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# ANALYSIS OF INJECTION MOLDING PROCESS TO REDUCED DEFECTS (SHORT-SHOT)

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**Abstract:**
***This paper deals with optimal injection molding process parameters for minimum short shot. In this study, analyses of injection molding process parameters were carried out to reduced defects and minimize short shots. Optimal injection molding conditions for minimum short shot were determined by the DOE technique of Taguchi and the analysis of variance (ANOVA) methods. For this study CPVC plastic specimen was tested. Determination of the optimal Injection molding process parameters were based on S/N ratios. According to results mold closing speed had significant effect on quality characteristic. Mold pressure and Injection pressure had no significant effect.***

**Keywords:** Injection Molding; Optimization; Short Shot; Taguchi Method; ANOVA; Signal-To-Noise Ratio.

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## 1. Introduction

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

The taguchi method is well known technique because of that provides a systematic and efficient methodology for process optimization. Taguchi method is widely used for process optimization and product design in 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. In taguchi method lesser number of experiments is required. 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

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their levels for each experiment. According to the taguchi technique entire parameter space is studied with minimum number of experiment is necessary. [3, 4] By using average output value of the quality characteristic each parameter level and main effect analysis is performed. Then Analysis of variance (ANOVA) is used to determine which process parameter is statistically significant and the contribution of each process parameter towards the output characteristic. With the help of main effect and ANOVA analysis, possible combination of optimum parameters of injection molding process can be predicted.

In an injection molding process development, DOE can be applied in identifying the machine process parameters that have significant influence in the injection molding process output. The easiest way to do the set-up on the injection-molding machine is based on the machine set-up operator or technician's experience, or trial and error method. This trial and error method is not acceptable because it is time consuming and not cost effective. Common quality problems or defects that come from an injection molding process include voids, surface blemish, short-shot, flash, jetting, flow marks, weld lines, burns, and war page. The defects of injection molding process usually arise from several sources, which include the pre-processing treatment of the plastic resin before the injection molding process, the selection of the injection-molding machine, and the setting of the injection molding 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 Method

Taguchi method is invented by Dr.taguchi and Konishi. [6] Traditional method of experimental design is very complicated and not easy to use. The number of process parameters increases. When large numbers of experiments carried out. To solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with only a small number of experiments [2]. Taguchi technique is widely use in engineering analysis and consist of a plan of experiments with the objective of acquiring data in a controlled way, in order to obtain information about the behavior of a given process. This technique is not complicated and this technique has many advantages like saving time, saving of effort in conducting experiments, reducing the cost, and determine significant parameters quickly Taguchi's robust design method is a powerful tool for the design of a high-quality system. In addition to the S/N ratio, a statistical analysis of variance (ANOVA) can be employed to indicate the impact of process parameters of injection molding machine. [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.
The steps applied for Taguchi optimization in this study are as follows.

- Select Quality Characteristics.
- Select control parameters and noise parameters.
- Select Taguchi orthogonal arrays.
- Result analysis.
- Conformation of experiment.

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### 2.1. Select Quality Characteristics

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. Signal to Noise analysis is designed to measure quality characteristic.

Three different types of quality characteristics use in taguchi methodology. It is given by

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

Where,
MSD = Mean Squared Division

Nominal is best characteristic,

$$MSD = [(Y_1 - m)^2 + (Y_1 - m)^2 + (Y_1 - m)^2 + \ldots\ldots)]/n \tag{2}$$

Smaller is a better characteristic,

$$MSD = (Y_1^2 + Y_2^2 + Y_3^2 + \cdots\cdots\cdots\cdots)/n \tag{3}$$

Larger is better characteristic,

$$MSD = (1/Y_1^2 + 1/Y_2^2 + 1/Y_3^2 + \cdots\cdots\cdots\cdots)/n \tag{4}$$

Where,
$Y_1, Y_2, Y_3$ = responses
n = number of tests in a trial
m = the target value of the result

Minimum short shot was improved when the value of weight is larger. [8] Therefore, a larger-the-better quality characteristic was implemented and introduced in this study.

### 2.2. Select Control Parameters

In this study 4 parameters which affect majorly on quality characteristic is to be considered such as (A) Injection Pressure in bar, (B) Mold Closing Speed in mm/s, (C) Mold Pressure in bar, (D) Screw Speed in rpm. One of the important attributes of Taguchi parameter design is that it could also consider uncontrollable (noise) parameters in the analysis.

### 2.3. Select Taguchi Orthogonal Arrays

Since four parameters were studied in this research, three levels of each parameter were considered. Therefore, an L9 orthogonal array was selected for this study.

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### 2.4. Result Analysis

Result Analysis was carried out by making analysis of variance (ANOVA). The purpose of the ANOVA is to determine percentage effect of each parameter on the quality characteristic.

## 3. Experimental Study

### 3.1. Material

Chlorinated Poly Vinyl Chloride (CPVC) was used for this study.

### 3.2. Injection Molding Process

Trials are taken on injection molding machine by injecting Chlorinated Poly Vinyl Chloride (CPVC) material in 3/4th inch Elbow mold. The specimen is shown in Figure 1.

