Optimizing the Design of an Injection Mold for Parts “Lower Cover” and “Upper Cover” by Using Computer Simulation

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Abstract. The production of plastic parts has found wide application because today everything can be produced as a product of different complexity and a large palette of colors from plastics with different chemical composition. Polymer products have wide applicability due to their mechanical, physical and chemical properties in our daily life. Simulation analyzes facilitate the design of injection molds. Flow analysis should be the starting point for the production of quality products. This saves time and money associated with possible mold defects.

The plastic molding process is characterized by high productivity, high level of automation, dimensional accuracy, high efficiency, good operational properties. It is possible to use a wide range of polymer materials depending on the requirements for the product.

Keywords: simulation, injection mold, analyses.

1. INTRODUCTION

Wide use of plastic parts requires the use of CAD/CAM/CAE systems both for their design, manufacture and simulations for their proper functioning. Modern computer systems allow simulation of virtually all levels of instrumentation implementation [1-3]. The software products used allow the implementation of simulations in various fields, not only in industry but also in teaching courses [4-6]. For the correct and long-lasting functioning of the tooling equipment, an important factor is the correct choice of the chemical-thermal treatment of the parts of the injection mold [7-8].

2. THEORETICAL BASIS

The syringe mold is a complex tool consisting of two main parts. The first part is the forming part where molten polymer is injected and after cooling creates the final shape of the product. It is more complicated to manufacture, in the manufacture of which high-quality materials are used. The second part is the structural system, which is generally similar in all forms and can be ordered as ready-made components. The active parts of the tool must meet the following requirements:

- contain the core and cavity of the matrix, which determines the shape of the part to be created;

- to provide an opportunity for the melt to reach the forming cavities;

- act as a heat exchanger that will:

- cool the part quickly;

- cooling the part evenly;

- to ensure that the part will be ejected from the mold;

- have a structure that will withstand the internal pressures of the melt, which could potentially be higher than the 200 MPa compressive strength of the closure elements;

- in the multiple forms, to ensure uniformity of dimensions in each cavity after cooling.

Injection molds can be classified as cold runner and hot runner systems. The first are used for simple and irresponsible details. The second type lacks a funnel system, which has the following advantages:

- reduces the cycle;
- the details do not need to be separated;

- it is more productive;
- allows easy automation;
- allows labels to be placed during injecttion itself;
- warm nozzles are used, which can feed one part or more if their volume is smaller.

For the proper functioning of the injection mold, an important role is played by the cooling system. It allows the molten material to cool down more quickly, therefore reducing its production time, thereby reducing production costs (Fig. 1).

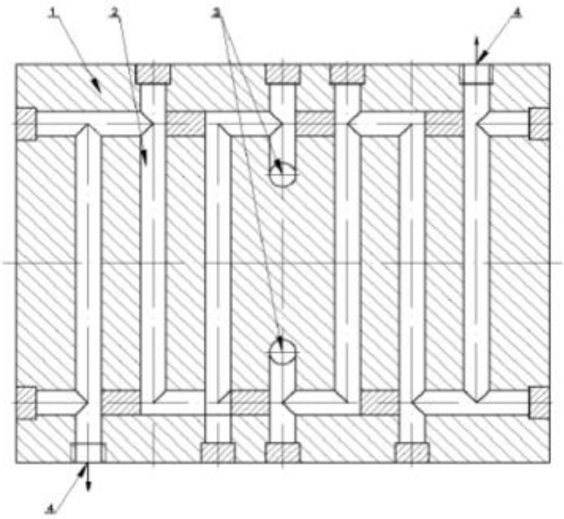

Fig. 1 Cooling system: 1-plate, 2-channels, 3-inlet, 4-outlet

The computer simulation was performed for the details shown in (Fig. 2), namely "lower cover" and "upper cover" with dimensions length 75.2 mm, height 12.7 mm and width 30.85 mm. The volumes are respectively lower cover 7775.15 mm^3 and upper cover 5273.90 mm^3.

