Experimental Study on Technological Parameters and Proportion of Selected Laser Sintered PS/PE Mixed Powders

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Abstract. Polystyrene/polyethylene (PS/PE) mixed powder was prepared by mechanical mixing in order to overcome the poor strength of the pure polystyrene (PS) selective laser sintering (SLS) molding parts. The optimum combination of process parameters was selected by orthogonal test and range analysis, and the effect of material ratio on bending strength and Z dimensional precision of PS/PE sintered parts was studied. The results show that the optimum process parameters are as follows: filling speed 1600mm·s⁻¹, preheating temperature 85°C and scanning distance 0.30mm. The optimum ratio of PS/PE mixed powder is 9:1 under the combination of the process parameters. Under the combined process parameters, the bending strength of sintered parts can reach 8.91Mpa, and the absolute value of Z relative dimension deviation is only 0.65%. Compared with pure PS under the same conditions, it increased by 6.5% and 62.86% respectively.

1. Introduction
Selective laser sintering is one of the most widely used technologies in the field of rapid prototyping at present. It is based on the idea of model discretization and stacking [1]. According to the cross section information of the model, the selective laser irradiating hot melt material is controlled under the action of computer, and the layer by layer sintering is accumulated until the model processing is completed, and the selective laser sintering process is often combined with the investment casting process in actual production. In order to improve the quality of casting parts, it is required that the materials of casting prototypes have the characteristics of low residual ash, so the casting prototypes have the characteristics of low ash content [2, 3]. In laser sintering process, polymer organic materials are usually used as sintering materials.

Polystyrene powder has been applied in SLS process because of its good fluidity, low shrinkage and low moisture absorption. However, the strength and precision of pure PS sintered parts are often difficult to meet the requirements of large size and complex model making [4]. As one of the commonly used polymer organic materials, polyethylene powder has lower melting point and better impact resistance, so it is often mixed with other polymer organic materials. At the same time, polyethylene and polystyrene have better compatible phase, the blending method is simple and the effect is good [5, 6]. In view of this characteristic, the author makes the PS/PE powder was prepared by mechanical mixing, and the filling scanning speed and preheating temperature were studied under the condition of delamination thickness 0.25mm, laser power 30W, scanning speed 3000mm/s and so
on. The optimum combination of process parameters was selected by orthogonal test and range analysis, and the effect of the ratio of polystyrene and polyethylene on the bending strength and Z dimensional precision of sintered parts was studied.

2. Experimental

2.1. Experimental materials
PS powder: KM-503, average particle size of 75μm, Dongguan Comai New material Co., Ltd.
PE powder: GRSN-9820 NT 7 P, average particle size of 75μm, Dow Chemical Corporation.

2.2. Experimental equipment and instruments
Electronic Tianping scale: MS32001L, Shenzhen Shengmei instrument Co., Ltd.
Digital display Vernier caliper: type: 91511, measuring range 150mm, Sida tools Co., Ltd.
Laser Rapid Prototyping Machine: XJRP SLS300, Shaanxi Hengtong Intelligent Machine Co., Ltd.
Universal Material Servo Testing Machine: WH-5000, Zhenhai Weiheng Testing Instrument Co., Ltd.

2.3. Preparation of sintered specimens
PS/PE composite powders were prepared by mechanical mixing method, and 5 bending strength specimens were sintered at each time by SLS300 laser rapid prototyping machine. The size of specimens is 80mm×10mm×4mm (length×width×height).

3. Experimental results and analysis

3.1. Orthogonal test
On the basis of the previous work, the scanning speed, preheating temperature and scanning distance of the process parameters are taken as orthogonal test variables, and the "three factors and three levels" orthogonal experiments are carried out respectively at three test levels of each variable. The orthogonal test factor level table is shown in Table 1. The scheme and results of the orthogonal test are shown in Table 2.

| Test level | Scanning speed (A) /mm·s⁻¹ | Preheat temperature (B) /°C | Scanning spacing (C) /mm |
|------------|-----------------------------|-----------------------------|--------------------------|
| 1          | 1600                        | 75                          | 0.29                     |
| 2          | 1800                        | 80                          | 0.30                     |
| 3          | 2000                        | 85                          | 0.31                     |

Table 1. "Three factors and three levels" orthogonal experiment list.
Table 2. Arrangement and results of orthogonal test.

| Number | A/mm·s⁻¹ | B/℃ | C/mm | Bending strength/Mpa | Z dimension relative deviation absolute value/% |
|--------|----------|------|------|----------------------|-----------------------------------------------|
| 1⁹     | 1600     | 75   | 0.29 | 7.51                 | 1.10                                          |
| 2⁹     | 1600     | 80   | 0.30 | 8.28                 | 1.45                                          |
| 3⁹     | 1600     | 85   | 0.31 | 8.61                 | 0.95                                          |
| 4⁹     | 1800     | 75   | 0.30 | 7.18                 | 1.10                                          |
| 5⁹     | 1800     | 80   | 0.31 | 6.35                 | 2.25                                          |
| 6⁹     | 1800     | 85   | 0.29 | 6.43                 | 1.40                                          |
| 7⁹     | 2000     | 75   | 0.31 | 4.88                 | 3.75                                          |
| 8⁹     | 2000     | 80   | 0.29 | 5.67                 | 3.20                                          |
| 9⁹     | 2000     | 85   | 0.30 | 5.92                 | 2.45                                          |

