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Study on the Mold Temperature Control for the Core Plate during Injection Molding Process

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Abstract: *During injection molding process, the mold temperature is one of the most important influences on the product quality. In this paper, the temperature of the core plate with the size of 100 mm × 100 m × 40 mm will be examined for different product sizes. Different types of heating and cooling channels are inserted in the core plate. The size of the plastic product will be changed from 40 mm to 80 mm, with varying heights. Simulation method will be utilized to observe the heating and cooling steps. The temperature values and distribution will be collected and compared. Results show that when the product size changes, the heating and cooling steps have a slight variation. However, the product height has a strong effect on the mold temperature. When the height increases from 1 mm to 9 mm, the highest heating temperature reduces from 104 °C to 82.5 °C. The simulation results were verified by an experiment. The comparison between the simulated and the experimental results shows a good agreement between them.*
Keywords: *Injection Molding, Mold Temperature Control, Mold Heating, Mold Cooling, plastic process.*

I. Introduction

Recently, injection molding has become one of the most widely used processing technologies for manufacturing plastic products. Among typical molding parameters, mold surface temperature is critical for product quality. At higher mold surface temperatures, the surface quality of the product improves [1–4]. In general, improving the quality of the injection molding product requires high mold temperatures during injection to minimize product thickness and injection pressure. However, maintaining high mold temperature during the filling process, while lowering the mold temperature to below the deflection temperature during the post-filling process, without a significant increase in cycle time and energy consumption is not easy. To solve this problem, a variety of mold temperature controls (MTC) have been explored recently [5–8]. Their purpose is to eliminate the frozen layer, ideally producing a hot mold during the filling stage and a cold mold for cooling [9].

In recent researches, the heater heating [10, 11]; the mold surface heating, such as induction heating [12–14]; and the gas-assisted MTC [8] can provide sufficient heating rates without significant increases in cycle time. In this study, an MTC combined with water cooling under varying product sizes (varying in width, length, and height) will be studied. The core plate will be heated in 70 s, and then, cooled in 80 s. In this cycle, the temperature of core plate will be simulated, and then, will be observed using the experiment.

II. Simulation and Experiment

MTC is an upcoming technology in the field of injection molding which can heat and cool the cavity surface during the injection molding process. In this research, the heating and cooling systems consist of a mold temperature controller, a heating system, and a mold plate. The mold plate will be heated by heaters in 70 s. Then, the mold temperature controller will drive the water flowing through the cooling channel for mold cooling. The dimensions of core plate are shown in Fig. 1. The dimensions of a product will be by varying the product length (L_p), product width (T_w), and product height (H_p). The definitions of product sizes are explained in Fig. 2 and Table 1. The plate material is aluminum. Three heaters will be inserted into this plate, and three cooling channel will be driving the water flow.

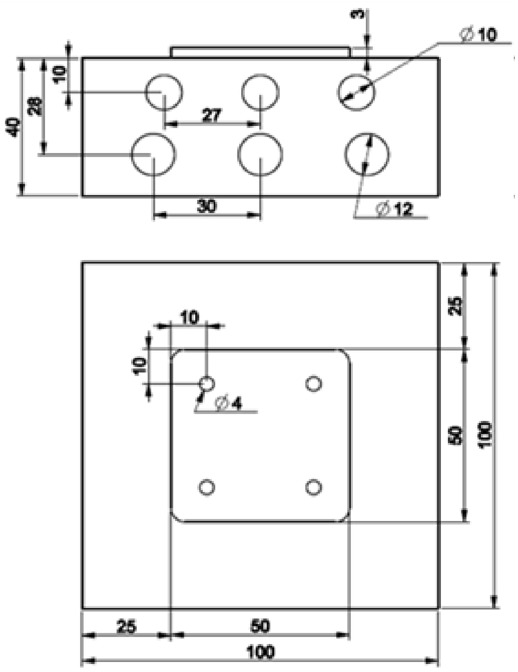


Figure 1. Dimensions of the mold plate

Table 1. Varying dimensions of the product.

