



INJECTION MOLDING PROCESS SIMULATION OF TENSILE STRENGTH AND IMPACT SPECIMEN TEST

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ABSTRACT

The characteristic of plastic which are easy made and shaped, make plastic become famous in industry. Injection molding is one of plastic shaping process that used by common industry due to its capability of mass producing of complicated plastic part. In this study, the mold cavity was designed for making tensile strength and impact specimen tests. This design was suitable with 900 ton capacity HAITIAN MA 900/260e injection molding machine. ASTM D638 was used for tensile strength specimen test standard dimension and ASTM D256 was used for impact specimen test standard dimension. The study started with draw the specimen tests, design the mold cavity such as number of cavity, layout cavity, channel system, and cooling system, and then do simulation. The parameters variance of simulation were melt temperature, mold temperature, packing pressure, and packing time. The simulation result was analyzed by using Taguchi method and ANOVA. The result of study said that this machine could have 12 specimen tests. Taguchi method had result that the best parameter of injection molding process is 180° for melt temperature, 60° for mold temperature, 70 Mpa for packing pressure, and 5 sec for packing time. ANOVA had result that the significant process parameters were melt temperature, packing pressure and packing time, where melt temperature was the most valuable process parameter.

Keywords: injection molding, mold, mold design, mold cavity, tensile strength test, impact test, taguchi method, ANOVA.

INTRODUCTION

Due to the characteristics and the advantages, plastic become the most popular material in packaging industry. 35% market demands request plastic as material beside paper (24%), metal (17%), glass (6%) and the others material [1]. Several kind of plastic material are often mixed with certain composition to obtain specific properties as market demands and strength of plastic become the important characteristic that has to be possessed by plastic product. ASTM D638 and ASTM D256 standards are usually used to measurement tensile and impact material plastic. The dimension of specimen test according to these standards are shown in Figure-1(a) and Figure-1(b).

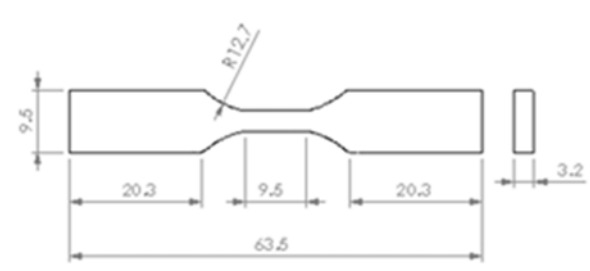


Figure-1(a). Dimension of tensile strength specimen test [2].

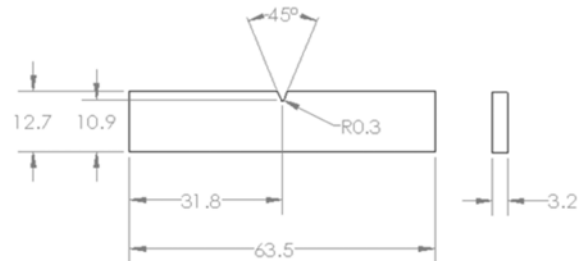


Figure-1(b). Dimension of impact specimen test [3].

Injection molding is one of manufacturing process that usually used for plastic production. Every plastic product can be easy made by this machine, eventhought its shape is very complicated. This machine is capable for mass producing and easy to use. Several researches have been proposed to obtain the best parameter process of injection molding for optimal result. Taguchi method and ANOVA can be conducted to find the optimal process parameter that can decrease defect of product such as warpage and shrinkage. The parameter process is melt temperature, mold temperature, injection pressure, packing pressure, packing time, and the other parameter. [4-5]. The purpose of this study is to determine the best parameter process of injection molding for tensile and impact specimen test. The parameter processes that would be optimized are mold temperature, melt temperature, packing pressure, and packing time towards to total shrinkage. Several simulation software was done and optimized by using Taguchi and ANOVA methods. Design of mold cavity was designed before did simulation. This design was suitable with 900 ton capacity



HAITIAN MA 900/260e injection molding machine and using PS (polysterine) as material. HAITIAN MA 900/260e machine specification is shown in Table-1.

Table-1. HAITIAN MA 900/260e machine specification.

