Numerical Study on the Heliacal Cooling Channel for Injection Molding Process

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Abstract

The helical cooling channel is a new technique for improving the cooling process in injection molding. However, its benefits are still not clearly understood, and designing a proper helical cooling channel is still a challenge for the mold designer. In this research, the effect of a helical cooling channel will be observed and discussed on the basis of numerical and experimental results. A helical cooling system with a 3 mm × 3 mm section was researched by experiments and simulations. Results show that with a single-turn channel, the difference temperature of the mold plate is approximately 7.6 °C. This temperature distribution was improved with a six-turn channel. In this case, the difference temperature was reduced to 2.5 °C.

Keywords: *Helical cooling channel, mold temperature, heat transfer, injection molding.*

1. Introduction

Injection molding is one of the most widely used processing technologies in the plastics industry [1–3]. The mold surface temperature has a great effect on plastic injection molding [4, 5]. In the injection molding field, the cooling system is important to the productivity of the injection molding process and the quality of the molded part. Many studies have been conducted on the analysis of cooling systems [6, 7], and commercial CAE software such as MOLDFLOW [8] and Moldex3D [9] are widely used for optimizing the cooling channel design. Many studies have also been conducted on techniques for optimizing a given cooling system [10–13]. Recently, methods to build better cooling systems by using new forms of fabrication technology have been also reported [14–16].

Furthermore, with the development of product design, the product geometry has become increasingly complicated. Therefore, to cool a part, the cooling channel has to appear at the concentrated temperature. In this paper, the cooling channel for an injection molding product with a U-cup shape will be researched by simulations and experiments.

2. Simulation and Experiment Method

First, a simulation will be used to observe the influence of the helical cooling channel on temperature distribution. In this step, ANSYS software will be used with the CFX module. The flow chart of the simulation are shown in Figure 1. On the basis of this procedure, the researching model will be built as shown in Figure 2. This model was built with the dimension shown in Figure 3. This figure also shows the temperature measurement points as PT and PB. These points will be used to compare the temperature with different helical cooling channel designs and compare the simulation and experiment results. The researching model will be meshed as in Figure 4. To increase simulation accuracy, the contact layer between the water and mold surface will be meshed with a smaller element size.

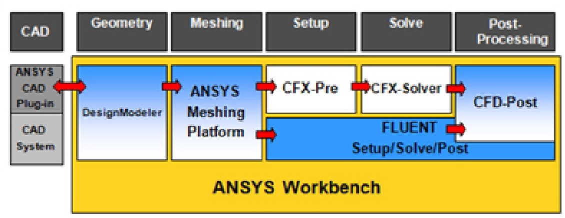

Fig. 1. Simulation procedure with ANSYS CFX.

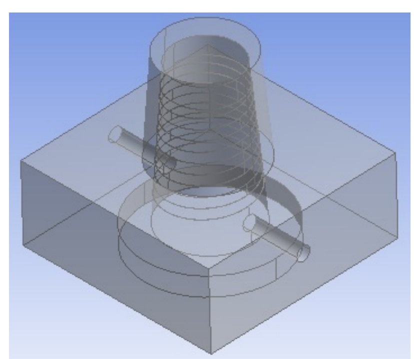

Fig. 2. The model of helical cooling channel.

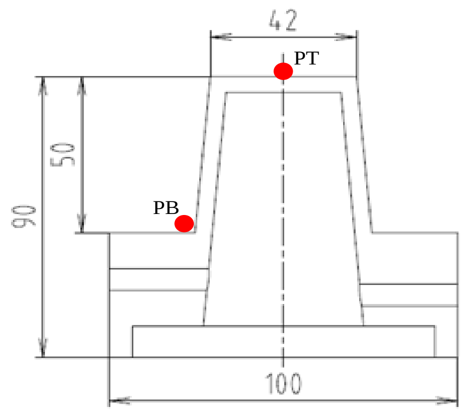

Fig. 3. The model dimension.

