Journal of Polish CIMAC
Gdansk University of Technology
The Faculty of Ocean Engineering and Ship Technology

SELECTED PROBLEMS OF TEMPERATURE CONTROL IN INJECTION MOULDS

Joachim Zimniak, Bartosz Sadowski

University of Technology and Life Sciences,
Faculty of Mechanical Engineering
ul. Kaliskiego 7, 85-789 Bydgoszcz, Poland
e-mail: zimniak@utp.edu.pl

Abstract

This paper contains the analysis and summary of the best solutions of temperature control of injection moulds put into production in recent years. It is also an attempt to design further, more advanced methods of temperature control, which may find wider application in future.

Keywords: *injection moulds, temperature tempering procedures, temperature control*

1. Introduction

In recent years there has been a marked development of methods and techniques of injection mould thermostating procedures. This development is related to the ever-increasing requirements in regards to the moulded pieces of the injection moulding process itself. Very strict quality requirements are now characteristic of the modern production processes of synthetic materials – for example in regards to the technical moulded pieces, the requirements specify the accurateness of the shapes, lack of deformation and manufacturing within narrow ranges of tolerance. The injection moulds used by the food, cosmetics and home appliances sectors need to fulfil stringent requirements in regards to their visual side – there can be no shrinkage sink marks, the mouldings need to have a regular shape, their colour needs to be the same, the lights need to be regularly reflected or refracted and the injection process cannot be prolonged. In order to achieve the above mentioned goals, correct planning of the injection mould thermostating procedures needs to be in place, with the use of all available modern techniques. This work describes some chosen modern methods and techniques of thermostating, which are often required as part of the injection moulding process, in order to ensure high quality and efficiency of the synthetic material manufacturing

2. Technological problems occurring during the thermostating processes of smaller moulded elements

It is not easy to achieve appropriate cooling of small mould cores within an injection mould. The small size of such a metal mould core causes it to warm up very quickly, over the allowed mould temperature values. At the same time its size prevents the use the traditional methods of material removal processing, like drilling, milling or hollowing, in order to drill holes or cooling channels in the surface of the mould core. If the moulded pieces have not been properly cooled, they often contain faults, such as shrinkage sink marks, deformations, knock-outs which come out into the moulded pieces or even fracturing, as well as an extended production cycle. The solutions which were available until now were either based on the process of hollowing of the cooling channels in the elements of the mould, which were adjacent to the over-heating area or carried out using the heat transfer rods – additional interconnecting elements which transfer the heat from the over-heating areas to the cooler ones. At present, the modern laser incremental techniques allow the cooling channels to have a very complicated geometry and a very small size [3, 4, 6, 7, 9]. Thanks to that, the conformal cooling channels can be designed to be carried out in areas which are inaccessible to other methods of machining, and the shape of the cooling channel can now relate to often complicated mould shapes. Figures 1a and 1b compare the cooling channels made using the traditional methods and the conformal channels carried out using the laser incremental techniques. The colour cross-sections made using the injection mould simulation techniques show a much more advantageous temperature layout in regards to the second mould core.

