

Parameter Design for Injection Molding Process of Terminal Box Based on Taguchi Method and Moldflow

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Abstract: Moldflow software was used to simulate the injection molding process. Combined with the Taguchi test design method, the effect of five process factors, including melt temperature, mold surface temperature, molding time, holding time and holding pressure on filling time, flow front temperature, warpage deformation and volume shrinkage were studied. The optimal level of each factor was obtained by the analysis of variance (ANOVA) and signal-to-noise ratio (SNR) of the simulation results, and the optimal process parameter combination was obtained. Moldflow analysis is performed on the injection molding of the optimal process parameter, which verifies the effectiveness of Taguchi method for optimizing injection molding process parameters.

Introduction

In the development of plastic products, the most important thing is how to choose the injection molding process parameters [1]. In order to obtain high quality injection molded products, suitable process parameters are required [2]. In this paper, the Taguchi test design method was used to study the effects of melt temperature, holding time and other factors on the volume shrinkage and warpage of plastic parts [3], and the simulation injection process was carried out in Moldflow software [4]. The results of the volume shrinkage and warpage of the piece are obtained by using the signal-to-noise ratio and ANOVA to find the optimal process parameters, and verify the correctness again [5].

Technological Analysis of Plastic Part

The plastic part of the terminal box is rectangular shells with complex internal structure. The structure of outside surface for the region is regular. There is a square hole at the side of the plastic part. Four threaded inner holes are located at the front of the plastic part. Moreover, the front of the threaded inner hole have two cylindrical guide pillars. There are two movable inserts on the upper surface. The overall shape dimension of plastic parts is 93mm×86mm×30mm. There are many convex platforms and holes in the inner cavity, and the wall thickness is uniform. The software of UG is used for modeling, and the three-dimensional model is shown in Fig. 1.

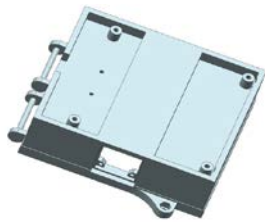
Taguchi Test Design

In the injection molding process, the influence of various process parameters on the warpage of the plastic parts is interactive. In this test, five test factors of melt temperature, injection time, holding pressure, holding time and injection pressure were selected. Each factor took five levels. The various factors and levels took are shown in Table 1.

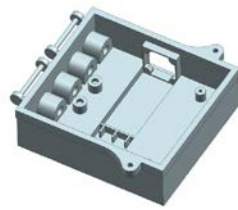
Table 1 Taguchi design table

The number	Melt temperature (°C)	Holding pressure (MPa)	Holding time (s)	Injection pressure (MPa)
1	210	35	10	60
2	220	40	12	80
...				
24	240	40	10	140
25	250	45	12	60

Process of Mold Flow Analysis. The simulation software of Moldflow is used to simulating the process of injection, including the analysis and optimization of the plastic part, injection mold, and process of injection. The three-dimensional model of terminal box is imported into the Moldflow for mesh generation. The result of grids is shown in Fig. 2. Through the mesh repair tool, the aspect ratio of the mesh is reduced below 6. Then the results, such as connectivity, orientation and overlapping elements, etc. are checked to guarantee the smooth progress of following mold flow analysis.



a. Outside of terminal box



b. Inside of terminal box

Fig. 1 Plastic part drawing of terminal box



Fig. 2 The result of grids

The materials of plastic parts and injection molding machine are selected in Moldflow. The best gate location of the terminal box can be obtained by simulation results, then the gating system and cooling system are establish. The relevant technological parameters are set up in Moldflow according to Table 1. The filling time, flow front temperature, warpage deformation and volume shrinkage are obtained. The result is shown in Table 2.

Table 2 The result of simulation

The number	Filling time (s)	Flow front temperature (°C)	Warpage deformation (mm)	Volume shrinkage (%)
1	1.102	210.6	0.577	8.764
2	1.543	220.7	0.5459	9.311
...				
24	1.967	240.8	0.5223	10.30
25	2.406	250.7	0.4943	10.76

The Analysis of Mold Flow Results. The first set of data is taken as example for the analysis of mold flow results.

Exact Filling Time. During the injection molding process, the exact filling time has a specific deviation from the input injection time. After the injection molding, the real injection molding time of the plastic part must be considered. The exact injection time is shown in Fig. 3.

