{2F}{\pi d_1^2} \leq [\sigma_p] \tag{6}$$

Shear strength conditions of bolts:

$$\tau = \frac{F}{\pi d_0^2/4} \leq [\sigma] \tag{7}$$

Extrusion strength of bolt and wall[15]:

$$\sigma_p = \frac{F}{d_0 L_{\min}} \leq [\sigma_p] \tag{8}$$

The error of oblique rod length can be corrected by comparing the measured length and design size of printing models, such as printing regular cuboid model, measuring its length and calculating printing error, correcting the length of diagonal bar according to the error value. Static connection strength condition:

$$\sigma_p = \frac{2T \times 10^3}{\varphi z h l d_m} \leq [\sigma_p] \tag{9}$$

Dynamic connection strength condition:

$$p = \frac{2T \times 10^3}{\varphi z h l d_m} \leq [p] \tag{10}$$

3. Motion analysis of 3D printer in parallel mechanism

In the 3D printer, the length of the diagonal bar is one of the main factors that affect the printing quality. If the actual length of the horizontal projection of the inclined rod is equal to the theoretical length, the actual length of the inclined rod is larger than the theoretical length, and the equation trajectory becomes a larger circle in the graph as shown in Figure.2.

As we can see in Figure.3, the error of oblique rod length can be corrected by comparing the measured length and design size of printing models, such as printing regular cuboid model, measuring its length and calculating printing error, correcting

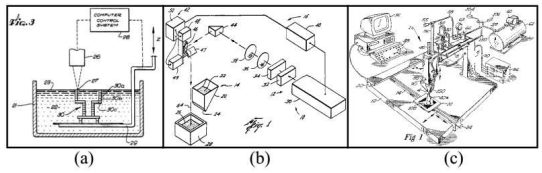

Fig. 2. 3D printing related patent diagram

the length of diagonal bar according to the error value.

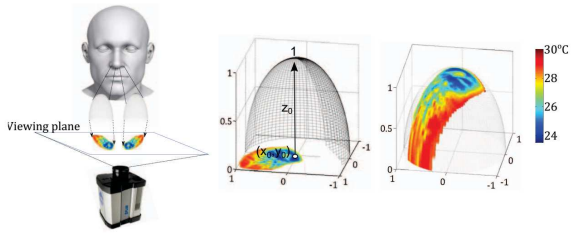

Fig. 3. Experimental layout

Horizontal deviation of the sprinklers to Z direction, resulting in a concave deviation bowl to print a plane. On the other hand, if the deviation of the movement is small, a convex deviation is produced to make the print plane into the dome as shown in Figure.4 and Figure.5.

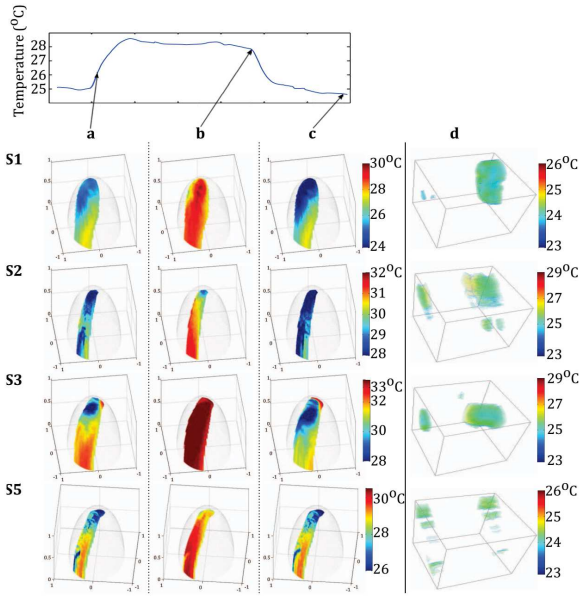

Fig. 4. Normal breathing cycles on the left nostrils of four subjects

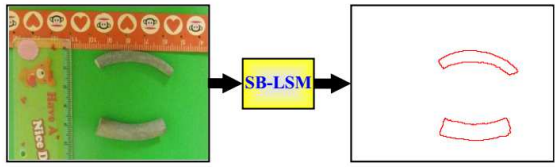

Fig. 10. Capture the contours of the ceramic ring using SB-LSM.

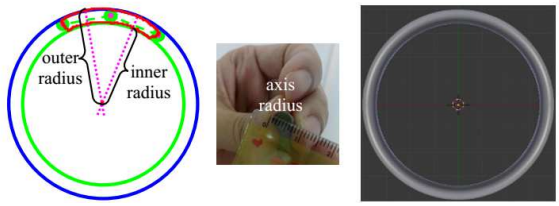

Fig. 5. 3D Model of ceramic ring

4. The influence of processing parameters on the precision of parts

In the process of 3D printing, the setting of the processing parameters directly affects the molding precision of the printing parts as shown in Table.1.