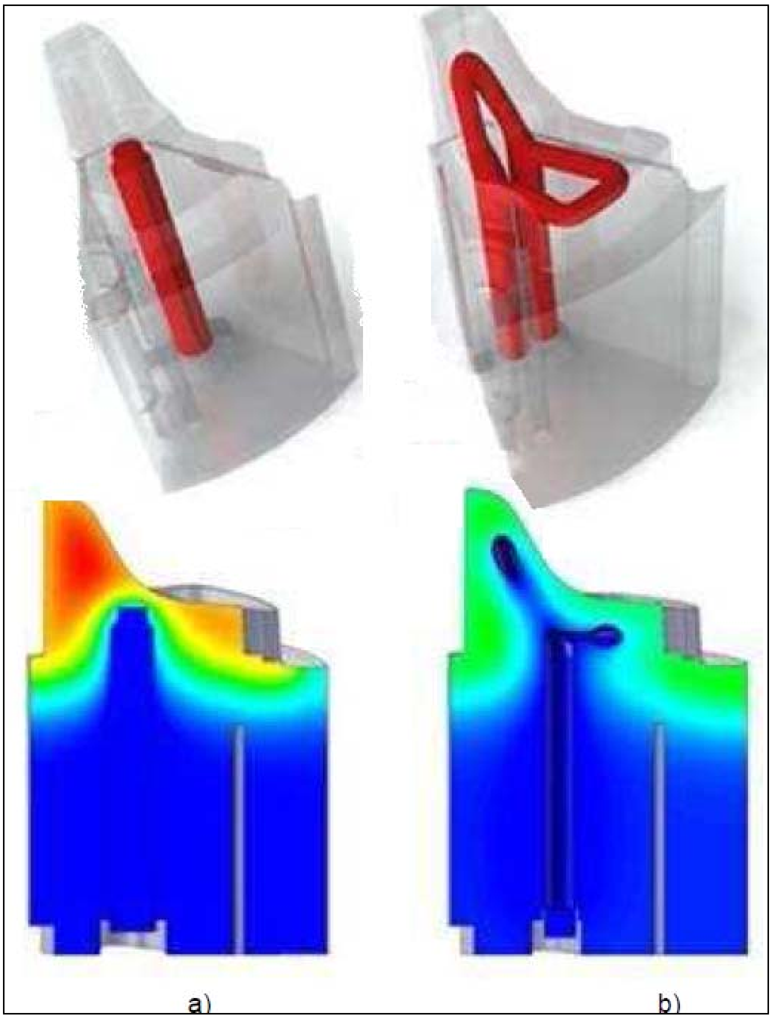

Fig.1. Shape of the cooling channel: a - traditionally drilled, b - produced by laser incremental techniques [1]

The cooling channels which are shaped to their advantage receive the heat from the cooling moulded piece also in a better and more uniform way. As a result, any deformations and other moulding sizing mistakes can be expected to be less frequent, the moulds are easier to fill and the production cycle is shortened. Fig. 2 and 3 show a mould cavity where the cooling surfaces have the shape of a honeycomb. Such a layout of channels, where they run strictly along the moulding surface, ensures the best and the most regular heat transforming from the moulded pieces. The cavity manufacturer JB Ventures BV confirms that their aim was the reduction in warpage and cycle time [5].

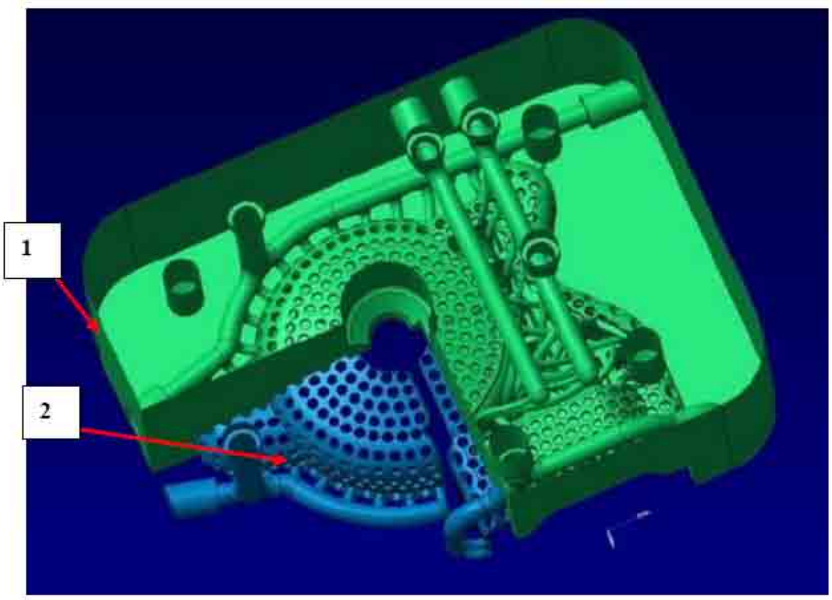

Fig.2 Mould cavity CAD model (1) with honeycomb shaped surface cooling (2) [3]

Fig.3 Front of the cavity insert in which the honeycomb shaped cooling was made [3]

When using the method of direct injection into a cavity with a hot nozzle, it often happens that there is a significant increase in temperature around the injection point – which in turns causes thickening or fullering of the material which is too hot and comes in the form of a string when the moulded piece is ejected from the mould, it also results in an extended cooling period.

At present the manufacturers of hot runner systems often suggest the use of an additional cooling bush, which includes the hot runner tip and aims to guarantee a direct cooling of the injection point. This area is, however, not very big and poses quite significant problems when using the traditional techniques to carry out the cooling channels. The laser incremental techniques also come to the rescue in such cases, as they allow to carry out more complicated cooling channels which are much smaller. Figure 4 shows cooling bushes with conformal channels which include the hot runners manufactured by DME. As it can be seen, the channels are located near the injection point and they regularly adhere to the over-heated areas of the moulded pieces.

