

RESEARCH ON INJECTION MOLD COOLING SYSTEM EFFICIENCY AND UNIFORMITY FOR ELECTRICAL CONNECTOR CASING

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Abstract: The hereby presented study consists of results of injection mold cooling system research for cooling efficiency of moulding used in electric and electronic industry. Electrical connector casings are special group of moldings due to their weight, dimensions and shape. The analysis process uses 3D model created in PTC Creo and any simulation was carried out by means of Autodesk Moldflow for PA 6.6 with trade name of FRIANYL RV0 GN A63. The considered form is equipped with cold injection channel and one surface of share. The issue of selection of technological parameters of the injection molding process is not taken and the values recommended by the manufacturer of the mold are used. The subject was taken in response to the increasing demands on the quality and efficiency of production parts.

Keywords: INJECTION MOLD, COOLING SYSTEM, COOLING EFFICIENCY, RAPID TEMPERATURE CYCLING

1. Introduction

Injection molds are the most important link in the plastic injection process and they are responsible for the design, aesthetic, usable and technical features of moldings. Apart from the technological parameters of the injection process itself is reduced to plasticity material, fill the mold cavity and shaping the cooling part. During the conventional injection process, the temperature of the whole system is maintained at a constant level (typically in the range 40 – 110 °C, depending on the type of plastic). Having to deal with thermoplastics, the mold temperature is always lower than the temperature of the injected plastic, so the system is usually called the cooling system.

One of the most important problems occurring during the injection process is to ensure the efficient and uniform dissipation of heat from the cooled melt so as to avoid the creation of excessive internal stresses which can cause deformation of the molding [1]. It should be emphasized that in the most cases the cooling accounts for approximately 50 – 80 % of the total cycle time and is one of the most important steps in the process of plastic injection [2].

Rising expectations for quality, aesthetic and technical features of plastic moldings make the most of the global companies and research institutes are involved in the research on improving of the efficiency and uniformity of the cooling system in injection molds [3].

The presented study focuses on minimizing of the cooling time in a broad aspect because the cooling system is not isolated from the mold and the entire forming system is considered. The paper also examines the influence of the wall thickness of the molded part on the cooling rate at the constant technological and design parameters.

2. Heat balance of a conventional injection mold

The main source of heat delivered into the mold is plasticized material injected by gating system into the cavity of the mold (Fig. 1). Optionally the mold can be equipped with a hot-channel system, which is designed to hearing of the plasticized material between succeeding injection cycles. Heat dissipation from the system is by conduction, thermal radiation and convection [4] to the adjacent medium of lower temperature, among other things to the coolant flowing in the closed cooling system, table of the injection molding machine (which is in direct contact with mounting plates or insulating plates of the mold) and ambient air. There are also technologies that introduce to the additional heating or cooling medium to the system to improve the molding quality [5, 6, 7].

The heat balance of conventional mold (Fig. 1) is as follows:

$$\sum Q = Q_{MT} + Q_{MH} + Q_{HR} + Q_{HC} + Q_{TC} + Q_{HH} + Q_{CHM} = 0 \quad (1)$$

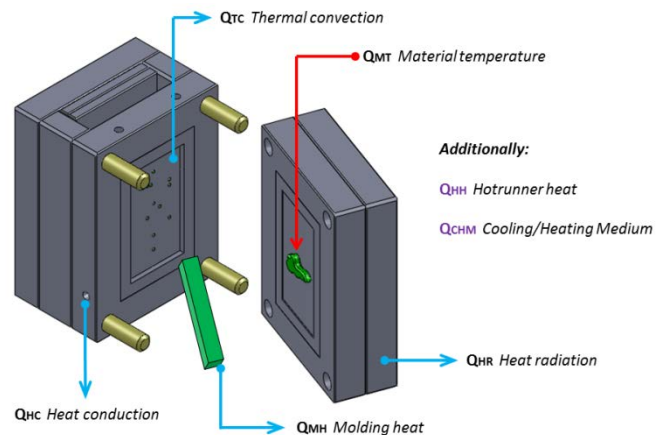


Fig. 1 The heat balance of a conventional injection mold.