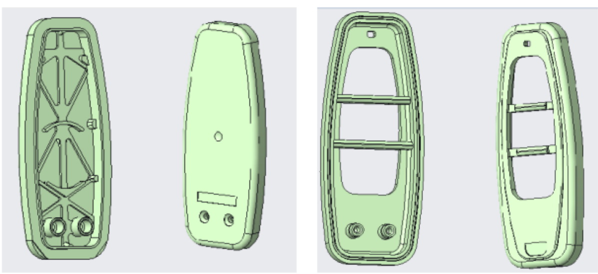

Fig. 2 Cover lower and upper.

The simulation analysis was performed using the Autodesk MoldFlow Adviser software product. After the material is selected, and it is provided by the customer, in this case it is Polystyrene 1811 of the company TotalEnergies, an estimated injection time is calculated (Fig.3). The tool cooling temperature is marked on the vertical axis, and the time of injection or filling of the material in the molds is marked on the horizontal axis. There are three zones:

- first in green, which shows the recommended cooling temperature and injection time. It is desirable to carry out the injection in this area;

- the second in yellow, where the injection can be done;

- the third in red, where injection is impossible.

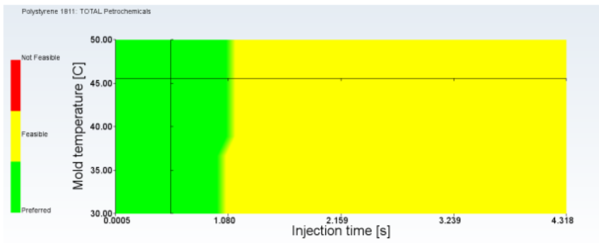

Fig. 3 Injection time.

The next stage of the design of the injection mold is to perform an analysis of the filling of material in the cavities of the active parts of the tool, initially choosing the place from which the material will be injected. This analysis is recommended, not mandatory, and indicates in which zone the pour point should be located, where the melt will flow most evenly, taking into account the selected material.

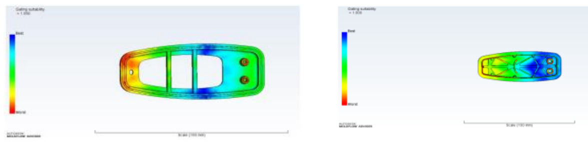

Fig. 4 Inflow Availability Analysis.

From Fig. 4 it can be seen that the most favorable inflow zone is in the middle of the model. Areas in blue are the best and areas in red are the worst. The areas colored in green are intermediate.

The next analysis that is recommended to be performed is an article fill analysis. This analysis aims to check whether the model can be injection molded and the molding quality. Once the analysis is complete, the results of fill suitability and quality prediction can be analyzed, as well as the results of fill time, injection pressure, pressure drop and flow temperature can be traced. It is necessary to locate the inlet, select and build a cooling and injecttion system. The result shows the time required for the melt to fill the mold cavities. From the figure below, a uniform melt flow distribution can be seen.

The maximum pressure is immediately at the entrance of the melt, namely 49.20 MPa, and at the farthest point it is zero. There are unfilled spaces that are filled using the additional pressure. Through this simulation, the machine on which the part will be produced can be selected. In this case, the required minimum closing force is 49.20 MPa (Fig. 6).

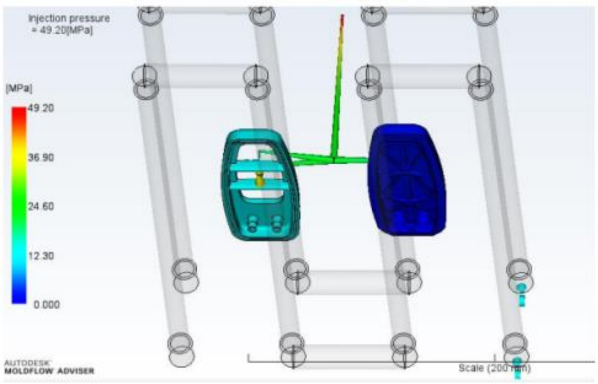

Fig. 6 Maximum injection pressure.

