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Optimization of Injection Pressure and Time of Injection Molding for Eye Drop Heads

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ABSTRACT

Injection molding is a plastic production process by injecting liquid plastic into a mold. One of the injection molding products is an eye drop head. Eye drops in its production experienced rejects reaching 37.5% due to defects. The purpose of this optimization is to obtain the optimum setting of injection pressure and time of injection molding machine using RSM. The method to achieve the goal through finite element approach with pre-processing includes design and setting boundary conditions for injection pressure (10.5, 11, and 11.5 MPa) and injection time (1.9, 2.0, and 2.1 seconds). Post processing displays the results of product mass, defects, and quality prediction which are further optimized using RSM to obtain optimum values. The simulation results show that higher injection pressure and lower injection time have given satisfactory results for all three parameters (product mass, defects, and quality prediction) observed. Based on the optimization results, the optimal injection molding settings were obtained at an injection pressure of 11.5 MPa and injection time of 1.9 seconds which resulted in a product mass of 0.429 g, weld line defect of 0.1384, and quality prediction of 80.9%.

Keywords: Injection Molding, Optimization, Injection Pressure, Injection Time RSM.

1. Introduction

Plastic is a synthetic material that can be deformed and can be maintained and hardened by adding other materials in a composite manner to it. [1]. When exposed to heat and pressure, the material formed from this polymer material can be formed into various desired shapes using the injection molding process. [2]. The injection molding process is a method used to produce geometrically complex products that are formed with high productivity and accuracy at a low cost. [3]. The advantages of injection molding machines are being able to make plastic products with complex shapes with high precision, high production capacity, little useless material and minimal labor. [4]. The plastic production process using injection molding machines or using blow molding machines has 4 main factors that can affect product quality, namely the selection of plastic materials, the setting process on the machine, product design and molding design. [5].

The injection pressure parameter is an influential parameter to push the molten plastic to fill the mold cavity, but if the injection pressure is excessive, it will make the plastic product flash (plastic liquid comes out of the mold) and if the injection pressure is less, it can cause short sort (less full of liquid plastic) so that the liquid plastic cannot form the desired product [6]. The effect of excessive injection pressure can increase the pressure in the cavity which affects the density of the liquid plastic and can increase the weight of the product [7]. Pressing time is the duration or length of time required to apply pressure to the piston that pushes the melted plastic. Setting the pressing time aims to ensure that the plastic material has completely filled the entire mold cavity [8]. Injection time will also affect the quality of the product, too long injection time can reduce the cavity pressure so that it can reduce the weight of the product [7]. The plastic production process to get the right injection machine parameters is done trial and error, because in injection molding there is no standardized process to produce products [9].

Eye drops are products produced by injection molding method, but during the production process of eye drops there are still short shot defects out of 8 there are 3 reject products that occur during the production process, this results in increased production costs caused by inefficient materials used. This study aims to analyze the effect of parameters on product quality and product defects and optimize them using RSM.

2. Materials and Methods

2.1. Materials

The material used in the toothbrush handle is polypropylene with properties of specific gravity 0.89417 g/cm3, thermal conductivity 0.1731 W/m°C, and specific heat 2887 J/Kg° C [10].

2.2. Simulation

2.2.1. Pre-Processing

Pre-processing begins with designing the eye drop head using Inventor 2018. The design was imported into Autodesk Moldflow Adviser 2017. The conditions given for simulation included injection pressure (10.5, 11, and 11.5 MPa) and injection time (1.9, 2.0, and 2.1 seconds).

2.2.2. Processing

Processing is the calculation stage performed by the computer based on the conditions given in pre-processing.

2.2.3. Post-processing

The simulation results obtained are product mass, product defect type, and quality prediction. Variations in input parameters (injection pressure and time) and output (quality prediction) were tested for significance using Anova and optimized using Minitab 19 to obtain the optimum parameter settings.