Seeking heat flux $\dot{Q}$ flowing from the hot mold surface to the cooling channel (Fig. 3) can be represented by the formula:

$$\dot{Q} = \frac{A\lambda}{l} (T_G - T_K) \quad (2)$$

where A is surface area of the cavity, λ – thermal conductivity of the cavity material, l – distance between cooling channels and the cavity surface, T_G – average temperature of the cavity, T_K – average temperature of the cooling channel surface.

Using Newton's law can determinate the value of the heat flux acquired by the coolant:

$$\dot{Q}_p = \alpha S (T_K - T_C) \quad (3)$$

where α is surface film conductance, S – surface area of the cooling channels, T_C – coolant temperature.

Taking into account the heat loss (radiation, convection and heat transfer from the injection mold to the injection machine table) can be determined the time of molding cooling time since the filling time until the achievement of the ejection temperature.

$$t_c = \frac{s^2}{a\pi^2} \ln \left(\frac{8(T_M - T_G)}{\pi^2 (T_E - T_G)} \right) \quad (4)$$

where s is thickness of the molding wall, a – thermal conductivity, T_T – melt temperature, T_E – ejection temperature.

3. Problem of injection mold cooling

As already mentioned, one of the major problems occurring during the process of plastic injection molding technology is cooling. Until now, the most common method of cooling are conventional drilled channels with flowing water. (Fig. 2). Technologically there is no problem with cooling process on the die side but on the other side the cooling channels very often have to be drilled beyond the forming area because of number of ejection holes and inserts.

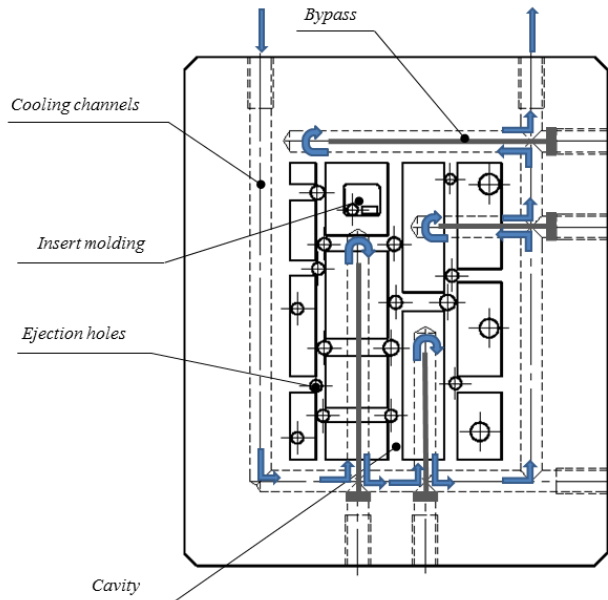


Fig. 2 The cavity insert equipped with conventional cooling system.

In such a situation it is not possible to achieve the effective and uniform cooling of the mold (Fig. 3).

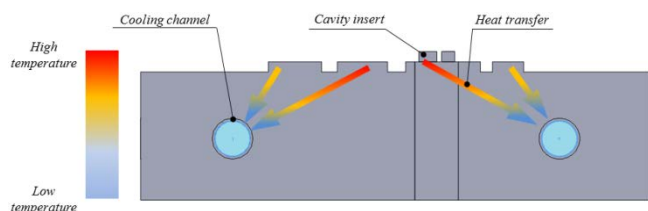


Fig. 2 Heat transfer from the forming surface to the cooling channels.

Below shows the issues that have an impact on the quality of the cooling process:

- diameter of the cooling channels,
- distance between the forming surface and cooling channels,
- number of the cooling channels,
- cooling channels distribution,
- additional chillers,
- thickness of the molding walls,
- number of ejection and insert holes.

The best solution would be simultaneous application of all the presented options, however, it is impossible because in many cases the actions are divergent.

