Optimization Injection Moulding Parameter Process Using General Factorial Design in Small Medium Enterprise Industries

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Abstract. Small and medium scale industries that are newly developed have many obstacles due to their ability and experience compared to other large industries. Plastic bowls for collecting rubber latex is one of the products that made from the injection moulding process. The company wants to improve its competitiveness by reducing raw materials used along with considering the quality of the products produced, but due to lack of information, this process is carried out trial & error. This study aims to determine the combination of parameters that can minimize the net weight of the product but still meet the product strength standards, the method used in this study is general factorial design because this method can investigate the effect of each factor and its interactions as additional information. In the analysis of variance (Anova), the temperature barrel in this study is a factor that has a contribution of 88.41% and 90.66% for the net weight and tensile strength of the product. The optimum conditions for this product are A3B1C1D1 by using the regression equation, the net weight of product is 17.3gr with product tensile strength 938.285N.

1. Introduction
Generally, the processing parameters of injection moulding are determined by experienced moulding personnel in industry based on trial and error method [1]. the parameter setting is a highly skilled job based on a long-term experience rather than through a theoretical and analytical approach [2]. The purpose of this research is to minimize the use of raw materials by reducing the net weight of the product produced by considering the effect on product strength from the change in process parameters that have been carried out for one of the products made from micro & small industries to increase its competitiveness. Therefore, to improve the quality of plastic products, it is necessary to set appropriate parameter variations [3]. Factorial design is usually to solve optimization problem [4]. Because with factorial design, every possible level of each factor and their interaction can be investigated [5].

2. Method and materials

2.1. Selection of the injection moulding parameter and their level
A large number of process variable affect the quality of products made by injection moulding process. All of the parameters involved during injection moulding process can be grouped into four basic categories: temperature, pressure, time and distance [2]. The factor used in this study were...
temperature, injection pressure, holding pressure and holding time, each factor was chosen because it would have an effect to the variable response. Based on previous research that conducted by Kamaruddin, Melting temperature is a significant factor affecting tensile and flexural strength in HDPE plastics while holding pressure has a strong influence on the compressive strength of molded products [2], and injection pressure will affect the net weight where if the pressure is applied too large it can result in thinner product that will affect the weight of the product [6]. Table 1 shows the injection moulding parameter and their levels.

Table 1 Injection Moulding Parameter and Level

| No | Factor             | Notation | Level 1 | Level 2 | Level 3 |
|----|--------------------|----------|---------|---------|---------|
| 1  | Temperature        | A        | 190°C   | 200°C   | 210°C   |
| 2  | Injection Pressure | B        | 75%     | 80%     | 85%     |
| 3  | Holding Pressure   | C        | 5%      | 8%      | 10%     |
| 4  | Holding Time       | D        | 1 sec   | 1.5 sec | 2 sec   |

2.2. Preparing material and sample
Material used in this research was polypropylene HI10HO and dye to give colour for the product. Product made in this research was plastic bowl for collecting rubber latex directly from the tree. Because this study using general factorial design as its method, there will be 81 combination with 2 replication that will be weighted and tested.

Figure 1 Raw material, dye and sample product

2.3. Test method
All of sample product that have been made from all treatment combination were weighed using digital scale as shown in figure 2, the product sample was cutted into rectangle shape (100mm x 10mm x 1mm) according to astm D882 for plastic that have thickness less than 1 mm and will be pulled till it break.
3. Results and discussion

3.1. Anova

The purpose of the analysis of variance (ANOVA) was to find which parameters significantly affected the variable response which is net weight and product strength. The percentage of contribution indicates the relative power of a factor or interaction to reduce diversity [7]. Percentage contribution obtained by using equation 1 and 2:

\[ SS'_A = SS_A - (MS_e \times db_a) \]

(1)

\[ P = \frac{SS'_A}{SS_T} \times 100 \]

(2)

| Symbol | Factor            | DOF | SS     | MS    | P-value | % Contribution |
|--------|-------------------|-----|--------|-------|---------|----------------|
| A      | Temperature       | 2   | 3.8278 | 1.9138 | 0.000   | 88.41%         |
| B      | Injection Pressure| 2   | 0.0272 | 0.0135 | 0.011   | 0.49%          |
| C      | Holding Pressure  | 2   | 0.0042 | 0.0021 | 0.477   | -              |
| D      | Holding Time      | 2   | 0.0082 | 0.0041 | 0.241   | -              |
|        | Error             | 81  | 0.2314 | 0.0028 |         |                |
| Total  |                   | 162 | 4.322  |       |         |                |

| Symbol     | Factor             | DOF | SS          | MS    | P-value | % Contribution |
|------------|--------------------|-----|-------------|-------|---------|----------------|
| A          | Temperature        | 2   | 4213559     | 2106780 | 0.000   | 90.66%         |
| B          | Injection Pressure | 2   | 218781      | 109391 | 0.000   | 4.68%          |
| C          | Holding Pressure   | 2   | 13026       | 6613   | 0.000   | 0.25%          |
| D          | Holding Time       | 2   | 56470       | 28235  | 0.000   | 1.18%          |
|            | Error              | 81  | 49750       | 614    |         |                |
| Total      |                    | 162 | 4.322       |        |         |                |

