Application of Taguchi method in parametric study of injection molding

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Introduction

In this study, optimum injection mold conditions for a door videophone front panel are investigated. The geometrical complexity of the panel design makes this component a difficult task for fabrication. This difficulty is compounded by various process control parameters such as heating temperature, mold temperature, injection pressure, injection speed, injection time, packing pressure, cooling channel, packing time, packing pressure, and clamp force. Therefore, recently researchers have used Taguchi method to approach optimum levels and inter-relationship among the process parameters.

In this study, Taguchi method of $L_{27}(3^8)$ is generated to find the optimum levels of process parameters and to determine the impact of those towards production of front panel by exploiting the S/N ratio.

Injection Molding Analysis

Product model

The door video panel has simple thin-wide geometry with width 300.4 mm, length 220.64 mm, and height 13 mm as shown in Fig. 1. This panel has a large rectangular cut in the middle for video screen and some additional holes at sides for buttons. The panel is reinforced a number of ribs. Wall thickness varies in the range of 2~2.5 mm. Particularly, at the bottom of panel, wall thickness is generally thicker than at the top, which is a clear indication that efficient cooling is needed at the bottom part during molding.

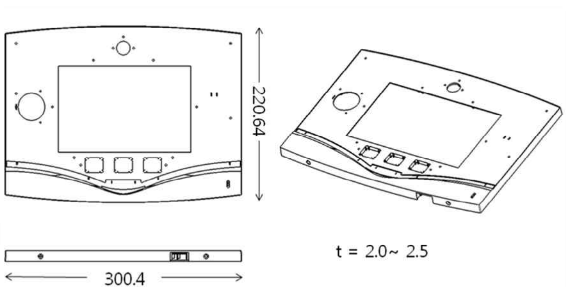

Fig. 1 Door video phone system panel model

Resin

Apart from its aesthetic look, ABS resin has a good advantage in terms of impact resistance and resistance toward chemical attack.

Thermoplastic analysis

For thermoplastic analysis of the panel, a commercial finite element based injection molding software. We performed analysis according to the injection molding and boundary condition.

Discussion of Problem

The problem associated with the conventional procedure adopted in fabricating the product by injection molding can be perceived from Fig. 2. Maximum deformation of real product measurement and that in simulation are almost coinciding to each other.

Fig. 2 Comparison between the deformation of actual product and analysis result

Deflection of panel may occur from the process parameters mentioned earlier. To realize the effect of those parameters on molding, we need to analyze it sequentially.

Decision of the parameters

We then analyze the rise in pressure due to various reasons using FEM analyses. This pressure is related to the cooling pattern, mold, heating temperature and injection control.

Application of Taguchi method

Analysis Model to Injection Mold

In this study, three stage designs are coupled to achieve optimum levels of process parameters to resolve the deflection problem of the front panel.

This study chooses the smaller the better quality characteristic to solve deflection problem through the orthogonal array of $L_{27}(3^8)$ optimal levels of process parameters.

Three level of orthogonal array equation. [1]

$$L_{3m}\left(3^{(3^m-1)/2}\right) \tag{3}$$

$(3^m - 1)/2$: orthogonal array

The smaller the better equation.

$$SN = -10\log_{10}\sum_{i=1}^{n}\frac{y_i^2}{n} \tag{4}$$

Taguchi Optimization Procedure and Analysis
Firstly, we should determine the control factors and their level value influencing the quality characteristics. Through a survey on injection molding production and consulting with field engineers for determining a group of suitable processing parameters and their levels of applications, the eight control factors were chosen as in Table 1.

Table 1 Design factors and levels

Factors	Description	Levels		
		1	2	3
A	Cooling pattern	(a)	(b)	(c)
B	Mold Temperature (℃)	65	70	75
C	Heating Temperature (℃)	210	225	240
D	Ram speed section 1 (%)	55	60	65
E	Ram speed section 2 (%)	15	20	25
F	Ram speed section 3 (%)	65	70	75
G	Ram speed section 4 (%)	35	40	45
H	Packing Pressure (%)	80	100	120

We know the main effect of each control factors based on the S/N ratio graph as shown in Fig. 3. Then optimal factor levels are combined to ensure efficient final panel product. Referring to Fig. 3 optimum combination chosen are A(b), B(3), C(3), D(3), E(3), F(3), G(2) and H(3).
Finally the deflection of panel is obtained to be around 1.288 mm. Simulation result based on optimum conditions gives a deflection of about 1.282 mm. Fig. 4 shows the deflection obtained through optimum levels.

Conclusion

This study proposes an application of Taguchi method to determine the optimal levels of process parameters for injection molding of front panel. In the analysis, byusing the optimized design parameters, the clamp force is changed to about 460 tonne. Shrinkage driving deviation

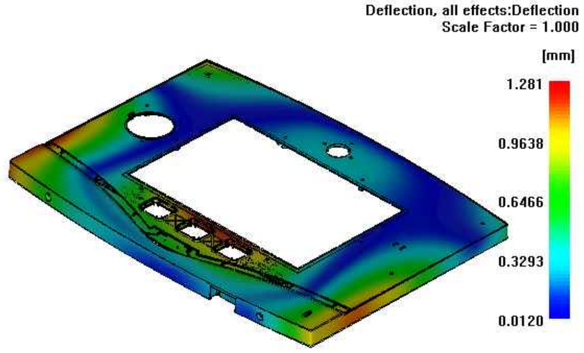

Fig. 4 Deformation analysis based on Taguchi method

is reduced by 0.471%(from 3.862% to 3.391%) and the process temperature difference is reduced by 54% from the original deviation "12.26℃". It is most notable thing that total deflection of the product is reduced by 21.07%. Besides, the S/N ratio indicates that the packing pressure and cooling channel are the most important control factors in numerical simulation. The mathematical regression model yields reasonable accuracy with less than 7% errors as predicted by the simulation data.

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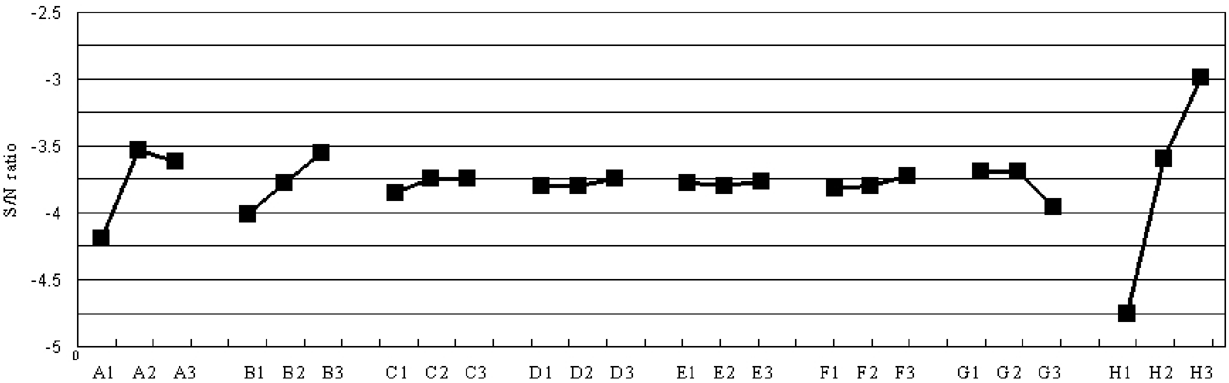

Fig. 3 The response graph for the front panel deflection