

Dimensional Precision Research of Wax Molding Rapid Prototyping based on Droplet Injection

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Abstract. The traditional casting process is complex, the mold is essential products, mold quality directly affect the quality of the product. With the method of rapid prototyping 3D printing to produce mold prototype. The utility wax model has the advantages of high speed, low cost and complex structure. Using the orthogonal experiment as the main method, analysis each factors of size precision. The purpose is to obtain the optimal process parameters, to improve the dimensional accuracy of production based on droplet injection molding.

1. Introduction

With the continuous development of manufacturing products in various industries, the shape of the casting requirements are more and more complex, the production cycle requires more compact, the traditional process has been unable to meet the actual production requirements [1, 2]. In view of the shortcomings of the traditional pressure-type manufacturing process, in the production of small and medium-sized scale, the application of rapid prototyping technology to solve a lot of traditional process defects [3-5].

Researchers at home and abroad to do a lot of exploration. Zhang Yu [6] that SLS, FDM, SLA technology can be used for the formation of wax mold, but the wax mold strength is low. Nicholas [7] have published a method for casting and 3D printing wax molds, including paraffin-based resin materials. University of Munich, Thomas Ottnad [8] found that piezoelectric actuators based on piezoelectric elements can produce drops of droplets. Shi Yusheng [9] suggested that rapid welding technology could solve the problems existing in the production of complex thin-walled castings, and reduce the production and development costs.

However, the rapid development of wax molds based on droplet jet molding is not yet mature, and there is great room for improvement in materials, equipment and technology [10]. This article use of traditional casting wax, compared with PS powder, casting wax has low-shrinkage, small-deformation, environmental-friendly non-toxic, recyclable characteristics. In addition, this process is suitable for a variety of solid cast wax on the market, not just limited to PLA-like wire. In this paper, dimensional accuracy is studied from the aspects of dimensional compensation and shrinkage characteristics. Improve the dimensional accuracy of the wax mold by optimizing the rapid prototyping process.

2. Equipment preparation

2.1. Equipment and materials

The main structure includes a set of three-dimensional motion console, a heating device with a heat preservation pipeline, a high-precision piezoelectric injection valve, as shown in figure 1. The main parameters are shown in the following configuration table 1. The main components of the material



used in the study are 316-2B medium temperature precision casting wax, forming surface high precision, low shrinkage, high strength, less ash, suitable for 3D printing.

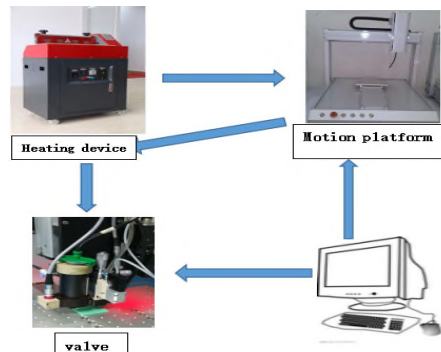


Figure 1. Equipment schematic diagram.

Table 1. Parameters of moving platform.

Project	Parameter
Spraying range	500/500/100mm
Platform speed	0--150 mm·s ⁻¹
Frequency range	20-200 HZ
Minimum delivery	2 nl
Operate temperature	0--130 °C

2.2. Mechanical error compensation

Place the precision cast wax in the heating tube to melt. Start the wax injection molding until the equipment is stable. Form a set of rectangle with a radius of 40 mm and a height of 2 mm.

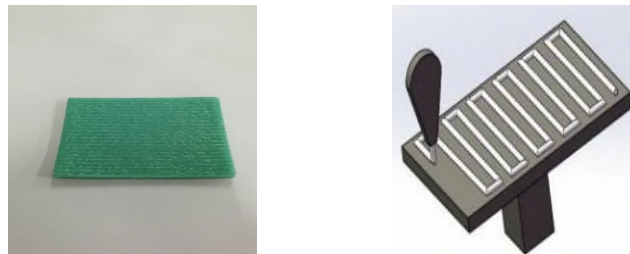


Figure 2. Machining methods and test sample pieces.

The dimensions are measured immediately after processing is complete. Respectively, take the average of each group as the measured size, calculate the X, Y, Z direction of the machining error compensation factor.