Item	Data
Screw diameter	36 mm
Injection capacity	153 cm ³
Injection pressure	173 Mpa
Clamp tonnage	900 KN
Ejector tonnage	33 KN
Space between tie bars	360 x 360 mm

MOLD CAVITY DESIGN

Number of Cavity

Number of cavity calculation was conducted according to maximum injection capacity (V_s) and volume of product (V_p) by using Equation. 1 [6]. Volume product is 4,15 cm³. From this calculation, 30 cavity could be made by this machine on one cycle time. But, the size of tie bar this mold cannot support this total cavity. So, the number of cavity was calculated according to tie bar dimension, and the result is 12 cavity as shown in Figure-2.

$$n = 0,8 \frac{V_s}{V_p} \quad (1)$$

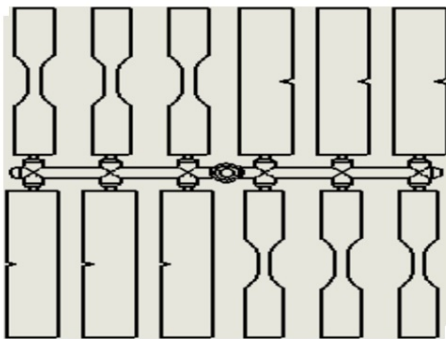


Figure-2. Layout of 12 cavity.

SIMULATION AND RESULT

Initial Simulation

First simulation was conducted by using parameter process as shown in Table-2. The simulation

result shows 5,58% shrinkage on part as shown in Figure-3. To minimize the shrinkage, taguchi method and ANOVA were conducted in this study.

Table-2. Parameter process of initial simulation.

Item	Data
Melt temperature	225°C
Mold temperature	45°C
Packing pressure	50 Mpa
Packing time	5 second

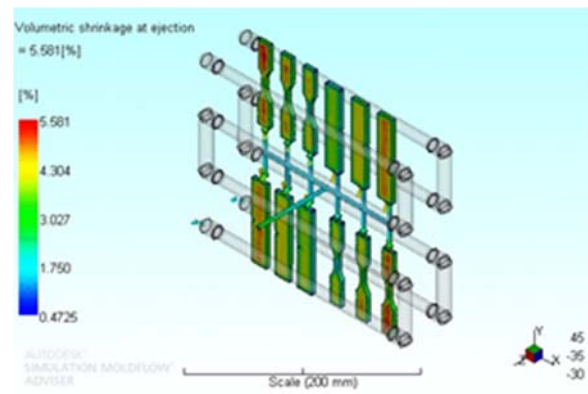


Figure-3. Total shrinkage on initial simulation.

Taguchi Method

L_{27} orthogonal array was used to determine the number of combination which can give more information of respon. S/N ratio “smaller the better type” was selected to calculated value of S/N ratio as shown in Equation. 2 [7]. This method was conducted to find the optimal parameter process that can minimize the total shrinkage. Parameter process and their level are shown in Table-3.

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

Where: n is total of shrinkage data and y_i is depreciation value on i data

Table-4 shows the combination of parameter process according to L_{27} orthogonal array, the total shrinkage and S/N ratio. In addition, Table-5 shows the average values from S/N ratio. Optimal parameter process is the highest S/N ratio value, i.e., melt temperature = 180 °C, mold temperature = 60 °C, packing pressure = 70 Mpa, and packing time = 5 second.

**Table-3.** Process parameter and their level.

Parameter Process	Level 1	Level 2	Level 3
Melt temperature (°C)	180	225	270
Mold temperature (°C)	30	45	60
Packing pressure (Mpa)	50	60	70
Packing time (second)	5	10	15

Table-4. Simulation result.