Table 1. Average displacement values

f [kHz]	Thick [nm]	Thin [nm]
1.4	0.84	0.78
2.6	1.85	1.41
8.5	0.09	0.3
12	0.01	0.04
1.7	1.61	1.26
2.69	1.12	1.05
9	0.14	0.21
12	0.019	0.021

The extrusion multiple refers to the matching degree of the extrusion speed of the PLA fuse from the nozzle and the filling speed of the nozzle along the filling path. The matching speed of extrusion speed and filling speed directly affects the processing quality of parts. If the extrusion ratio is too large, there will be too much wire and the extrusion layer will make uneven distribution of material distribution. If the extrusion multiple is too small, the material is not filled, the spray wire is discontinuous, and the printing will fail.

The diameter of the nozzle affects the diameter of the ejection fuse. In general, the finer the fuse is, the denser the filling path will be, and the longer the scanning

path will be, the higher the molding accuracy will be. The thickness of the slice is the slice thickness of the three dimensional solid model. The smaller the layering thickness is, the higher the printing accuracy is, but the thickness of the slice cannot be set too small. Otherwise, due to too much extrusion wire, the printing piece is deformed due to the stacking of material. In order to make a close adhesion between the layer and the layer, the thickness of the slice is less than the diameter of the nozzle. The selected nozzle diameter is 0.3mm, and the thickness of the set is 0.25mm.

The temperature of the nozzle is the temperature that is heated to the nozzle during the printing process, and the temperature of the hot bed is the temperature of the printing platform. Printing consumables select PLA, the temperature is too low, the extrusion and bonding can be difficult, the temperature is too high, the surface of the molding parts will have pimple. When the temperature of the hot bed is too high and the distribution of the thermal stress in the upper and lower parts of the forming part is uneven, the warpage will occur. If the temperature is too low, the first layer is not easy to adhere to the printing platform. After many experiments, the printing temperature of this PLA consumable material is 200 degree C, the extruded silk is viscoelastic fluid state, the temperature of the hot bed is kept at 65 degree C, and the forming quality of the printing part is high.

A 3D printing system with parallel transmission mechanism is designed, and the following conclusions are obtained.

(1) 3-PSS parallel mechanism has the advantages of compact structure, high stiffness, good dynamic performance and high positioning precision. It is suitable for the requirements of 3D printing system movement.

(2) 3D printer structure size affects the machining quality. If the actual length is greater than the length of the diagonal rod theory, the print is too large, otherwise, the print is too small; when the diagonal angle of actual value is lower than the theoretical value, the print is too large, otherwise, the print is too small; if the horizontal moving deviation increases, will have a bowl shaped, concave deviation, so that the printing plane is generated on the other hand, convex deviation, to print a plane into the dome.

(3) The accuracy of parts processed by 3D printing with PLA material is related to the working parameters such as extrusion ratio, nozzle diameter, lamination thickness, nozzle temperature and hot bed temperature. Reasonable working parameters can guarantee the accuracy requirement of parts.

(4) The fuel cell performance test results show that the 3D printed fuel cell has the same working performance and working condition as that of the traditional processed fuel cell. The 3D printing system can complete the bipolar plate structure of fuel cell.

References

[1] A. G. Miko, G. Sarakinos, S. M. Leite, J. P. Vacanti: *Laminated three-dimensional biodegradable foams for use in tissue engineering.* Biomaterials *14* (1993), 323–330.

[2] D. C. Sin, X. G. Miao, G. Liu, G. Chadwick, C. Yan: *Polyurethane (PU) scaffolds prepared by solvent casting/particulate leaching (SCPL) combined with centrifugation.* Materials Science and Engineering C *30* (2010), 78–85.

[3] W. J. Li, C. T. Laurencin, E. J. Caterson, R. S. Tuan: *Electro spun Nano fibrous structure: A novel scaffold for tissue engineering.* Journal of Biomedical Materials Research *60* (2002), 613–620.

[4] K. Whang, G. H. Thomas, K. E. Healy: *A novel method to fabricate bioabsorbable scaffolds.* Polymer *36* (1995), 837–842.

[5] Y. S. Nam, T. G. Park: *Porous biodegradable polymeric scaffolds prepared by thermally induced phase separation.* Journal of Biomedical Materials Research *47* (1999), 8–17.

[6] C. X. F. Lam, D. W. Hutmacher, J. T. Schertz, M. A. Woodruff: *Evaluation of poly-stone scaffold degradation for 6 months in vitro and in vivo.* Journal of Biomedical Materials Research *90* (2009) 906–919.

[7] S. Kim, M. S. Park, O. Jeon, C. Y. Choi: *Poly (lactose-co-glycol ide)/hydroxyapatite composite scaffolds for bone tissue engineering.* Biomaterials *27* (2006), 1399–1409.

[8] F. Zhao, Y. Yin, W. Lu, J. Leong, W. Zhang: *Preparation and histological evaluation of biomimetic three-dimensional hydroxyapatite/chitosan-gelatin network composite scaffolds.* Biomaterials *23* (2002), 3227–3234.

[9] H. Yoshimoto, Y. M. Shin, H. Teri: *A biodegradable nanofiber scaffold by electrospinning and its potential for bone tissue engineering.* Biomaterials *24* (2003), 2077–2082.

[10] A. Ovsianikov, A. Deiwick, S. V. Vlierberghe, S. Dubruel: *Laser fabrication of three-dimensional CAD scaffolds from photosensitive gelatin for applications in tissue engineering.* Bio macromolecules *12*, 851–858.

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