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AIP Conf. Proc. 2065, 040002 (2019)
https://doi.org/10.1063/1.5088322

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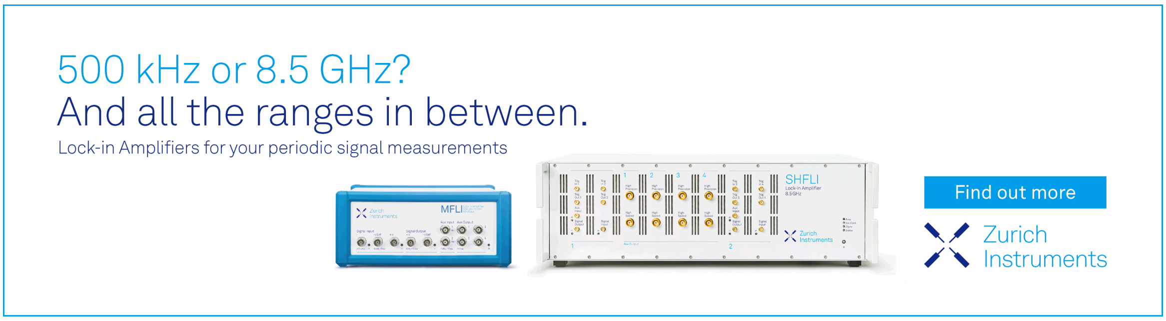

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Innovative design and simulation study of a mould for rapid temperature control in micro-injection moulding

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Abstract. Precise temperature control of the mould surface is a key factor for optimising product quality in micro-injection moulding. The ability to rapidly rise or decrease the temperature during the moulding cycle adds further processing benefits including increased productivity, increased freedom of design, and increased quality levels in the finished part. In this work, an innovative concept of mould design was developed for the rapid temperature control in micro-injection moulding. A mould cavity geometry of area equal to 40 mm^2 and a thickness of 200 μm was created in a small and removable insert. Temperature control was implemented using very thin heating layers and thermocouples that can be attached near the surface of the cavity. In order to minimize the thermal dispersion, a push-pull system for the cavity seat was created. When the mould plates are in the open position, the push-pull system allows a quick separation of the cavity seat from the rest of the mould. For the temperature control, two steps are considered: the heating and the cooling. When the mould is in the open position and the cavity seat is pulled from the mould, the heating step is activated. Because of the air gap between the mould and the cavity, large increases in cavity temperature are feasible in a few seconds. When the mould is closed, conversely, the cavity seat is pushed toward the mould reducing the air gap and permitting a rapid cooling. This step involves also the injection of the polymer in the cavity. In addition, an evaluation of the heat transfer, by means of simulations was carried out. The study demonstrates that during the heating step, the use of the system allows the reduction of the thermal dispersion and the achievement of a temperature increase of the order of several hundred degrees at the cavity surfaces. Furthermore, the high thermal conductivity of the cavity permits to obtain a fast cooling when the mould is closed.

Keywords: Micro-injection moulding, Computer modelling and simulation, Heat conduction, Polymer processing
PACS: 83.50.Uv, 44.10.+i, 07.05.Tp, 47.85.md

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INTRODUCTION

Nowadays, micro-moulding is being used to produce a variety of polymer components, due its low cost and potential for high-volume production [1]. The micro-parts, for example, are adopted in the field of micro optics and micro fluidic devices. The correlation of the replication accuracy to the processing conditions is quite a complicated issue [2, 3]. If the mould surface temperature could be efficiently controlled during the micro injection moulding process, the replication accuracy of moulded micro features are greatly improved without a significant increase in cycle time. Maintaining a high cavity temperature during the filling process and lowering it below solidification during the post-filling process without significantly increasing cycle time and energy consumption is not easy.

In our recent investigations [4, 5, 6], we have proposed the use of thin heaters combined with insulation layers for variable cavity surface temperature control. Our previous research found that less than 10 s was required for the mould surface temperature to rise from 60°C to 160°C, and the same time is required to cool from 160°C to 60°C. Our results lead to the question of what happens with a different geometry of the mould and if different materials, and related properties, are in contact with the insert mould during different steps of the moulding cycle.

Proceedings of PPS-34
AIP Conf. Proc. 2065, 040002-1–040002-4; https://doi.org/10.1063/1.5088322
Published by AIP Publishing. 978-0-7354-1793-9/$30.00

MATERIALS AND METHODS

The study involved the design of an innovative mould in which the geometry of the cavity is obtained from the machining of two removable inserts. The cavity has a rectangular shape, it is wide 3.5 mm and long 10.5 mm, with a thickness of 0.2 mm.

