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Research on Accurate 3D FDM of Sheet Part

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Abstract: Since it is easy for thin plastic product to have surface defects during molding, this research analyzed, on the basis of FDM principle, the main factors for errors in molding and designed the relative experiment. The research focused on the co-relation between surface problem and the factors of layer thickness, extruding and printing speed in molding, and obtained the combined parameters with the least errors for accurate molding. Layer thickness is 0.2mm; extruding speed: 30mm/s; printing speed: 40mm/s. A general principle for optimizing molding parameters is also obtained, which provides a guide for research on accurate 3D FDM for thin plastic part.

Keywords: 3D printing technologies, FDM, Thin plastic parts, The errors for quality, Accurate surface quality

1. Introduction

With the fast development in many aspects of social life, people increasingly like to use thin and light plastic products, which have already appeared in various industrial areas, with the advantages of light weight, low cost and compact structure. Rapid prototyping has attracted much attention since its appearance, for the reason of its rapid typing, low cost, high integration, no restriction of material, and capability of typing complex structures and shapes that can not be molded by conventional techniques. However, the present 3D FDM, like injection molding, has not satisfying accuracy in typing parts. So how to improve accuracy in typing is an important researching area in rapid prototyping. Eric and Kannan with their colleagues[1-3] established a field of reasonable temperature for fused deposition modeling based on ANSYS finite element simulation polymer filament molding. Ahn and Pandey[4] respectively did a research on how to improve the surface quality in FDM. Wang Tianming[6] did research about the effect of factors such as layers, environmental temperature, section length and the material's linear shrinking ratio on buckling of the product. These researches show that the key for sheet part's accurate typing with a good surface quality is to choose a proper typing technique. This paper focuses on accurate typing of platy thin-walled part. In order to solve errors appearing in sheet part typing with the technique of FDM, research has been done to find out the relationship between technological parameters and printing precision, which can help to optimize printing parameters in practical production.

2. Technological Process and Principle of Rapid Prototyping

This is a computer aided rapid prototyping, aimed at obtaining a target sample, with some following processing to meet the requirements of the design in the product's appearance, strength and functions, so as to precisely produce a model or physical product.FDM is a molding technique in which fuse of thermal plastic material or wax or metal with hot melting and caking properties is squeezed out from spray nozzle, and deposits according to scheduled track and speed to mold a part. This process is controlled by the computer, in which the hot nozzle moves according to scheduled data of X,Y interface outline and sprays the solution smoothly on each interface. After each spray, the solution soon clots and bonds with the previous layer.

3. Experiment of accurate FDM for sheet part

3.1 Experiment equipment and conditions

The equipment for this experiment is a ColiDo2.0 desktop 3D printer with 0.1mm accuracy and a single nozzle. The material to be typed is filiform PLA, with a diameter of 1.75mm. Extrusion speed is 30mm/s; the nozzle diameter is 0.4mm; the nozzle temperature is 205℃; the temperature for vitrification platform is 70℃; the flowing speed is 20-120mm/s; layer resolution ratio is 0.1-0.4mm (adjustable); the printed part's maximum size is 225mm×145mm ×150mm. Fig 4 shows the ColiDo2.0 desk, and 3D printer. The measuring tool for this experiment is TERMA micrometer caliper and ordinary PD-153 vernier caliper.