<table>
<tr><th rowspan="2">No.</th><th colspan="3">Product size (mm)</th></tr>
<tr><th>Width (W_p)</th><th>Length (L_p)</th><th>Height (H_p)</th></tr>
<tr><td>1.</td><td>40</td><td rowspan="4">50</td><td rowspan="8">3</td></tr>
<tr><td>2.</td><td>50</td></tr>
<tr><td>3.</td><td>60</td></tr>
<tr><td>4.</td><td>80</td></tr>
<tr><td>5.</td><td rowspan="8">50</td><td>40</td></tr>
<tr><td>6.</td><td>50</td></tr>
<tr><td>7.</td><td>60</td></tr>
<tr><td>8.</td><td>80</td></tr>
<tr><td>9.</td><td rowspan="4">50</td><td>1</td></tr>
<tr><td>10.</td><td>3</td></tr>
<tr><td>11.</td><td>6</td></tr>
<tr><td>12.</td><td>9</td></tr>
</table>

For temporally observing the temperature of the core plate during the heating and cooling steps, the temperature sensor will be used for collecting the temperature values at the top mold surface as shown in Fig. 2. In this paper, both simulation and experiment methods will be used. By simulation, the core plate model was built as Fig. 3a and meshed as Fig. 3b. The ANSYS software will be run with an aluminium core plate to find the changes in mold temperatures caused by varying the product dimensions. Next, the simulation results will be collected and compared. The actual core plate is manufactured with the same dimensions as those used in the simulation, while the product dimensions used are lengthof 50 mm, width of 50 mm, and height of 1 mm. The real mold is shown in Fig. 4.

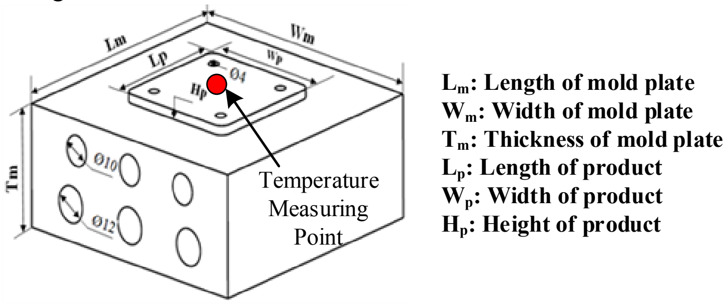
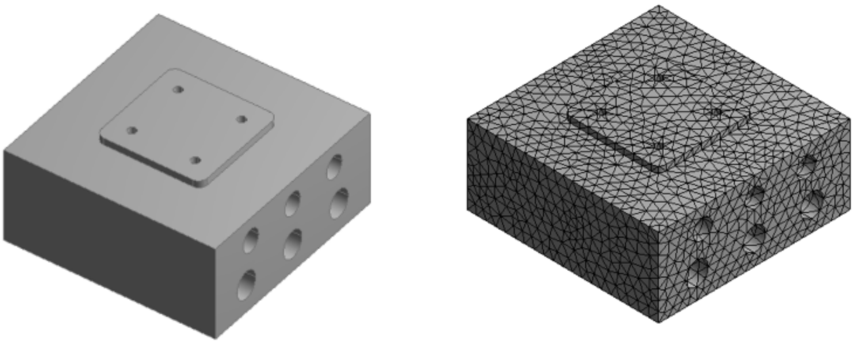
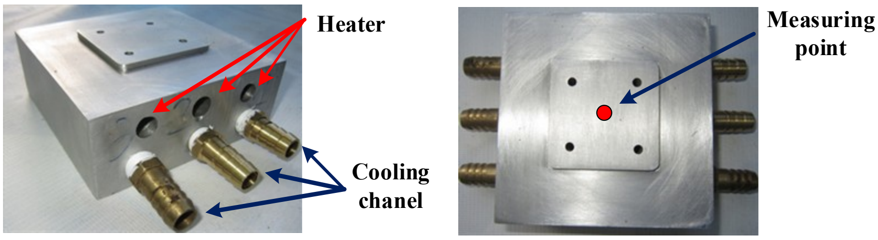


Figure 2. Parameters of product sizes.



