The influence of laser power and scanning speed on the dimensional accuracy of SLS formed parts

Gaoyan Hou¹, Zhongzhen Yu¹ and Dong Ye¹

¹School of Electrical and Mechanical Engineering, Wuhan Polytechnic, Wuhan, Hubei, 430081, China

*Corresponding author’s e-mail: haozhiqiang@wust.edu.cn

Abstract. In SLS sintering forming, laser power and scanning speed are two important process parameters, which directly affect the dimensional accuracy of sintered parts. Using PA2200 powder as the forming material, the influence of laser power and scanning speed on the dimensional accuracy of the sintered part was analyzed. Through theoretical analysis and experimental verification, the best combination of parameters was obtained. The laser power is 40 W and the scan speed is 5000 mm/s. The dimensional accuracy of the sintered parts is obtained by X-direction deviation -0.35 %, Y-direction deviation -0.4 %, and Z-direction deviation -0.25 %.

1. Introduction

Selective Laser Sintering (SLS) technology through laser sintering, the powder layer is stacked into a three-dimensional entity. The formed parts have high precision and strong mechanical properties, and are widely used in all walks of life[1-2]. The dimensional accuracy and mechanical properties of sintered parts are affected by the forming process parameters. The main forming process parameters include: laser power, scanning speed and scanning distance. Different forming materials require different forming process parameters[3]. The optimization of forming process parameters is a hot topic in the research of SLS technology[4].

Song Juan[5] analyzed the influence of laser power, scanning speed, scanning distance, and single layer thickness on the bending strength of molded parts for PS/SBS/Nano-CaCO₃ powder materials. The optimal combination of process parameters was obtained through single factor experiment, orthogonal experiment and range analysis. Li Xiaorong[6] conducted an experimental study on the selective laser sintering molding process of PA 6, and analyzed the effects of preheating temperature, laser power and scanning speed on dimensional accuracy and surface roughness. Yang Laixia[7] used the dimensional accuracy and surface quality of the PS wax model as evaluation indicators, and analyzed the influence of laser power, filling speed, powder layer thickness, scanning distance and other factors on the wax model. Wu Haihua[8] conducted experiments on graphite/phenolic resin mixed powder molding, studied the changing law of the dimensional accuracy of graphite prototypes, analyzed the extent of the influence of laser power, scanning distance, layer thickness and scanning speed on the relative dimensional accuracy in the Z direction. The optimal combination of process parameters that minimizes the relative error of the Z-direction dimension is obtained.

Different forming materials require different process parameters. The current research is relatively simple, and the general rule of forming process parameters cannot be obtained. This subject uses PA2200 powder as the forming material, analyzes the influence of laser power and scan rate on the X, Y, and Z-dimensional accuracy of the formed part, and obtains the best combination of parameters.
through theoretical analysis and experimental verification.

2. Experimental part

2.1. Experimental Materials
Powder: PA2200, the appearance is white powder, the average particle size is 60μm, Germany EOS Optoelectronics Technology Co., Ltd. (EOS), the mixing ratio of new and old powder is 1:1\textsuperscript{[9]}. 

2.2. Laboratory equipment
Selective laser sintering rapid prototyping machine(EOS P396), Germany EOS Optoelectronics Technology Co., Ltd. (EOS); high-speed mixer: XHS-50KG, Ningbo Beilun Tongsheng Machinery Manufacturing Co., Ltd.; sieving machine: Auspack-und Siebstation P1/P3, Germany EOS Optoelectronics Technology Co., Ltd. (EOS); Sandblasting machine: 9070, Ningbo Yinzhou Wuxiang Xinzhe Machinery Factory.

2.3. Sample preparation
The test piece is determined according to the plastic tensile specimen standard GB/T1040-2006, and the standard type 1B sample piece (as shown in Figure 1) is used.

![Figure 1. Tensile sample structure.](image)

Use selective laser sintering rapid prototyping machine to print, preheating temperature 168 ℃, printing layer thickness 0.12 mm, scanning distance 0.5 mm, laser power (unit: W) selection: 30, 40 and 50 three levels; scanning speed (unit: mm/s) selection: 3000, 4000 and 5000 three levels. The laser power and scanning speed adopt the orthogonal experiment method. There were 9 groups of data, and 5 samples were printed for each group.

2.4. Sample test
Dimensional accuracy test: The total length (150mm), end width (20mm) and thickness (4mm) of the sample are measured with a digital vernier caliper, and the average value of 5 samples in each group of data is taken.