During the filling phase, the temperature should not drop by more than 2 °C to 5 °C (Fig. 7). The large change in field temperature is mainly caused by the melt having to travel a long way to fill the entire pattern in all walls. A time-to-injection analysis was performed. This resulted in a decrease in the deformation rate, but increased the injection pressure many times, which will therefore affect the closing force of the machine. This large temperature change is the result of the large walls and ribs, as well as the intense cooling of the mold cavity.

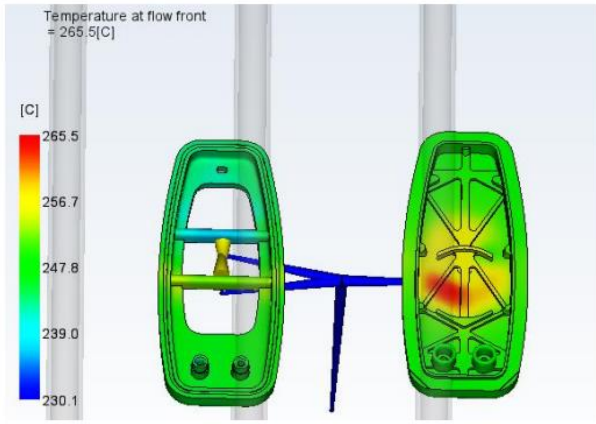

Fig. 7 Melt temperature.

Air bubbles are usually created at the furthest point of melt flow into the mold cavity. In this case, they occur near the main parting plane. After the molds are closed, the cavity does not have to be perfectly sealed in order for the mold to “breathe” (Fig. 8). This means that air trapped in the mold cavity, which is subsequently displaced by the melt, must be released back into the atmosphere. Air can also return through the sliding jaws or push pins.

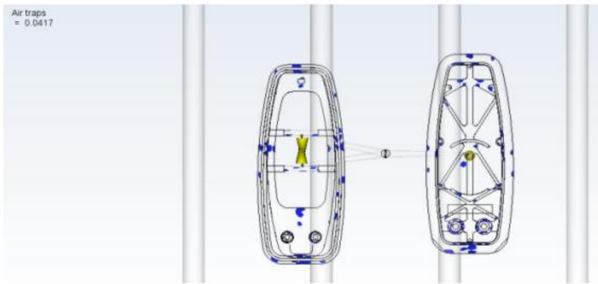

Fig. 8 Analysis for air bubbles.

Cold junctions form at the meeting point of the two sides of the polymer melt. These regions tend to have generally the worst mechanical and optical properties. Places of probable such an event need to be moved to the areas with the least claims to mechanical stress. From Fig. 9 it can be seen that the cold nodes are in unloaded places.

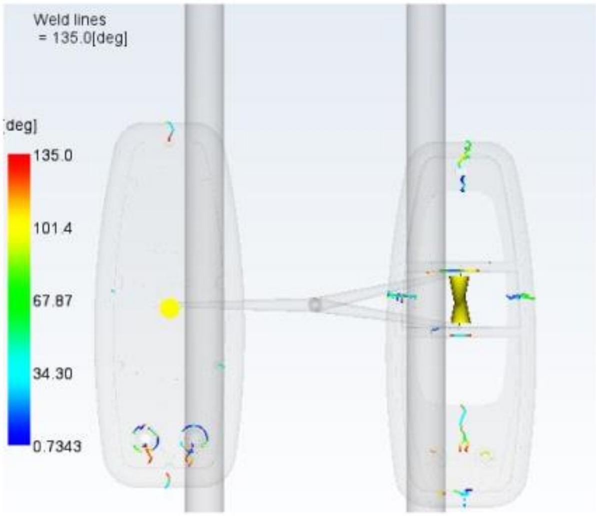

Fig. 9 Analysis of weld lines.

