30th International Conference
ENGINEERING MECHANICS 2024
Milovy, Czech Republic, May 14 – 16, 2024

TEMPERATURE FIELD EVALUATION USING INJECTION MOLD THERMAL INSERTS

Holesovský F.*, **Hejna M.****

Abstract: *This article deals with thermal inserts in injection molds and their effect on the mechanical properties of crystalline plastics. Description and solution of the temperature field, mathematical-physical analysis of the solution of temperature fields, methods of temperature measurement, non-contact temperature measurement, touch temperature measurement, course of temperature fields in the injection mold, evaluation of the effect of thermal inserts on the distribution of the temperature field in the injection mold are given. Methods of evaluating the temperature field are presented here. In this part, the measurement of temperature fields in an injection mold containing thermal inserts is also performed.*

Keywords: Thermal inserts, temperature field, injection mold.

1. Introduction

The processing of plastics is currently a field that is still developing, mainly because their processing is cheap and at the same time productive. The great development of the use of plastics is mainly in engineering, especially in the automotive industry, electrical engineering, construction and packaging technology (Hejna, 2004).

In practice, more and more demands are placed on the product to be as cheap as possible, produced in the shortest possible time and have the appropriate properties. These demanding requirements are met by the processing of plastics using injection technology. This technology can produce products with good dimensional and shape accuracy. Other advantages also include the high utilization of processed material, thus meeting the requirements for waste-free technology. However, the purchase price of both the machinery and the injection mold is quite high, which is why this technology is suitable for large-scale and mass production (Hejna, 2004).

The injection molding process can be shortened mainly by the cooling time, i.e. by removing heat from the shaped cavity of the mold, this can be achieved by tempering the injection molds. One of the many methods of tempering injection molds is the use of thermal inserts, which remove heat from the mold cavity. Whether this method of tempering will affect the mechanical properties of crystalline plastics is discussed in this article (Hejna, 2004).

2. Temperature field in injection form

2.1. Description and solution of the temperature field

The process of cooling the injection mold is a non-stationary, cyclically repeating process that takes place in the temperature range from the melt temperature to the mold temperature. This temperature system creates a cyclic three-dimensional temperature field, which is most influenced by the choice, construction,

* Prof. Dr. Ing. František Holešovský: University of West Bohemia in Pilsen, Street Univerzitni 2732/8; 301 00, Pilsen; CZ, holesovf@fst.zcu.cz

** Ing. Marek Hejna: University of West Bohemia in Pilsen, Street Univerzitni 2732/8; 301 00, Pilsen; CZ, marek78@fst.zcu.cz

doi: 10.21495/em2024-118

method of location and efficiency of the temperature system, or Tempering agent, mold and product material.

Taking into account the characteristics of the injection molding, cooling should take place uniformly and at the same speed in all parts of the injection mold. However, this depends on the design of the tempering system and the distribution of the temperature fields in the tool. In the ideal case, which cannot be achieved in practice due to very rapid changes in temperature over time, the spray should have the same temperature during cooling at all points in the layer at the same distance from the surface. Uneven distribution of temperatures in the mold cavity and on the surface of the injection, i.e. an inhomogeneous temperature field, results in the risk of dimensional and shape deviations of the injection. Temperature differences between individual injection areas cannot be avoided, but due to knowledge of the distribution of temperature fields, they can be influenced so that they are within acceptable limits and reproducible in each cycle.

The temperature field in the jet is clearly determined by its geometry (shape and dimensions), material properties, temperature distribution at a certain moment and conditions of heat transfer over the entire surface of the body and during the investigated phase. If we use rectangular coordinates x, y, z, the 3D non-stationary temperature field (temperatures at points with coordinates x, y, z are functions of time) at time t is generally described by the following function (Hejna, 2004):

$$T = T(x, y, z, t) \tag{1}$$

where: T … temperature [K],
x, y, z … Cartesian coordinates [m],
t … time [s].

The uneven distribution of temperature in the body results in a heat flow in the direction of decreasing temperature:

$$q = -\lambda \, . \, grad \; T \tag{2}$$

where: λ … coefficient of thermal conductivity [W/m.K],
grad T … temperature gradient in form [K/m].

Injection molds are most often metal, and for other solutions it can be considered that the material forms a homogeneous environment and heat is shared in it by conduction. Non-stationary heat conduction in the body (in our case in injection and injection form) is described by the partial differential Fourier equation (3). This equation describes the temperature distribution in the injection mold at any instant of time.

$$\frac{\partial T(x,y,z,t)}{\partial t} . \rho . c_v = \frac{\partial T(x,y,z,t) . \partial T(x,y,z,t)}{\partial t . \partial t} . \lambda_x + \frac{\partial T(x,y,z,t) . \partial T(x,y,z,t)}{\partial t . \partial t} . \lambda_y + \frac{\partial T(x,y,z,t) . \partial T(x,y,z,t)}{\partial t . \partial t} . \lambda_z + q_{zdr} \tag{3}$$

