ISSN 2706-655X Vol.6, Issue 1: 35-41, DOI: 10.25236/IJFET.2024.060106

Design of Arc 3D Printer Control System and Research on Slicing Algorithm

Su Fu, Jun Yan, Sen Yang

School of Mechanical Engineering, Xi´an Shiyou University, Xi´an, 710065, China

Abstract: *3D printing technology is a new molding method that uses advanced computers to simulate the complex and changeable particle size and shape of different materials in the real world, and realizes the automation of the product manufacturing process through digital processing. Moreover, due to its good testability and strong adaptability, it is widely used in various fields. This article mainly studies the 3D printing method with arc as the heat source, design the control system well, and study the slicing algorithm. The purpose is to realize the low cost and high efficiency of the manufacturing process. This article mainly uses experimental methods, comparison methods, data analysis methods and other methods to test and analyze the 3D printing control system, and conduct in-depth research on arc surfacing and slicing algorithms. The experimental results show that the error of positioning accuracy control using 3D printing technology is less than 0.5, indicating that the 3D printing control system designed in this paper is feasible.*

Keywords: *Arc; 3D Printing; Control System; Slicing Algorithm*

1. Introduction

3D printing technology is a manufacturing process that has emerged in recent years, and its application range has continued to expand and deepen, which not only improves the quality of the process, but also avoids some dangerous behaviors. Although 3D printing is currently very popular, there are still some problems. The material requirements for 3D technology are relatively simple, and problems such as the lack of heat on the printing equipment need to be solved. Therefore, this article is very necessary for the research of slicing algorithm and the design of arc 3D printing control system. The use of arc heating to realize the accurate implementation of the 3D printing control system is the design requirement of this article.

There are many results in the research of 3D printing control system. For example, Gao Jinlan designed an automatic control system for metal component 3D printing equipment, and at the same time designed wire feeding system hardware [1]. Aiming at the disadvantages of traditional three-dimensional 3D printers such as slow running speed, Wang Zhenhua has developed a new type of 3D printer control system that can accurately control the temperature of the heating rod and extruder to achieve precise printing positioning [2]. Yang Xiuzhi said that the arc 3D printing forming process of metal wire has the advantages of high manufacturing efficiency, high flexibility, and low energy consumption [3]. Peng Qiulin discussed the structure and working principle of a 3D printer based on FDM technology. Through a comparative analysis of traditional PID control and fuzzy PID control, a more appropriate control algorithm was selected to provide a reference for 3D printers [4]. Shen Qingchao said that 3D printing technology has brought a lot of convenience to social production and life, but the 3D printing equipment currently on the market is expensive and difficult to control [5]. Therefore, in this article, the design of a 3D printing control system using arc heating is a time-saving, labor-saving and cost-saving approach. The research on the design and algorithm of the system is an improvement of the arc 3D printing process.

This article first explores the robotic welding process, and conducts research on droplet transfer and arc surfacing. Secondly, this article has a preliminary understanding of 3D printing technology, and then the principle of fused deposition molding process control and process exploration. Then analyze the decomposition steps according to the file algorithm, analyze the intermediate steps of the control system, and design the control system based on FDM. Finally, the model data is processed, experiments are designed for testing, and the results are obtained.

ISSN 2706-655X Vol.6, Issue 1: 35-41, DOI: 10.25236/IJFET.2024.060106

2. Arc 3D Printer Control System Design and Slicing Algorithm

2.1 Robot Welding Process

(1) Arc welding robot control system

As the name suggests, the system includes robots and welding equipment. The teaching box and electrical cabinet are the core components of the robot control system. For the robot, the teaching of operating conditions means that in order to perform superior welding, it is necessary to ask for advice in accordance with parameters such as the thickness of the welded part, the shape of the weld, and the quality. As a kind of energy supply equipment, the welding power source can provide the energy needed for welding operations. The function of the wire feeding mechanism is to provide the required welding wire for the robot welding operation to ensure that this welding operation can be performed continuously [6-7].

