Research on the Influencing Factors of FDM 3D Printing Accuracy

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Abstract. Printing accuracy is a general issue of FDM 3D Printing, take rectangular pieces made of PLA as an example, The effects of bottom/top thickness, filling density and placement position on the dimensional accuracy of printed pieces are studied. The results show that the influence of each factor on the dimensional accuracy of the workpiece has a directional difference.

1. Introduction
Fused deposition modeling (FDM) is a kind of technology which can heat the filamentous material to melt state, spray the filamentous material on the worktable according to the model outline through the nozzle, and accumulate layer by layer until the whole workpiece is printed. FDM has the advantages of cheap material, low equipment maintenance and operation costs, small occupied space, environmental protection and rapid forming of workpiece, etc. it is one of the most promising forming technologies in 3D printing technology [1]. But in the forming process, it also generates surface roughness, poor precision, low strength and other quality problems [2]. These problems are usually affected by the printing parameters, so the industry has done a systematic study on the printing process parameters, slice parameters, scanning speed and so on [3-8]. Galantucci et al [9]. analyzed the effects of process parameters such as layer height and printing speed on Surface roughness; The results of Chen Jinying [10] showed that, when the model was converted into STL format, low-level parameters, model wall thickness and water tightness had obvious influences on the printing quality of the parts; Han Jiang et al [11]. and Yang Jiquan et al [12]. used orthogonal experimental method to select the optimal parameter ratio and realize the optimization of printing parameters. In this paper, the factors affecting the precision of FDM are studied experimentally.

In this paper, samples of the same material and different experimental parameters of the same size are prepared by using FDM 3d printer. According to the experimental results of samples’ size and shrinkage in the direction of length, width, height, maximum warpage, the influence of 3D printer parameters on sample’s precision is analyzed. The data and experience have been accumulated for the proper selection of printing parameters, which has guiding significance for obtaining the correct samples’ size quickly after printing.

2. Experimental Method

2.1 Experimental Equipment
This experiment uses the FDM desktop 3D printer. It is mainly composed of worktable, nozzle of 0.4 mm, control panel and control system. When facing the operation panel, the left and right direction is defined as the X-axis, the front and back direction as the Y-axis, and the top and bottom direction as
the Z-axis. It supports files in XJ3DP format, which can be copied and printed by U disk or memory card, with simple operation and high printing precision.

2.2 Experimental Material
In this experiment, polylactic acid (PLA) filament with a diameter of 1.75mm is used as the material.

2.3 Experimental Model
A 30mm x 20mm x 10mm rectangular model is established by Ug software, and the STL format file is derived.

3. Set Process Parameters

3.1 Set the Bottom/Top Thickness
The paper uses Cura software to set the bottom/top parameters of the model under the same conditions of other parameters, as shown in Table 1.

| sample | Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | Group 6 | Group 7 |
|--------|---------|---------|---------|---------|---------|---------|---------|
| Bottom/top thickness(mm) | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 |

3.2 Set the Packing Density
The paper uses Cura software to set the packing density of the model under the same conditions of other parameters, as shown in Table 2.

| sample | Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | Group 6 |
|--------|---------|---------|---------|---------|---------|---------|
| Packing density(%) | 0 | 20 | 40 | 60 | 80 | 100 |

3.3 Set the Locating Place
The paper uses Cura software to set the locating place of the model under the same conditions of other parameters, as shown in Table 3.

| sample | Group 1 | Group 2 | Group 3 |
|--------|---------|---------|---------|
| locating place | 30 mm x 20 mm for bottom | 30mm x 10mm for bottom | 20mm x 10mm for bottom |

4. Results and Analysis
The XJ3DP file is transferred to the printer by using a U disk to complete printing. When printing, record the printing time of each part, use micrometer to measure the size of the part in the direction of length, width and height, in order to ensure the accuracy and comprehensiveness of measurement, use a dial indicator to measure the planeness of the part in the direction of length, width and height. In order to avoid the error caused by non-uniform datum during measurement, in planeness measurement, the plane far away from the workbench in the z-axis direction during printing is first taken as the datum, and then the two adjacent sides are taken as the other two datum. Study the effects of different process parameters on the printing shape size.
Table 4. Dimensions of samples with different bottom/top thicknesses

| sample        | Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | Group 6 | Group 7 |
|---------------|---------|---------|---------|---------|---------|---------|---------|
| Length(mm)    | 29.99   | 30.02   | 29.98   | 30.02   | 30.01   | 29.98   | 30.01   |
| Width(mm)     | 19.66   | 19.64   | 19.62   | 19.63   | 19.66   | 19.64   | 19.63   |
| Height(mm)    | 10.11   | 9.97    | 9.86    | 9.87    | 9.86    | 9.85    | 9.86    |
| Shrinkage in  | 0.01    | -0.02   | 0.02    | -0.02   | -0.01   | 0.02    | -0.01   |
| the direction of length   |         |         |         |         |         |         |         |
| Shrinkage in  | 0.34    | 0.36    | 0.38    | 0.37    | 0.34    | 0.36    | 0.37    |
| the direction of width    |         |         |         |         |         |         |         |
| Shrinkage in  | -0.11   | 0.03    | 0.14    | 0.13    | 0.14    | 0.15    | 0.14    |
| the direction of height   |         |         |         |         |         |         |         |

