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The Key Technology Research Based on Desktop 3D Printer of Parallel Mechanism

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Abstract: The paper aims at desktop 3D printer of parallel mechanism. It describes the performance requirements of the 3D printer mechanism. It compares the common performance institutions, obtaining the more suitable mechanism for 3D printer. It uses Solidworks to complete the overall printer model design. Then analysis and compare the key technology 3D printer, motor selection, positioning way and extrusion device obtaining for the suitable design scheme. Complete 3D printer machine design and prototyping; finally use the prototype to print out high-precision products.

Keywords: parallel mechanism, 3D printer, motor selection, positioning way, extrusion device

INTRODUCTION

3D printing technology originated in the1980s [1]. Different from traditional printing technology, 3D printing models the three-dimensional digital design model, through layering software and CNC machining molding and other steps, using plastic, ceramic powder, metal powder through the emerging technologies by layer by layer to stack and construct a physical product. 3D printing technology compared to conventional material removal processing technology, which can minimize or even avoid wasting containment materials. With the rapid development of 3D printing, 3D printing technology has been widely used in aerospace, marine, defense, medical, construction and other areas. In 2005, the originator of desktop 3D printer- Rep Rap appeared, with the appearance of desktop 3D printer, it makes the manufacturing mode of development starting from the mass production of small-scale custom personalized. Everyone can even be able to complete the invention, innovation, customization and low-cost production process [2]. 3D printing industry in China is still in its infancy. Desktop 3D printer 'price on the domestic market substantially 8,000 to tens of thousands of dollars, it can't walk into people's lives. Therefore, the design and manufacture of a low-cost to meet the printing needs of individual desktop 3D printer is necessary.

1. AGENCYPERFORMANCE REQUIREMENTS OF 3D PRINTERS AND APPLICABLE AGENCIES

1.1 Agency performance requirements of 3D printers

It is essentially saying that 3D printer is through a variety of means to achieve the position control of the mechanical organization's directions of XYZ [3] from the motion area. When the directions of XYZ motions, the basic physical conditions [4] of rapid prototyping technology is as follows. The direction of X, Y control plane and scan by the scanning driving system control. The direction of Z control perpendicular to the XY plane of movement by a servo motor. Z axis should have a certain carrying capacity and smooth motion. From the sports performance, it requires good acceleration performance to achieve rapid movement. From the motion accuracy requirements of small errors, it is in order to improve the accuracy of the product. Common 3D printer institutions have tandem structures and parallel institutions.

1.2 Tandem structure and parallel structure

3D printer of tandem structure is the most popular on the market. However, this structure is more complex during the installation, maintenance is also very difficult, and there is a large movement of inertia, low stiffness, error accumulation and other shortcomings. Besides, because of the high precision machining of screw, the optical axis, the machine has high cost.

Parallel structure is a new mechanism. It uses Parallel motion mechanism which uses traction nozzle, limiting the nozzle rotational degrees of freedom in all directions. Therefore it ensures the nozzle in a horizontal plane work in order that the nozzle has a good trajectory and precision work.

1.3 Suitable mechanism for desktop-level 3D printer

Based on the analysis of desktop 3D printer performance, it requires for desktop 3D printer mechanism to have smooth motion, high-speed, high-precision features. Therefore, it requires the parallel mechanism to have the features such as structural stability, high accuracy, stiffness, low inertia, high carrying capacity, low load sports; sports inverse solution is simple and easy to control. In parallel mechanism, Delta [5] mechanism can achieve three-dimensional translational and positioning accuracy is much higher than the series model agency. Today has been successfully applied in the case of 3D printing technology, shown in Figure 1. This desktop 3D printer is based on the Delta mechanism to optimize the design of parallel.

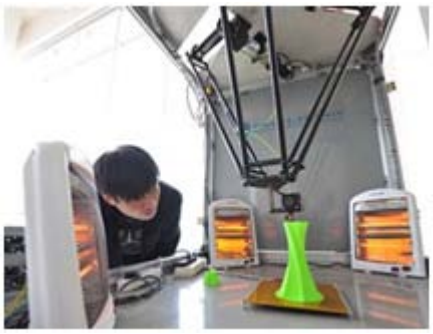

Fig1: the actual case of 3D printer

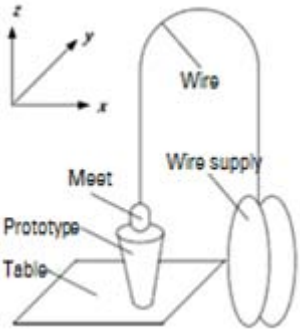

Fig 2: working principle of FDM 3D printer

2 BASED ON PARALLEL MECHANISM DESKTOP 3D PRINTER DESIGN

2.1Working principle of FDM 3D printer

FDM melt laminated molding technology is one of the most commonly used 3D printing technologies. It uses the high temperature to melt into a liquid material through the print head extrusion to cure, and finally arranges in three-dimensional space on a physical perspective.

