Study on the Temperature Distribution of Core Plates during Injection Molding

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Abstract: In this paper, a baffle channel was applied to a core plate during injection molding. The temperature was observed through simulation and heating rate. The results showed that the baffle channel can support a temperature distribution better than that supported by the common channel, with a heating rate at the top point reaching up to 1.8°C/s and a core height of 50 mm. The temperature distribution also shows that the top area tends to have a higher temperature than that of the bottomowing to the thinner wall. With a higher core, the heating rate will decrease with the top area; however, with the baffle channel, the heating rate stays high.

I. INTRODUCTION

Nowadays, injection molding is considered to beone of the most popular methods for manufacturing plastic products. However, with the higher product quality demand of customers as well as the more complex product geometry, injection molding requires more improvements. There are many methods for improving the molding process. Among these methods, mold temperature control is an efficient method for solving the problems of the melt filling step [1–3]. In general, when the mold surface temperature increases, the quality of the part improves, although the cooling time increases, and the cycle time rises as well. Decreasing the mold surface temperature reduces the cooling time, but there is no benefit for the surface quality of the part itself [4, 5]. Therefore, a critical requirement for current studies is to increase the mold surface temperature and still maintain a cycle time that is not too long.

In injection molding, the cooling system is very important for the productivity of the injection molding process and the quality of the molded part. Much research has been conducted on the analysis of cooling systems [6, 7].Commercial computer-aided engineering software such as Moldflow [8] and Moldex3D [9] is widely applied for optimizing the cooling channel design. Many studies on the techniques of optimizing a given cooling system have also been reported [10]. Recently, methods to build better cooling systems using new forms of fabrication technology have also been reported.

In addition, with the development of product design, product geometry has become more and more complicated. Therefore, in order to cool down the part of interest, the cooling channel have to appeared at the concentrated temperature. In this paper, a cooling channel for injection molding with a U-cup shape will be researched by simulation and experiment.

II. SIMULATIONAND EXPERIMENT

Here, a simulation is first used to observe the influence of a helical cooling channel on the temperature distribution. In this step, ANSYS software will be used with the module of ANSYSCFX. The flowchart of this simulation is shown in Fig. 1. On the basis of this procedure, the research model is built, as shown in Fig. 2. The dimensions of this model areshown in Fig. 3. This model was then meshed, as shown in Fig. 4. In order to compare the temperatures of different cooling channels, two points (P1 and P2) will be selected, as in Fig. 5. To increase the accuracy of simulation, the contact layer between the water and the mold surface is meshed with a smaller element size.
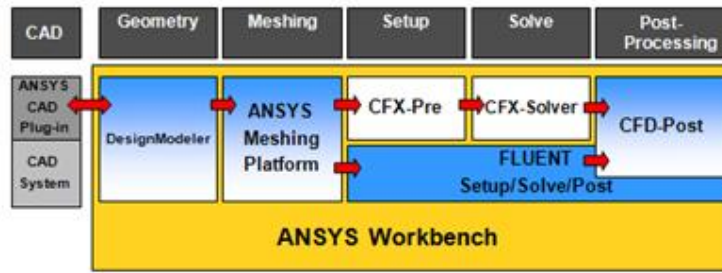
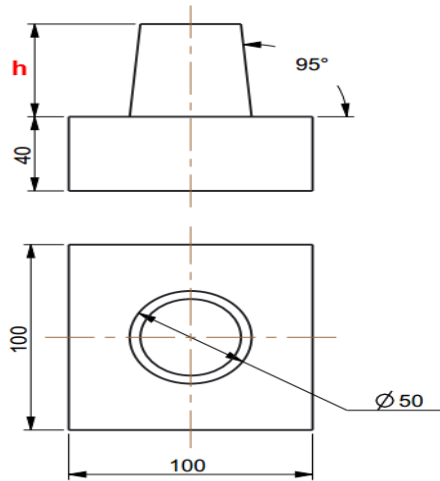**Figure 1.**Simulation procedure with ANSYS CFX.