3. Result and Discussion

3.1. Results

3.1.1. Product Shortshot and Mass

Shortshot is a condition where the injected liquid plastic does not fill the mold, resulting in a non-ideal product mass that shown in Figure 1. Therefore, the indicator of shortshot is the mass of the product. The mass for each simulated injection pressure and time is shown in Figure 2. The mass of the product increases as the pressure value increases. Meanwhile, a longer time resulted in a lower product mass. The highest product mass of 0.429 grams was obtained with an injection pressure setting of 11.5 MPa and an injection time of 1.9 seconds.

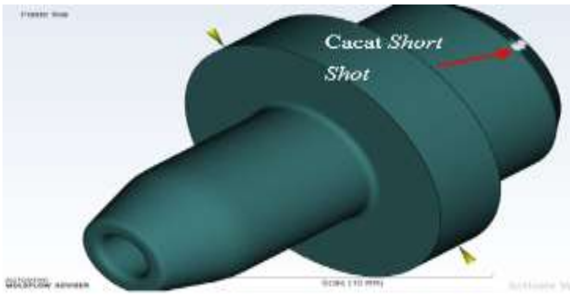


Figure 1. Shortshot in product

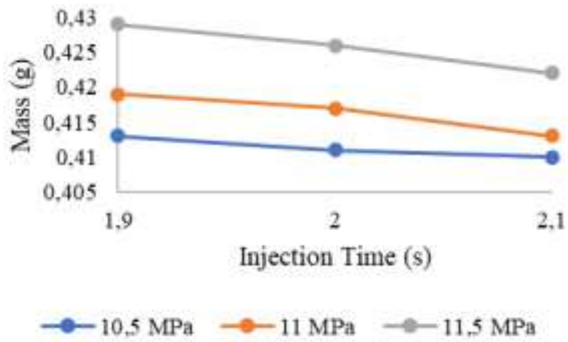
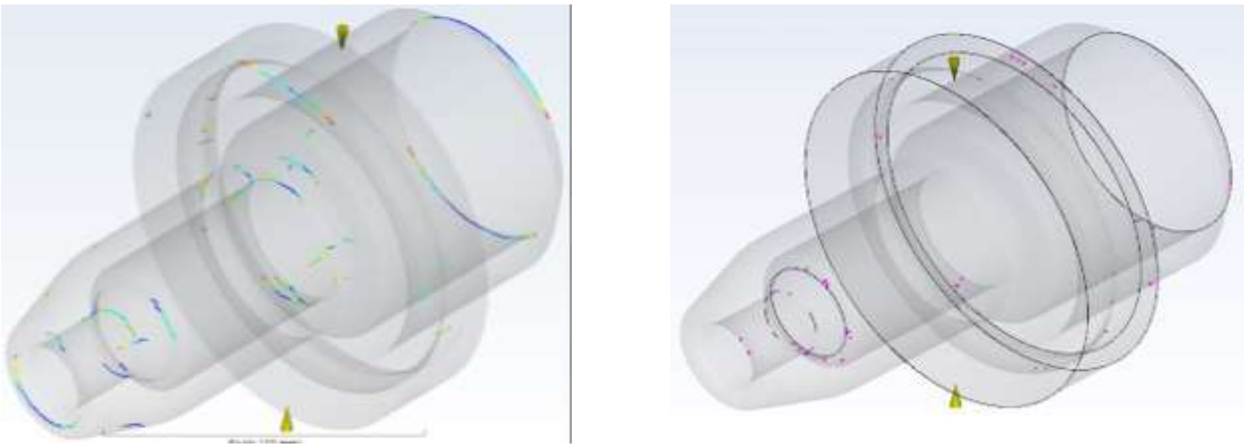


Figure 2. Injection Time vs Mass

3.1.2. Product Defects

The types of product defects that appear for all test parameter values include bubble and weld line that shown in Figure 3. Bubble defects can be observed visually with a transparent color on the print. Bubble itself is caused by the temperature of the molten plastic being too hot and the cooling time being too fast. The weld line defects for each test parameter are shown in Figure 4.



