The Influence of SLS Process Parameters on the Tensile Strength of PA2200 Powder

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Abstract. In the process of selective laser sintering, the forming parameters will affect the dimensional accuracy and performance of the forming parts. At present, there is no reference standard for the optimal forming parameters of PA material. Aiming at this problem, the three factors of laser power, scanning pitch and scanning speed are analyzed, and the influence of the tensile strength of PA2200 material forming parts is analyzed. Through theoretical and experimental analysis, the optimal combination of process parameters is obtained by orthogonal experiment. The best combination of parameters is laser power 40W, scanning speed 3000mm/s, scanning pitch 0.4mm, and tensile strength up to 46.42MPa.

1. Introduction

Selective Laser Sintering (SLS) technology is based on the principle of layered and superimposed manufacturing. It uses slicing software to slice layer by layer, spreading powder to a layer thickness, and sintering the contour of the layer. In this way, layer by layer is stacked repeatedly to form a three-dimensional entity. SLS can form arbitrarily complex parts, does not need to design molds during processing, and has the advantages of high material utilization. It is widely used and has become the mainstream technology of 3D printing\cite{1-2}.

SLS technology is developing rapidly, but the forming process parameters are one of the bottlenecks restricting the further development of SLS. In practical applications, the lack of quantitative characterization usually depends on the experience of technicians. The parameters of forming process include laser power, scanning distance, scanning speed, heating temperature and printing layer thickness. Unreasonable setting of forming process parameters will affect the accuracy and mechanical properties of the formed part, and even cause warping, printing failure and other phenomena\cite{3}. Therefore, the optimization of SLS forming parameters has important research significance and value.

In recent years, scholars at home and abroad have done a lot of research. Hongbing Zhang\cite{4} has conducted experimental research on the selective laser sintering bending strength of PS/GF composite powder, using orthogonal experiment and analysis of variance to process the layer thickness, scanning pitch and scanning speed. The parameters were optimized and the optimal combination of process parameters was obtained. Laixia Yang\cite{5} studied the optimization of selective laser sintering process parameters for PS/PET/GF composite powder, and optimized the combination of layer thickness, scanning pitch and scanning speed. Ran Yan\cite{6} used response surface method to optimize the parameters of selective laser sintering for polystyrene powder, and studied the effects of laser power,
scanning pitch, single layer thickness, scanning speed and their interactions on the forming accuracy of SLS. The current research work is relatively single and limited, unable to summarize general rules, and there is insufficient research on the optimization of PA powder process parameters\cite{7,9}.

In view of the above problems, this paper selects PA2200 powder as the research object, and takes the tensile strength of the formed part as the evaluation index to study the influence of laser power, scanning pitch, scanning speed and their interaction on the tensile strength of the formed part, using the orthogonal test method Get the optimal combination of process parameters\cite{10}.

2. Experimental part

2.1. Experimental Materials
PA powder: PA2200, the average particle size is 60μm, the appearance is white powder, Germany EOS Optoelectronics Technology Co., Ltd. (EOS), the mixing ratio of new and old powder is 1:1.

2.2. Laboratory equipment
Selective laser sintering rapid prototyping machine: EOS P396, Germany EOS Optoelectronics Technology Co., Ltd. (EOS), as shown in Figure 1; 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; Electronic universal testing machine: UTM-1422, Chengde Jinjian Testing Instrument Limited company.

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 2) is used. The sample size is shown in Table 1.

| Symbol | Name                                | Size/mm |
|--------|-------------------------------------|---------|
| L      | Total length                        | 150     |
| H      | Distance between fixtures           | 115     |
| C      | Length of middle parallel part      | 60      |
| G      | Gauge length (or effective part)    | 50      |
| W      | End width                           | 20      |
| d      | Thickness                           | 4       |
| b      | Width of middle parallel part       | 10      |
| R      | Radius                              | 60      |
The selective laser sintering machine was used for printing and the preheating temperature was 168°C. The printing layer thickness is 0.12mm; laser power (unit: W) selection: 30, 40, 50 three grades; the scanning pitch (unit: mm) is 0.3, 0.4, 0.5, 0.6. scanning speed (unit: mm/s): 3000, 4000, 5000. The laser power, scanning pitch and scanning speed were tested by orthogonal test. There were 36 groups of data, and 5 samples were printed for each group.

2.4. Sample test
Tensile strength test: At room temperature, the electronic universal testing machine is used to conduct a tensile test on 5 samples of each set of data. The tensile strength is averaged and the test rate is: 50mm/min.

3. Results and discussion

3.1. The influence of laser power on the tensile strength of formed parts
The size of the laser power affects the amount of energy absorbed by the powder. When the laser power is small, the formed part is looser, less compact and less tensile due to insufficient energy. When the laser power increases, the compactness of the formed part increases due to the increase in energy. The tensile strength is increased, but too high laser power can easily cause the formed parts to become yellow and hard, and the processing cost is also relatively high.