3.2. Range analysis
Under the same experimental factors, the greater the extreme difference of the experimental results, the greater the influence of the experimental factors on the experimental results. The bending strength and Z dimensional accuracy of the mixed powder sintered parts with PS/PE are analyzed by the range analysis results as shown in Table 3 and 4. Taking each factor level as the horizontal coordinate and the corresponding factor level K as the vertical coordinate, the curves between the bending strength and the Z dimensional accuracy of the PS/PE mixed powder sintered parts are obtained, as shown in Fig 1 and Fig 2 respectively.

Table 3. Results of bending strength range analysis of sintered parts [Mpa].

| Calculated value | A     | B     | C     |
|------------------|-------|-------|-------|
| K₁               | 24.40 | 19.57 | 19.61 |
| K₂               | 19.96 | 20.30 | 21.38 |
| K₃               | 16.47 | 20.96 | 19.84 |
| R                | 7.93  | 0.99  | 1.77  |

Table 4. Results of Z dimensional precision range analysis of sintered parts [%].

| Calculated value | A     | B     | C     |
|------------------|-------|-------|-------|
| K₁               | 3.5   | 5.95  | 5.7   |
| K₂               | 4.75  | 6.9   | 5.69  |
| K₃               | 9.4   | 4.8   | 6.95  |
| R                | 5.9   | 1.1   | 1.95  |

For the bending strength of PS/PE mixed powder sintered parts, the higher the bending strength K value, the higher the bending strength value of sintered parts is at the level of this factor, which is the optimum process parameters corresponding to the maximum bending strength K value. Therefore, combining with Fig 1, we can get the technological parameter combination of the bending strength of the sintered part as the index: A₁B₃C₂, which is scanning speed 1600mm·s⁻¹, preheating temperature 85℃, scanning interval 0.30mm. The smaller the Z dimensional accuracy of sintered parts is, the smaller the absolute value of Z dimensional deviation is the higher the forming accuracy. Fig 2 shows that when the Z dimensional precision of the sintered parts is optimal, the process parameters are: A₁B₃C₂, which is speed 1600mm·s⁻¹, preheating temperature 85℃, scanning spacing 0.30mm. Therefore, it can be seen that when the bending strength and Z dimensional precision of PS/PE mixed powder sintered parts are optimal, the process parameters are the same, which are filled scanning speed 1600mm·s⁻¹, preheating temperature 85℃, scanning spacing 0.30mm.
The K value of the bending strength/Mpa

Factor level diagram

Figure 1. Relationship curve between bending strength K value and each factor level of sintered parts.

The K value of the bending strength %

Factor level diagram

Figure 2. Relationship curve between Z dimensional accuracy K value and each factor level of sintered parts.

3.3. Experimental study on the mixture ratio of PS/PE Powder

The PS/PE mixed powder was sintered with the best technological parameters mentioned above. The influence of the ratio of PS and PE on the bending strength of the sintered parts and the shaping precision of the Z direction was studied. The effect of PE content on the bending strength of the sintered parts and the forming precision of Z to the molding precision was obtained as shown in Figure 3. It can be seen from the diagram that the bending strength and Z dimensional deviation of pure PS sintered parts are 8.36Mpa and 1.75% respectively. It is also seen that when the flexural strength of the PS/PE mixed powder sintered parts is the maximum and the Z dimension precision is optimal, the ratio of the material in the PS/PE mixed powder is 9:1. At this time, the bending strength of the S/PE mixed powder sintered parts is up to 8.91Mpa, the absolute value of the Z direction size is only 0.65%, and the pure PS sintered parts under the same conditions are compared. It can be increased by 6.5% and 62.86% respectively.
Figure 3. The effect of PE content on bending strength and Z-direction forming accuracy of sintered parts.

4. Conclusion
(1) In the range of experiment, When the sintering part of PS/PE mixed powder has both higher bending strength and better Z dimensional precision, the optimum sintering process parameters as follows: Scanning speed 1600mm/s, Preheating temperature 85℃, Scanning distance 0.30mm.
(2) Under the optimum technological conditions, the best ratio of PS/PE mixed powder is 9:1, and the bending strength of PS/PE mixed powder sintered parts can reach 8.91 Mpa, Z dimension deviation absolute value is only 0.65, which can be increased by 6.5% and 62.86% than that of pure PS sintered parts under the same conditions.

Acknowledgements
This work was supported by the National 863 high-tech research project of China (No. 2015AA042503).

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