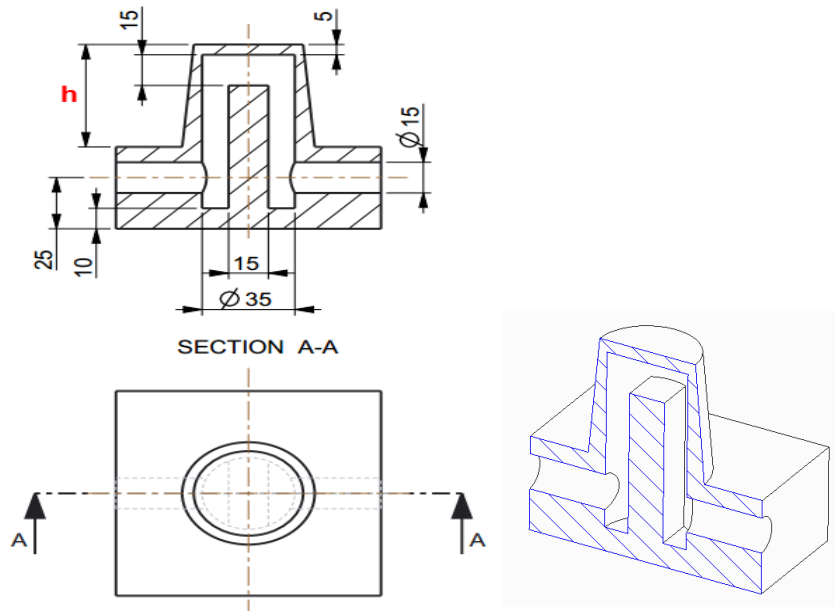**Figure 2.**Model ofthehelical cooling channel.

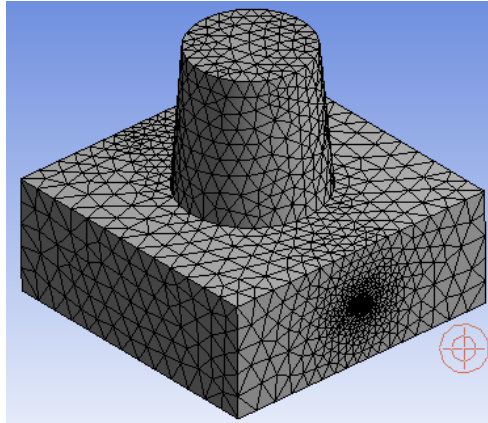
SECTION A-A

Figure 3. Modeldimensions.
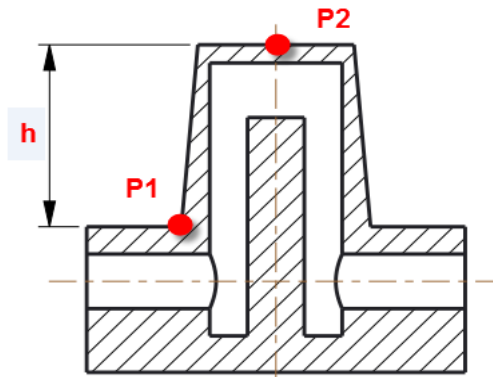
Figure 4. Meshing model.

Figure 5. Measurement points.

The meshing model is then import into the ANSYS CFX software with the mold material of C45. The material properties are listed in Table 1.

Table 1: Material properties of C45 steel.

Mold material	Heat transfer coefficient (W/m·K)	Specific heat(J/kg·K)	Density (kg/m³)
C45 steel	54	502,416	7,800

The governing equation used to describe the heat transfer during the cooling process is the steady-state Laplace equation,which is expressed asfollows [11]:

$$k_m \left(\frac{\partial^2 T_m}{\partial x^2} + \frac{\partial^2 T_m}{\partial y^2} + \frac{\partial^2 T_m}{\partial z^2} \right) = 0. \tag{1}$$

The heat transfer phenomena nearby shell plastic are governed by Poisson's equation:

$$\rho C_p \frac{\partial T}{\partial t} = k_m \left(\frac{\partial^2 T_m}{\partial x^2} + \frac{\partial^2 T_m}{\partial y^2} + \frac{\partial^2 T_m}{\partial z^2} \right), \tag{2}$$

where T_m is the mold temperature,k_m is the thermal conductivity, ρ is the density,C_p is the specify heat,t is the time, and$x$, y,and$z$ are the Cartesian coordinates

The simulation shows the temperature distribution at the end of the molding cycle. In order to estimate the simulation accuracy, the experiment will be carried out with the same design of simulation. The mold used in the experiment is shown in Fig. 6.