The mechanical error compensation factor in the X direction is 0.99, the mechanical error compensation factor in the Y direction is 0.98, and the mechanical error compensation factor in the Z direction is 1.04.

3. Orthogonal test

Select the spray molding sample shown in figure 2, the test parameters include: spray wax temperature (T), molding speed (V), layered thickness (D). The orthogonal test was designed to measure the shrinkage of X, Y and Z dimensions, and the variance analysis was carried out to quantitatively obtain the influence of each process parameter on the experimental results.

The reasonable range of the three factors: spray wax temperature range of 75 - 95°C, processing speed range of 0-100 mm*s-1, the thickness of the layer is 0.2-1mm. Based on the above data, select

the three-factor four-level orthogonal table, the establishment of test factors group table, as shown in table 2.

Table 2. Experimental factors and levels.

Lvl	factors		
	Wax spraying temperature °C (T)	Forming speed mm/s (V)	Thickness height mm (D)
1	75	20	0.2
2	80	40	0.4
3	85	60	0.6
4	90	80	0.8

The sample size is 90mm (X) * 90mm (Y) * 60mm (Z), the middle cylinder diameter is 40mm, the test sample is shown in figure 2.

According to the design principle of orthogonal experiment, each factor is arranged in different ways according to the orthogonal way, forming 16 groups of tests, each group made three samples, processed immediately after the completion of measuring its size, and then put 20°C constant temperature container for 24 hours after the insulation, and then measure the sample X, Y, Z direction size, and find the amount of each measurement direction of the amount of expansion and contraction. Data in table 3.

Table 3. Shrinkage in all directions.

Average Shrinkage (mm)																
x	1.16	0.97	1.23	1.42	1.20	1.26	1.44	1.27	1.36	1.41	1.39	1.51	1.48	1.46	1.53	1.66
y	1.23	1.04	1.25	1.45	1.13	1.21	1.37	1.32	1.46	1.53	1.46	1.48	1.61	1.48	1.69	1.62
z	1.07	0.95	0.99	1.13	1.21	1.09	1.20	1.13	1.28	1.29	1.16	1.41	1.46	1.27	1.39	1.42

The analysis of the measured data (in the X direction as an example), analysis of the impact of various factors significant degree.

Table 4. Effect of four factors on shrinkage.

	Quadratic sum	Free degree	Square deviation	F-value	P-value	Significance
T	9.18	3	3.06	50.51	0.0010	Significantly
V	1.62	3	0.54	8.92	0.0125	
D	0.35	3	0.11	1.93	0.2253	
error sum	0.36	6	0.06			
sum	11.52	15				

According to this table can be seen in the X direction, the three factors affect the ability of the order: spray wax temperature> molding speed> layer thickness. The following clear in the multi-factor role and single factor, the three factors on the specific impact of specimen contraction trend.

4. Result analysis

4.1. Influence of size accuracy on multi - factor interaction

The figure above shows the effect of the three factors on the amount of contraction, where the three coordinates represent the grouping in the orthogonal level table, and the color change represents the change in shrinkage. It can be seen that the range of the optimal parameters is consistent with the previous three-factor variables.

At the molding speed of 60 mm / s, the effects of spray wax temperature and layer thickness were studied. According to the above study, the first three horizontal ranges of wax spray temperature and stratified thickness in table 2 were divided into five Group test level. Each level of manufacture of three samples, measuring shrinkage method above.

It can be seen from the figure 6 that the optimum temperature of the spray wax is the second orthogonal level, about 80°C; the optimum stratification thickness parameter is the second orthogonal level, about 0.4 mm.

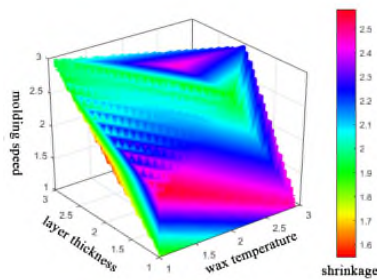


Figure 3. Effect of three factors on shrinkage.

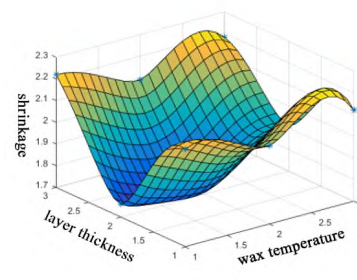


Figure 4. Effects of two significant factors on shrinkage.