(a) (b)

Figure 3. Product defect (a) weld line (b) bubble

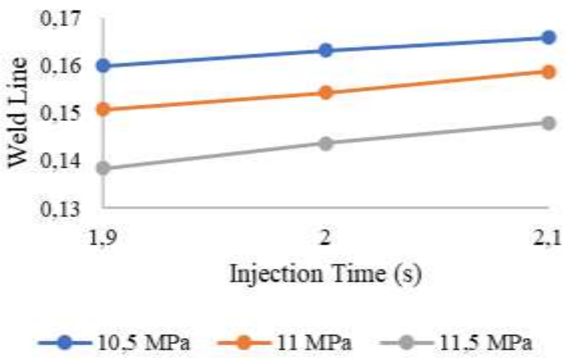


Figure 4. Injection Time vs Weld Line

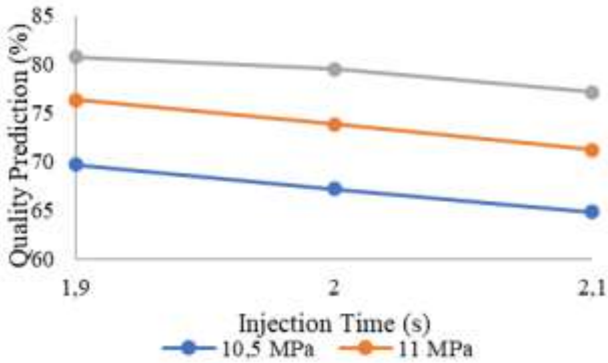


Figure 5. Injection Time vs Quality Prediction

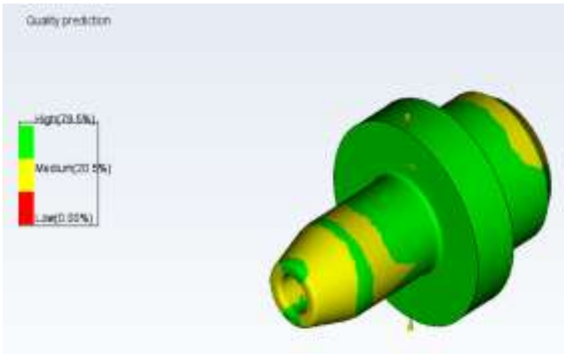


Figure 6. Quality prediction plot contour

In Figure 4 it can be seen that the injection pressure is inversely proportional to the weld line, lower injection pressure results in a higher weld line and vice versa. While the magnitude of the weld line and injection time are linearly proportional. The longer the injection time, the greater the weld line. The lowest weld line value (0.1384^{o}) was at the injection pressure setting of 11.5 MPa and injection time of 1.9 seconds.

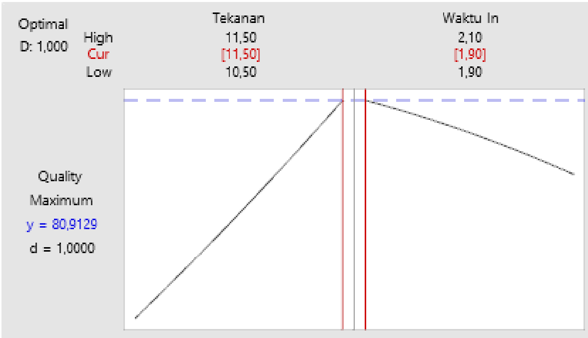
3.1.3. Quality Predictions

The quality prediction results for the eye drop head product are shown in Figure 5. Based on Figure 4, the longer the injection time, the lower the predicted quality. Conversely, the higher the injection pressure, the higher the predicted quality. The highest quality prediction with a value of 80.7% occurred with the highest injection pressure setting (11.5 MPa) and the shortest time (1.9 seconds). Plot contour for quality prediction are shown in Figure 6. It can be seen that most of the quality predictions are high and followed by medium, which indicates that the quality predictions show good results.