The negative values in Table 4 indicate the increase in size of the sample, indicating that no shrinkage has occurred. As shown in the table, the sample has the smallest error in the direction of length and the largest error in the direction of width, indicating that the contraction of the sample is different in printing directions, and the contraction of the sample has directivity. The size values of the first group and the second group are relatively large in the direction of height, due to the uneven surface caused by fewer filling layers at the top; From the third group to the seventh group, the size change in the direction of height is small, indicating that the bottom/top thickness is greater than or equal to 0.4mm and no uneven surface is generated. After linear fitting of the width, height and length of the sample with the bottom/top thickness of 0.2mm, 0.3mm, 0.4mm, 0.5mm, 0.6mm, 0.7mm and 0.8mm, the fitting formulas for the length $f_l(t)$, width $f_w(t)$ and height $f_h(t)$ of the sample are obtained as follows:

$$f_l(t)=0.0036t+29.9996$$  \hspace{1cm} (1)

$$f_w(t)=-0.0179t+19.6489$$ \hspace{1cm} (2)

$$f_h(t)=-0.0464t+9.889$$ \hspace{1cm} (3)

Table 5. Dimensions of samples with different filling density

| sample        | Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | Group 6 |
|---------------|---------|---------|---------|---------|---------|---------|
| Length(mm)    | 29.96   | 29.97   | 29.98   | 30.00   | 30.01   | 30.02   |
| Width(mm)     | 19.64   | 19.65   | 19.65   | 19.69   | 19.71   | 19.74   |
| Height(mm)    | 9.8     | 9.82    | 9.81    | 9.78    | 9.8     | 9.85    |
| Shrinkage in  | 0.04    | 0.03    | 0.02    | 0       | -0.01   | -0.02   |
| the direction of length   |         |         |         |         |         |         |
| Shrinkage in  | 0.36    | 0.35    | 0.35    | 0.31    | 0.29    | 0.26    |
| the direction of width    |         |         |         |         |         |         |
| Shrinkage in  | 0.2     | 0.18    | 0.19    | 0.22    | 0.2     | 0.15    |
| the direction of height   |         |         |         |         |         |         |
As shown in Table 5, the sample shrinks differently in the direction of length, width and height, with the smallest shrinkage and the smallest error in the direction of length. At the same time, the filling density has certain influence on the direction of shrinkage. After linear fitting of the width, height and length of the sample with the filling density of 0, 20%, 40%, 60%, 80% and 100%, the fitting formulas for the length $f_L(t)$, width $f_W(t)$ and height $f_H(t)$ of the sample are obtained as follows:

$$f_L(t) = 0.0629a + 29.9586$$  \hspace{1cm} (4)  

$$f_W(t) = 0.1029a + 19.6286$$  \hspace{1cm} (5)  

$$f_H(t) = 0.0229a + 9.7986$$  \hspace{1cm} (6)  

| Table 6. Different locating places          |
|--------------------------------------------|
| locating place   | Group 1 | Group 2 | Group 3 |
|------------------|---------|---------|---------|
| Length (mm)      | 30.01   | 30.01   | 29.70   |
| Width (mm)       | 19.76   | 19.76   | 19.98   |
| Height (mm)      | 9.85    | 9.85    | 9.88    |
| error in length  | -0.01   | 0.3     | 0.3     |
| error in width   | 0.24    | 0.02    | 0.12    |
| error in height  | 0.15    | 0.12    | 0.12    |

As shown in Table 6, the first group and the second group have the smallest shrinkage in the direction of length, and the third group has the smallest shrinkage in the direction of width and the highest accuracy. The minimum direction of the three sets of shrinkage is located in the x-axis direction of the printer, which shows that different positions have little effect on the direction of shrinkage. The height direction of the first group, the width direction of the second group and the length direction of the third group contracts relatively larger. These three directions are the direction of the z-axis of the printer, indicating that the accuracy of the direction accumulated layer by layer along the samples during printing is relatively poor.

5. Conclusion
This paper uses FDM desktop 3D printer to print PLA products under different parameters. The influences of bottom/top thickness, filling density and placement position on printing accuracy is studied. The conclusions are as follows:

(1) Each parameter factor has a certain influence on the printed parts, and the influence is relatively small. The workpiece has a certain degree of shrinkage in all directions, and its shrinkage has a certain directivity.

(2) Due to the influence of printer precision and printing algorithm, under the same printing parameters, the shrinkage along the direction of printer X is the smallest and the accuracy is the highest.

6. References
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