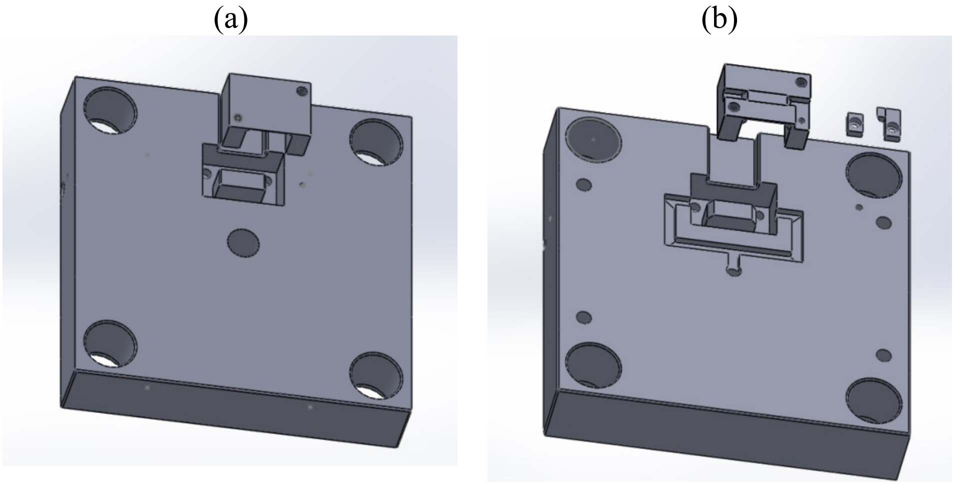

FIGURE 1. CAD mould design: (a) fixed half (b) moving half.

28 September 2023 11:07:21

The insert-mould system is schematized as a multi-layer model as in Fig.2a using electrical resistances as a heat source and an air gap, which limit the heat flow towards the mould. The layers and their properties considered are listed in Table 1.

The electrical resistances are grids of constantan foil sealed in a polyimide film with a nominal resistance of 120 Ω. The resistances cover the entire area of the cavity impression and the insert is not fixed to the rest of the mould so it automatically moves from the plate when the mould opens while in the closed position it is pushed into the seat to reduce the air gap to the desired value. The air gap can be tuned to 0 or 0.2 mm. This push-pull system for the cavity seat is created to minimize the thermal dispersion, during the heating just before the polymer injection in the cavity. When the mould plates are in the open position, the push-pull system allows a quick separation of the cavity seat from the rest of the mould up to 1 mm (Fig. 2b).

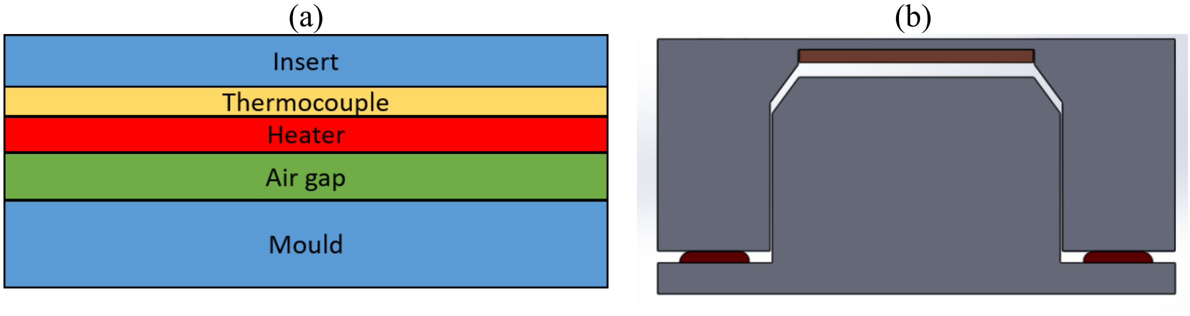

FIGURE 2. (a) Schematic of the layers (b) sketch of the push-pull system.

TABLE 1. Layers and properties considered in the simulations.

Layer	Material	ρ [g/cm^3]	c_p [J/kg K]	k [W/m K]	Thickness [mm]
Insert	Steel P20	7.8	460	29	0.300
Thermocouple	Polyimide	2.138	1090	2.74	0.155
Heater	Default properties within Moldflow	default	default	default	0.140
Air gap	Air	1.292	1005	0.026	0 - 1
Mould	Steel P20	7.8	460	29	10

SIMULATIONS

By using Moldflow software, a Cool FEM analysis of the mould [7] with heating sources was conducted to evaluate the thermal response in both heating and cooling stage. The three dimensional (3D) mesh model of the layers for Cool FEM simulation is shown in the Fig. 3.

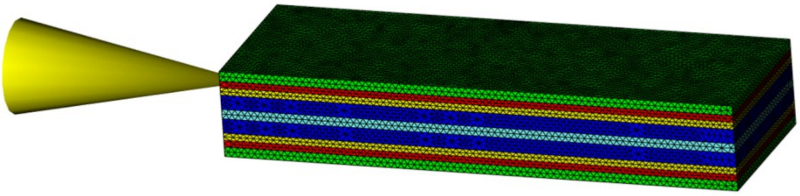

FIGURE 3. 3D mesh model for Moldflow simulations.

The simulations were conducted by fixing the boundary conditions:

- the initial mould temperature is the same as the ambient temperature, i.e. 25°C;
- the heat exchange between the mould surface and surrounding environment belongs to air free convection;
- the heat generated by each heater is equal to 110 kW/m^2, with the applied voltage of 12 V.