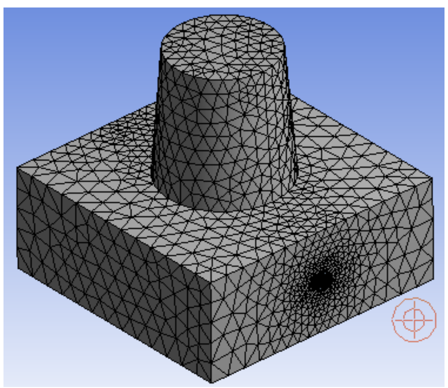

Fig. 4. The meshing model.

The meshing model will be imported into the ANSYS CFX software with the mold material of C45. The material properties are shown in Table 1.

Table 1. Material properties of C45 steel.

Mold material	*Heat transfer coefficient (W/m.K)*	*Heat specific (J/Kg.K)*	*Density* (Kg/m^3)
C45 steel	54	502,41	7800

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

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

The heat transfer phenomena nearby the shell plastic can be governed by the following Poisson equation:

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

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; x, y, and z are the Cartesian coordinates

The simulation will show the temperature distribution at the end of the molding cycle. To estimate the simulation accuracy, the experiment will be conducted with the same simulation design. The mold for the experiment is shown in Figure 5.

Figure 5. Experiment model.

3. Results and Discussion

In this research, the helical cooling channel will be studied with the number of turns changed from one turn to six turns. The channel section will be selected as 3 mm × 3 mm. Cooling water with a temperature of 30 °C will flow inside the helical channel. The temperature distributions of the mold and water at the section (Figure 3) are shown in Figures 6 and 7.

The result shows that the number of turns has a strong influence on the temperature distribution of the mold plate. Figure 6 shows that with one turn, the difference temperature of the mold plate is approximately 7.6 °C. This temperature distribution was improved with a six-turn channel. In this case, the difference temperature was reduced to 2.5 °C. The effect of the turn number is also observed on the water temperature (Figure 7). With the single-turn channel, the contact area between the water and mold is small. Therefore, the thermal energy that the water absorbs from the mold plate is small. However, the thermal energy increases when the channel was designed with more turns. With the six-turn channel, the temperature at the outlet of the channel was increased to 31.5 °C. This difference could be observed clearly in Figure 7.

To estimate the accuracy of the simulation, experiments were conducted. The temperatures at points PB and PT were collected and compared (Figure 8). This figure shows that the highest temperature at the PT point is higher than the PB point in both the simulation and experiment. This result is due to the PT point having less material than the

PB point; therefore, the thermal energy from the hot melt affects this area more than the PB point area.