The Temperature of the Flow Front. It will produce a certain heat loss during the melt flow in injection molding. If the heat loss is too large, the plastic part will not be filling enough. As a result, the temperature of flow front needs to be analyzed, and the temperature of the flow front is shown in Fig. 4.

Warpage Deformation. The value of warpage deformation is one of the essential factors. It affects the quality of plastic during injection molding. It is necessary to reduce the value of warpage deformation for the variety of plastic parts. The value of warpage deformation is shown in Fig. 5.

Volume Shrinkage. Volume shrinkage is another factor that affects the quality of plastic injection molding. The larger volume shrinkage will caused production defects and low forming quality. The volume shrinkage is shown in Fig. 6.

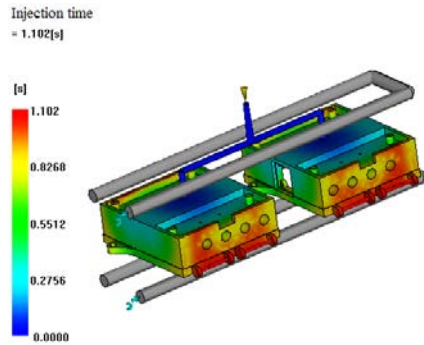


Fig. 3. Injection time

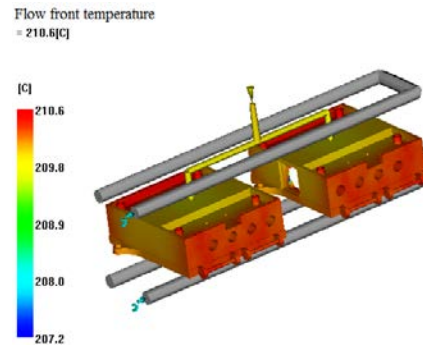


Fig. 4. Flow front temperature

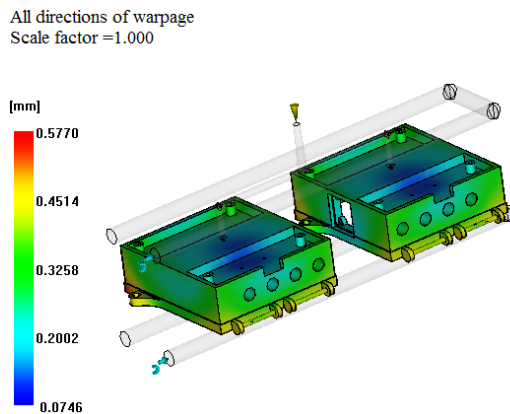


Fig. 5 All directions of warpage

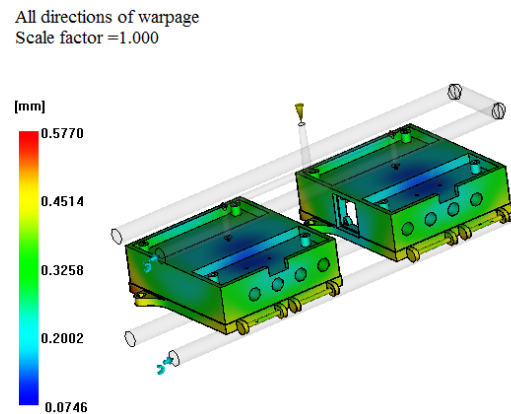


Fig. 6 Volume shrinkage

In this paper, ANOVA and signal-to-noise ratio (SNR) of the simulation results is analyzed for the volume shrinkage and warpage deformation. The results of ANOVA for warpage deformation are shown in Table 3. The results of SNR for warpage deformation are shown in Fig. 7.

Table3 ANOVA

	<i>DOF</i>	<i>Adj SS</i>	<i>Adj MS</i>	<i>F value</i>	<i>P value</i>
Melt temperature	4	0.0021	0.0005	3.43	0.130
Injection time	4	0.0058	0.0014	9.38	0.026
Holding pressure	4	0.0011	0.0030	19.19	0.007
Holding time	4	0.0027	0.0007	4.42	0.090
Injection pressure	4	0.0004	0.0001	0.72	0.622
Error	4	0.0006	0.0002		
Total	24	0.0235			

It can be seen from Table 3, the influence of holding pressure on the warpage deformation of plastic parts is a highly significant factor, the injection time is a significant factor, and the impact of melt temperature, holding time and holding pressure on the warpage deformation are not substantial. Similarly, the sequence of injection molding process parameters affecting volume shrinkage rate is injection time> melt temperature> holding time> injection pressure> holding pressure.