(2) Droplet transition

When the welding current continues to increase, the phenomenon of droplet transition will occur, which is a transition form of the transition from coarse droplets to jet flow. In the case of welding with a further increase in current, a jet transition phenomenon will occur, and its volume will become smaller. The short-circuit transfer uses a constant speed to feed the wire, but in the arc combustion stage, the welding wire melting speed cannot make the arc length stable, and the arc length becomes shorter, which will eventually cause the welding wire to contact the workpiece molten pool and cause contentment problems [8-9].

(3) Welding arc characteristics

Under normal conditions, this kind of protection welding has a linear relationship between its average current and voltage in the form of short-circuit. The relationship is as the formula:

$$\mathrm{U} = \mathrm{K} + \mathrm{VI} \tag{1}$$

U represents voltage, I represents current, and K and V are two constants.

(4) Surface modification of arc surfacing

Arc surfacing technology is an important branch in the field of surface modification. It uses the welding arc as the heat source to melt the filler wire and coat it on the modified workpiece. Analysis of the surfacing process can determine the best arc surfacing process.

(5) Surfacing and laser remelting heat source

The selection of the heat source model is very important in the calculation of the temperature field. According to the computer processing speed, the Gaussian heat source is selected as the heat source model. The expression of the Gaussian heat source is formula (2):

$$\mathrm{s}(g) = s_{\max} \exp(-3\frac{g^2}{(\overline{g})^2}) \tag{2}$$

Among them, g is the center distance; $\overline{g}$ is the effective heating radius; $s_{\max}$ is the maximum heat source density. There are formulas for mobile heat sources (3)

$$\mathrm{s}_{\max} = (\frac{3}{\pi(\overline{g})^2})s \tag{3}$$

2.2 3D printing Technology

At present, 3D printing technology cannot completely replace traditional manufacturing. The main reason is that there are still deficiencies in materials, precision, and software support. However, 3D printing technology can develop in these directions:

(1) Diversification of materials. New printing materials such as nanomaterials will be continuously developed in the future, making 3D printing materials diversified and reducing material costs [10-11].

ISSN 2706-655X Vol.6, Issue 1: 35-41, DOI: 10.25236/IJFET.2024.060106

(2) Two types of printing equipment. At present, the appearance and scale of 3D printers are developing in the direction of lightness and large-scale.

(3) Development of printing software. 3D printing software will progress toward intelligence, achieving control over material composition and distribution, sample structure, and physical property distribution.

2.3 Process Control of Fused Deposition Molding

(1) Working principle

Before casting begins, the kinematics will be positioned. Then, the temperature of the mold cavity was controlled to be maintained at 55°C, and the hot melt nozzle increased the temperature to 210°C. Then the wire feeding mechanism pushes the wire feeding according to the set forming speed, and scans at the same time. Repeat the above process until the whole part is manufactured without interference in the whole process [12].

(2) Temperature control

1) It is the hot melt nozzle that affects the melt deposition molding technology. Closed-loop automatic control technology uses feedback-based adjustment. The formula for simulating closed-loop automatic control law is as (4)

$$s(g) = Q_e f(g) + Q_i \int_0^g f(g) vg + q_v \frac{vf}{vg} \tag{4}$$

In the formula, s(g) is the target output, f(g) is the error between the given value and the output value, Q_p, Q_i, Q_d are the proportional coefficient, the differential coefficient, and the differential coefficient, respectively.