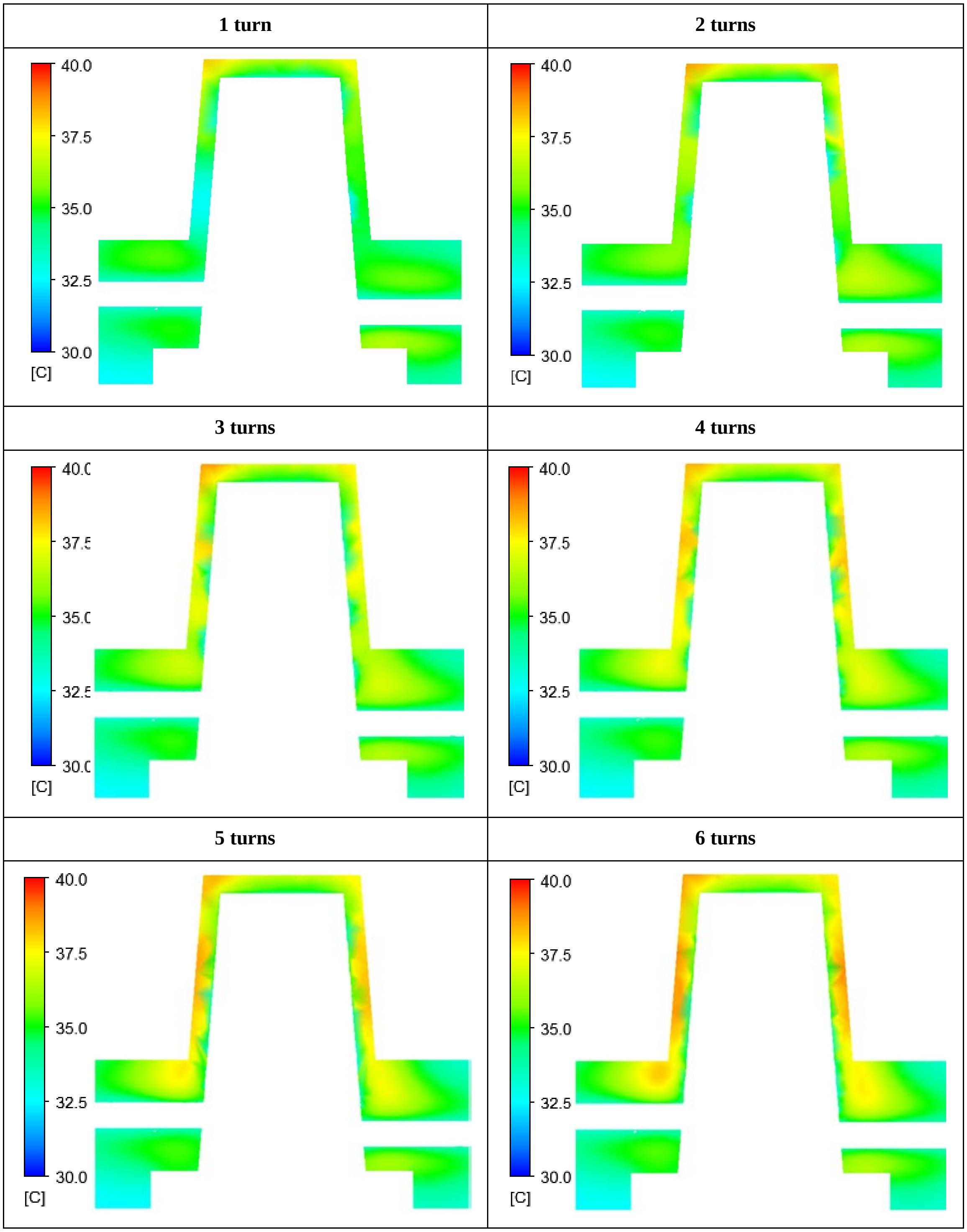

Fig. 6. Temperature distribution of the mold plate at the end of the injection molding cycle.