Figure 6: Experiment model.

III. RESULTS AND DISCUSSION

In this research, we will study a cooling channel with a core plate height ranging from 0 to 50 mm. The initial mold temperature is 32°C. At the first step, 80°C water flows inside the channel to heat the mold. Then, 32°C water is used to cool it down. For all cycles, the temperature at points P1 and P2 will be collected. In addition, the temperature distribution is observed by simulation.

Figure 7 shows the temperature distribution of the core plate. This result proves that the baffle channel can provide good heating for the top of the core plate. In detail, when the height of the core plate increases from 0 to 50 mm, the temperature at point PT varies from 52.87 to 63.54°C. Compared with the common channel, this result shows a bright heating ability for the core plate. This is due to the fact that the hot water can reach the top area of the core plate. This advancement is clearer with a higher core plate. On the other hand, the top point of the core plate tends to have a higher temperature than that at the bottom point. This is because of the thinner wall at the top area. With the thinner wall and the same heating source from the hot water, the thermal energy easily increases the wall temperature.

In order to compare the heating rates between the case of the baffle cooling channel and thatof the common cooling channel, the heating rates at points PT and PB were calculated and compared, as shown in Fig. 8. This result shows that, with a lower core plate, the heating rate is almost the same with the value varied from 0.8 to 1.1°C/s. However, when the core height increases, the heating rate of the common channel clearly drops,whereas with the baffle channel, the heating rate tends to increase. At the top area, the heating rate can reach 1.8°C/s.

In order to estimate the accuracy of simulation, the experiment had been achieved. The temperature at points PB and PT was collected and compared, as shown in Fig. 8. This figure shows that the highest temperature at point PT is higher than thatat point PB with both simulation and experiment. This result is due to the fact thatpoint PT has less material than point PB has, so the thermal energy from the hot melt can more easily heat this area compared to the point PB area.
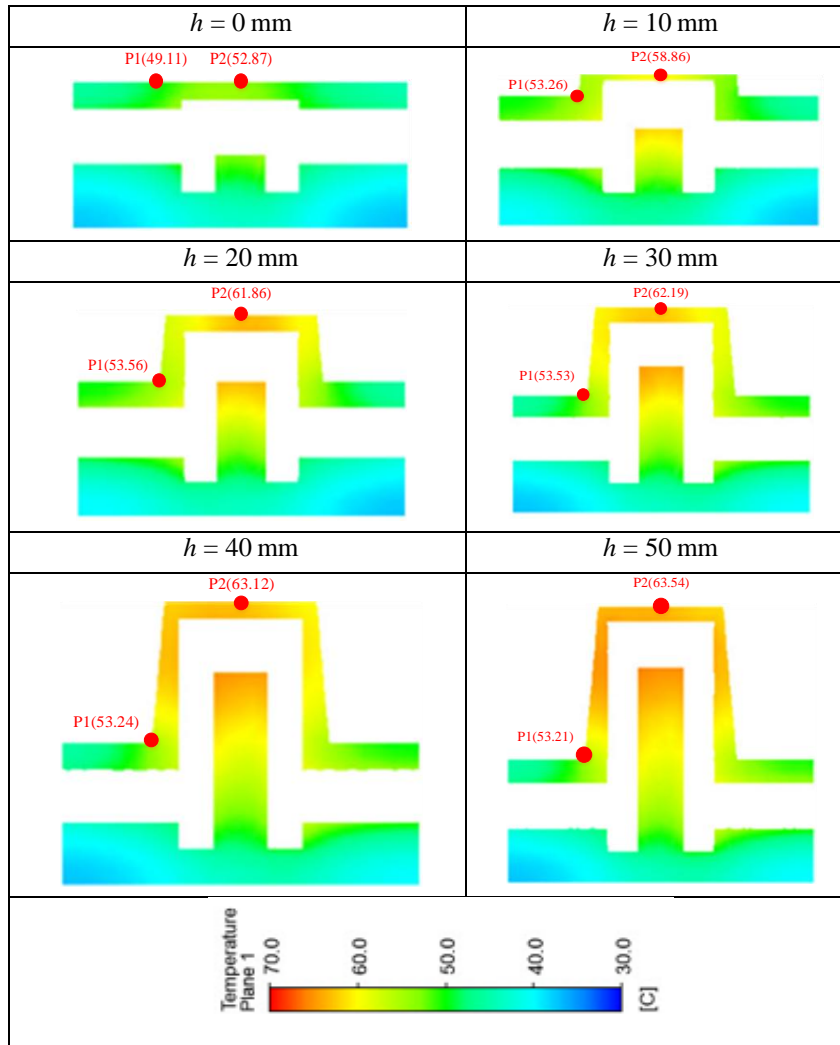
Figure 7: Temperature distribution of the mold plate at the end of the heating step.
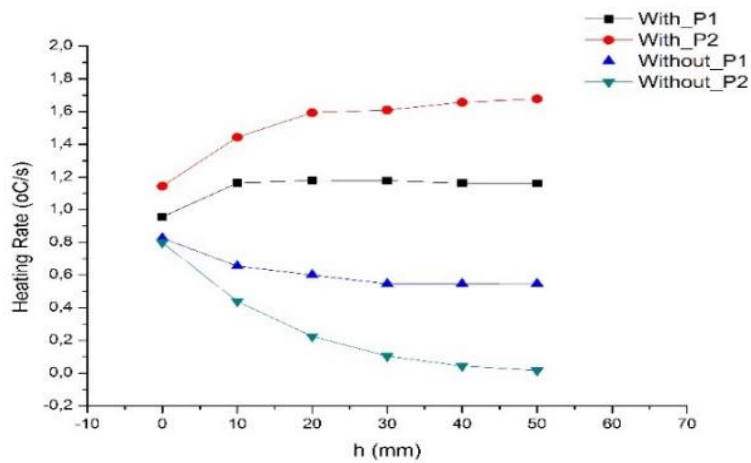