Based on the principle FDM 3D printer is shown in Figure2. Computer controlled rapid prototyping machine heating nozzle, basing on cross-sectional data for each layer of the x-y plane motion. The wire feeder sent the wire to the nozzle, heated, melted and extruded adhesive from the nozzle print material to the working platform, and then rapidly cooled and solidified. This process is repeated until the completion of the entity.

2.2The overall model design on desktop 3D printer of parallel mechanism

Based on FDM melt laminated molding technology and Delta mechanism design, desktop 3D printer parallel is designed as shown in FIG. 3. The overall structure uses aluminum alloy structures which is made regular triangular prism .It consists of the group parts, transmission parts, and the execution group parts. The overall design flow chart shown in Fig3, and the design model shown in Figure 4.

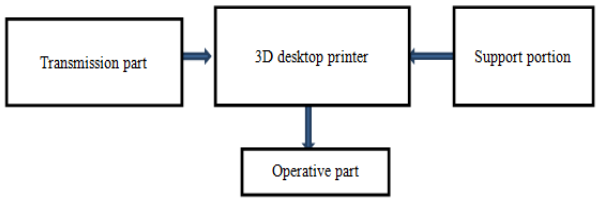

Fig 3: the design flow of Desktop 3D printer

Bracket part is the overall framework. It ensures the stability of the printer. Transmission part is responsible for power supply during the printing process. Operative part is responsible for implementing the print command.

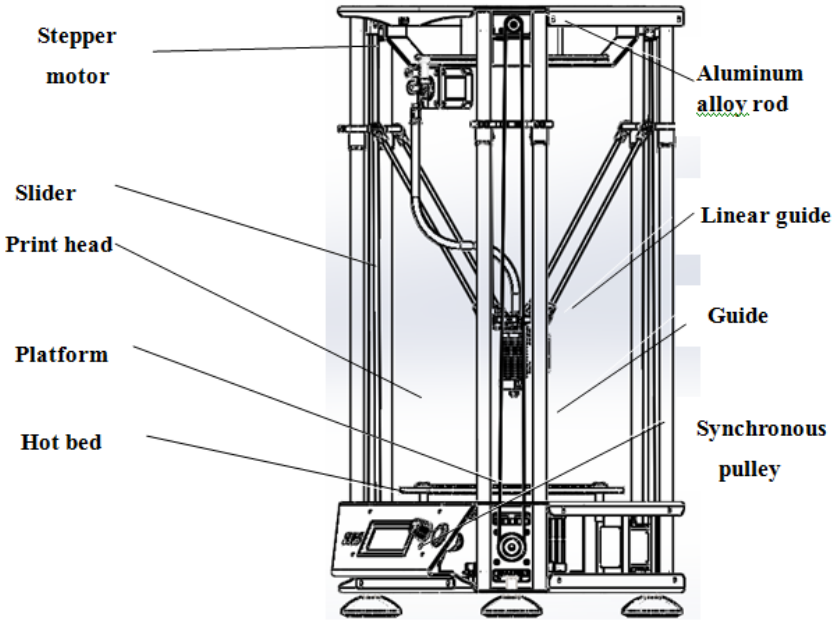

Fig 4: Schematic of parallel desktop 3D printer

Overall model shown in Figure 4 as the author designed parallel desktop 3D printer. The overall structure of the printer is made of aluminum alloy structures are of triangular prisms. It cooperates with the linear guide, so

that the overall structure of rigid, solid and strong, easy to control assembly accuracy. The size of overall printer highs 60cm, the length of triangular prism is 30cm. The three sides of a triangular prism edge mounted rails. It relies on the aluminum material side edge machining accuracy to ensure vertical slide and rigidity. The bottom rail is equipped with three stepper motors. Stepper motor drives the belt wheel on the shaft to rotary motion. Pulleys rely on the slider together with the timing belt. It toothed pulley rotational motion into linear motion of the slider. And drive the slider above and below the rail travel. Three sliders rely on six sliders connecting to the printer head. When the stepping motor to drive the slider up and down, relying on the nozzle rod rigidity to complete traction, realizing the print head position control. Printed materials required by a polyethylene tube which is fed from the top of the print head. Fed power which the raw materials needs is provided by a stepper motor. The stepping motor is rotated clockwise when feed. Clockwise rotation is discharged. The bottom of the printer is the printer working platform which is equipped with a hot bed platform. Purpose of hot bed is when printing ABS to let the first layer be not deformed and easily stick to the platform. Printer use open frame. So it is easy to level printer platform and late printer's expansion and maintenance. In the top side of the printer is a LCD display for real-time monitoring of the position of the nozzle, the nozzle temperature and time display.