(a) (b)

Figure 3. Simulation model (a) and mesh model (b).



(a) (b)

Figure 4. Experiment model with the side view (a) and top view (b)

III. Results and Discussions

The variation in the product widths (Fig. 2) versus time for a heating time of 70 s and cooling time of 80 s is described in Fig. 5. For an initial mold temperature of 40 °C, it can be seen that the heater system can heat the plate to above 95 °C in 70 s. Then, using the cooling water (40 °C) for 80 s, the mold plate temperature was decreased to 57.5 °C. According to Fig. 5, when the product width changes from 40 mm to 80 mm, the temperatures used are almost the same. However, simulation results show a slight variation in the difference temperature at the top surface of core plate. At the end of heating step, the temperature differences are 6 °C, 4.8 °C, 4 °C, and 3 °C for the product widths of 40 mm, 50 mm, 60 mm, and 80 mm, respectively. This means that the smaller product, the better the temperature uniformity that could be reached during the heating step.

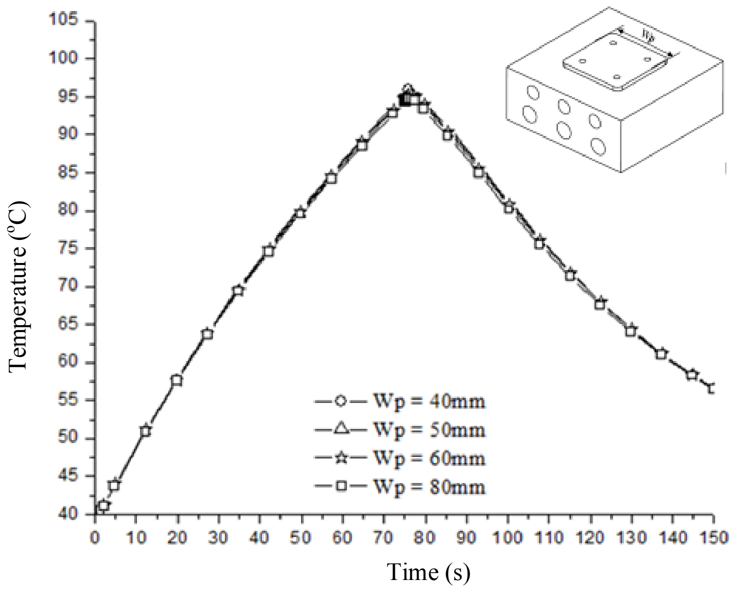


Figure 5. History of mold temperatures with different product widths.

For the second parameter, the influence of product length on the mold temperature was simulated. At the end of the heating step, the mold temperature distribution was collected and compared, as shown in Fig. 6. With the same heating time of 70 s, the temperature difference at the top surface is the same as that with the above cases. From the Fig. 6, a higher temperature is located at the middle of the core plate. This result could be explained by the position of heaters. Thus, the thermal energy will focus more at the center of the mold plate than on the sides. Hence, the temperature at the middle will be higher than the sides. However, this result subsides as the product length increases.

For the third parameter, the product height will be varied from 1 mm to 9 mm as shown in Fig. 2. By simulation, the temperature distribution is as shown in Fig. 7. From the Fig., the temperature difference is clear as the product height is varied. The higher the product height, the lower the temperature that could be used at the end of the heating step. This result is described clearly in Fig. 8. At the end of heating step, the maximum temperatures are 104.0 °C, 94.7 °C, 82.5 °C, and 82.1 °C for the product heights of 1 mm, 3 mm, 6 mm, and 9 mm, respectively.