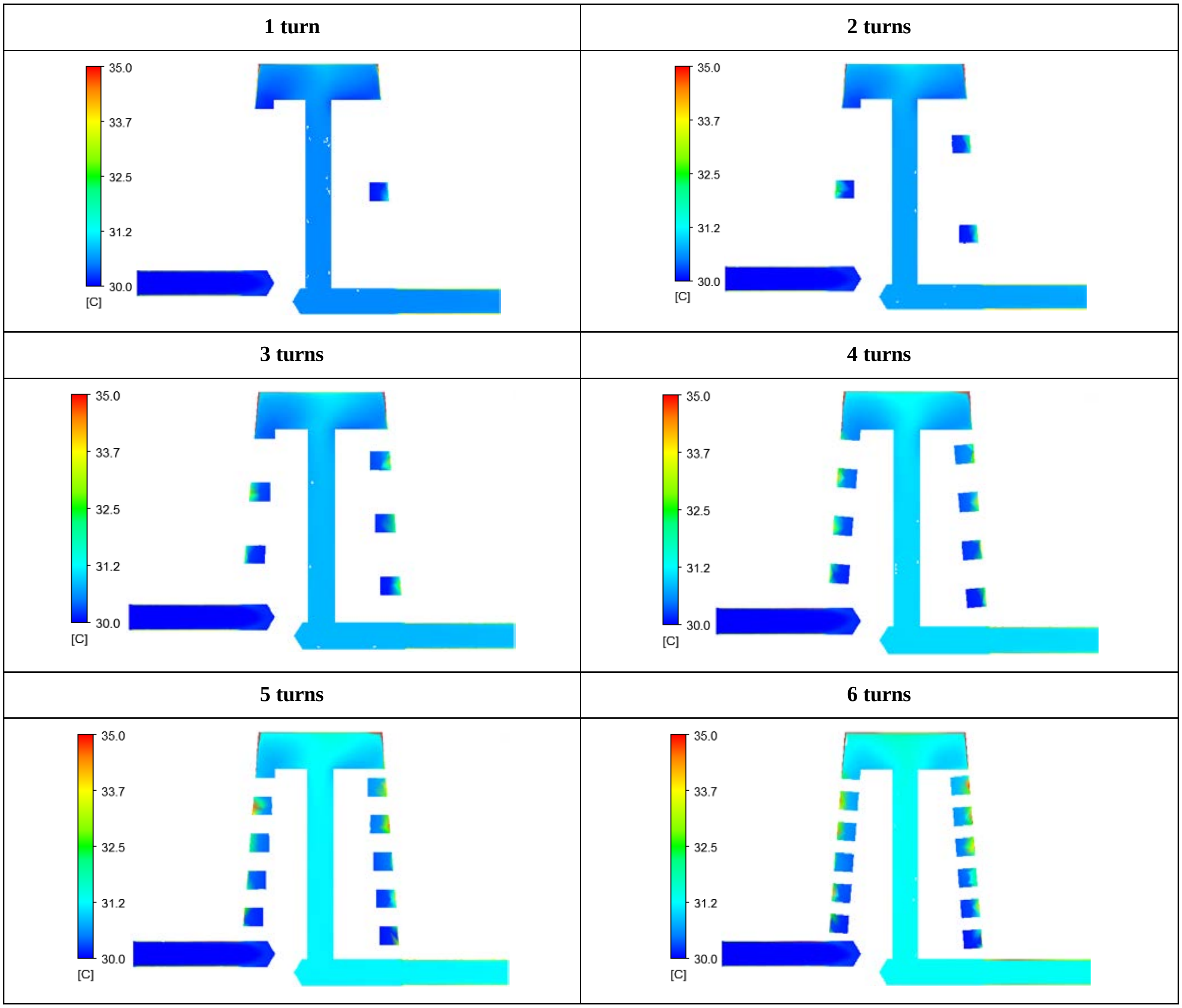

Fig. 7. Temperature distribution of the water at the end of the injection molding cycle.

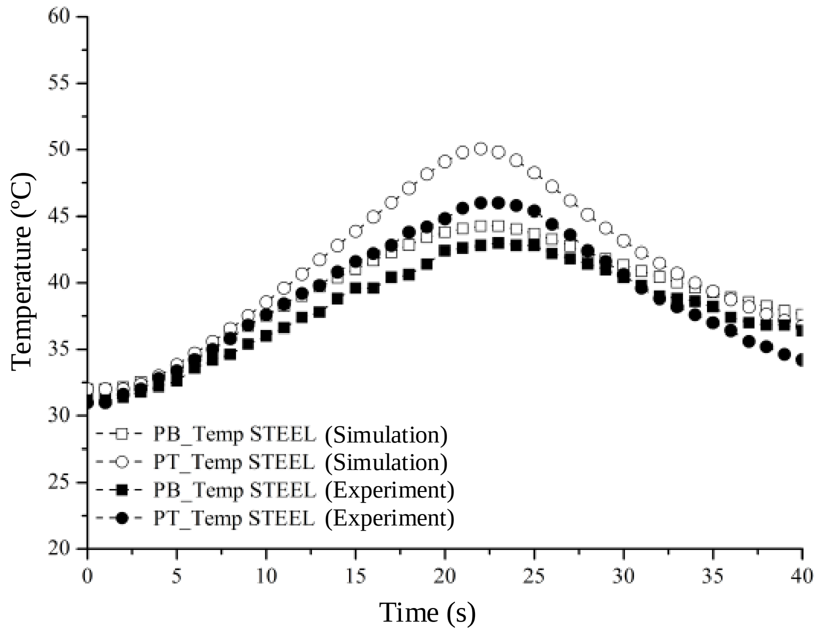

Fig. 8. Temperature comparison between the simulation and experiment.

4. Conclusions

In this paper, a helical cooling system with a 3 mm × 3 mm section was studied by experiments and simulations. In general, the following conclusions can be made:

- More turns in a channel lead to a more uniform temperature distribution in the mold plate.
- The temperature at the top point (PT point) will be higher than the bottom point (PB point) because of the different mold plate thickness of the two points.

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