For a homogeneous environment ($\lambda_x = \lambda_y = \lambda_z = \lambda$) of the mold material, the following relation applies:

$$\frac{\partial T}{\partial t} = a . \left(\frac{\partial T . \partial T}{\partial t . \partial t} + \frac{\partial T . \partial T}{\partial t . \partial t} + \frac{\partial T . \partial T}{\partial t . \partial t} \right) + \frac{q_{zdr}}{\rho . c_v} \tag{4}$$

where: $\frac{\partial T}{\partial t}$… temperature change with time [K/s],
a… coefficient of thermal conductivity [m ^{2}/s] defined by the relation: $a = \lambda/\rho.c_v$,
ρ… density [kg/m^3],
c_v… specific heat capacity at constant volume [J/kg^3.K],
t… time [s],
λ_x, λ_y, λ_z … thermal conductivity coefficient of the form in the direction (x,y,z) [W/m.K],
q_{zdr}… heat output of internal sources [W/m^2].

The term q_{zdr} is added to the right side of Eq. (3) when heat is released in the material of the body as a result of chemical or physical changes. It represents the specific heat output of internal sources.

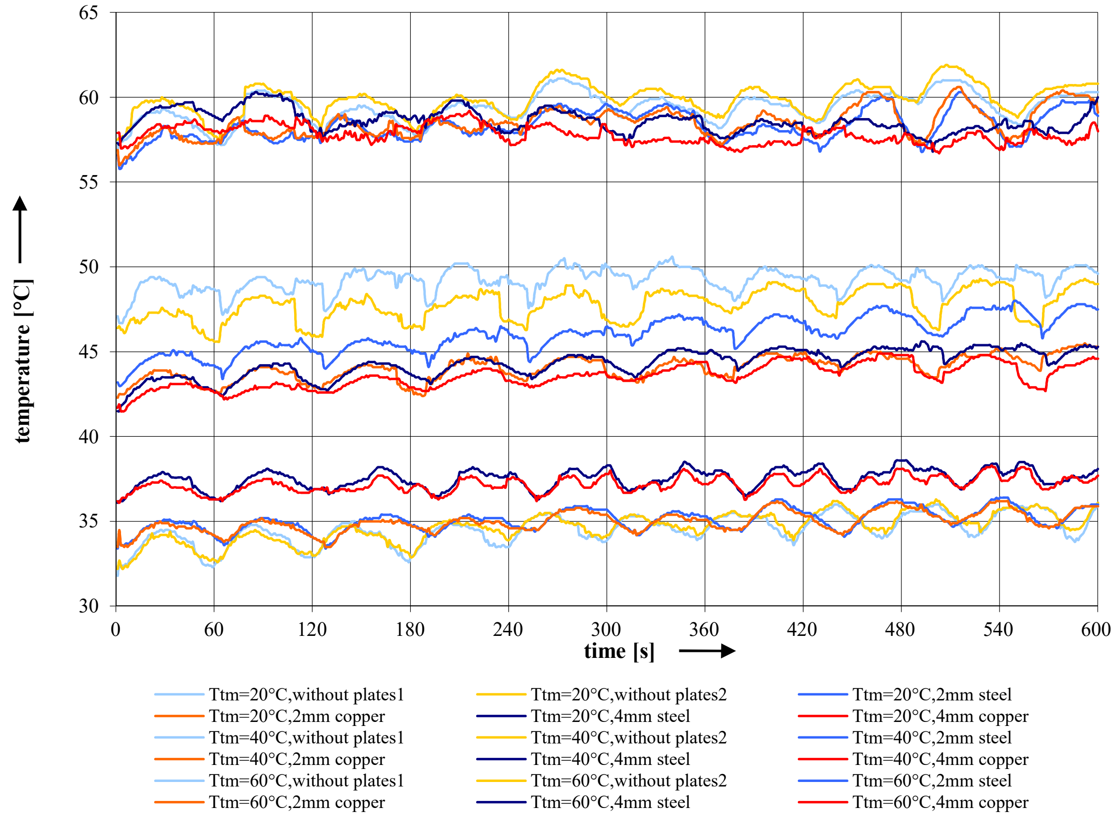

Fig. 1: Temperature field in the injection mold with different methods of tempering and different temperatures of the tempering medium (Hejna, 2004).