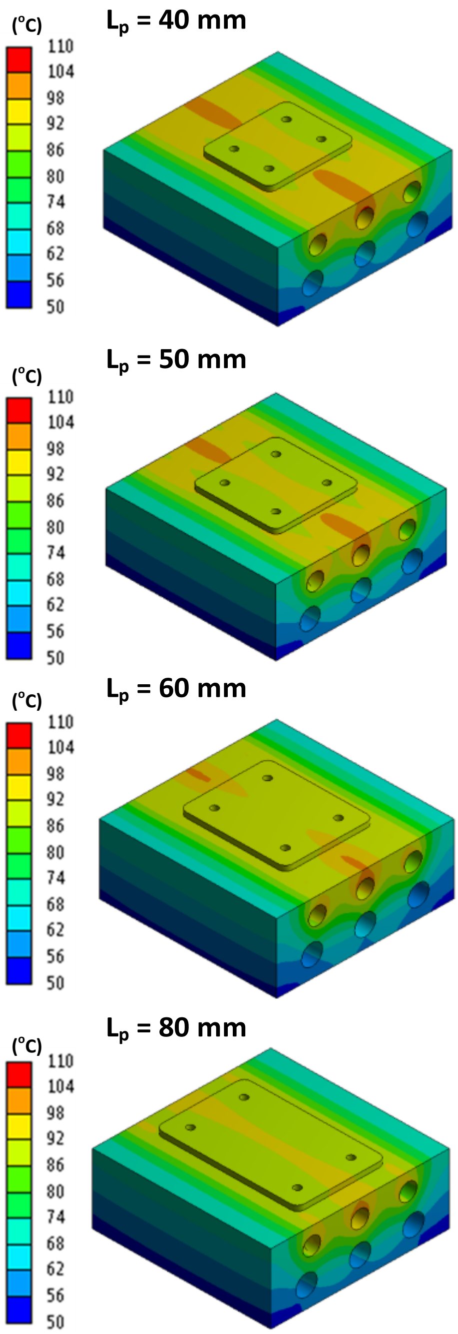


Figure 6. Mold temperature distribution with different product lengths.

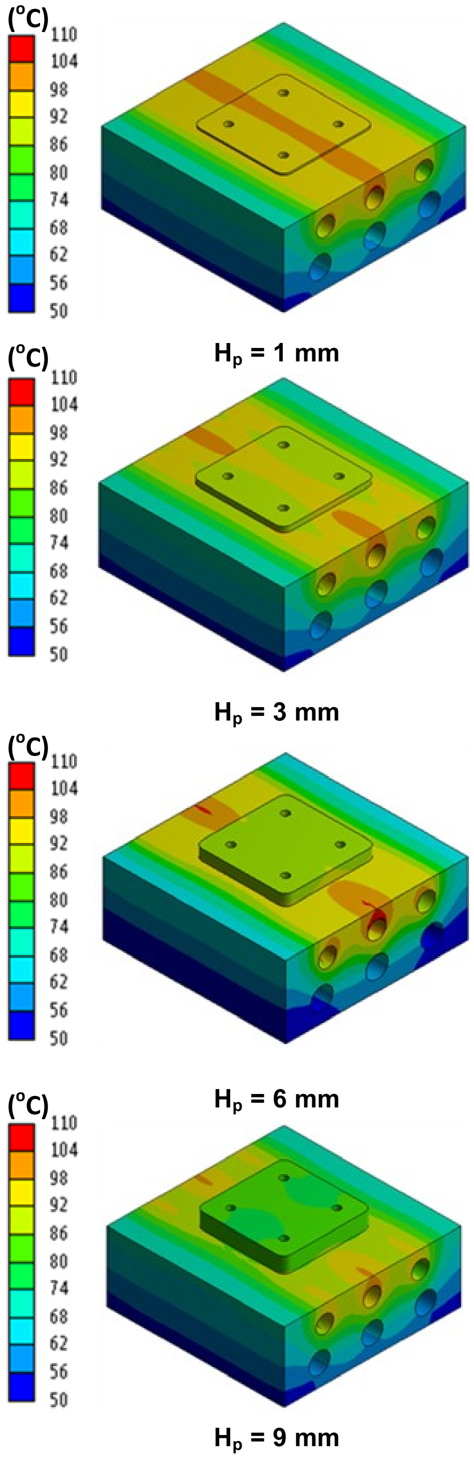


Figure 7. Mold temperature distribution with different product heights.

