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Analysis Of Injection Moulding Process Parameters

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Abstract

In this study, analysis of injection moulding process parameters was carried out to minimize short shots. Optimum level of factors are determined by DOE technique of Taguchi and *the analysis of variance (ANOVA) methods. For this study CPVC specimens were tested. Determination of optimum machine settings was based on S/N ratios. According to results mould closing speed had significant effect on quality characteristic. Mould pressure and Injection pressure had no significant effect.*

1. Introduction

Plastic injection molding uses plastic in the form of pellets or granules as a raw material. It is then heated until a melt is obtained. Then the melt is injected into a mould where it is allowed to solidify to obtain the desired shape. The mould is then opened and the part is ejected. The process parameters such as cycle time, fill time, cooling time, injection time, injection speed, injection pressure, holding pressure, melting temperature, mould temperature and so on need to be optimized in order to produce finished plastic parts with good quality. Various studies have been conducted to improve and optimize the process, so as to obtain high quality parts produced on a wide range of commercial plastic injection molding machines. [1]

The Taguchi method is a well-known technique that provides a systematic and efficient methodology for process optimization. It has been widely used for product design and process optimization worldwide. [2] This is due to the advantages of the design of experiment using Taguchi's technique, which includes simplification of experimental plan and feasibility of study of interaction between different parameters.

Lesser number of experiments is required in this method. As a consequence, time as well as cost is reduced considerably. Taguchi proposes experimental plan in terms of orthogonal array that gives different combinations of parameters and their levels for each experiment. According to this technique, the entire parameter space is studied with minimal number of necessary experiments only. [3, 4] Based on the average output value of the quality characteristic at each parameter level, main effect analysis is performed. Analysis of variance (ANOVA) is then used to determine which process parameter is statistically significant and the contribution of each process parameter towards the output characteristic. With the main effect and ANOVA analyses, possible combination of optimum parameters can be predicted.

In an injection moulding process development, DOE can be applied in identifying the machine process parameters that have significant influence in the injection moulding process output. The easiest way to do the set-up on the injection-moulding machine is based on the machine set-up operator or technician's experience, or trial and error method. This trial and error method is unacceptable because it is time consuming and not cost effective. Common quality problems or defects that come from an injection moulding process include voids, surface blemish, short-shot, flash, jetting, flow marks, weld lines, burns, and war page. The defects of injection moulding process usually arise from several sources, which include the pre-processing treatment of the plastic resin before the injection moulding process, the selection of the injection-moulding machine, and the setting of the injection moulding process parameters. [5] The objective of this paper is to obtain the optimal setting of machine process parameters that will influence Quality Characteristic (i.e. Weight) and subsequently, reduce the short shots.

2. Taguchi Technique

Taguchi and Konishi had developed Taguchi techniques. [6] These techniques have been utilized widely in engineering analysis to optimize the performance characteristics within the combination of design parameters. Taguchi technique is also power tool for the design of high quality systems. It introduces an integrated approach that is simple and efficient to find the best range of designs for quality, performance, and computational cost. [7]
In this study, parameter design is coupled to achieve the optimum levels of process parameters leading to minimum Short Shots during the manufacturing of plastic parts

Taguchi Parameter Design Fallows chronological sequence as

- Selection Of Quality Characteristics
- Selection of Control Factors and Noise Factors
- Selection of Orthogonal Arrays
- Analysis of Results
- Confirmation of results

2.1. Selection of Quality Characteristic

From the discussion with company peoples strongly felt that weight of production part bears a direct relationship with occurrence SHORT-SHOTS. Recent production parts measurement revealed that average weights of qualified parts fell on the higher side of the distribution while those with SHORT-SHOTS were on the lower end so that weight of the part in grams is taken as quality characteristics.
In Taguchi Method Desirable Performance is classified in three categories such as the-smaller-the-better, the-larger the-better, and the-nominal-the-best. Signal to Noise analysis is designed to measure quality characteristic. It is given by

$$S/N = -10 \log_{10}(MSD) \quad (1)$$

Where MSD= Mean Squared Division
For the smaller the better characteristic,

$$MSD = (Y_1^2 + Y_2^2 + Y_3^2 + \cdots\cdots\cdots)/n \quad (2)$$

Larger the better characteristic,

$$MSD = (1/Y_1^2 + 1/Y_2^2 + 1/Y_3^2 + \cdots\cdots\cdots)/n \quad (3)$$

Nominal the best characteristic,

$$MSD = [(Y_1 - m)^2 + (Y_1 - m)^2 + (Y_1 - m)^2 + \cdots)]/n \quad (4)$$

Where Y_1, Y_2, Y_3 are the responses and n is the number of tests in a trial and m is the target value of the result. [8] Larger Weight values represent better or improved minimum short shot. Therefore, a Larger -the-better quality characteristic was implemented and introduced in this study.

2.2. Selection of Control Factors

In this study we have consider 4 factors which affect majorly on quality characteristic such as (A) Injection Pressure, (B) Mold Closing Speed, (C) Mold Pressure, (D) Backpressure, (E). One of the advantages of Taguchi parameter design is it can also consider uncontrollable factors (Noise Factors) but in this study we have considered only controllable factors.

2.3. Selection of Orthogonal Array

Since 4 controllable factors and three levels of each factor were considered L9 Orthogonal Array was selected for this study.

2.4 Analysis of Results

Result Analysis was carried out by making ANOVA to determine percentage effect of each parameter on the quality characteristic.