Fuzzy temperature control. With the advancement of technology, 3D printers are gradually developing in the direction of large-capacity, multi-function, precise control, and intelligence. 3D printer temperature control is generally divided into nozzle temperature and hot bed temperature. 3D printer temperature control is easily affected by changes in the external environment, so fuzzy control can be performed. The key link of the fuzzy control system is the fuzzy controller, as shown in Figure 1. Its composition is as follows:

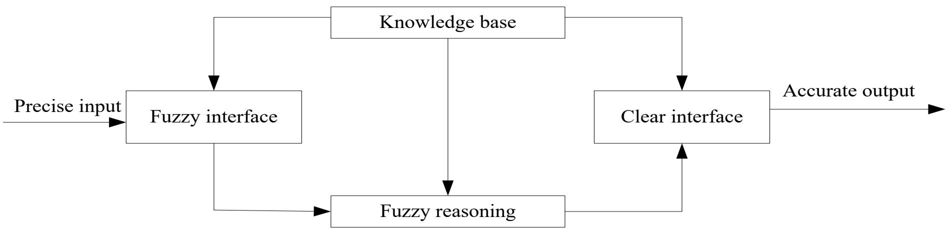

Figure 1: Basic Composition of Fuzzy Controller

The knowledge base plays a decisive role in the fuzzy controller, and the fuzzy interface makes the universe of fuzzy values conform to a certain range.

2.4 3D Printing File Parsing Algorithm

(1) STL file analysis

The STL file is a format that uses triangular patches to record the solid surface. The general flow chart of the data processing of the 3D printing rapid prototyping system based on STL files is shown in Figure 2.

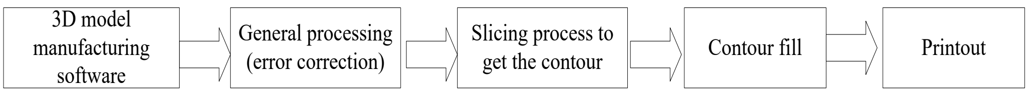

Figure 2: 3D printing data processing flow

ISSN 2706-655X Vol.6, Issue 1: 35-41, DOI: 10.25236/IJFET.2024.060106

(2) Slicing process

The file slicing process in 3D printing rapid prototyping technology is to use a series of parallel planes (the normal direction is generally the Z axis direction) to cut the STL model, which can be sliced at equal distances or unequal distances.

(3) Slicing algorithm

1) Direct intersecting line slicing algorithm: According to the normal thinking mode, first set the height Z of the target slice level, and calculate the positional relationship between the three vertices of all triangle faces and the slice face.

2) The algorithmic idea of dynamic topology reconstruction: As the STL file itself stores only the coordinate information of all vertices of the 3D model and does not contain the topology information, we need to first reconstruct the topology of the 3D model by establishing a suitable data structure.

3) The implementation of slicing algorithm based on model continuity is more complicated.

The recursive relationship of the intersection coordinates between adjacent layers is:

$$\begin{cases} F_a = (a_1 - a_2)/(b_1 - b_2) \\ F_c = (c_1 - c_2)/(b_1 - b_2) \end{cases} \tag{5}$$

Where F_a and F_c are the scale coefficient.

2.5 3D Printing Control System Based on FDM

(1) The specific workflow of the 3D printing system is as follows:

1) Use AutoCAD modeling software to make 3D models and generate corresponding STL files;

2) Connect the host computer and the printer through the communication port, so that the data is transmitted and downloaded to the main controller of the printer;

3) The main controller receives data through the interface;

4) Controlled by the stepping motor drive circuit, the object is printed layer by layer until the positioning is completed.

(2) 3D printing mechanical system

The axis motion system uses a stepping motor as the driving element. The relationship between motor speed and motor drive frequency is:

$$\mathrm{s} = 60\mu[(360R) * p] \tag{6}$$

Among them, s is the speed, μ is the frequency, R is the step angle, and p is the number of subdivisions.

(3) 3D printer control system hardware design

The microcontroller module mainly controls the operation of the system and completes the path planning of 3D printing. In order to achieve precise control of the stepping motor, the drive chip of the stepping motor adopts the micro-step drive chip. The SD card is small in size, has the advantages of fast speed and good security, and is suitable for storing data.

(5) Software design

The main program flow mainly completes functions such as system initialization, online communication, human-computer interaction, temperature control, stepper motor drive control, and Gcode analysis.