No	Melt Temperature (°C)	Mold Temperature (°C)	Packing Presssure (Mpa)	Packing Time (s)	Shringkage (%)	S/N (dB)
1	180	39	50	5	4,343	-12,755797
2	180	45	60	10	4,089	-12,232342
3	180	60	70	15	4,090	-12,234466
4	180	30	50	10	4,328	-12,725745
5	180	45	60	15	4,093	-12,240835
6	180	60	70	5	3,894	-11,807919
7	180	30	50	15	4,308	-12,685514
8	180	45	60	5	4,078	-12,208944
9	180	60	70	10	4,071	-12,194022
10	225	45	70	5	4,780	-13,588558
11	225	60	50	10	5,797	-15,264066
12	225	30	60	15	5,748	-15,190335
13	225	45	70	10	5,383	-14,620488
14	225	60	50	15	5,924	-15,452301
15	225	30	60	5	5,337	-14,545944
16	225	45	70	15	5,629	-15,008625
17	225	60	50	5	5,565	-14,909303
18	225	30	60	10	5,689	-15,100719
19	270	60	60	5	5,504	-14,813569
20	270	30	70	10	5,904	-15,422927
21	270	45	50	15	6,634	-16,435509
22	270	60	60	10	5,954	-15,496177
23	270	30	70	15	6,267	-15,941194
24	270	45	50	5	6,025	-15,599141
25	270	60	60	15	6,283	-15,963341
26	270	30	70	5	5,113	-14,173516
27	270	45	50	10	6,458	-16,201961

**Table-5.** Response table for S/N ratio.

Level	Melt Temperature (°C)	Mold Temperature (°C)	Packing Presssure (Mpa)	Packing Time (s)
Level 1	-12,34284269	-14,28241002	-14,66992634	-13,82252119
Level 2	-14,85337098	-14,23737814	-14,19913397	-14,36204955
Level 3	-15,56081491	-14,23724043	-13,88796826	-14,57245784
Difference	-3,21797222	-0,045169593	-0,781958078	-0,749936648

Table-6. ANOVA for significant parameter process.

Source value	Sum of aquares	Degree of freedom	Mean square	F-Ratio (%)	P-value	C (%)
Melt Temperature (°C)	17,0357	2	8,5178	228,83	0	85,00499
Mold Temperature (°C)	0,126	2	0,063	1,69	0,212	0,258604
Packing Presssure (Mpa)	1,0211	2	0,5106	13,72	0	4,744579
Packing Time (s)	1,1005	2	0,5502	14,78	0	5,142508
Error	0,67	18	0,0372			4,84932
Total	19,9533	26				100

Anova

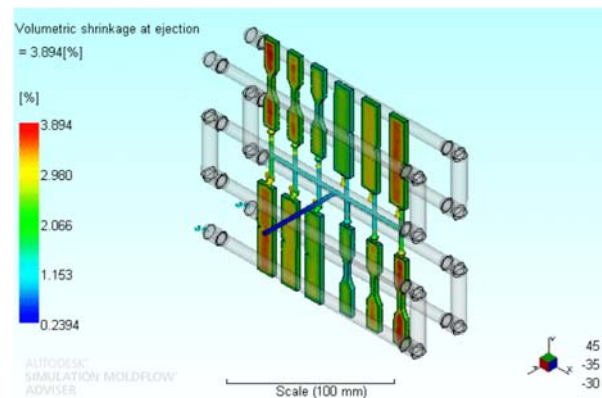
ANOVA was used to find the most significant parameter process that influences the total shrinkage. Table-6 is the result of the ANOVA analysis, and melt temperature was the most significant parameter process with 95% confident level. Melt temperature has 85% contribution on shrinkage variation, so it has to be controlled very carefully to minimize shrinkage. Mold temperature was not significant parameter process on shrinkage variation due to its P-value was higher than 0,05 and its precentage contribution is the smallest.

Final Simulation

Final simulation was conducted by using parameter process from Taguchi method as shown in Table-7. The simulation result shows the total shrinkage is 3,894% and this result was smaller than the initial simulation. The final simulation result can be shown in Figure-4.

Table-7. Parameter process of final simulation.

Item	Data
Melt temperature	180 °C
Mold temperature	60 °C
Packing pressure	70 Mpa
Packing time	5 second

**Figure-4.** Total shrinkage on final simulation.

CONCLUSIONS

This study has investigate the design of mold cavity for HAITIAN MA 900/260e and the best parameter process that can minimize the shrinkage for PS material. Due to the tie bar size of this machine, 12 cavity can be made by this machine. Taguchi method has result that the best parameter of injection molding process is 180° for melt temperature, 60° for mold temperature, 70 Mpa for packing pressure, and 5 sec for packing time. This parameter can decrease the total shrinkage of product. ANOVA had result that the significant process parameters were melt tempaerature, packing pressure and packing time, where melt tempaerature was the most valuable process parameter. Mold temperature doesn't have significant influence on shrinkage reduction.

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