

OPTIMIZATION OF PARAMETERS & MINIMIZATION OF DEFECT BY APPLYING TAGUCHI & MOLDFLOW METHOD FOR INJECTION MOLDING COMPONENT

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ABSTRACT

This paper describes about the parameter optimization using the combination of design of experiment (DOE) Taguchi method and Moldflow simulation tests. By this method, it can gain the experiment data which can reflect the overall situation using fewer number of simulation test. Furthermore, the effects degree of different molding process parameters for surface sink marks are investigated, optimized parameter combination is obtained. It can solve the unreasonable appearance of process parameter settings. The mold design above mentioned can fasten the mold developing schedule, thus shorten the cycle of product development, and improve the quality of products and the competitive ability of enterprise.

Keywords-; mold flow; optimization; processing parameter; sink marks; Taguchi method.

I. INTRODUCTION

The plastics injection molding process is integral to many of today's mainstream manufacturing processes. Industries such as telecommunications, consumer electronics, medical devices, computers and automotive all have large, constantly increasing demands for injection molded plastic parts. There are thousands of different grades of commercial plastics materials with widely varying processing characteristics and complex part and mold designs are constantly pushing the limits of the process. The injection molding process requires the use of an injection molding machine, raw plastic material, and a mold. The plastic is melted in the injection molding machine and then injected into the mold, where it cools and solidifies into the final part ^[1,2]. The production of injection molded parts is a complex process where, without the right combination of material, part, mold design and processing parameters, a multitude of manufacturing defects can occur, thus incurring high costs. The injection molding process itself is a complex mix of time, temperature and pressure variables with a multitude of manufacturing defects that can occur without the right combination of processing parameters and design components. Determining optimal initial process parameter settings critically influences productivity, quality, and costs of production in the plastic injection molding (PIM) industry. The traditional injection molding design based on the designer's knowledge and experience is very difficult to design the injection mold with high quality ^[3,4]. However, with the development of CAE technology, especially the Moldflow software, the number of testing mold can be reduced ^[5]. In this work, the combined effects of process

parameters are analyzed by the combination of orthogonal experiments and Moldflow simulation tests, and then the optimized parameter combination is obtained.

II. THE TAGUCHI METHOD

The quality engineering method proposed by Taguchi is commonly known as the Taguchi method or Taguchi approach. His approach provides a new experimental strategy in which a modified and standardized form of design of experiment (DOE) is used. In other words, the Taguchi approach is a form of DOE with special application principles. By this method, it can gain the experiment data which can reflect the overall situation using fewer number of simulation test ^[1]. The proposed approach can effectively help engineers determine optimal initial process settings, reduce set-test iterations, and achieve competitive advantages on product quality and costs. The tool used in the Taguchi method is the orthogonal array (OA). OA is the matrix of numbers arranged in columns and rows. The Taguchi method employs a generic signal-to-noise (S/N) ratio to quantify the present variation ^[5,6]. These S/N ratios are meant to be used as measures of the effect of noise factors on performance characteristics. S/N ratios take into account both amount of variability in the response data and closeness of the average response to target.

III. FINITE ELEMENT MODEL

In this work, the automobile switch base has adopted as an example to demonstrate the whole optimizing process. The plastic material used in the product is ABS; the thickness of plastic product is 2mm, and the three dimensional molding sizes shown in Fig.1 are 35mm×20mm×30mm. Its exterior quality is relatively high, so the sink marks must be strictly controlled ^[2]. There are three major mesh types in Moldflow software, including Mid plane, 3D and Fusion. Due to the plastic average thickness is small, we adopt the surface meshes (Fusion), and used grid Mesh Tool to modify the mesh defects. Finally, the data for the mesh is obtained, including 3271 grids, 1848 nodes and the match percentage up to 96.2%, satisfied the analysis requirement ^[7,8].