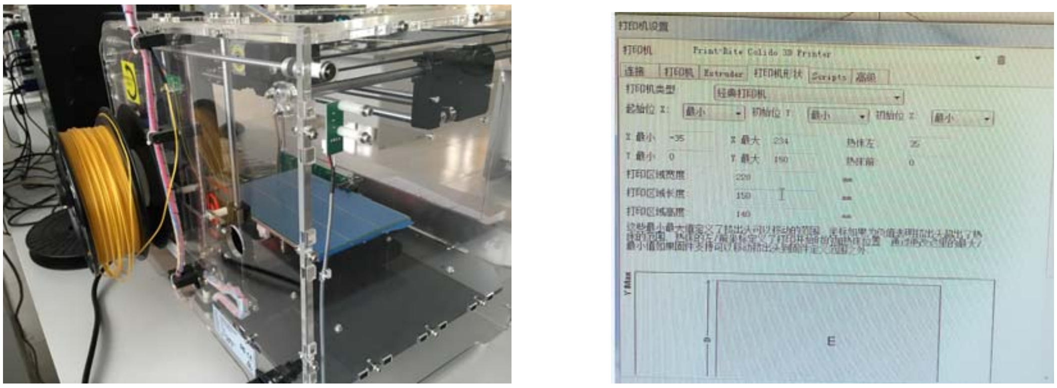

Fig.1 CoLiDo2.0 desktop 3 D printer

3.2 Experiment design

Factors that can affect accuracy of sheet part printing include printing system errors, layer thickness, extrusion speed, CAD disperse section, material shrinking, fuse width, etc. This research focuses on the factors of layer thickness and extrusion speed. With the controlling variate method, the two factors are taken as two dependent variables, for each of which three experiments are designed. The sizes of the printed part from the six experiments are compared with the the designed sizes. Then a conclusion can be drawn. Material for the experiment is PLA, a product made from starch extracted from reproducible and biodegradable plant. PLA has the properties of heat stability and smooth surface. Its processing temperature is 170~230℃,with good physical and mechanical properties. The printed part is easily processed and has strength of extension and wide application. In the experiment, the part's size of 80mmx(length), 80mmx (width), and 2mm (height) are set up and put into the data bank of the 3D printer. During the printing, the factors of layer thickness and extrusion speed are changed for times and the printed parts are measured with vernier caliper and micrometer caliper to compare its size with the ones in X, Y, Z directions. The size error is difference value between the sizes of the printed sheet part and the designed one.

(1) The effect of thickness on the printed part

The filling way is set up for the printer as that of around the linear type, shown in Fig 2. The speed is set up as 30mm/s; layer thickness is respectively 0.1mm, 0.2mm and 0.25mm, the printed entity pictures.

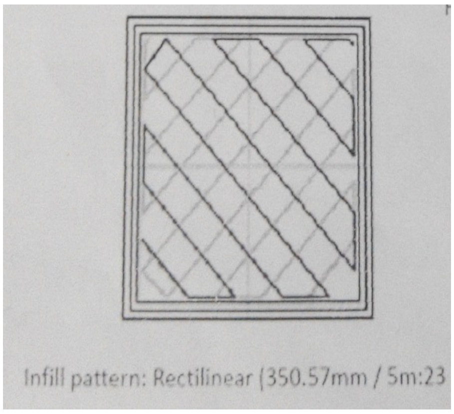

Fig.2 Layering thickness of sheet material and fill method

Tab.1 The size of error (mm) under the different layer thickness

Layer thicknes (mm)		0.1	0.2	0.25
The number of layers		20	14	10
The size error	X	0.13mm	0.04 mm	0.09 mm
	Y	0.28 mm	0.08 mm	0.1 mm
	Z	0.28 mm	0.06 mm	0.12 mm

(2) The effect of extrusion speed on the accuracy of sheet part printing

Based on the previous experiment, now the layer thickness is set up as 0.2mm; filling way is of round the linear type; the extrusion speed is respectively 30mm/s, 40mm/s and 60mm/s. The data of the above sheet entities measured are shown in Table 2.

Tab.2 The size of the error (mm) under different extrusion speed

Size error(mm/s)		30	40	60
The size error	X	0.03mm	0.05 mm	0.12 mm
	Y	0.02 mm	0.09 mm	0.18 mm
	Z	0.02 mm	0.07 mm	0.2 mm

3.3 The effect of speed on the surface of the printed part

For this experiment, JB-6C contact pin type surface roughness measuring instrument is used, which is often used to measure various different shapes and its assessment method is fitting process. The measurement parameters for various different shapes include straight line, step, arc, convex-concave, straightness, groove pitch, gradient, horizontal distance, vertical distance, arc radius, etc. This device can also measure the surface roughness, such as that of plane and arc. It is used to measure the roughness of the surface of slope, bore, out cylinder, quirk and sphere. The parameters obtained by this instrument are shown in Table 3.