3.1.4. Optimization

The RSM optimization to analyze the response generated by the dependent variable is shown through the surface contour plot and response plot in Figure 7. The contour plot in Figure 7a is colored blue-green with different intensities indicating the range of quality predictions. The highest intensity in green indicates the optimum value and it is this region that outlines the optimum point of the observed variable as shown by the response plot line in Figure 7b. The significance of the response variables to the quality prediction was observed using ANOVA calculations. The results of the calculation are shown in Table 1.

(a)



(b)

Figure 7. Optimization result (a) surface contour plot (b) response plot

Table 1. ANOVA Results

Source	DF	Contribution	F-Value	F-Table	P-Value
Injection Pressure	2	87.44%	6021.23	4.46	0
Time Pressure	2	12.20%	840.46	4.46	0
Error	8	0.36%			
Total	12	100%			

3.2. Discussion

Injection pressure and injection time have an impact on product mass, defects, and quality prediction. Higher pressure (11.5 MPa) and lower time (1.9 s) gave satisfactory results for all three parameters observed. In terms of product mass, the highest pressure influenced the molten plastic which tended to fill the mold cavities resulting in a denser product and increased mass. Thus, shortshot can be overcome with high pressure and short injection time. Product defects in the form of bubbles and weld lines at all values of pressure and injection time actually always appear. So that the pressure value and injection time set will produce bubble and weld line defects or in other words that the pressure and bubble parameters do not have an effect on eliminating bubbles and weld lines. Bubble itself is a defect that is influenced by liquid plastic temperature and cooling time, while weld line is influenced by melt temperature, mold temperature, holding pressure, and flow rate [11]. Dimensionally, however, weld line differences in pressure and time variations can be found. Due to the low weld line defects and shortshot, the quality prediction value is highest for the highest pressure and lowest injection time compared to the other variations.

The analysis obtained based on the simulation results is further verified using optimization. The optimization in question aims to determine the optimum point on the observed variables for quality prediction [12]. The relationship of the observed variables (pressure and time) to the quality prediction has a significant effect as evidenced through ANOVA testing with a P value of less than 0.05 and a calculated F value greater than the F table. Based on the optimization results in Figure 8, the optimal injection molding settings were obtained at an injection pressure of 11.5 MPa and injection time of 1.9 seconds which resulted in a product mass of 0.429 g, a weld line defect of 0.1384, and a quality prediction of 80.9%.

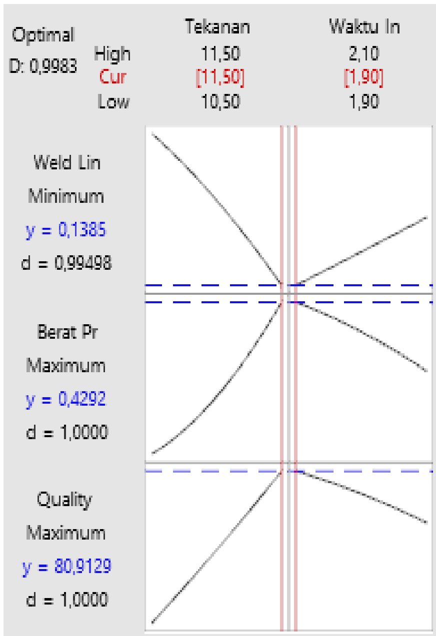


Figure 8. Predicted Optimization Response

4. Conclusion

Optimization to obtain optimum values of injection pressure and time using RSM was carried out. Higher injection pressure and lower injection time have given satisfactory results for all three parameters (product mass, defects, and quality prediction) observed. Based on the optimization results, the optimal injection molding settings were obtained at an injection pressure of 11.5 MPa and injection time of 1.9 seconds which resulted in a product mass of 0.429 g, weld line defect of 0.1384, and quality prediction of 80.9%.

5. Acknowledgement

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