Figure 3 shows the effect of laser power on the tensile strength of forming parts (blue line, red line, green line and black line represent scanning pitch of 0.3mm, 0.4mm, 0.5mm and 0.6mm respectively). It can be seen from the figure that when the power increases between (30W,40W), the tensile strength gradually increases with a generally large increase. When the power increases between (40W,50W), the tensile strength increases slightly.

3.2. The influence of scanning pitch on the tensile strength of formed parts
The distance between the center of two adjacent laser scanning lines is called the scanning pitch. The diameter of the laser spot determines the size of the scanning pitch (i.e. the larger the laser spot diameter is, the larger the scanning pitch is), and the size of the scanning pitch determines the coincidence degree of the two adjacent laser lines (i.e. the smaller the scanning pitch is, the higher the coincidence degree is).

Figure 4 shows the influence of scanning pitch on the tensile strength of forming parts (blue line, red line and black line respectively represent scanning speed of 3000mm/s, 4000mm/s and 5000mm/s). It can be seen from the figure that when the spacing increases between (0.3mm,0.4mm), the tensile strength gradually increases. When the spacing increases between (0.4mm,0.5mm), the tensile strength decreases gradually.
3.3. The influence of scanning speed on the tensile strength of formed parts

The scanning speed determines the time it takes for the laser to scan and heat the powder, and also the time it takes for the workpiece to be formed. When the scanning speed is high, the forming time of powder melting and sintering is insufficient, and the effect is poor. When the scanning speed is low, the powder is fused and sintered with good compactness, high tensile strength, but long heating time.

![Graph showing the influence of scanning speed on tensile strength.](image)

Figure 5. The influence of scanning speed on tensile strength.

Figure 5 shows the impact of scanning speed on the tensile strength of forming parts (blue line, red line, green line and black line respectively represent scanning pitch of 0.3mm, 0.4mm, 0.5mm and 0.6mm). It can be seen from the figure that when the laser speed increases between (3000mm/s,4000mm/s), the tensile strength gradually increases. When the laser speed increases between (4000mm/s,5000mm/s), the tensile strength decreases gradually.

3.4. Optimization of process parameters

The orthogonal test method was used to analyze the mean value and variance of tensile strength of 36 groups of test data composed of three variables, namely laser power, scanning pitch and scanning speed. When each group of variables were changed by the control variable method, the mean value and variance of tensile strength were analyzed, and then several groups of data with large mean value and small variance were selected for parameter optimization. Table 2, Table 3 and Table 4 show the changes of laser power, scanning speed and scanning pitch, respectively. Table 5 shows several parameter combinations at the maximum tensile strength.

| Serial number | Scanning pitch | Scanning speed | Maximum | Minimum | Average | Variance |
|---------------|---------------|----------------|---------|---------|---------|----------|
| 1             | 0.3           | 3000           | 46.6    | 44.02   | 45.48   | 1.08     |
| 2             | 0.4           | 3000           | 46.42   | 42.72   | 45.1    | 1.68     |
| 3             | 0.3           | 4000           | 46.38   | 43.6    | 45.44   | 1.30     |

Table 2. When the laser power changes.
| Serial number | Scanning speed | Laser power | Tensile strength |
|---------------|---------------|-------------|-----------------|
|               | Maximum       | Minimum     | Average         | Variance |
| 1             | 46.42         | 42.79       | 45.07           | 1.38     |
| 2             | 46.38         | 40.12       | 43.64           | 2.31     |

Table 4. When the scanning pitch changes.

Table 5. The combination of parameters with the greatest tensile strength.

As can be seen from Table 2 to Table 4, the optimal parameter combination is when the laser power is 40W, the scanning speed is 3000mm/s, and the scanning pitch is 0.3mm. At this time, the tensile strength is 45.83MPa. As can be seen from Table 5, the group with the highest tensile strength is the laser power of 30w, scanning speed of 3000mm/s and scanning pitch of 0.3mm, which takes a long time. Combined with the effect of laser power, scanning speed and scanning pitch on tensile strength, the best parameter combination is laser power 40W, scanning speed 3000mm/s, scanning pitch 0.4mm, tensile strength up to 46.42mpa.

4. Conclusion

Comprehensive analysis, in the process of selective laser sintering, the laser power, scanning pitch and scanning speed all affect the tensile strength of the forming part. The increase of laser power will improve the tensile strength, the increase of scanning pitch and scanning speed will make the tensile strength first increase and then decrease. Therefore, the optimal combination of parameters will achieve the highest tensile strength, while also considering the cost and processing cycle. According to theoretical and experimental data analysis, the best parameter combination is laser power 40W, scanning speed 3000mm/s, scanning pitch 0.4mm and tensile strength up to 46.42mpa from the perspective of tensile strength, processing cost and processing cycle. The optimal parameter combination obtained can provide a basis for studying the forming of PA material SLS, and also provide a solution for improving the tensile strength of PA forming parts.

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