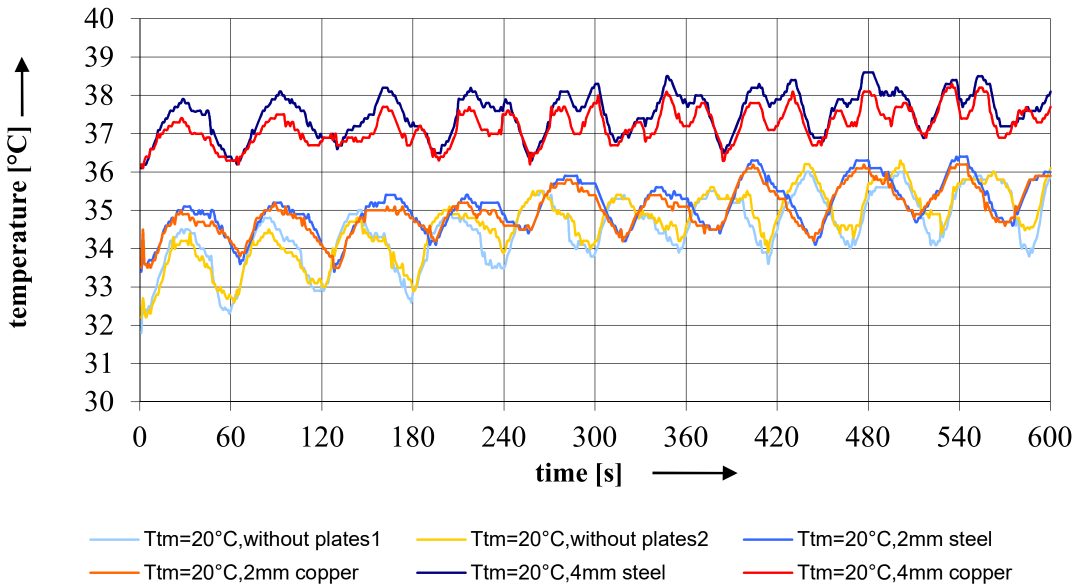

Fig. 2: Temperature field in the injection mould for different tempering methods at Ttm = 20 °C (Hejna, 2004).

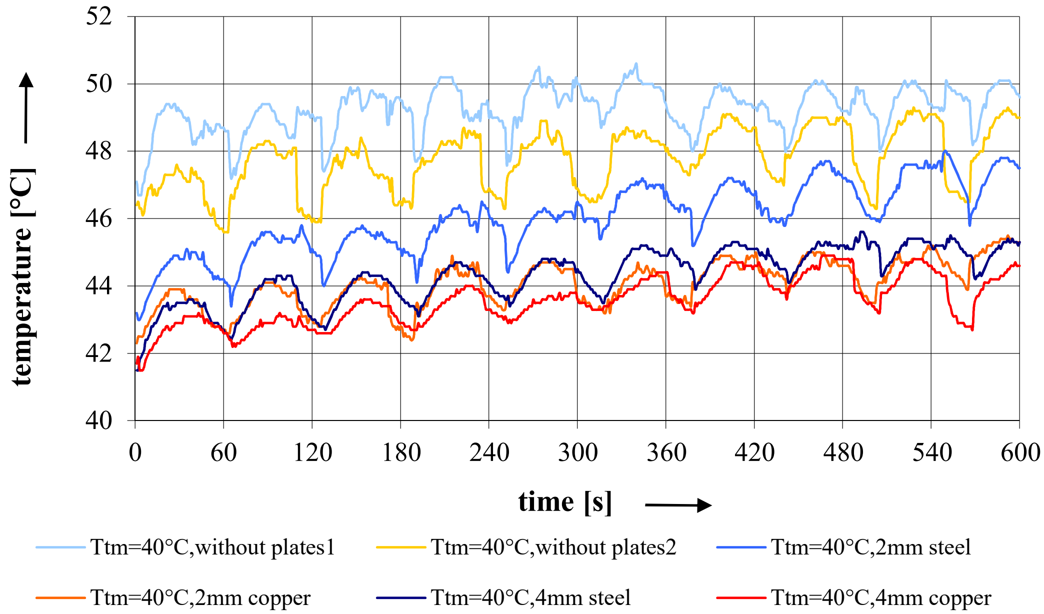

Fig. 3: Temperature field in the injection mould for different tempering methods at Ttm = 40 °C (Hejna, 2004).

3. Conclusions

From the time dependences of temperatures (see Figs. 1–3) it can be seen that when using thermal inserts in the injection mold, heat was removed from the shaped cavity of the injection mold in both measured locations, due to their greater ability to accumulate heat than the mold material. At the temperature of the tempering medium Ttm = 20 °C, more heat was removed from the shaped cavity of the injection mold than at the temperature Ttm = 40 °C and Ttm = 60 °C. There is also slightly greater heat dissipation with copper thermal inserts than with steel ones, which is due to the higher thermal conductivity of copper (Hejna, 2004).

An interesting and important finding is the finding that when thermal inserts are used in the tool, the difference between the maximum and minimum temperature of the mold decreases.

Disadvantages of measuring the temperature field in the injection mold by the non-contact method using thermocouples include the disturbing effects of the hydraulic mechanism of the injection press. Although a galvanically isolated converter was used and the thermocouples were placed in a steel jacket, it was not possible to eliminate these effects. Among the other external influences that caused the course of the curves to oscillate, we can consider the opening of the barrier in the closing unit of the injection press, the operation of the pump during the plasticization of a new batch of material and, in particular, the movement of the moving part of the mold. Unfortunately, even after the introduction of additional filtering of the measured values to suppress interfering signals, the adverse effects were not eliminated (Hejna, 2004).

Acknowledgement

First of all, I would like to thank my parents for their full support during my doctoral studies at the University of West Bohemia in Pilsen.

I also thank all the members of the Department of Machining Technology. In particular, I would like to thank Professor Holešovský for his professional guidance in writing this article, for his valuable comments and suggestions for its publication.

References

Hejna, M. (2004) *Thermal inserts in injection moulds and their effect on mechanical properties*. Diploma thesis, TU Liberec.