4.2. Effect of single factor on dimensional accuracy

The influence of various factors on the forming precision was studied. Get a set of superior parameters, the following single factor control variable method to verify the above parameters.

4.2.1. Effect of spraying temperature on sample forming accuracy. Orthogonal experiments show that the wax spray temperature has the greatest influence on the precision of wax mold forming. Spray the temperature is too low, prone to broken wax or plug the nozzle. If the temperature of the spray is too high, the sprayed wax can not be rapidly solidified, resulting in a significant reduction in machining accuracy and a tendency to produce bubbles. It can be seen that when the wax spray temperature is about 84°C, the sample forming precision is the best.

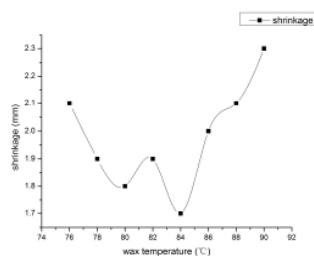


Figure 5. Temperature on shrinkage.

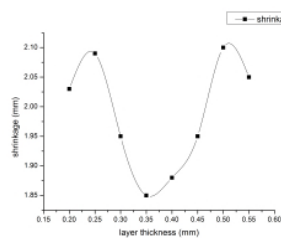


Figure 6. Thickness on shrinkage.

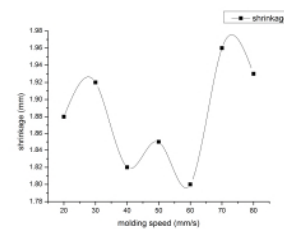


Figure 7. Speed on shrinkage.

4.2.2. Influence of Layered Thickness on Sample Forming Accuracy. The effect of stratified thickness on specimen shrinkage is obvious, especially for Z direction. The higher layers caused by the interlayer fusion, the higher the accuracy of the molding. When the wax spray temperature 80°C, forming speed 60 mm / s case, only to change the thickness of the layer, the data shown in the following figure. As can be seen from figure 6, when the stratified thickness is 0.35 mm, the contraction is shown to be minimal.

4.2.3. Effect of Molding Speed on Sample Forming Accuracy. In a certain range, with the molding speed increases, the specimen of the molding accuracy should be improved. As the speed of the platform increases, the problem of material spillage caused by the long injection time is prevented, and the temperature distribution of each molding is made more uniform. Analysis shows that when the

platform moving speed in a large range of changes, the impact on the specimen shrinkage is minimal. The optimum value is 60mm / s.

5. Conclusion

(1) Droplet injection wax mold 3D rapid prototyping, the three process parameters of the significant ability of the order of the order is: spray wax temperature> layer thickness> forming speed.

(2) The best process parameters: molding speed 60 mm / s, spray wax temperature 80°C, layer thickness 0.35 mm, forming speed 60mm/s.

(3) The shrinkage rate in the x direction is 1.6%, the shrinkage in the y direction is 1.9%, the shrinkage of the z direction is 2.3%, and the compensation coefficient in the x direction is 1.006, the y direction. The compensation coefficient is 0.998 and the compensation coefficient in the z direction is 1.064. After the size is corrected, the size of the specimen in the size of the contraction accuracy control within 1mm

References

- [1] Fan Z T 2012 *Foundry* **06** 583-91.
- [2] Charbonnier B et al. 2016 *J. European Ceram. Soc.* **36** 4269-79.
- [3] Sun d 2016 *Spec. Cast. Nonferr. Alloy.* **11** 1172-4.
- [4] Jiang T L 2017 *Electr. Mech. Eng.* **01** 48-51.
- [5] Xiao K 2005 *Found. Tech.* **08** 712-3 + 6.
- [6] Zhang Y 2016 *Found. Tech.* **04** 759-64.
- [7] Nicholas W B et al. 2015 *Science* **6244** 161-5.
- [8] Thomas O, Markus K and Franz I 2012 *IEEE* **978** 117-121.
- [9] Schumacher C M, et al., 2014 *RSC Adv.* **4(31)** 1603-9.
- [10] Shi Y S et al. *Foundry* **10** 749-52.