Study of Injection Molding Warpage Using Analytic Hierarchy Process and Taguchi Method

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Abstract

This study integrated Analytic Hierarchy Process and Taguchi method to investigate into injection molding warpage. The warpage important factor will be elected by Analytic Hierarchy Process (AHP), the AHP hierarchy analysis factor from documents collected and aggregate out data, then through the expert questionnaire delete low weight factor. Finally, we used Taguchi quality engineering method to decide injection molding optimized combination factors. Furthermore, the paper used injection pressure, holding pressure, holding time, mold temperature to analyze four factors, three levels Taguchi design data. Moreover, the paper discussed the reaction of each factor on the S / N ratio and analysis of variance to obtain the best combination of minimal warpage.

Keywords: Injection molding, Analytic Hierarchy Process (AHP), taguchi method

1. Introduction

Plastic molding methods are injection molding, extrusion molding, blow molding, co-injection molding method, gas-assisted molding method, of which the injection molding method is the most widely used plastic molding technology.

Kamaruddin [1] used Taguchi to improve mixed plastic products. The analysis of the results shows that the optimal combination for low shrinkage are low melting temperature, high injection pressure, low holding pressure, long holding time and long cooling time. Shuaib [2] performed to determine the factors that contribute to warpage for a thin shallow injection-molded part. The process used Taguchi and ANOVA technique. The result shows that by S/N response and percentage contribution in ANOVA, packing time has been identified to be the most significant factors on affecting the warpage on thin shallow part. Radhwan et al. [3] applied Taguchi method for the optimization of selected process parameters such as the mold temperature, melt temperature, packing pressure, packing time, and cooling time. The S/N ratio and analysis of variance were utilized to see the most significant factors contributing to shrinkage. Nasir et al. [4] designed mold in single and dual type of gate in order to investigate the deflection of warpage for thick component in injection molding process.

Opasanon and Lertsanti [5] implemented the analytic hierarchy process (AHP) to evaluate and rank the importance of the logistics issues according to the needs and requirements of the company's policy makers. Four criteria considered in the AHP include cost, responsiveness, reliability, and utilization. Kil et al. [6] study to identify the major variables identified as important for considering the stabilization of slope revegetation based on hydro seeding applications and evaluate weights of each variable using the analytic hierarchy process (AHP).

This study integrated Analytic Hierarchy Process and Taguchi method to investigate into injection molding warpage.

2. Results and Discussion of AHP and Taguchi Method

2.1. Analytic Hierarchy Process (AHP)

In this study, injection molding gather relevant information, collate and analyze the relevant factors. As shown in the present study hierarchical structure shown in Fig. 1. In this study, interviews the way interviews professors from this and related industry contains several interviews with scholars States to carry out

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private visits to the volume.

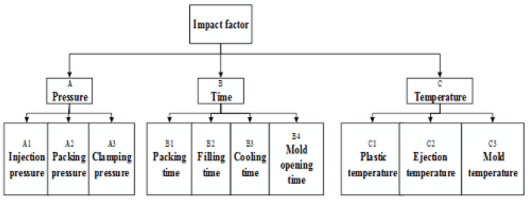

Fig. 1 Hierarchy architecture diagram

Using Microsoft Excel software to analyse all questionnaires, one of the factors to estimate the impact of the overall configuration of the inner surface of the weight value, you can understand the factors within all facet degree of importance the key factors for overall warpage of injection molding, as a result as shown in table 1.