Hereby the paper presents an analysis of the action set and the possibility of their simultaneous application for achieving the highest possible efficiency of the cooling system while striving for a uniform distribution of temperature fields on the surface of the cavity.

4. Analyzed model

Figure 4 shows the molding and its fundamental parameters.

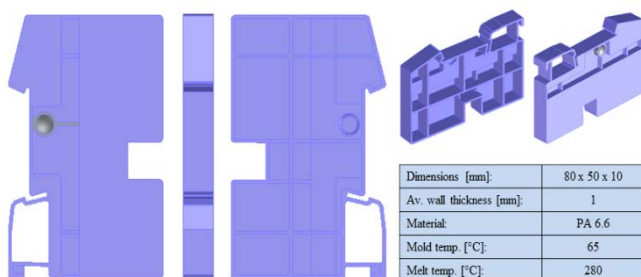


Fig. 3 Analyzed model

The part is used for the production of electrical connectors as the cover unit. From the technological side the molding has a simple geometric design (one parting surface) and fairly intense ribbing demanding application of 10 – 12 ejectors. Research object is a double cavity mold weighing 280 kg and overall dimensions 392 x 270 x 446 mm (Fig. 5).



Cavity number:	2
Injection system:	Hot channel
Number of parting surfaces:	1
Insulation plates:	Yes
Number of ejectors:	10 - 12

Fig. 4 Injection mold.

The quality of the cooling system depends not only on its effectiveness, but also on its uniformity. Unbalanced cooling can lead to the formation of high stress inside the molding, which in the end may cause the distortion or even crack (Fig. 5).



Fig. 5 Factor and direction of distortion depending on the temperature.

The uniformity of the cooling process directly depends on diameter, shape and placement of cooling channels. These, in turn largely depend on other areas of the mold design and these are: number of ejectors, the number and shape of the mold inserts, course and kind of injection system, etc. In practice a great number of designers at first focus on the forming area and after that complement the mold with cooling system. Such an action could adversely affect the quality of the part.

5. The preliminary injection process analysis

The MoldFlow analysis began with the pre-injection process by which the direction of the material flow (Fig. 6), weld lines, temperature and the pressure drop can be observed.

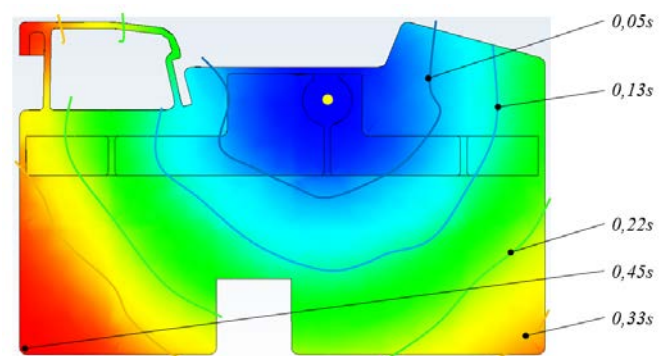


Fig. 6 The preliminary injection process analysis - time of filling

The weld lines are one of the most frequent defects during the injection process. They affect not only on the aesthetic properties but also on its durability and functionality [8]. In addition to internal stresses weld lines are the main cause of cracking of moldings during the assembly process and during their use. The fact is that it is not possible to eliminate the weld lines, however, during the stage of the mold design can greatly affect the conditions in which they are formed. The places of weld lines formation should largely determine the design of cooling system particularly when there is a pressure drop there. Pressure drop is usually accompanied by a

temperature drop of flowing melt, which make it difficult to get high quality joint. In such places the intensive cooling should be avoided.

5. The design of cooling system

During the design of cooling system the diameter, the number, the distribution and the distance between the cooling channels and forming surface have been taken into account. In the first stage, the cooling system of the punch was designed because of the great number of ejector holes and then adjusted to the circuit on the side of matrix. A series of simulations were carried out, based on which the optimal cooling system was designed. The figure 7 presents selected sequences of the cooling systems.