2.6 Model Data Processing

For 3D printing, the design of the model is very important. There are two methods for 3D model establishment, one is forward modeling technology, and the other is three-dimensional reconstruction. Forward modeling techniques are divided into three types, namely solid modeling, surface modeling

ISSN 2706-655X Vol.6, Issue 1: 35-41, DOI: 10.25236/IJFET.2024.060106

and parametric modeling.

(1) The STL data file is a standard model file for 3D printing.

(2) The slicing algorithm is a crucial step in the 3D printing process.

(3) The scanning path algorithm is used to determine the movement path of the print head.

3. 3D Printing Control System Test and Verification

3.1 Hardware Selection

The hardware system includes main control processing, motion system control, forming temperature control, data storage, communication, liquid crystal display module, etc. The execution components of the hardware system mainly include the main control board, stepper motors, X, Y, and Z axis stepper motor drivers, limit switches, heating elements, etc.

(1) Motherboard selection

Appearance size: 150×100mm

Microprocessor: STM32

Input voltage: 12~24V

Output current: 10~15A

Motor drive interface: single head is 4 channels

Temperature sensor interface: 3 channels 100K NTC (thermistor)

Support file format: G-code

(2) The stepper motor is an open-loop control motor.

(3) The limit switch is a miniature circuit board with a switch.

(4) The driver controls the number of pulses to control the angular displacement.

(5) The heating actuator is mainly completed by heating rods and hot beds.

3.2 Choice of Software System

The software system of the 3D printer mainly realizes the function of converting the three-dimensional model of the part into data instructions (Q code). The slicing software selected in this article is a derivative version of Cura, and the motherboard firmware is Marlin.

3.3 System Calibration and Accuracy Test

After the hardware and software parts of the system are configured, the device must be calibrated before printing can be officially started. It consists of three parts: measuring the parameters of each component, calibrating the original position and leveling the workbench. Positioning accuracy is an important performance index of 3D printing. The higher the accuracy, the smaller the gap between the printed object and the model.

4. Experimental Verification

4.1 Absolute Positioning Accuracy Test

After the system returns to the origin, control the print head to move to 8 vertices, and return to the origin after the position data is measured. The specific conditions are shown in Table 1:

ISSN 2706-655X Vol.6, Issue 1: 35-41, DOI: 10.25236/IJFET.2024.060106

Table 1: Absolute Positioning Accuracy Measurement Data

Instruction location	Actual location	error
200,200,0	199.7,199.6,0	-0.3,-0.4,0
-200,200,0	-200.2,199.7,0.1	-0.2,-0.3,0.1
200,-200,0	199.9,-200.1,0	-0.1,0,0
-200,-200,0	-200.1,-199.8,0.1	-0.1,-0.2,0.1
200,200,100	199.8,200.1,100.1	-0.2,0.1,0.1
200,-200,100	199.7,-200.3,100.2	-0.3,-0.3,0.2
-200,-200,100	-199.6,-199.9,99.9	-0.4,-0.1,-0.1
-200,200,100	-200.1,199.8,100	-0.1,-0.2,0

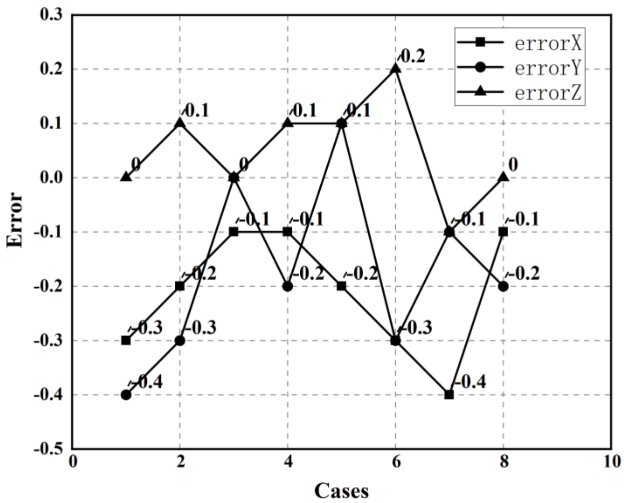

Figure 3: Absolute Positioning Accuracy Measurement Error

As shown in Figure 3, we can conclude that the absolute positioning accuracy error of the control system is maintained at 0.5, and its error value is small.

