APPLICATION OF SOLIDWORKS SIMULATION FOR DESIGN OF COOLING SYSTEM FOR INJECTION MOLDING

ПРИЛОЖЕНИЕ НА SOLIDWORKS SIMULATION ПРИ ПРОЕКТИРАНЕ НА ОХЛАЖДАЩА СИСТЕМА ЗА ШПРИЦФОРМИ

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Abstract: The cooling system in injection molding is very important and affects the production cycle time. That is directly linked with cost and also has effects on part quality. For this reason, the main objective of this paper was to determine an optimal design for cooling channels using thermal head transfer analysis. There is an advanced method with cooling system that “conforms” to the shape of part in the core. The model of part and injection mold is designed in SolidWorks. The part cooling time has been optimized by using conformal cooling channels and compared with circle and ellipse cross section using thermal simulation software SolidWorks Simulation. Results are presented based on model of part and injection mold is designed in SolidWorks. The part cooling time has been optimized by using conformal cooling channels close vicinity to the walls of the mold.

Keywords: COOLING SYSTEM, INJECTION MOLD, SIMULATION ANALYSIS

1. Introduction

Most of the everyday used and domestic products are produced of plastics. For this purpose the most frequent used method is injection mold. In this method, for every type of detail, a mold tool is designed and produced. This usually is done with the help of CAD/CAE/CAM systems that allow the automation of the whole cycle – from the design to the very production of the molding tools. One possible software decision is SolidWorks® of Dassault Systèmes. The program allows not only construction but carrying of simulation analysis for the investigation of the qualities of the designed injection mold tools. In this publication we will focus on the selection of the injection mold tools that provides high production rate of the products without leading to aggravation of their quality. The efficiency of the process of injection mold depends mostly on the time of molding that is a sum of the times for filling-in of the cavity, cooling and taking out of the ready product.

2. Analysis of the status

The level of heat transfer between the detail and the mold is a key factor for the production of plastic products. The heat of the melt must be removed and the detail may reach a temperature that allows taking it out from the mold. The time necessary for this task is called time for cooling. The time for cooling is of crucial importance for the output and hence – for the price of the products. Important here is the correct design of the cooling system. A lot of scientific teams have been working in this direction and several types of cooling systems have been developed. According to the construction of the cooling channels/ducts/, most generally they can be divided as follows:

- Standard cooling systems;
- Systems with conformal cooling channels;
- Cooling systems with dynamic temperature control.

We will consider in short each one of these types.

2.1. Standard cooling system

The simplest way for control of the temperature in the press-molds is by creation of several canals in the mold in which the cooling fluid is circulating [3]. Usually these are straight channels. It is established that this type of cooling is not sufficiently efficient because the heat transfer is irregular especially for molds with more complex geometrical form. The basic problem here is the impossibility for development of complex channels especially in close vicinity to the walls of the mold. The time for cooling is comparatively long. In order to avoid these disadvantages cooling systems are constructed in which the channels follow the form of the detail (Fig.1).

2.2. Conformal cooling channels

With the purpose of achieving better quality of the plastic products and shorter production time the idea appeared for construction of cooling system that follows the form of the details. In this way the injection molding tools become more complicated but this happens for the cost of improving a number of production parameters. Most often the cross section of the cooling canals is a circle. Experiments have been carried out for establishing of appropriate diameter of the cross section and a recommended distance between the channel and the cooled detail [2]. These dimensions depend on the thickness of the detail walls.

The disadvantage of this method is the more difficult preparation of the mold elements. For details with more complex geometrical form the molding equipment may be produced by rapid prototype methods. This allows on the one hand the cross section of the canals to take different forms and on the other – the molding elements not to be broken in many compound parts.

In the last years the technologies for rapid prototypes undergo strong development. Part of the methods (like selective laser sintering, for example) produce prototypes that have the qualities of a product, produced by the standard technologies. More and more often this type of cooling systems substitute the standard.