Tab.3 JB-6C contact pin type surface roughness measuring instrument parameters

measurement repeatability	3%
Accuracy of straightness Measurement	0.4μm
Measurement range	800μm
Scan length	25mm, 50mm (mm)
Measurement speed	0.1mm/s, 0.32mm/s, 0.5mm/s
Assessment length	λc×3, 4, 5, 6, 7 (1.0-17.5mm) (mm)
Sample length	λc×3, 4, 5, 6, 7 (1.0-17.5mm) (mm)
Measurement parameter	Ra.(Rmax.Ry).Rt.Rp.Rpm.Rz(jis).Rr.Rv.R_{3Z}.Rsm.Rsk.R

On the surface roughness measurement instrument there is a drive box, which has a 10mm standard linear guide rail. During measurement, the sensor just does rectilinear motion alongside the guide rail and at the same time data are collected through the motion of the raster and contact pin of the inductive sensor. The motion of the pin can be controlled to move horizontally or vertically by the drive box button or software interface.The speed affects the surface of the printed part to a certain degree. In measuring process, the start point is the center of the part and goes along the edge-ways until the pin leaves the part. The filling way is of around the linear type; printing speed is 40mm/s, 60mm/s and 80mm/s. It is conducted in the following way:

3.4 Analysis and Conclusion of the Experiment

with the increase of typing speed, the distance between the two crests or two troughs increases on the surface roughness curve, therefore the surface is becoming rougher and the accuracy decreases. So when the extrusion speed is 40mm/s, the printed part has the best surface. If extrusion speed is faster than the filling speed, the material is easily accumulated excessively around the nozzle; vice versa, if the fuse ceases at the nozzle, the filling may pauses. Therefore the speed of extruding fuse must match with the filling speed, so as to obtain a better surface for the printed part. For another factor in FDM, the thickness of layer directly affects the printed quality. Generally, the thicker the layer is, the more obvious the staircase effect will be. Nevertheless, the thinner the layer is, the slighter the staircase effect will be in the printed part. In order to improve the efficiency and the quality of part printing, the best match of extrusion speed and filling speed is very important. It is suggested to adopt polishing process after typing with the reasonable thickness of layers. At the same time, in typing, the precompensation for curing shinkage of the part size and the precompensation for fuse width are definitely necessary. The staircase error appears mainly from greater thickness of layers. To eliminate this error, the fundamental method is to optimize layer direction, decrease the layer thickness, and decides on reasonable thickness.

4. Conclusion

(1) This research describes the principle and technology of FDM, and on the bases of analysis of error principle and errors during typing and aftertreatment, the affecting factors are discovered from FDM for sheet typing and the solution is worked out.
(2) This research focuses on the effect of the three factors of extrusion speed, thickness of layers and typing speed on the sheet part typing quality, and provides a general principle for optimizing technological parameters for high quality FDM.
(3) For thickness of layer, this research discovers that the thinner the 2D layer is, the slighter the staircase effect for the part will be and the higher the accuracy for typing will be. Oppositely the thicker the layer is, the more obvious the staircase effect of the printed part will be. In order to improve the accuracy and production efficiency, it is better to choose reasonable layer thickness and give the printed part a polishing after typing.
(4) This research has the conclusion that typing speed affects surface quality of the printed part. With the increase of typing speed, the curve of the part surface roughness has a increasingly longer distance between the two crests or the two troughs, and the surface roughness value increases, too. Therefore, if the typing speed is set up at 40mm/s, the accurate surface of the printed part will be obtained.

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