4.2 Print Test

After the system is powered on, it first performs the operation of returning to the origin to level the printing plane, and at the same time heat the printing nozzle to melt the filaments and wait for printing. This article describes a mountain eagle. It can be seen from Table 2 that the error in the horizontal direction is the largest, as follows:

Table 2: Mountain carving printing error

	Theoretical value	Actual value	Error
X	30	29.95	0.05
Y	40	40.03	0.03
Z	50	49.98	0.02

5. Conclusion

3D printers will become an important direction in the future of high-tech development of mechanical processing equipment, aerospace, biomedicine, and electronic information engineering, and gradually show its strong vitality. The rapid development of 3D printing technology has brought convenience to people and solved many problems for us. This paper studies arc surfacing and 3D printing control systems and slicing algorithms, and has a detailed understanding of the role and process principle of arc surfacing. It also designs the control system in the aspects of establishment of models, file generation, file analysis, data processing and target generation. The experimental results found that the control system designed in this paper has relatively small errors, and can be used in real

ISSN 2706-655X Vol.6, Issue 1: 35-41, DOI: 10.25236/IJFET.2024.060106

life where accuracy is not strictly required. Of course, in order to improve the accuracy of the control system, further research is needed.

Acknowledgments

The authors are grateful for the support of Innovation and Practical Ability Project Fund of Xi 'an Shiyou University (Project Number: YC22121022).

References

[1] Gao Jinlan, Zhu Jiali, Li Zhuo.(2019) Design of automatic control system for 3D printing of large metal components [J]. Automation Technology and Application, 038(006): 15-19.
[2] Wang Zhenhua, Xue Yanbing, Xu Linna.(2017) Control system design of stereo 3D printer based on STM32 [J]. Automation Technology and Application, 36(003): 130-134.
[3] Yang Xiuzhi, Hua Wenlin, Dong Chunfa, et al. (2016)Research on arc 3D printing forming of metal wire[J]. Journal of Hubei Institute of Technology, 32(003):1-4.
[4] Peng Qiulin. (2018)Analysis and research of 3D printer control technology based on FDM technology [J]. Internal Combustion Engine and Parts, 000(013):242-243.
[5] Shen Qingchao, Li Zhirui.(2017) Design of 3D printing control system based on ardunio[J]. Electronic Testing, 000(018): 9-11.
[6] Liu Jin, Bu Yanan, Jin Yuhan, et al.(2016) Design and implementation of desktop 3D printer control system[J]. Computer Applications and Software, (10):325-327.
[7] Zhang Jing, Wang Yangping, Wang Wenrun.(2018) Design and research of innovative experiment of 3D printing in colleges and universities[J]. Heilongjiang Science and Technology Information, 000(001):173-174.
[8] Zhang Jing, Wang Yangping, Wang Wenrun. (2018)3D printing innovation experiment design and research in colleges and universities[J]. Science and Technology Innovation, (01):178-179.
[9] Huang Jianfeng, Yang Xin, Luo Senlin.(2017) Research on motion control of embedded 3D printer system[J]. Wireless Internet Technology, (5):44-46.
[10] Lai Xuhui, Wei Zhengying. (2019)3D printing slicing algorithm and partition scanning strategy for CNC machining system[J]. Transactions of the Chinese Society of Agricultural Engineering, 35(12): 58-64.
[11] Shang Zhigao, Guo Tao, Wu Yuxuan, et al.(2019) Design and research of foldable FDM 3D printer[J]. Technology and Innovation, (10):47-49.
[12] Xia Wei, Zhang Lichao, Xiong Haiyang. (2016)Design and implementation of metal composite 3D printer control system based on Simotion[J]. Mechanical and Electrical Engineering, 033(002): 151-154, 159.