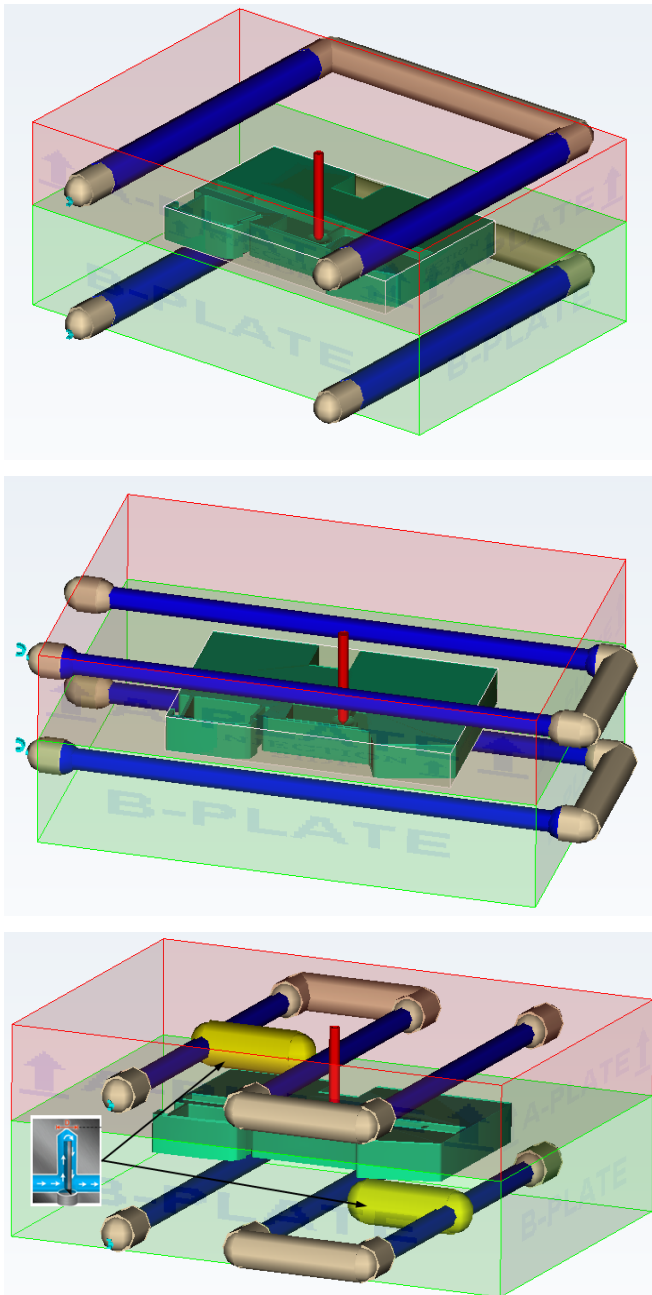


Fig.7 Selected exemplary courses of cooling systems

There is a distinction between hard and soft cooling system. In mass production it is necessary to apply rapid cooling in order to obtain shorten cycle time. This leads to great difficulties in achieving uniform cooling. Ideal for filling process and mechanical properties of the product would be when the temperature of the mold during the injection corresponds to the melting temperature but technologically such a process is very difficult to achieve.

The heat flux transferred from the molding to the punch is greater because the material shrinking crimped into a stamp and that allows to direct transfer of heat. Between the die and the molding arises air cushion which is very good insulator.

6. Results and conclusions

The figure 8 presents the results of simulation research. Based on these results it can be concluded that:

- the cooling efficiency increasing follows with decreasing of distance between cooling channels and cavity surface,
- the increasing of the cooling channels diameter for small-sized moldings has a little effect on the rate of cooling and may have an adverse effect on the uniformity of the process,
- in order to improve the uniformity of cooling it is recommended to increase the number of cooling channels at the expense of their diameter,
- when considering the injection process of cold-channel injection system is not possible to optimize the cooling process,
- it is advisable to reduce the wall thickness of the molding if possible.