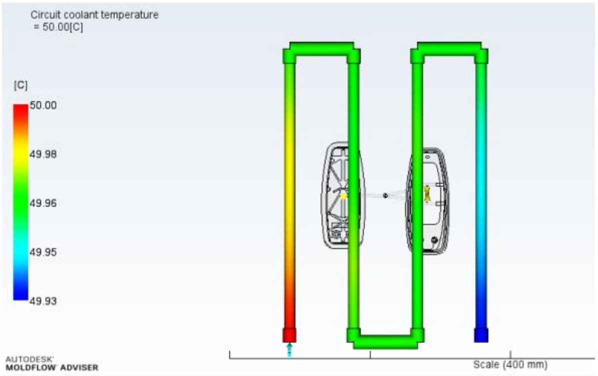

Fig. 10 Analysis of the temperature of the cooling circuits.

Reynolds number is a dimensionless quantity, one of the so-called "Similarity Factors" that define the type of fluid flow Fig. 10. It shows the relative importance of the viscous effect compared to the inertial effect. The Reynolds number is proportional to the inertial force divided by the viscous force Fig. 11.

It is calculated according to one of the following formulas (1):

$$R_e = \frac{\rho . V_S . L}{\mu} \quad \text{or} \quad R_e = \frac{V_S . L}{V} \qquad (1)$$

where:

- Vs is the mean velocity of the fluid;

- L – characteristic size (channel diameter, drain plate length);

- μ – (absolute) dynamic viscosity of the fluid;

- V kinematic viscosity of the fluid;

- ρ - fluid density.

Reynolds number is the ratio of inertial forces to viscous forces and is used to determine whether a flow is laminar or turbulent. Laminar flow occurs at low Reynolds numbers where viscous forces are predominant and is characterized by smooth and steady fluid motion, while turbulent flow occurs at high Reynolds numbers and is dominated by inertial forces forming eddies, eddies and other fluctuations of the stream. The transition from laminar to turbulent flow is often determined by the critical Reynolds number, which depends on the exact flow configuration and is determined experimentally. The flow in circular pipes is:

- laminar if Re < 2300

- transient if 2300 < Re < 2600

- turbulent if Re > 2600.

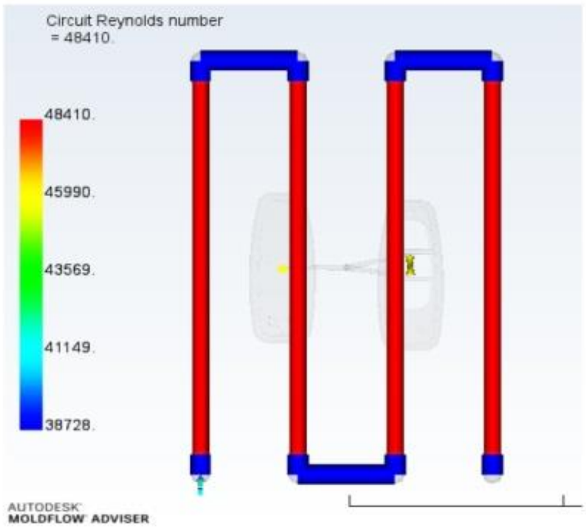

Fig. 11 Reynolds number analysis.

3. COMMENTS AND CONCLUSIONS

According to the result, the injection time is 0.82 sec, which is in the green zone for the material comparison (Fig. 3) and is achievable for this material. The location of the inlet should be in the center of both parts. The different volume of the two parts (seen Table 2.4) also contributes to the complexity of casting the melt, therefore, in order to achieve uniform casting, it is planned to pour the upper cover from two places with two smaller inlets by means of a funnel between the two ribs, and the bottom cover to be poured directly from the nozzle of the heat channel system.

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