By performing test significance with 95% confidence level, all factor was used in this study is significantly affecting the product strength because the p-value is below than 5% (Shown in table 3),
but there only two factors that significant for net weight of product, therefore, since it was insignificant the contribution can’t be computed (Table 2).

3.2. Main Effect
In order to figure out mean response at each level of the factors, the average value of the performance characteristic for each factor at different levels were computed and plotted into a graph as shown in Figure 3

3.3. Regression model
As shown in Figure 3, temperature is the most significant factor compared to the others for net weight and product strength, Net weight has a direct relationship to the strength of the product where the reduction in weight will result in a decrease in the tensile strength of the product due to the material getting thinner and brittle. Using help from statistical software, the regression equation acquired for net weight and product strength are:

\[ \text{Net weight} = 14.3485 + 0.01612 \text{Temp} + 0.08464 \text{IP} - 0.00043 \text{Temp} \times \text{IP} \quad (1) \]

\[ \text{strength} = 10198 - 40.967\text{T} - 71.83\text{IP} - 707.29 \text{HP} + 44.75 \text{HT} + 0.29T \times \text{IP} \]
\[ + 3.37T \times \text{HP} + 9.52 \text{IP} \times \text{HP} - 0.04T \times \text{IP} \times \text{HP} - 0.0012T \times \text{IP} \times \text{HT} + 0.031 \text{IP} \]
\[ \times \text{HP} \times \text{HT} \quad (2) \]

From the experiment conducted in this study, product that has minimum net weight but still meet the requirement of product strength is using temperature at level 3 (A3) with injection pressure at level 1 (B1), since holding pressure and holding time wouldn’t affect the product strength nor net weight of the product really much and considering the cycle time of product the optimum combination was decided at A3B1C1D1. Henceforth, by using the regression equation, the net weight of the product is obtained will be 17.30 gr with 938,285 N for product strength which meet the requirement at least 900 N.

4. Conclusion
The conclusion from this research is:
1. The main factors that significantly affecting are the temperature and injection pressure with a contribution percentage of 88.41% and 0.49% for the net weight while for the product tensile strength the four main factors are significant factors for the strength of the product with a contribution percentage of 90.66%, 4.68%, 0.25% and 1.8% respectively
2. Temperature is the most dominant factor in this study, which contributes 88.41% to changes in net weight and 90.66% of product strength
3. Net weight has a one-way relationship where a reduction in weight will result in a decrease in the tensile strength of the product due to the material getting thinner and brittle.
4. Considering the product net weight, tensile strength and cycle time for determining holding time, the optimum combination obtained is A3B1C1D1 which will produce a product net weight of 17.30gr and a strength of 938.285N

5. References

[1] Shie, J.R. 2008. Optimization of injection-moulding process for mechanical properties of polypropylene components via a generalized regression neural network, Polymers for Advanced Technologies, 19,73–83

[2] Kamaruddin,S. et al. 2011. Experimental Investigation On The Recycled HDPE And Optimization Of Injection Moulding Process Parameters Via Taguchi Method. International Journal of mechanical and materials engineering (IJMME), Vol. 6. No. 1, 2011: 81-91.

[3] Kavande, M.V dan S.D. Kadam. 2012. Parameter Optimization of Injection Molding of Polypropylene by using Taguchi Methodology. IOSR Journal of Mechanical and Civil Engineering.4 (4):49-58.

[4] Montgomery, Douglas.C., 1997. Design and Analysis Experiment 4th edition. John Wiley and Sons. New York

[5] Salomon, L.L. Kosasih, W. Angkasa, S.O. 2015. Perancangan Eksperimen untuk Meningkatkan Kualitas Ketangguhan Material dengan Pendekatan Analisis General Factorial Design (Studi Kasus: Produk Solid Surface). Jurnal Rekayasa Sistem Industri. Vol 4, No 1. 2015

[6] Tjahyono, R.A dan Haryono. 2006. Optimasi Proses Injection Molding dengan Pendekatan Combined Array. Prosiding Seminar Nasional Manajemen Teknologi III, 4 Februari 2006

[7] Ross, P. J. 1996. Taguchi Techniques for Quality Engineering, Second Edition. Mc Graw –Hill Companies Inc. New York