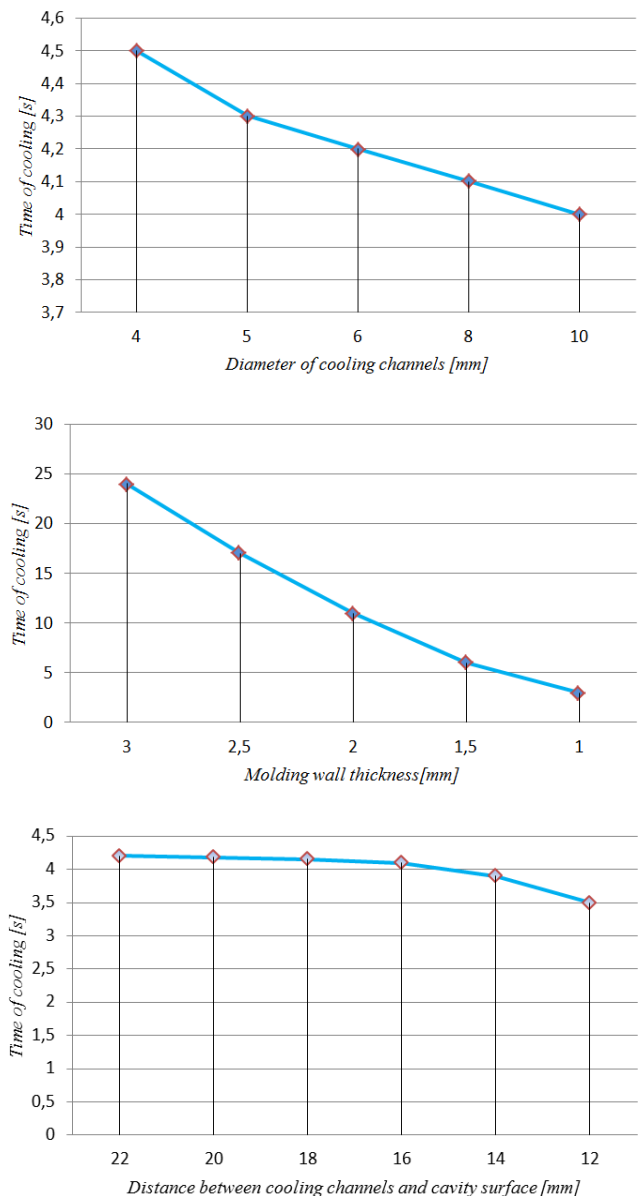


Fig. 8 Results of simulation analysis

After taking into account the results the verification research was carried out. The final results are presented in the table 1 and figure 9.

Table 1: Considered cases

Case	Cooling			Injection system	
	Mold base	Cavity inserts	Conformal cooling	Cold-runner	Hot-runner
1	+	-	-	+	-
2	+	+	-	+	-
3	+	+	-	-	+
4	+	+	+	-	+

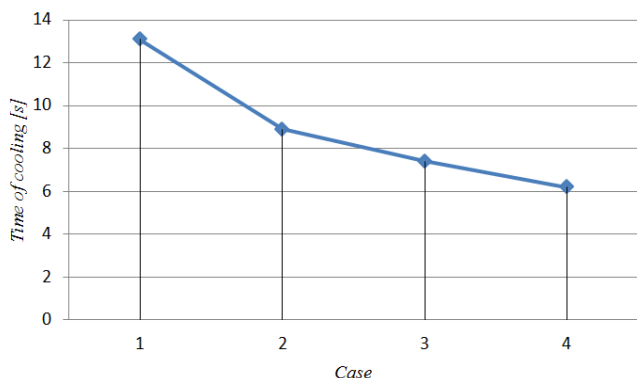


Fig. 10 Results of verification research on cooling efficiency and uniformity

To sum up, in order to achieve efficient and uniform cooling process system must be designed with a large number of cooling channels located near the surface of the mold at the expense of their diameter (e.g. conformal cooling) [9]. In case of thin-walled moldings the hot-channel injection system should be used in order to avoid the heat centers which are cold sprues.

7. References

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