3. Experimental Study

3.1 Injection Molding Process

Trials are taken on Milacron 110 Injection Molding Machine by injecting Chlorinated Poly Vinyl Chloride (CPVC) material in 3/4th inch Tee mold. The specimen is shown in Figure 1

Figure 1. 3/4th inch Tee

3.2. Experimental Design

In order to determine the optimal process conditions and the effect of the processing parameters on the quality Characteristic i.e. weight of CPCV 3/4th inch TEE, the Taguchi method, experimental design was utilized. The controllable factors selected were the (A) Injection Pressure, (B) Mold Closing Speed, (C) Mold Pressure, (D) Backpressure, (E. Table 1 gives the variable factors and their levels. Four controllable factors with three levels were studied, as shown in Table 1; therefore, the L9 orthogonal array (OA) was selected for this study therefore there were 9 trial conditions, four trials with each trial condition was taken. The signal- to-noise ratios (S/N) for each experiment were determined by using larger is the better characteristic.

Table 1. Controllable factors and levels

Notation	Factor Description	Level 1	Level 2	Level 3
A	Injection Pressure (Bar)	85	105	125
B	Mold Closing Speed (mm/s)	90	145	200
C	Mold Pressure (Bar)	80	85	90
D	Back Pressure (Bar)	15	28	40

4. Result Analysis

4.1. Trial Conditions and Results

According to L9 layout there are nine trial conditions as shown in Table 2

Table 2. Layout for Experimental Design according to L9 Array

Exp. No.	A Injection Pressure (Bar)	B Mould Closing Speed (mm/s)	C Mould Pressure (Bar)	D Back Pressure (Bar)
1	85	90	80	15
2	85	145	85	28
3	85	200	90	40
4	105	90	85	40
5	105	145	90	15
6	105	200	80	28
7	125	90	90	28
8	125	145	80	40
9	125	200	85	15

Four trials with each trial condition were taken there S/N ratios with Larger is the better quality characteristic were calculated and summarized in Table 3

Table 3 Summary Report for Different trials conducted during Experiments

Trial	Weight In Grams				S/N Ratios
	Sample 1	Sample 2	Sample 3	Sample 4	
1	127	128	132	129	42.209
2	139	138	140	139	42.859
3	149	151	150	150	43.521
4	124	125	127	124	41.936
5	153	157	156	154	43.805
6	155	154	153	154	43.75
7	139	140	141	140	42.922
8	138	141	141	140	42.921
9	169	170	171	170	44.608
	Grand Average				**43.17**

Above test results were studied and effect of each parameter on S/N ratio was calculated and plotted as shown in Figure 2

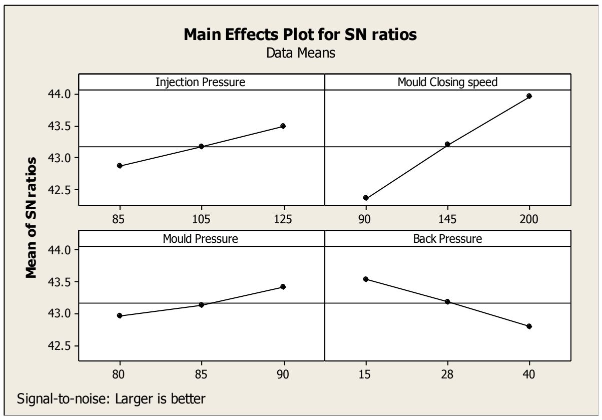

Figure 2 Effect of Process parameters on S/N Ratio

4.2. Analysis of Variance by QT-4 Software

ANOVA was performed by using a software qualitek-4 which gives significance of each factor in terms of Percent in the last column of the Table 4

Table 4. ANOVA Table

Sr. No.	Factor	DOF	SS	Variance	Pure Sum	P
1	Injection Pressure	2	0.587	0.293	0.587	10.50
2	Mold Closing Speed	2	3.837	1.918	3.837	68.66
3	Mold Pressure	2	0.323	0.161	0.323	5.795
4	Back Pressure	2	0.839	0.419	0.839	15.02
	Other/ Error	0	0.000	0.000		0.000
	Total	8	5.589			100 %

From ANOVA it is clear that Mould closing speed and Back Pressure is the most significant factors. The Optimum conditions and the optimum results are calculated with the help of ANOVA and given in Table 5

Table 4.4 Optimum Condition and performance

Sr. No.	Factors	Level Description	Level	Contribution
1	Injection Pressure	125	3	0.313
2	Mould Closing Speed	200	3	0.789
3	Mould Pressure	90	3	0.245
4	Back Pressure	15	3	0.370

Total Contribution from All Factors 1.717
Current Grand Average of Performance 43.170
Expected Result at Optimum Condition 44.887

5. Conclusion

Taguchi and ANOVA methods were used to investigate the effects of injection pressure, Mould Closing Speed, Mould Pressure and Back Pressure on the quality Characteristic (i.e. Weight) of 3/4th inch Tee Samples . In Taguchi method, S/N ratios were used for determining the optimal set of process parameters. The results showed that 125 Bar of Injection Pressure, 200mm/s of mould closing speed, 90 Bar of Mould Pressure and 15 Bar of Back Pressure gave maximum weight of samples. ANOVA method gave the significance degree of the each process parameter. According to the P-values more than 68, the Mould Closing Speed was effective parameter for Short Shots.

6. References

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