It can be seen from Fig. 7, the optimized parameters can be obtained. When melt temperature is

250°C, injection time is 2.2s, holding pressure is 55MPa, holding time is 10s, and the injection pressure is 80 MPa, the warpage deformation is minimum. Similarly, when melt temperature is 210°C, injection time is 1s, holding pressure is 45MPa, holding time is 18MPa, and the injection pressure is 120MPa, the volume shrinkage is minimal.

The optimum process parameters of volume shrinkage were entered into the Moldflow software, and the results are shown in Fig.8. The volume shrinkage was 5.889%, and the minimum volume shrinkage of the designed 25 sets of field test tables was 6.521%. The combination of parameters obtained by the SNR analysis was optimal. In the same way, the results of the warping deformation are optimized, and the warpage deformation is 0.4341 mm, which is similar to the minimum warpage deformation in the Taguchi test table.

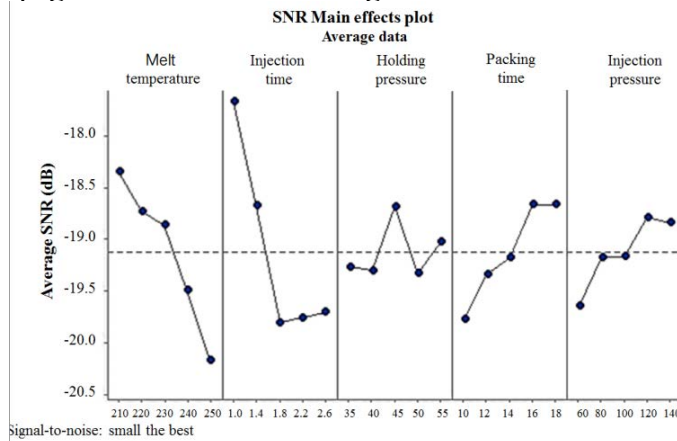


Fig.7 Analysis of the amount of warpage SNR

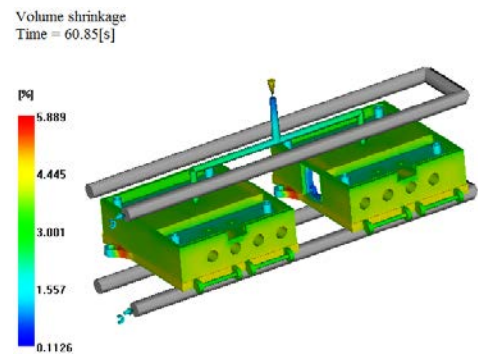


Fig. 8 Volume shrinkage

Summary

Experiments are designed and tested according to the Taguchi method. The optimization goals, namely the filling time, flow front temperature, warpage deformation and volume shrinkage, are obtained with Moldflow. The minimum warpage deformation and volume shrinkage of the plastic are obtained by the ANOVA and SNR. The minimum warpage deformation is 0.4341mm when the injection time is 2.2s, holding pressure is 55MPa, holding time is 10s, injection pressure is 80 MPa and melt temperature is 210°C. Similarly, the minimum volume shrinkage is 5.889% when the injection time is 1s, the holding pressure is 45MPa, holding time is 18s and the injection pressure is 120MPa. With ANOVA and SNR, the best injection molding process parameters obtained are input into the Moldflow software. The results show that the optimum injection parameters obtained by Taguchi method are reliable.

Acknowledgments

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References

- [1] M.H. Othman, S. Hasan, S.Z. Khamis, M.H.I Ibrahim and S.Y. M.Amin: Procedia Engineering, 184 (2017), p. 673–680.
- [2] Z.J. Guan and J. Lu: Engineering Plastics Application, 38(2010), p. 36-38.
- [3] M.C. Huang and C.C. Tai: J. Mater. Process. Tech, 110(2001), p.1-9.
- [4] W.H. Kuang, L.S. Chen, Z.Y. Xian and Y.h. Chen: Procedia Engineering, 15 (2011), p. 4352–4356.
- [5] E. Oliaei, B.S. Heidari, S.M. Davachi, M. Bahrani, S. Davoodi, I. Hejazi and J. Seyfi: J. Mater. Sci. Tech, 32 (2016), p. 710–720.