Figure 1: 3/4$^{th}$ inch elbow

### 3.3. Experimental Design

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

Table 1: Injection molding parameters

| **Symbol** | **Parameters** | **Unit** | **Level 1** | **Level 2** | **Level 3** |
|---|---|---|---|---|---|
| A | Injection Pressure | Bar | 87 | 107 | 128 |
| B | Mold Closing Speed | mm/s | 89 | 144 | 198 |
| C | Mold Pressure | Bar | 85 | 90 | 95 |
| D | Screw Speed | Rpm | 55 | 63 | 70 |

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## 4. Analysis of Result

### 4.1. Trials Experimental Conditions and Results

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

Table 2: Experimental plan using L9 orthogonal array

| Experiment No | A Injection Pressure (Bar) | B Mold Closing Speed (mm/s) | C Mold Pressure (Bar) | D Screw Speed (rpm) |
|---|---|---|---|---|
| 1 | 85 | 89 | 85 | 55 |
| 2 | 85 | 144 | 90 | 63 |
| 3 | 85 | 198 | 95 | 70 |
| 4 | 107 | 89 | 90 | 70 |
| 5 | 107 | 144 | 95 | 55 |
| 6 | 107 | 198 | 85 | 63 |
| 7 | 128 | 89 | 95 | 63 |
| 8 | 128 | 144 | 85 | 70 |
| 9 | 128 | 198 | 90 | 55 |

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

Table 3: Report of Different trials conducted during Experiments

| Experiment No. | Weight in Grams | | | S/N Ratios | Means |
|---|---|---|---|---|---|
| | Trial 1 | Trial 2 | Trial 3 | | |
| 1 | 130 | 129 | 131 | 42.2784 | 130.000 |
| 2 | 140 | 141 | 141 | 42.9637 | 140.667 |
| 3 | 151 | 151 | 152 | 43.5986 | 151.333 |
| 4 | 128 | 126 | 126 | 42.0525 | 126.667 |
| 5 | 159 | 155 | 156 | 43.8980 | 156.667 |
| 6 | 156 | 157 | 156 | 43.8809 | 156.333 |
| 7 | 142 | 141 | 142 | 43.0252 | 141.667 |
| 8 | 143 | 140 | 142 | 43.0243 | 141.667 |
| 9 | 172 | 170 | 172 | 44.6764 | 171.333 |
| Average Total | | | | 43.2664 | 146.259 |

Study the above test results and the effect of each parameters on S/N ratio and Mean was calculated and plotted as shown in figure 2 and figure 3

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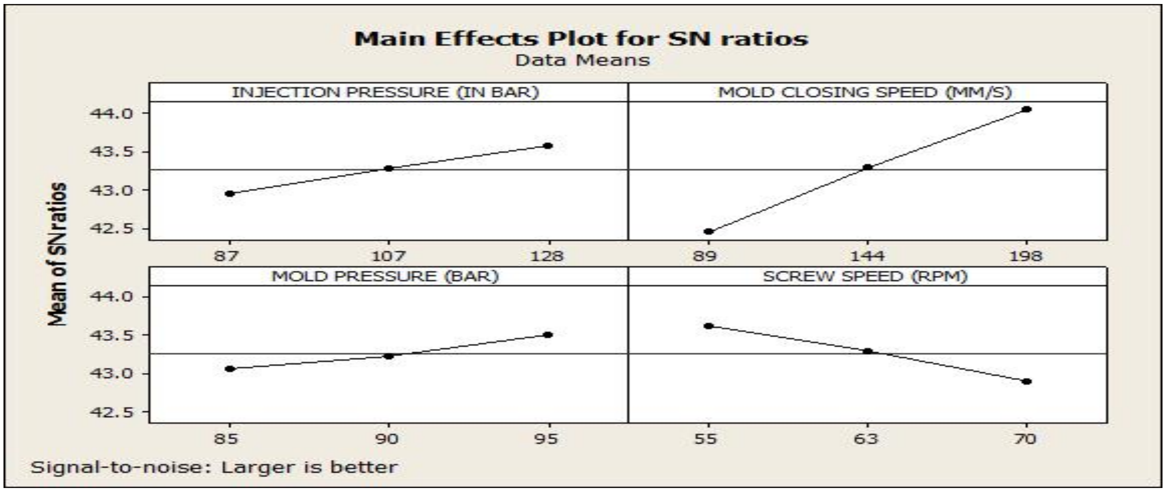