For the heating step, the cycle time for the injection moulding is set to 32 s. After that, the heater is kept active for 20 s. The Fig. 4 shows the temperature evolutions calculated for the heating and cooling stages, respectively Fig. 4a and Fig. 4b, obtained with different configuration of the system described in this work. For the two configurations considered in Fig. 4a, temperature rapidly rises once the heater is activated. The values reached depend on the thickness of the air gap. If the air gap is set to zero, a small increase of the temperature is achieved whereas the temperature reaches several hundred degrees in 2.5 s when there is an air gap equal to 1 mm. In Fig. 4a, once reached the value of 190°C, that is the melt temperature for many thermoplastic polymers, like polypropylene and poly-lactic acid, the control system regulates the current supplied to the heater maintaining the temperature at the desired value equal to 190°C.

The analysis of the cooling step was conducted by considering the mould in closed position and the cavity empty (without polymer). Thanks to the push-pull system, during this step it is possible to regulate the distance between the insert and the rest of the mould. As showed in Fig. 4b, when the mould is closed, if the air gap is zero value and the heater is off, namely R OFF, the cavity surfaces reach 100°C in 1 s. The same behaviour is observed in the case of an air gap equal to 0.2 mm. This time is acceptable for a filling of less than 1 s. Otherwise, it is possible to maintain an air gap and tune the thermal history switching on/off the heaters.

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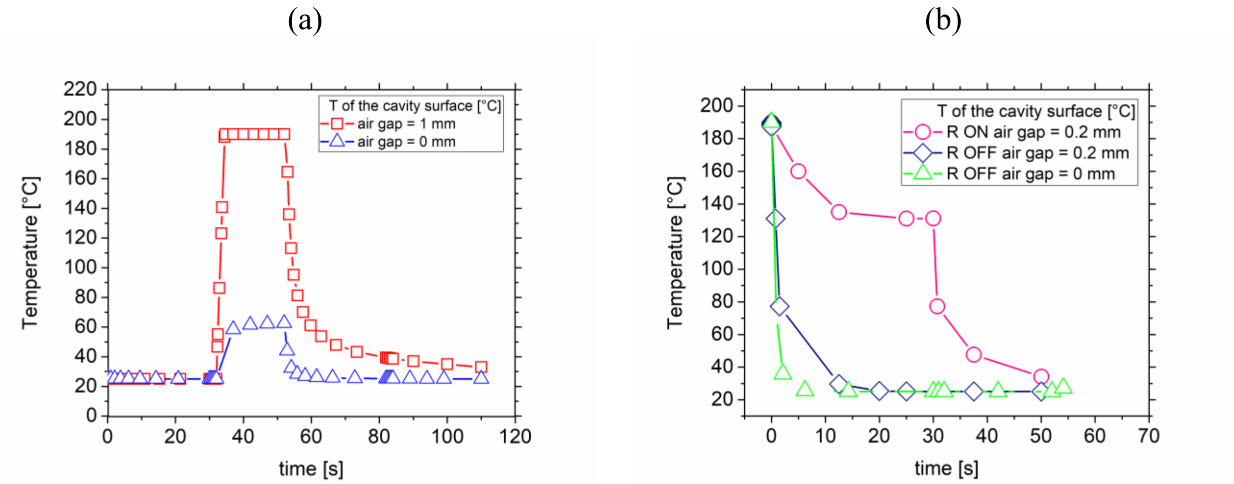

FIGURE 4. Temperature evolutions during (a) the heating step, (b) the cooling step (R ON = Heater ON, R OFF = Heater OFF).

CONCLUSIONS

This study shows that during the heating step, the use of the system allows the reduction of the thermal dispersion and the achievement of a temperature increase of the order of several hundred degrees at the cavity surfaces when an air gap is considered. However, a slight increase is achieved when the air gap is zero and the layers are in contact with the mould. Furthermore, the high thermal conductivity of the steel permits to obtain a fast cooling when the mould is closed, it can be tuned by the heater activation and a very small air gap.

REFERENCES

1. B.R. Whiteside, M.T. Martyn, P.D. Coates, G. Greenway, P. Allen & P. Hornsby, Plastics, Rubber and Composites, 33:1, 11-17, (2004).
2. S. Liparoti, M. Calaon, V. Speranza, G. Tosello, R. Pantani, N. H. Hansen, G. Titomanlio, AIP Conference Proceedings 1914, 140007 (2017).
3. V. Speranza, S. Liparoti, M. Calaon, G. Tosello, R. Pantani, G. Titomanlio, Materials & Design Volume 133, 5, 559-569, (2017).
4. F. De Santis, and R. Pantani, J. Mater. Process. Technol., 237, 1 (2016).
5. A. De Meo, F. De Santis, R. Pantani, Polymer Engineering & Science Volume 58, Issue 4 (2017).
6. A. De Meo, F. De Santis, V. Iozzino, R. Pantani, Proceeding of the 33rd International Conference of Polymer Processing Society – Cancuun (Mexico) to be published on AIP Conference Proceedings (2018).
7. M. R. Barahate, M. T. Shete, International Research Journal of Engineering and Technology (IRJET) Volume: 04 (2017).

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