3. Results and discussion

3.1. The influence of laser power on the dimensional accuracy of formed parts
The laser power is one of the important factors that affect the dimensional accuracy of the formed part, and determines the amount of energy absorbed by the formed powder. Determines how much energy is absorbed by the shaped powder. As the laser power increases, the energy provided for powder sintering increases. The sintered parts absorb more energy and have good compactness and high forming accuracy. However, higher laser power will cause the powder to absorb too much energy, causing the sintered parts to be too hard and yellow. As the laser power decreases, the energy provided
for powder sintering is insufficient, resulting in poor compactness of the sintered parts, loose surface structure, and low dimensional accuracy.

Figure 2 shows the influence of laser power on the dimensional accuracy of sintered parts in X, Y, and Z directions (blue line, red line and green line represent scanning speed of 3000 mm/s, 4000 mm/s, and 5000 mm/s, respectively). It can be seen from the figure that the dimensional accuracy of the sintered part is used as the evaluation index, and the laser power of 40 W is the better molding parameter. As the laser power increases in the (30W, 40W) interval, the proportion of dimensional accuracy deviations in the X, Y, and Z directions gradually decreases, and the dimensional accuracy gradually increases. As the laser power increases in the (40W, 50W) interval, the proportion of dimensional accuracy deviation in the X, Y, and Z directions gradually increases, and the dimensional accuracy gradually decreases.

3.2. The influence of scanning speed on the dimensional accuracy of formed parts
The scanning speed is the speed of the laser sintering according to the process route, which will determine the molding time of the sintered part and the overall processing efficiency. When the scanning speed is gradually increased, the processing efficiency of the sintered part is improved, but the time for the powder to absorb energy is insufficient. A higher scanning speed will cause the sintered part to be less dense and have a loose surface. When the scanning speed is gradually reduced, the powder molding has sufficient time to absorb energy, and the processing efficiency of the sintered part is reduced. A lower scanning speed will cause the sintered part to absorb too much energy, resulting in high density and hard surface.
Figure 3 shows the effect of scanning speed on the dimensional accuracy of sintered parts (blue line, red line, and black represent the laser power of 30W, 40W, and 50W, respectively). It can be seen from the figure that when the scanning speed increases in the range of (3000mm/s, 4000mm/s), the proportion of the dimensional accuracy deviations in the X, Y and Z directions gradually decreases, and the dimensional accuracy gradually increases. As the scanning speed increases in the (4000mm/s, 5000mm/s) interval, the proportion of the dimensional accuracy deviation in the X and Y directions gradually increases, and the dimensional accuracy gradually decreases. The proportion of the dimensional accuracy deviation in the Z direction gradually decreases, and the dimensional accuracy gradually increases.

3.3. Optimization of process parameters

Using the controlled variable method, the influence of 9 sets of test data composed of two variable factors of laser power and scanning speed on the dimensional accuracy of sintered parts is analyzed. Analyze the average value and variance of each group of variables to the sintered parts X, Y, Z dimensional accuracy deviation, and then optimize the parameters for several groups of data with smaller average values and smaller variances. Table 1 and Table 2 show the conditions when the laser power and scanning speed are changed in sequence. Table 3 shows several parameter combinations with the best dimensional accuracy deviations in the X, Y, and Z directions.

### Table 1. When the laser power changes.

| Serial number | Laser power /W | X direction | Y direction | Z direction |
|---------------|----------------|-------------|-------------|-------------|
|               | average value  | variance    | average value | variance    | average value | variance    |
| 1             | -0.44          | 0.06        | -0.45        | 0.16        | 2.17          | 0.82        |
| 2             | -0.38          | 0.02        | -0.30        | 0.17        | 0.42          | 0.63        |
| 3             | -0.41          | 0.08        | 0.08         | 0.12        | 1.58          | 0.96        |
Table 2. When the scanning speed changes.

| Serial number | Scanning Speed/mm/s | Proportion of dimensional accuracy deviation (%) |  |  |  |
|---------------|---------------------|-----------------------------------------------|---|---|---|
|               |                     | X direction | Y direction | Z direction |  |
|               |                     | average value | variance | average value | variance | average value | variance |
| 1             | 3000                | -0.47       | 0.06       | -0.03       | 0.21     | 1.83          | 0.62     |
| 2             | 4000                | -0.36       | 0.04       | -0.27       | 0.22     | 1.92          | 1.12     |
| 3             | 5000                | -0.40       | 0.05       | -0.37       | 0.25     | 0.42          | 0.62     |

