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Study on selective laser sintering of glass fiber reinforced polystyrene

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Abstract. In order to improve the bending strength of Polystyrene (PS) sintered parts by selective laser sintering, Polystyrene/glass fiber (PS/GF) composite powders were prepared by mechanical mixing method. The size distribution of PS/GF composite powders was characterized by laser particle size analyzer. The optimum ratio of GF was determined by proportioning sintering experiments. The influence of process parameters on the bending strength of PS and PS/GF sintered parts was studied by orthogonal test. The result indicates that the particle size of PS/GF composite powder is mainly distributed in 24.88 μm~139.8 μm. When the content of GF is 10%, it has better strengthen effect. Finally, the article used the optimum parameter of the two materials to sinter prototype, it is found that the PS/GF prototype has the advantages of good accuracy and high strength.

1. Introduction

Selective laser sintering technology (SLS) is relying on the 3D model driven. According to the section information of slice, high energy laser beam selectively scans irradiation powder solid powder material, and manufactures layer accumulation so as to achieve three-dimensional solid parts under the control of the computer [1]. SLS process has the advantages of high molding speed, high accuracy, and material reuse and so on.

Polystyrene (PS) is a thermoplastic. Its sintered parts have the advantages of high forming precision, but the strength of PS powder is low and can not meet the requirements of bending strength of plastic functional parts [2]. Glass fiber (GF) is often used to strengthen thermoplastics [3]. The performance of sintered parts in SLS process is the result of many factors. In many factors, the choice of materials and technological parameters have a the most significant influence on the forming quality of sintered part [4]. In view of this, the author takes PS/GF composite powder as the object of study, and the influence of process parameters on the bending strength of sintered parts was studied. Because of the poor compatibility PS matrix and glass fiber, surface modification of glass fiber powder is needed [5].

2. Preliminary preparation of the experiment

2.1. Experiment material

(1) PS powder: average particle size 150 μm, Shanghai Hesheng plastic micropowder Co., ltd.;

(2) Glass fiber: average size 75 μm, Shenzhen Yatai technology company;
(3) Anhydrous ethanol: Mass fraction 99.7%, Tianjin Tianli Chemical Reagent Co., Ltd.;
(4) Silane coupling agent: KH-550, Nanjing Tianwei Chemical Co., ltd.;

2.2. Preparation of sintered specimens

PS/GF 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 80 mm ×10 mm ×4 mm (length×width×height).

3. Experimental results and analysis

3.1. Particle size distribution of composite powders

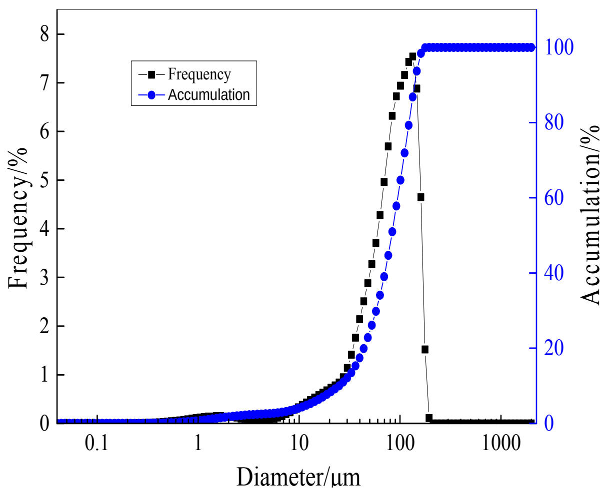


Figure 1. Distribution of particle size for under PS/GF composite powder.

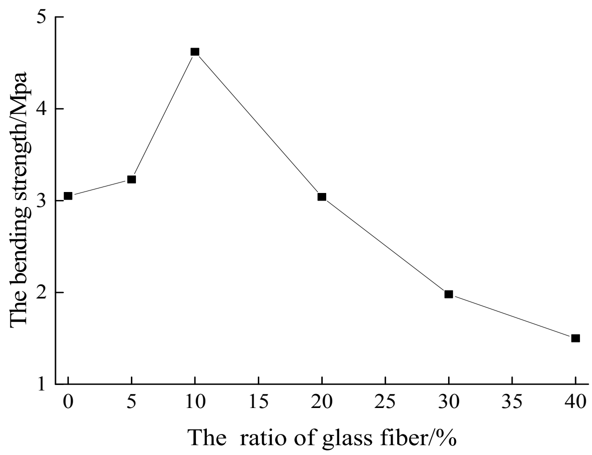


Figure 2. Bending strength values different GF ratios.