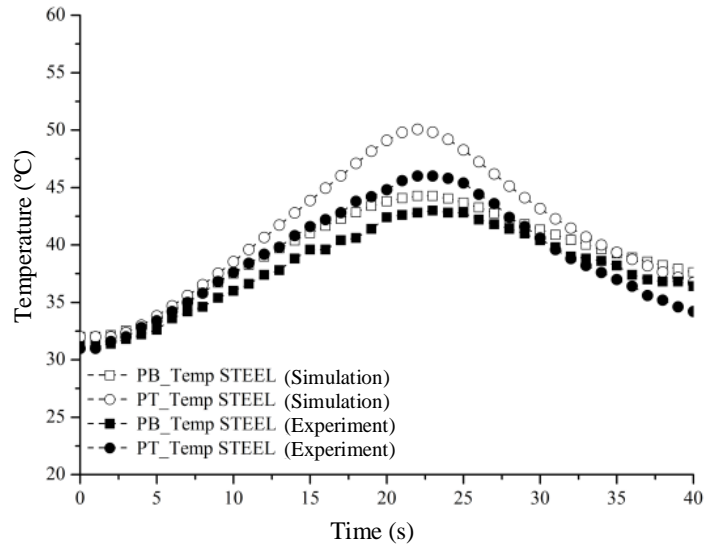**Figure 8:** Heating rate at P1 and P2.

Figure 9: Temperature comparisonbetween simulation and experiment.

IV. CONCLUSION

In this paper, we tested a baffle cooling system with a cross section of 15 mm for a core plate through experiment and simulation. The temperature distribution and the heating rate were collected and compared between the baffle channel and the common channel. In general, conclusions could be drawn as follows:

- With the baffle channel, the heating ability is much better than with the common channel. The heating rate at the top of the core plate could reach 1.8°C/s with a height of 50 mm.
- With the temperature distribution, the baffle channel can support a higher temperature at the top of the core plate because of the thinner wall at this area.

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