Table 3. Several sets of parameter combinations with the smallest deviation of dimensional accuracy.

| Serial number | Laser power /W | Scanning Speed/ mm/s | Proportion of dimensional accuracy deviation (%) |  |  |  |
|---------------|----------------|---------------------|-----------------------------------------------|---|---|---|
|               |                 |                     | X direction | Y direction | Z direction |  |
|               |                 |                     | average value | variance | average value | variance | average value | variance |
| 1             | 40              | 4000                | -0.41       | -0.4      | 0.5          |  |
| 2             | 40              | 5000                | -0.35       | -0.4      | -0.25        |  |
| 3             | 50              | 5000                | -0.39       | -0.05     | 0.25         |  |

It can be seen from Table 1 to Table 2 that the optimal parameter combination is when the laser power is 40-50 W and the scanning speed is 4000-5000 mm/s. It can be seen from Table 3 that the group with the largest dimensional accuracy has a laser power of 50 W and a scanning speed of 5000 mm/s, but the laser power is larger. Considering the dimensional accuracy of the formed part, processing cost and processing efficiency, the best combination of parameters is the laser power 40 W, the scanning speed is 5000 mm/s, and the dimensional accuracy of the formed part accounts for -0.35% of the deviation in X direction, the Y-axis deviation accounts for -0.4%, Z-direction deviation accounts for -0.25%.

4. Conclusion
Comprehensive analysis shows that the laser power and scanning speed during the SLS sintering process will affect the dimensional accuracy of the sintered part. The optimal combination of process parameters will result in a sintered part with high accuracy and good surface quality. Through theoretical analysis and experimental research on the two molding parameters of laser power and scanning speed, the sintered parts dimensional accuracy is used as the main evaluation index, combined with processing efficiency and processing cost factors, and the best parameter combination is obtained. The best combination of parameters is laser power 40W, scanning speed 5000mm/s, and the dimensional accuracy of the formed part is obtained by X-axis deviation -0.35%, Y-axis deviation -0.4%, and Z-axis deviation -0.25%.

Acknowledgements
This work is supported by Science and Technology Research Project of Hubei Provincial Department of Education-Guiding Project (Numbering: B2020384) and (Numbering: B2019401).

References
[1] Shi Yusheng, Yan Chunze, Wei Qingsong, et al. Polymer composites for 3D printing by selective laser sintering[J]. Science in China: Information Sciences, 2015, 45(2):204-211.
[2] Liu Jingbo, Liu Shifeng, Liu Quanming, et al. Research progress in powder materials for selective laser sintering[J]. Ordnance Material Science and Engineering, 2018, 41(4): 111-116.

[3] Gan Xinpeng, Wang Jinzhi, Fei Guoxia, et al. Progress on polymer material for SLS 3D printing[J]. New Chemical Materials, 2020, 48(8): 27-31,41.

[4] Zhang Dedong, Li Lei, Yang Weijing, et al. Research Progress of Selective Laser Sintering 3D Printing of Polypropylene Powder[J]. China Plastics Industry, 2020, 48(9): 6-12.

[5] Song Juan, Yang Laixia, Gao Bo. Effects of Process Parameters on Bending Strength of PS/SBS/Nano CaCO3 Parts Made by Selective Laser Sintering[J]. Engineering Plastics Application, 2021, 49(2): 80-85,91.

[6] Li Xiaorong, Zhang Wu. Experimental Study on Selective Laser Sintering of Nylon 6[J]. China Plastics Industry, 2020, 48(4): 61-66.

[7] Yang Laixia, Bai Xiang, Wang Xinyu. Dimension Accuracy of Selective Laser Sintered Polystyrene Wax Mold[J], Engineering Plastics Application, 2020, 48(3): 48-54.

[8] Wu Haihua, Yan Junneng, Li Tengfei, et al. Experimental study on selective laser sintering accuracy of graphite / phenolic resin mixed powder[J]. Progress in Laser and Optoelectronics, 2017, 54(8): 216–222.

[9] Hou Gaoyan, Zhu Hong, Xie Dan. The Influence of SLS Process Parameters on the Tensile Strength of PA2200 Powder [J]. IOP Conference Series: Earth and Environmental Science, 2020, 571: 1-6.