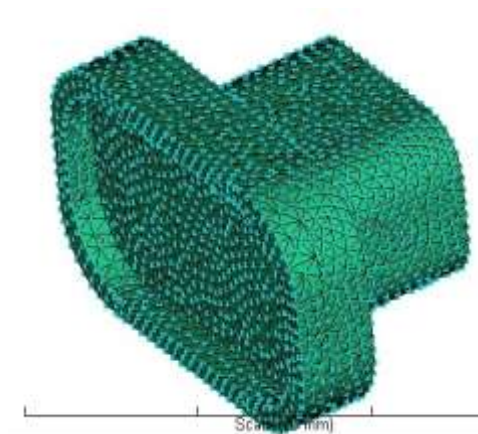


Fig- 1: The meshing model

IV. INJECTION MOLDING EXPERIMENT

Table -1: Range of process parameters

MELT TEMP	(M.T)	(°c)	230-245
INJECTION PRESSURE	(I.P)	(bar)	70-85
HOLDING PRESSURE	(H.P)	(bar)	40-55
COOLING TIME	(C.T)	(sec)	35-50

According to the experience and simulation analysis, the melt temperature, injection pressure, holding pressure, and cooling time are considered as the main factors of effecting surface sink marks. As shown in Table 2, four levels are uniformly taken within the range of factors for experiment ^[6].

Table - 2:. 4 Levels value of 4 factors

Number	M.T (°c)	I.P (bar)	H.P (bar)	C.T (sec)
1	230	70	40	35
2	235	75	45	40
3	240	80	50	45
4	245	85	55	50

Taguchi L16 screening experiments were conducted to identify the “most significant” input variables by ranking with respect to their relative impact on the sink mark. The Sink marks, index is an indication of the potential shrinkage due to a hot core. Higher Sink marks, index value shows higher potential shrinkage. However, whether or not the shrinkage would result in sink mark depends on geometry characteristics. Table 3 shows the Taguchi’s array for L16 experimental runs ^[3].

The S/N ratio η is given by:

$$\eta = -10\log (\text{MSD}) \quad (1)$$

Where MSD is the mean-square deviation for the output characteristic. MSD for the smaller-the-better quality characteristic is calculated by the following equation,

$$\text{MSD} = \frac{1}{N} \left[\sum_{i=1}^n Y_i^2 \right] \quad (2)$$

Where Y_i is the sink index value for the i th test, n denotes the number of tests and N is the total number of data points. The function ‘-log’ is a monotonically decreasing one, it means that we should maximize the S/N value. The S/N values were calculated using equations (1) and (2). Table -4 & 5 shows the response table for S/N ratios & data means using smaller-the-better approach. ^[9]

Table -3: Taguchi L16 Array

Number	M.T (°c)	I.P (bar)	H.P (bar)	C.T (sec)	Sink index(%)
1	230	70	40	35	4.03
2	230	75	45	40	3.689
3	230	80	50	45	2.92
4	230	85	55	50	2.605
5	235	70	45	45	2.559
6	235	75	40	50	3.139
7	235	80	55	35	2.693
8	235	85	50	40	2.805
9	240	70	50	50	3.156
10	240	75	55	45	3.186
11	240	80	40	40	3.284
12	240	85	45	35	3.412
13	245	70	55	40	3.042
14	245	75	50	35	3.32
15	245	80	45	50	3.18
16	245	85	40	45	3.61

Table -4: Response table for S/N ratios using smaller-the-better

Level	M.T	I.P	H.P	C.T
1	-10.267	-9.978	-10.88	-10.448
2	-8.915	-10.44	-10.052	-10.072
3	-10.259	-9.572	-9.668	-9.671
4	-10.321	-9.771	-9.162	-9.571
Delta	1.406	0.868	1.718	0.878
Rank	2	4	1	3

Table -5: Response table for Means using smaller-the-better

Level	M.T	I.P	H.P	C.T
1	3.311	3.197	3.516	3.364
2	2.799	3.334	3.21	3.205
3	3.26	3.019	3.05	3.069
4	3.288	3.108	2.882	3.02
Delta	0.512	0.314	0.634	0.344
Rank	2	4	1	3