Fig. 4. Cooling bushes with conformal channels manufactured by laser incremental techniques [6]

Recently it can be seen that there is a marked development of the materials which are used to make mould cavities for injection moulds, which are characterised by significantly higher thermal conductivity values and larger endurance to the forces present during the injection of the material. The materials which were up to now known to have high thermal conductivity values, such as beryllium bronze, had lower compression strength and lower resistance to the forces present during the injection of the material. As a result, these materials cannot be used in many instances. At present, the materials designed by the Mecobond firm are coming into use (fig. 5) – steel cavities with a copper core and HTCS-130 steels which are quick to conduct heat (fig. 6) - thermal conductivity of these types of steel is between 48-58 W/m K, depending on the operating temperature.

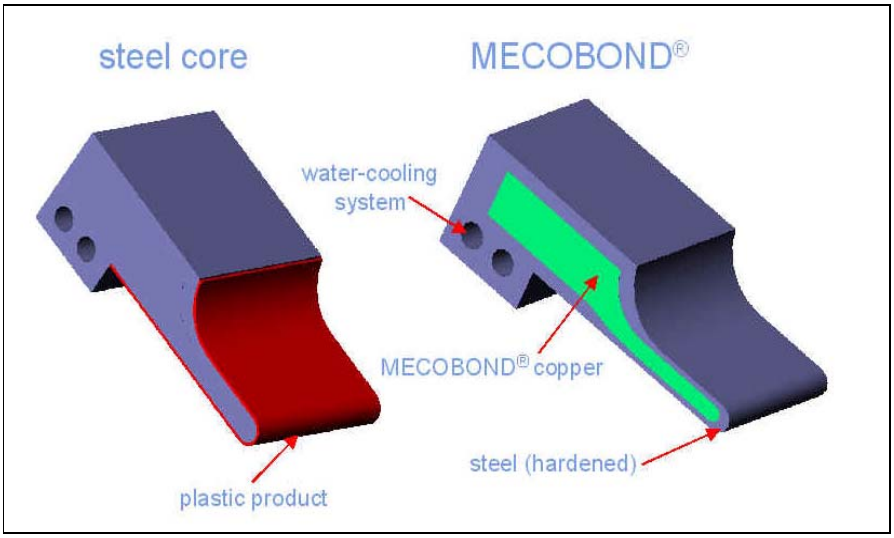

Fig. 5. Mould inserts containing copper core by Mecobond [2]

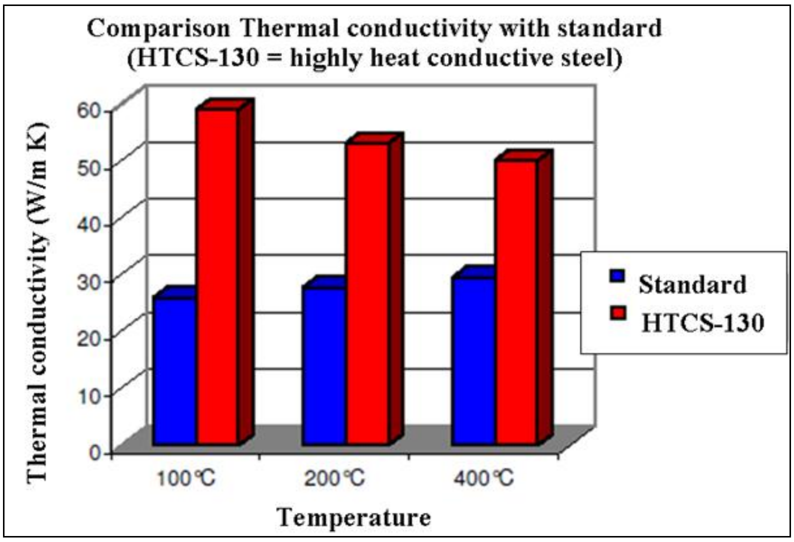

Fig. 6. Comparison of thermal conductivity of HTCS-130 steel with special thermal properties and the standard tool steels [2]

As it is commonly known, the injection process has a cyclic nature, where at a certain point the material is heated to the injection temperature, and after the moulded piece is given its respective shape, it is followed by a cooling process, when the temperature is lowered to one allowing for the material to be ejected from the moulded piece. Therefore, it is desired to use a pulse cooling system (fig. 7) [2, 5, 8].