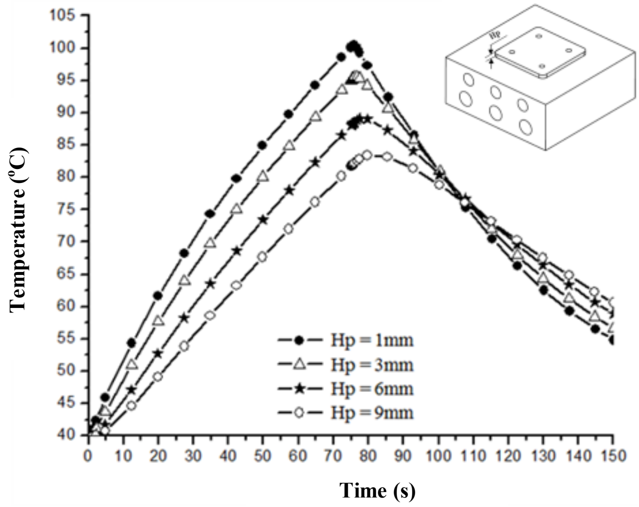


Figure 8. Simulation result of mold temperature history for different product heights.

To verify the simulation result, a core plate with the product height of 1 mm, product width of 50 mm, and product length of 50 mm was manufactured. The real mold is shown in Fig. 4. From the experiment conducted with boundary condition identical with the simulation, the temperatures at the top surface (as shown in Fig.s 2 and 4) were collected. Fig. 9 shows the comparison between simulation and experiment results. The results show that the temperature difference at the end of the heating step is approximately 13 °C and at the end of cooling step is 1.5 °C. In general, during the heating step, the simulation temperature is higher than the experiment value. However, during the cooling step, the simulation value is lower than the experiment value. This is due to the fact that during simulation, the thermal radiation was ignored. However, during experiment, this energy was transferred to the air during all heating and cooling cycles. This effect led to a lower temperature in the experiment than that in the simulation during the heating step and an opposite result during the cooling step.

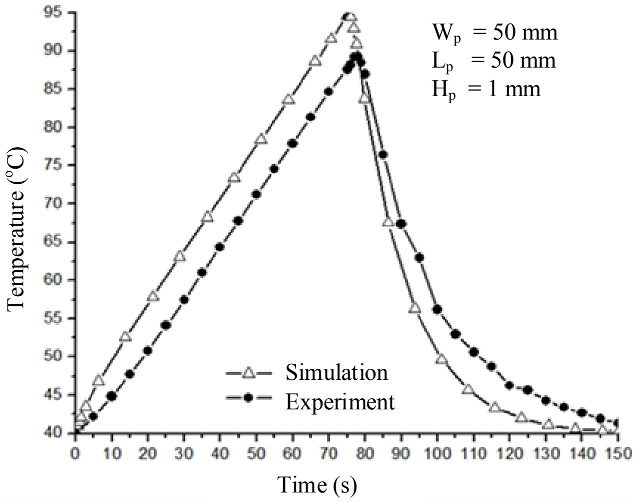


Figure 9. Mold temperature comparison between simulation and experiment results

IV. Conclusions

In this study, the heater and water cooling systems were designed for controlling the core plate temperature. According to the results of the simulation and experiment, the following conclusions were obtained:

- When the product size changes, the heating and cooling steps have a slight variation.
- The product height has a strong effect on the mold temperature. When the height increases from 1 mm to 9 mm, the highest heating temperature reduces from 104 °C to 82.5 °C.
- From the experiment, the temperature has the largest difference at the end of the heating step. However, in general, the simulation can precisely describe the temperatures of core plate during the heating and cooling cycles.

Acknowledgements

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