2.3. Dynamic cooling control

The method is based on conceptually different model of the equipment (Fig.2). They are produced as shells. The surface which is in contact with the detail is of material with higher heat conductivity and the external part of the molding elements is with lower heat conductivity. In the cavities of the molding tools fluid is circulating whose temperature is controlled during the process of molding. At the first moment of injection process of the material, the temperature of the molding tools must be as close as possible to the temperature of the melt material. Then the fluid is with high temperature. After that fluid with low temperature is fed which cools the detail quickly. With this method details are produced with very good quality and good time for cooling is achieved. The high
price of the technological equipment is a serious disadvantage –
molding elements and system for control of fluid temperature. That is
why similar systems are used very rarely.

- The cooling system must be sufficiently close to the detail in order to support its fast cooling-up;
- The form of the cross section of the channels must not create conditions for turbulence of the fluid;
- etc.

**Table 1. Recommended parameters of the cooling system**

<table>
<thead>
<tr>
<th>Thickness of the detail walls, mm</th>
<th>Diameter of hole, mm</th>
<th>Distances between the channels a</th>
<th>Distance between channels and the detail c</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ÷ 2</td>
<td>4 ÷ 8</td>
<td>(2-3) b</td>
<td>(1.5-2) b</td>
</tr>
<tr>
<td>2 ÷ 4</td>
<td>8 ÷ 12</td>
<td>(2-3) b</td>
<td>(1.5-2) b</td>
</tr>
<tr>
<td>4 ÷ 6</td>
<td>12 ÷ 14</td>
<td>(2-3) b</td>
<td>(1.5-2) b</td>
</tr>
</tbody>
</table>

After preparation of the model for the molds together with the cooling system and the detail, the next important moment is the method for investigation of the proposed structure. In order the simulation analysis to be correct it is important that the technological time periods to be properly determined, used materials to be predetermined and the initial conditions are defined. When the process of detail cooling in the mold is traced, the properties of the used plastics are important – melting temperature, temperature of material solidification, temperature at which the detail can be taken out of the equipment without destruction of its form. Since for speeding-up of the cooling process a cooling system is used, it is important to have in mind also the fluid parameters – type, speed, temperature, etc.

The software product that is used by us for simulation and investigation of the obtained model is SolidWorks. This software offers excellent media for design of different types of engineering objects. Together with this the objects may be investigated through a great variety of simulation analyses and to be optimized yet before their real production.

In our case we can use thermal analysis from the application SolidWorks Simulation or analysis with inclusion of fluid from the application SolidWorks Flow Simulation. The fluid analyses are very labor consuming and take a lot of computational time. By certain approximations, better results may be achieved and without real inclusion of fluid [5, 7] but only with its simulation by defining convection with appropriate coefficient of convection and fluid temperature. The following formula is used:

\[
h_c = 0.023 \frac{k}{D} Re_{cp}^{0.8} Pr^{0.4}
\]

where:
- \( h_c \) – coefficient of heat transfer;
- \( k \) – heat conductivity of the cooling fluid for the corresponding temperature;
- \( D \) – diameter of the cooling channels;
- \( Re_{cp} \) – Reynolds number;
- \( Pr \) – Prandtl number.

**4. Results and discussions**

Fig.4 shows an option of cooling system with round cross section of the cooling channels. With the purpose of additional shortening of the time for detail cooling an experiment is carried out with the same disposition and surface area of the channels. The form of the cross section in the second case is ellipse with the same surface as are the round cross section.
а) with round section of the cooling channels

б) with elliptic section of the cooling channels

Fig.4. Simplified model of the mold with round section of the cooling channels

Fig.5. Temperature distribution in the detail after 20 seconds

Fig.6. Results from the sensors

After inspection of the results obtained it is seen that the use of the system for cooling that follows the form of the detail leads to uniform cooling of the specific detail. This improves the quality of the products and prevents the production from defects and waste. These advantages justify the higher price of the molds. Besides, the continuous development of the technologies for prototyping additionally facilitates the production of the proposed cooling systems.

In order to check the efficiency of each new type of cooling it is necessary, besides proving of the quality of the produced details, to prove the increase of the productivity of the new method. The productivity depends mostly on the time for cooling of the detail. In our case the temperature at which we can take out the detail from the mold is 80°C. With the option with round cross section of the channels this temperature is reached after 15 seconds. For comparison this temperature with the channels with elliptic cross section is available after 9 seconds. This result is due to the higher temperature flow in the case of elliptic cross section.
2. When elliptic cooling channels are used the irregular temperature distribution in the cooled product is reduced.

**Literature:**

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