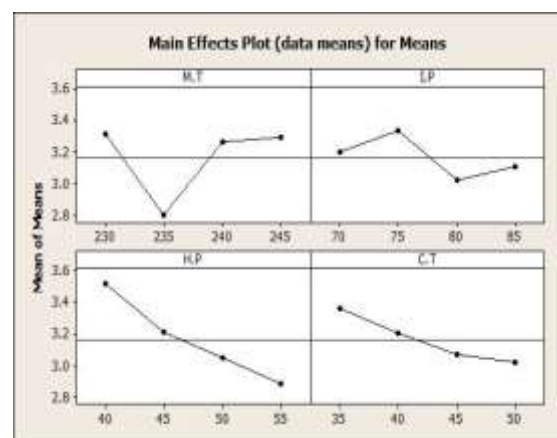
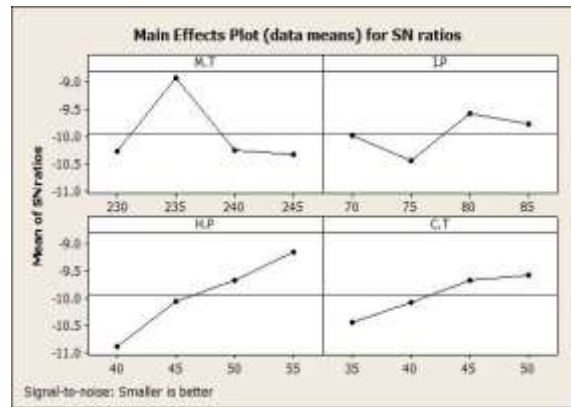


Fig- 2: Main effect plots

V. TEST OPTIMIZATION RESULTS

As shown in Fig. 3, The result of maximal sink index using the parameter combination of melt temp 235°C; injection pressure 80 bar; holding pressure 55 bar & cooling time 50 sec (Table 6) to simulate by Moldflow software is 2.674, which is the best data compared to the data of Table 3, so this parameter combination is considered as the optimized process parameters for minimizing sink mark.

Table 6: Optimizing process parameters

MELT TEMP	(°c)	235
INJECTION PRESSURE	(bar)	80
HOLDING PRESSURE	(bar)	55
COOLING TIME	(sec)	50

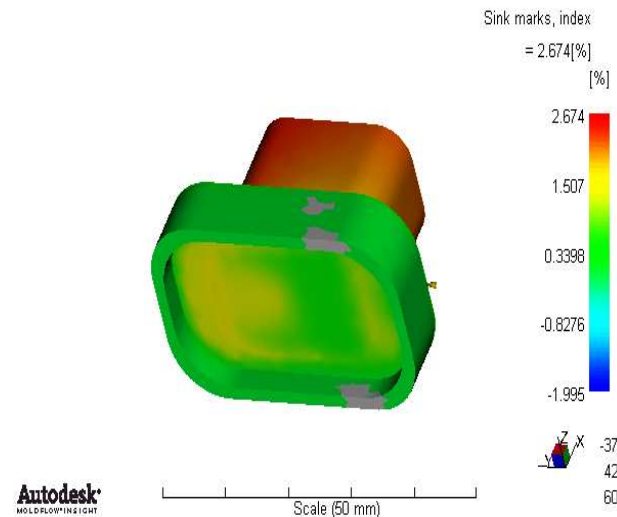


Fig- 3: The optimized sink index

VI. CONCLUSION

In the present study, the simulation for optimization of plastics injection molding processing parameters Based on The Minimization of Sink Marks have been performed by Taguchi method & Moldflow software. The following conclusions were obtained.

- 1) The simulation considering the sequence of effects degree of different molding process parameters for surface sink marks ranked in the holding pressure; melt temperature, cooling time and injection pressure. The holding pressure is the most important effect.
- 2) The optimized parameter combinations of different factors are considered as melt temp 235°C; injection pressure 80 bar; holding pressure 55 bar & cooling time 50 sec, and its sink marks index is 2.674, which is the best data compared with other parameter combinations.

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