The particle size distribution of PS/GF composite powder is shown in Fig. 1 The particle size distribution of composite powder is 24.88 μm~139.8 μm and the average particle size is 82.81 μm. It can be seen that the composite powder has a wide range of particle size distribution. PS/GF composite powder can meet the requirements of SLS molding process.

3.2. PS/GF proportioning sintering test
Based on the previous experimental setting: the preheating temperature is 75 ℃, laser power is 25 W, scanning mode is XYSTA, scanning speed is 2000 mm/s, scanning spacing is 0.32 mm, thickness is 0.25 mm. In the experiment, equal interval sintering method was adopted to form 5 bending specimens at each time, and the experimental value of each group was the average value of the 5 bending specimens. The experimental results was shown in Fig. 2.

As is shown in Fig. 2, with the increase of GF ratio in PS/GF composite powder, the bending strength of sintered parts firstly increases and then decreases. When the GF ratio is 10%, the bending strength of sintered parts is the biggest.

When the proportion of GF in PS/GF composite powder is lower than 10%, the bending strength of sintered parts increases with the increase of GF ratio. Because the GF powder treated by KH-550 coupling agent can be well combined with PS powder, and the interface bonding force between the two powders is stronger, so the effect of effective enhancement is achieved .When the ratio of GF is close to 10%, the binding between GF and PS reaches saturation. Therefore, when the proportion of GF is higher than 10%, the bending strength of sintered parts decreases with the increase of GF proportion. So the optimum ratio of PS/GF is 9:1.

3.3. Orthogonal test
Under the premise of ensuring the experimental result, the orthogonal test can effectively reduce the number of tests. For orthogonal test, the greater range shows that the experimental factors also have more influence on the experimental results, and vice versa. In conclusion, 4 parameters, such as preheating temperature (A), laser power (B), scanning speed (C) and scanning distance (D), are taken as experimental indicators. According to the previous single factor experiment [4], combined with the forming quality of the sintered parts, each experiment index selected 3 better experimental points as the experimental level. In order to explain the enhancement effect of glass fiber on polystyrene, sintering experiments were conducted in the same parameter combinations. Table of orthogonal test was shown in Table.1

Table 1. Orthogonal scheme and experimental results

Number	Experimental factors				Bending strength [MPa]	
	Preheating temperature [℃]	Laser power [W]	Scanning speed [mm.s^{-1}]	Scanning interval [mm]	PS	PS/GF
1#	75	25	1300	0.28	6.12	10.12
2#	75	27	1400	0.30	6.27	9.99
3#	75	29	1500	0.32	6.42	8.26
4#	80	25	1400	0.32	6.37	9.70
5#	80	27	1500	0.28	6.89	9.94
6#	80	29	1300	0.30	11.10	13.12
7#	85	25	1500	0.30	6.23	8.32
8#	85	27	1300	0.32	8.51	8.50
9#	85	29	1400	0.28	11.81	15.78

Table 2. Range analysis of sintered parts of pure PS powder [MPa]

Calculated value	Preheat temperature (A)	Laser power (B)	Scanning speed (C)	Scan interval (D)
K_1	18.81	18.72	25.73	24.82
K_2	24.36	21.67	24.45	23.60
K_3	26.55	29.33	19.54	21.30
R	7.74	10.61	6.19	3.52

Table 3. Range analysis tables for PS/GF sintered parts [MPa]

Calculated value	Preheat temperature (A)	Laser power (B)	Scanning speed (C)	Scan interval (D)
K_1	28.37	28.14	31.74	35.84
K_2	32.76	28.43	35.47	31.43
K_3	32.60	37.16	26.52	26.46
R	4.39	9.02	8.95	9.38

The orthogonal table shows that the bending strength of PS/GF sintered parts is generally higher than the flexural strength of PS sintered parts in the same parameters. As for the bending strength of sintered parts, the value is the greater, the mechanical properties of the sintered parts is the better. The experimental factor level is used as a horizontal coordinate, and the ki values of each level's strength and accuracy are used as ordinate to obtain the change trend of factor level and experimental factor, as shown in Fig. 3 and Fig. 4.