3 THE KEY TECHNOLOGY OF 3D PRINTER OF PARALLEL MECHANISM

3.1 Motor selection

Table 1: Comparison of motor performance parameters

motorparameter	stepper motor	DC motor	servo motor
torque and speed	Low-speed full torque, speed increases the speed dropped	Speed increases, the torque variation is small	Almost linear force and speed
dynamic characteristics (speed / acceleration)	Small	Small	Good acceleration characteristics, high-speed
stability	Acceleration fixed frequency will cause problems	Over the entire dynamic range of smooth, quiet movement	Wide dynamic inner smooth motion
target location	Open-loop control, if the overload or over speed, the target position cannot be reached	Closed-loop control to achieve the target location (unknown error correction function)；Under PID tuning is not correct, correct the position error；Possible position beyond or persistent error	More speed, smaller step away, no backlash.

Motor is one of the important parts of the printer, which is used in positioning systems, extrusion systems. It has a great influence on the stability and the print resolution. According to Table 1 the Characteristics of the DC motors, stepper motors and servo motors, Considering the printer's speed and cost, select the stepper motors. Which selection of the feedback signal is not required, velocity output is directly controlled stepper motor. Stepper motor receives an order and executes a step. Compared to ordinary motor, selecting stepper motor can make the accuracy of the 3D printer more convenient to control.

3.2The selection of positioning way

3D printer's positioning way influences the shaping accuracy and stability of the printer in a large extent. Commonly used in 3D printers targeting methods are Cartesian positioning and Core XY positioning.

Cartesian coordinate targeting is often used in tandem printer. It represents the position of point in space, but it is different from rectangular coordinates. These two coordinates can be converted to each other. Cartesian coordinate positioning's stability is not enough; it is likely to cause targeting errors which lead to poor accuracy printout. Parallel 3D printing is a new spatial positioning structure which is in Core XY location [6]. It is an indirect way of targeting by joint control of the plurality of nodes via slider, realizing the displacement of the slider. Since the joint indirect control, making every error of control terminal is shared with each node. It makes the positioning error be greatly reduced. It's positioning principle shown in Figure 5.

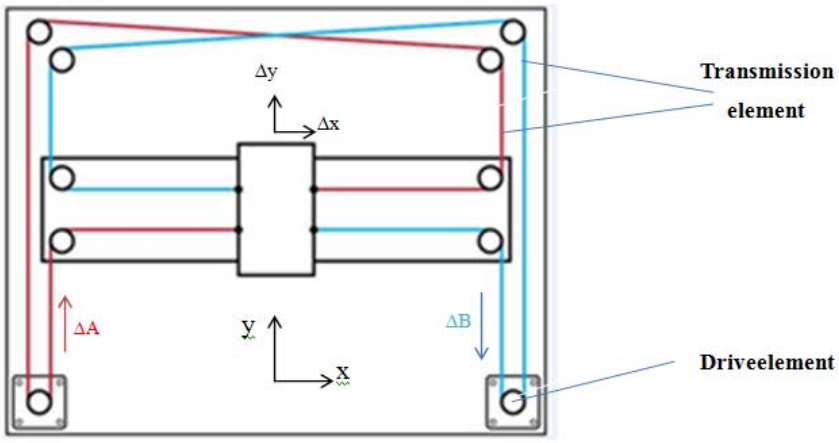

Fig 5:Core XY positioning principle diagram

As shown in Figure 5，the drive element is a stepper motor. The red belt and the blue belt is the transmission element. Stepper motor through a belt and the belt bypass the small pulley. Extrusion apparatus moving operation and drive the center.

The transmission element is under the action of the driving element. If it along the ΔA, ΔB arrow's opposite direction, equal value of the displacement move, the actuator will move along the Y-axis. If it along the ΔA, ΔB arrow's same direction, equal value of the displacement move, the actuator will move along the X-axis. If ΔA, ΔB isn't equal, then the actuator will achieve XY axis. Among them, the mathematical relationship of ΔA, ΔB and the amount of displacement ΔX, ΔY is as follows [7].

$$\Delta X = \frac{\Delta A + \Delta B}{2};\ \ \Delta Y = \frac{\Delta A \times \Delta B}{2};$$

$$\Delta A = \Delta X + \Delta Y;\ \ \Delta B = \Delta X - \Delta Y$$

In expression, ΔA,ΔB- the actuator's direction of movement ;

ΔX、ΔY- the actuator's amount of displacement ;

The subject of 3D printers used parallel positioning technology which is the improvement program based on the Core XY positioning. Through introducing a third stepping motor drive, actuator force to each other by three 120 ° angle of traction. Through a differential control, actuator positioning, achieving three-axis print head.