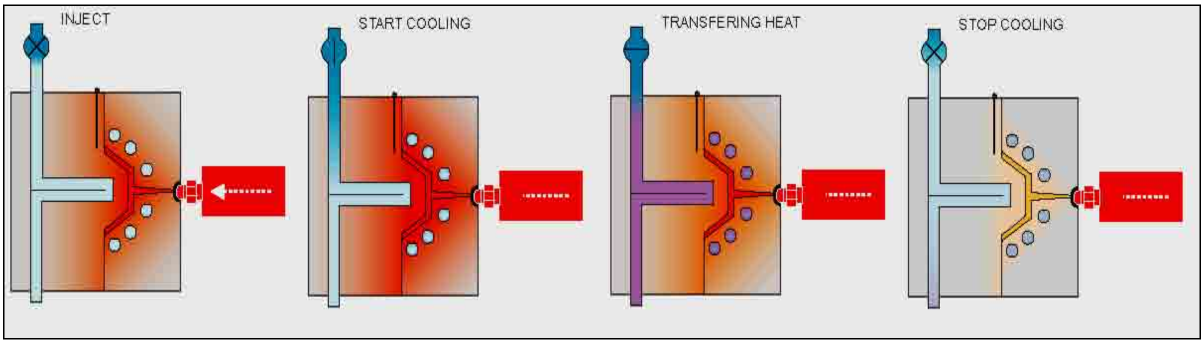

Fig. 7. Diagram of the pulse cooling system in the injection mould during the operation of an injection moulding machine [2, 5]

Such a thermostating procedure allows for an intensive cooling period when the material is freezing in the mould and allows the cooling to stop during the injection, the extruder material feeding and while the mould is being closed, which means that the core does not get unnecessary cool when the material is filling the mould.

The areas which have become too cool, especially if the moulded pieces are larger and thin-walled, might mean that the material is slower to flow, can signify that the gates and cold runners can freeze too early and can prevent the cores of the moulds from becoming full and the details caused by the holding pressure may not be completed. It applies mostly to the moulded pieces where the walls are thin – approx. 0.6 – 1.5 mm and the material quickly looses its heat and freezes before the final points are reached [5, 9].

In such cases, using pulse cooling systems for the moulds will allow the core to maintain a higher temperature during the injection itself and will enable to carry out an intensive cooling process to go ahead when the moulded piece is being cooled down. Using pulse cooling systems also allows the total manufacture process of a moulding to be shortened by about 10-30%

depending on the type of the material.

4 Conclusion

Most up-to-date injection mould thermostating procedures are aiming to secure a more uniform way of heat removal from the whole volume of the moulded piece. In many instances it is now possible to design cooling channel shapes in areas which are prohibitive to the traditional machining methods. As a result of this, the products are of much higher quality – they are more accurate when it comes to size, the deflections and sink marks are avoided.

The modern methods of injection mould thermostating procedures also allow for the details in thin-walled moulds to be achieved and make the production processes shorter – which is caused by the variation of the temperatures of the cooling liquid during the injection cycle – the mould is being intensively cooled down before the moulded piece is ejected from the core and it is cooled down less intensively during the injection itself, so as not to slow down the flow of the hot material.

Using the modern techniques of injection moulding can be financially viable and can also relate to the product quality. In many cases using one of the above described methods becomes a necessity when the ever-growing requirements are taken into account – in regards to the accuracy of the moulded pieces size, the shortening of the production cycles and in relation to the amount of the material being used to manufacture thin-walled products.

References

[1] Abbot, R., Combs, R., Kazmer, D., E*limination of Process Constraints in Plastic Injection Molding,* International Polymer Processing, Vol.13 Issue 3, 2003, s. 249-255.

[2] Cha, S., Lai, F.S.: *Analytical study of thin-wall injection moulding: Filling and cooling analysis*, Conference Proceedings Annual Technical Conference – ANTEC'96, 1996.

[3] Dimla, D.E., Camilotto, M., Miani F., *Design and optimisation of conformal cooling channels in injection moulding tools*, Journal of Materials Processing Technology 164–165 (2005), s. 1294–1300.

[4] Ferreira, J.C., Mateus, A., *Studies of rapid soft tooling with conformal cooling channels for plastic injection moulding.* J. Mat. Proc. Technol. 2/2003, (**142**), s. 508–516.

[5] http://www.lasercusing.nl

[6] Oczoś, K.E., Rozwój kształtowania przyrostowego wyrobów. Mechanik, 2/2007 (**80**), s. 65 ÷ 73.

[7] Saifullah A.B.M., Masood S.H.: *Cycle Time Reduction in Injection Molding with Conformal Cooling Channels*, Conference Proceedings of the International Conference on Mechanical Engineering,2007 s. 29- 31.

[8] Xu, X., Sachs, E., Allen, S., *The Design of Conformal Cooling Channels in Injection Molding Tooling*, Polymer Engineering & Science, Vol. 41, Issue 7, pp 1265-1279, 2007.

[9] Shia-Chung, C., Pham-Son, M., Sheng, H., Yan-Chen, C., *Improve Cooling Effect of Injection Molding by Pulse-Cooling Method*, Conference Proceedings Annual Technical Conference – ANTEC'09, 2009.

Acknowledgments:

This research work was supported by Polish Ministry of Education and Science (**Project No. 6170/B/T02/2011/40**)