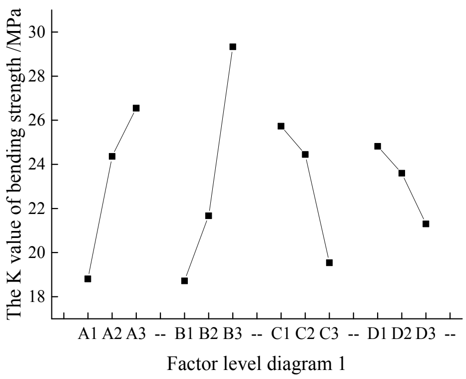


Figure 3. Factor level of sintered parts of pure PS powder

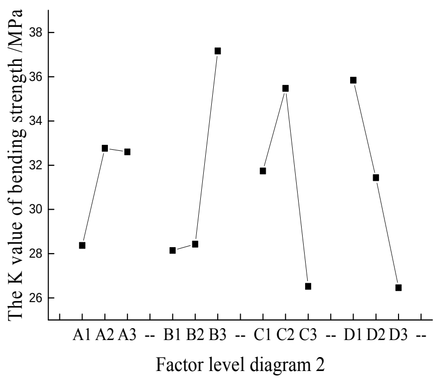


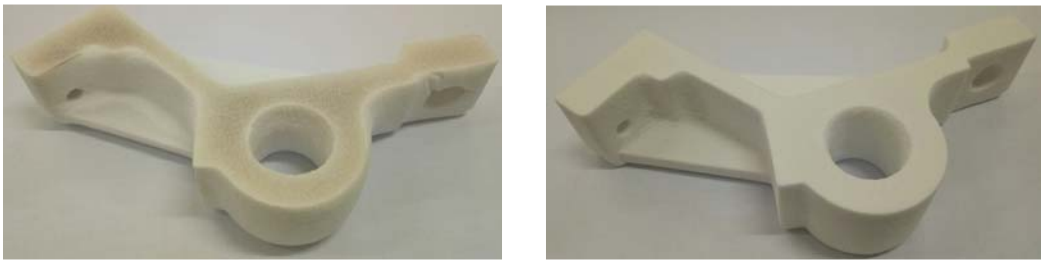
Figure 4. Factor level of PS/GF powder sintered parts

It is shown by Table. 2 and Fig. 3 that the optimum level of sintered parts of pure PS powder is $A_3B_3C_1D_1$. So the optimum combination of process parameters: the preheating temperature is 85 ℃, the laser power is 29 W, the scanning speed is 1300 mm/s and scanning distance is 0.28 mm.

It is shown by Table. 3 and Fig. 4 that the optimum level of sintered parts of PS/GF powder is $A_2B_3C_2D_1$. So the optimum combination of process parameters: the preheating temperature is 80 ℃, the laser power is 29 W, the scanning speed is 1400 mm/s and scanning distance is 0.28 mm.

4. Comples Sintered Parts

The sintered models under the optimum set of parameters was shown in the fig. 6. It can be seen that the surface of the pure PS powder is darker and has slight curling. But the contour feature of PS/GF prototypes is clear with good surface quality.



(a). Pure PS (b).PS/GF

Figure 5. The sintered complx parts

5. Conclusion

(1) The particle size of PS/GF composite powder prepared by mechanical mixing method is mainly distributed in 24.88 μm~139.8 μm, which can meet the needs of experiment.

(2) The optimum mass ratio of PS/GF composite powder is 9:1 by means of proportioning sintering test.

(3) The optimum technological parameters of the sintered parts of pure PS powder are as follows: the preheating temperature is 85 ℃, the laser power is 29 W, the scanning speed is 1300 mm/s, and the scanning distance is 0.28 mm. At this time, the bending strength is 11.94 MPa. The optimum technological parameters of the sintered parts of PS/GF composite powder are as follows: the preheating temperature is 80 ℃, the laser power is 29 W, the scanning speed is 1400 mm/s, and the scanning distance is 0.28 mm. At this time, the bending strength is 16.34 MPa, compared to the pure PS powder, the bending strength increased 36.85%.

(4) The same prototype was sintered under the optimum technological parameters, and the quality of PS/GF composite powder molding was better than that of pure PS powder.

Acknowledgements

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