Figure 2: Process Parameter effect on S/N ratio

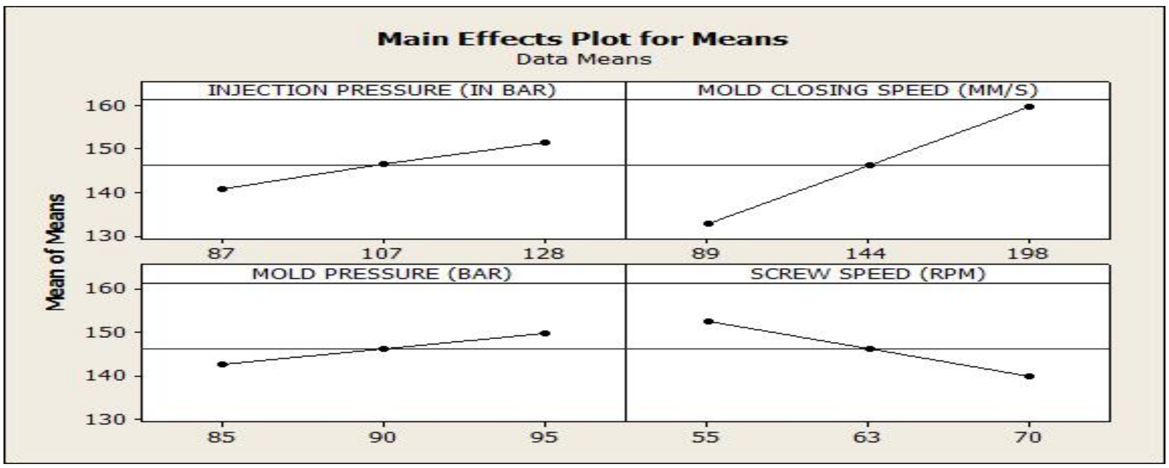


Figure 3: Process Parameter effect on Means

## 4.2. Analysis of Variance (ANOVA) by Using QT-4 Software

QT-4 Software is used to performed ANOVA and last column of table 4 which gives the significance of each parameter in terms of percentage.

Table 4: ANOVA Results Table

| Sr N. | Parameters | DOF | Sum of square | variance | Pure Sum | P |
|---|---|---|---|---|---|---|
| 1 | Injection Pressure | 2 | 0.570 | 0.285 | 0.570 | 10.252 |
| 2 | Mold closing Speed | 2 | 3.902 | 1.951 | 3.902 | 70.189 |
| 3 | Mold Pressure | 2 | 0.323 | 0.161 | 0.323 | 5.822 |
| 4 | Screw speed | 2 | 0.763 | 0.381 | 0.763 | 13.733 |
| | Other/Error | 0 | 0.000 | 0.000 | | 0.000 |
| | Total | 8 | 5.559 | | | 100% |

From above results table of ANOVA it is clear that Mold closing speed and screw speed is the most significant parameters in this study. With the help of ANOVA the optimum results and optimum conditions are calculated which is given in Table 5

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Table 5: Optimum Condition and Performance

| Sr. No | Parameters | Level description | Level | Contribution |
|---|---|---|---|---|
| 1 | Injection Pressure | 128 | 3 | 0.304 |
| 2 | Mold Closing Speed | 198 | 3 | 0.793 |
| 3 | Mold Pressure | 95 | 3 | 0.249 |
| 4 | Screw Speed | 55 | 1 | 0.346 |

Total Contribution from All Factors... 1.692
Current Grand Average of Performance... 43.270
Expected Result at Optimum Condition... 44.962

## 5. Conclusion

The effects of injection pressure, Mold Closing Speed, Mold Pressure and Screw Speed this injection molding parameters on the quality Characteristic (i.e. Weight) of 3/4th inch Elbow Samples is investigated by using Taguchi and ANOVA methods. In Taguchi method, optimal set of process parameters is determined by using S/N ratios. In this study, the results showed that 1258 Bar of Injection Pressure, 198 mm/s of mold closing speed, 95 Bar of Mold Pressure and 55 RPM of Screw Speed gave maximum weight of samples. ANOVA method gave the significance degree of each process parameter. According to the Percent-values more than 70, the Mold Closing Speed was effective parameter for Short Shots.

## References

[1] Chen, R.S., Lee, H.H., and Yu, C.Y., “Application of Taguchi’s Method on the optimal process design of an injection molded PC/PBT automobile bumper”. Composite Structures, 39, 1997, pp. 209-214.
[2] Wang, W.H., and Tarng, Y.S., “Design Optimization of cutting parameters for turning operations based on the Taguchi method”. Journal of Materials Processing Technology, 84, 1998, pp. 122-129.
[3] Phadke, M.S., “Quality Engineering Using Robust Design”. Prentice Hall International Inc., New York, 1989.
[4] Roy, R.K., “A primer on the Taguchi method”. Competitive Manufacturing Series, Van Nostrand Reinhold, New York 1990.
[5] Shaik Mohamed Mohamed Yusoff, Jafri Mohd. Rohani, Wan Harun Wan Hamid & Edly Ramly “A Plastic Injection Molding Process Characterisation Using Experimental Design Technique: A Case Study”, Jurnal Teknologi, 41, 2004.
[6] Taguchi G, Konishi S. Taguchi methods, orthogonal arrays and linear graphs, tools for quality American supplier institute. American Supplier Institute; 1987.
[7] Taguchi G, Introduction to quality engineering, (Asian Productivity Organization, Tokyo, 1990).
[8] Roy, R. A Primer on the Taguchi Method. New York: Van Nostrand Reinhold; 1990.

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