Table 1 The overall weight table

Main weight	Secondary eight		Overall weight	
A. pressure	A1	0.52	0.25	(1)
0.48	A2	0.34	0.16	(2)
	A3	0.12	0.06	(8)
B. time	B1	0.44	0.13	(3)
0.29	B2	0.19	0.05	(9)
	B3	0.22	0.06	(7)
	B4	0.13	0.03	(10)
C. temperature	C1	0.29	0.06	(6)
0.22	C2	0.34	0.07	(5)
	C3	0.35	0.05	(4)

2.2. Taguchi Design of Experiment

(1) Choose quality characteristics

In order to measure the output quality and characteristics from desired value, Taguchi has utilized the Signal-to-Noise ratio; S/N. S/N ratio also used to classify the results and evaluates them to determine the optimum parameters. There are three S/N ratio's characteristics; the nominal the better, the smaller the better and the higher the better. Since this research is carried to reduce warpage, the smaller the better characteristic has been chosen and it is expressed as:

$$S/N = -10\log\left[\frac{1}{n}\sum_{i=1}^{n} y_i^2\right] \tag{1}$$

y_i represents the observation, n is the number of tests in one trial.

(2) Choose Control factor

As shown Table 2, there are four factors identified to be the parameters in this research. They are the injection pressure (A), packing pressure (B), packing time (C),and the mold temperature (D).Taguchi method is used to analyze these four injection molding process parameters based on three-level design of experiments and orthogonal array $L_9(3^4)$ is created . The levels, factors and orthogonal array variance and the combination are shown in Table 3 respectively.

Table 2 Selected Factors and Levels

Factor	Level 1	Level 2	Level 3
A. Injection Pressure	100	110	120
B. Packing pressure	65	75	85
C. Packing time	7	9	11
D. Mold temperature	80	90	100

Table 3 Combination of parameters in Orthogonal Array Variance

	A	B	C	D
1	100	65	7	80
2	100	75	9	90
3	100	85	11	100
4	110	65	9	100
5	110	75	11	80
6	110	85	7	90
7	120	65	11	90
8	120	75	7	100
9	120	85	9	80

(3) Experimental data analysis

After Moldex3D analysis, the results of the experiment to measure out the amount of warpage calculated S/N ratio, calculated by Equation (1) S/N ratio of each group, as shown in Table 4.

In Table 4 can be obtained by injection molding of each factor on the table and the amount of warpage of the reaction the reaction diagram, as shown in Table 5 and Figure 2. In smaller quality characteristics S / N ratio greater the better quality characteristics, according to tables and graphs can identify the best factor level combination A3B2C3D1, injection pressure 120Mpa, packing pressure 75MPa, packing time 11Sec, mold temperature 80℃.

Table 4 Results of S/N and warpage of results

	A	B	C	D	Warpage	S/N

					(mm)	Ratio
1	1	1	1	1	0.0684	23.2989
2	1	2	2	2	0.0688	23.2482
3	1	3	3	3	0.0722	22.8293
4	2	1	2	3	0.0788	22.0695
5	2	2	3	1	0.0555	25.1141
6	2	3	1	2	0.0764	22.3381
7	3	1	3	2	0.0621	24.1382
8	3	2	1	3	0.0830	21.6184
9	3	3	2	1	0.0602	24.4081
Ave.					0.0694	23.2292

Table 5 The response table of S/N ratio

	A	B	C	D
Level 1	23.13	23.17	22.42	**24.27**
Level 2	23.17	**23.33**	23.24	23.24
Level 3	**23.39**	23.19	**24.03**	22.17
Effect	0.26	0.16	1.61	2.10
Rank	3	4	2	1
combination	A3	B2	C3	D1

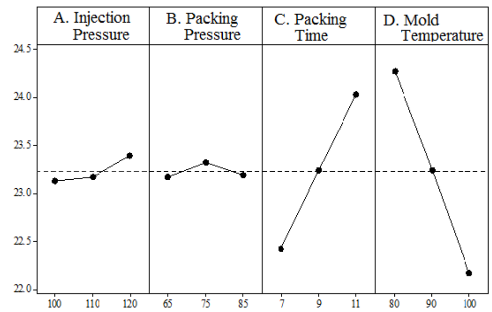

Fig. 2 S / N ratio reaction

(4) Analysis of Variance (ANOVA)

Analysis of variance (ANOVA, Analysis of Variance) is mainly determined change of each factor on the quality characteristics variation effect, which is another way to find the most influential factor for the entire experiment, in order to assess the experimental error. Table 6 initial variance analysis results of the present experiment.