3.3Extrusion device

Extrusion apparatus consists of the feeding device and the extrusion nozzle. Extrusion device feeding method and melt extrusion nozzle continuity have great influence on parts of print quality. Smooth feeding can ensure the smooth progress of the printing process and ensure extrusion nozzle clogging do not occur.

Common extrusion device has Direct Driver Extruder and Wade's Extruder. Direct driver Extruder uses a stepping motor directly connecting to the squeeze rolls to squeeze the wire. It requires a large torque stepper motor, simple structure and good maintenance. But it is not suitable for long distances squeeze wire. Gear squeeze wire uses a stepper motor to connect a pair of gears deputy to squeeze wire. The advantage of this device is that the current parameters have less demand on the stepper motor. While the introduction of gear afterburner, therefore, it would be better to squeeze the power wire. Therefore, this device uses a gear squeeze wire mode. The principle is shown in Figure 6.

Feeding device is responsible for the strip delivery, feeding gear and auxiliary gear with each other. The principle diagram of the feeding device is shown in Figure 6. Schematic diagram of the extrusion apparatus is shown in figure 7.

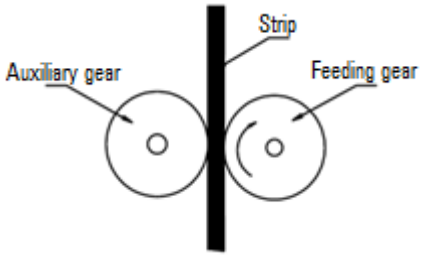

Fig 6: The principle diagram of the feeding device

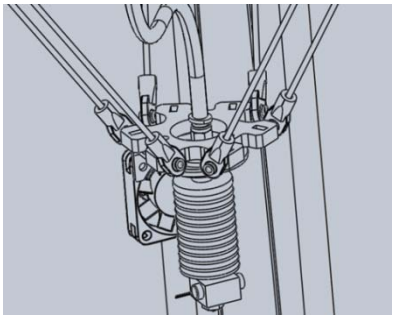

Fig 7:Schematic diagram of the extrusion apparatus

Feeding Gear as a capstan is primarily responsible for providing strip feeding power required. Auxiliary gear from the role of positioning and can effectively reduce the drag strip feed. The gap slightly smaller than the diameter of the strip between the feed gear and the auxiliary gear. So when squeezed into the strip feeding gap between the gear wheel and auxiliary friction generated. So that strip move the direction as figure 5. It utilizes the elastic force of the strip itself to ensure the grip feeding gear. Ensure the material not to withdraw [8]. The feeding accuracy can be guaranteed by adjusting the angle of the step.

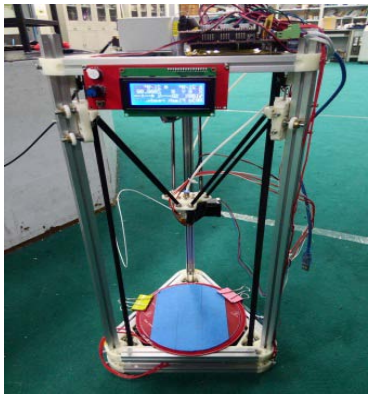

Fig 8:The printer object

Fig 9:Some parts print

Taking into account the key technical points when designing desktop 3D printing, the final design of the desktop 3D printer is shown Figure 8. And use the printer to print out the various parts shown in Figure 9.It is found that the printer motor speed is appropriate when printing. Extrusion positioning device and sprinklers all meet the design requirements. The parts print out have high precision. The effective working stroke of X, Y, Z-axis is not less than 150mm. Repeat positioning accuracy is not greater than 0.1mm, the resolution of 0.01mm. It can achieve the same precision equipment in the market, but the cost is greatly reduced.

4.CONCLUSION

In summary, parallel desktop 3D printer is based on the design optimization of the Delta .It by means of high precision, rigidity; inertia is small, easy to control, etc. It adopts new spatial targeting Core XY positioning. It take the stepping motor as the driving force control and has reasonable speed output. Extrusion device by means of a gear pair of wire feeding and crowded, can not only reduce the feeding resistance but also achieve good ejection of molten material. Prototype tests show that after parallel mechanism desktop 3D printer was designed with this several key technology, it can print out the same high precision equipment, high-intensity product in the market efficiently. But the printing cost compared with the equipment available in the market is low. It is suitable for families and small businesses and it is widely used.

SOURCE OF PROJECT

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