Table 6 The first analysis of variance

Factor	SS	DOF	Variance
A	0.1173	2	0.05866
B	0.0438	2	0.02189
C	3.8826	2	1.94131
D	6.6239	2	3.31196
Other	0.0000	0	0.000
Total	10.6676	8	1.33345

In Table 6 that the variance B factor holding pressure variation compared to the number of other factors to low, so the integration of this factor to the error vector for a second analysis of variance.

Table 7 shows D factor for the entire injection molding mold temperature have a significant impact, accounting for 62.1% of the overall experiment, followed by C packing time and A. Injection pressure.

In Table 5 choose the best combination A3B2C3D1 for mold flow analysis again to verify that the best combination of parameters, the optimum amount of warpage results about 0.0549 mm are shown in Table 8. Fig. 3 shows the simulation of best combination A3B2C3D1.

Table 7 The second analysis of variance

Factor	SS	DOF	Var.	F-Ratio	Confi-dence	ρ%
A	0.117	2	0.0586	2.68	72.81%	1.09
B	Pooled					
C	3.882	2	1.9413	88.69	99.99%	36.4
D	6.623	2	3.3119	151.3	99.99%	62.1
Error	0.043	2	0.0218	*At Least 99% Confidence		
Total	10.66	8				

Table 8 best combination of parameters

	A	B	C	D	Warpage
Combination	120 MPa	75 MPa	11 Sec	80 ℃	0.0549

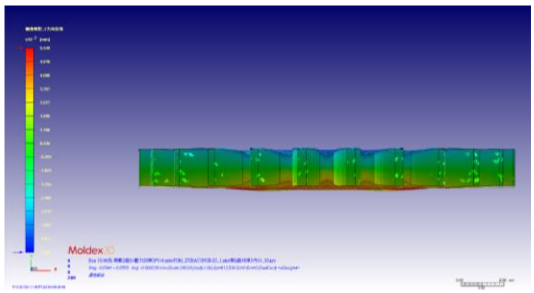
Fig. 3 Simulation of combination A3B2C3D1

3. Conclusions

The paper used Taguchi quality engineering method to decide injection molding optimized combination factors. The results have shown that: (1) the best factor level combination A3B2C3D1, injection pressure 120Mpa, packing pressure 75MPa, packing time 11sec, mold temperature 80 ℃; (2) the entire injection molding mold temperature have a significant impact, accounting for 62.1% of the overall experiment; and (3) the optimum amount of warpage results about 0.0549 mm.

References

[1] S. Kamaruddin, "Application of taguchi method in the optimization of injection moulding parameters for manufacturing products from plastic blend," International Journal of Engineering & Technology, vol. 2, no. 6, Dec. 2010.

[2] N. A. Shuaib, "Warpage factors effectiveness of a thin shallow injection-molded part using Taguchi method," International Journal of Engineering & Technology IJET-IJENS, vol. 11, no. 1, Feb. 2011.

[3] H. Radhwan, M. T. Mustaffa, A. F. Annuar, H. Azmi, and M. Z. Zakaria, "An optimization of shrinkage in injection molding parts by using Taguchi method," Journal of Advanced Research in Applied Mechanics, vol. 10, no. 1, pp. 1-8, 2015.

[4] S. M. Nasir, K. A. Ismail, Z. Shayfull, and N. A. Shuaib, "Comparison between single and multi gates for minimization of warpage using Taguchi method in injection molding process for ABS material," Key Engineering Materials, vol. 594-595, pp. 842-851, 2013.

[5] S. Opasanon and P. Lertsanti, "Impact analysis of logistics facility relocation using the analytic hierarchy process (AHP)," International Transactions in Operational Research, pp. 325–339, 2013.

[6] S. H. Kil, K. L. Dong, J. H. Kim, M. H. Li, and G. Neman "Utilizing the analytic hierarchy process to establish weighted values for evaluating the stability of slope revegetation based on hydroseeding applications in South Korea," Sustainability, vol. 8, p. 58, 2016.