Design of Sliding Cores. The thermal design of movable cores in injection molds is hampered by the restricted available space and the additional parting lines. Therefore, the IKV has compared different cooling concepts for sliding cores and made recommendations for their design. The thermal boundary conditions of the movable installation position are supported with measurement data for use in injection molding simulation.

Temperature Control Systems in Motion

WALTER MICHAELI
SILKE ALLERT

The cooling of injection molds has a crucial influence on the efficiency of the process and the quality of the parts produced [1–5]. Ever-rising quality specifications mean that cooling systems must now meet the toughest requirements. At the same time, the increasing functional integration within injection molded parts allows ever more complex part geometries to be realized [6, 7]. This complicates the design of the cooling system.

The aim of improving the heating/cooling channel profile is in particular to prevent overheating of the mold in the vicinity of melt accumulations or functional elements such as ribs and screw bosses [8–10].

These functional elements are typically demolded by means of slides or followers. The required cycle times can often no longer be achieved, or the quality specifications are not met. One of the reasons is the restricted space within the movable core, which often hampers optimum arrangement of the cooling channels. Because of the additional parting planes, a separate cooling circuit is also necessary. If this is not feasible, the heat from the moving core must be removed solely via convection and thermal conduction.

Translated from Kunststoffe 2/2010, pp. 24–27
Article as PDF-File at www.kunststoffe-international.com; Document Number: PE110325

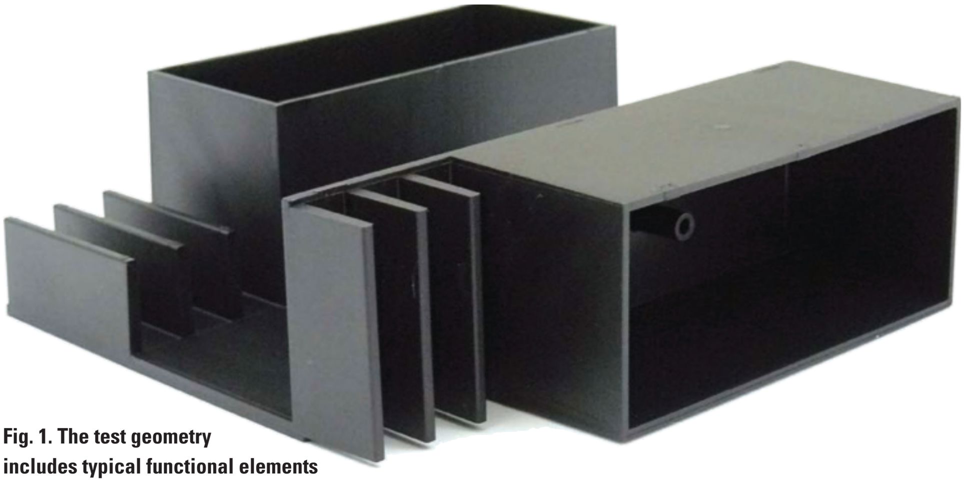

Fig. 1. The test geometry includes typical functional elements of injection molded parts (figs.: IKV)

Increased Thermal Resistances in Movable Installation Positions

The movable installation position entails increased thermal resistances at the interfaces to the surrounding mold areas, since these are not subject to the clamping force and in many cases there are even relatively large clearances. However, the magnitude of the heat transfer coefficient is not precisely known. It is complicated and relatively inaccurate to measure [11]. The modeling for thermal simulation has therefore been based on rough estimates, resulting in relatively high error rates in the simulation. This complicates the goal-oriented design of moving mold cores [12, 13].

For this reason, the thermal balance of a slide mold was systematically analyzed. The results of these studies help to increase the reliability of thermal design of moving mold elements.

First a test part is constructed (base area: 110 × 110 mm^2; wall thickness: 2 mm, **Fig. 1**), designed to allow the effect of the installation position to be considered in isolation. The part consists of a main body containing a box, a rib field and a screw boss. These functional elements are each duplicated, with one of them being molded by means of a fixed mold core and the other by means of a moving sliding core (**Fig. 2**). This allows a direct comparison of the two cores. The part is gated via a hot runner on the underside of the base surface.

Testing Three Differently Cooled Exchangeable Cores

For both installation positions, three differently cooled exchangeable cores are used (**Fig. 3**). First a conventional cooling layout of bored channels and cooling standards is chosen. This channel profile uses a first core of conventional tool steel (hot work steel X37CrMoV5-1, thermal conductivity: approx. 25 W/(m · K) and a →

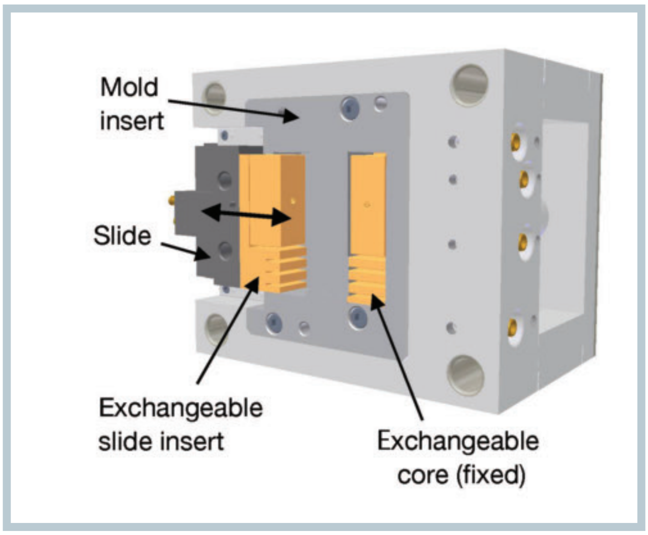

Fig. 2. The construction of the trial mold permits a direct comparison of a moving mold core with an identical fixed core

The difference between the sliding core and fixed core is negligibly low as regards the average demolding temperatures of the parts **(Table 1)**. However, there are significant differences in the maximum temperatures occurring at the hotspots. With conventional cooling, they are 8.1 K higher in the sliding core than in the fixed core. Where the Ampcoloy cores are used, the rise in maximum temperature is even greater at 8.6 K. The thermal conduction in the rear areas of the sliding core is most pronounced with this cooling concept. The changed heat transition to the surrounding mold regions apparently has the greatest effect on the thermal balance. When the Contura cores are used, by contrast, the temperature rise is only 4.7 K.

second core of a highly thermally conductive copper alloy (Ampcoloy 940, manufacturer Ampco Metal S.A., Marly, Switzerland; thermal conductivity: approx. 208 W/(m·K). Furthermore, interchangeable cores from Contura MTC GmbH, Menden, Germany, are used, which contain a combination of conformal cooling channel and heat-conducting pins.

The different exchangeable cores are systematically compared in injection molding trials. The effect of the cooling system on the thermal balance of the mold is analyzed using sensors in the mold. The demolding temperatures of the parts are assessed by means of a thermal imaging camera **(Fig. 4)**. It is clear that the average temperature of the part surface is lowest when Ampcoloy cores are used and highest with conventional cooling. Using alternative mold materials and conformal cooling, the heat can be removed more rapidly so that the parts are demolded at a lower temperature.

Because of its proximity to the hot runner, all three cooling concepts show a hotspot at the right outer edge of the base surface of the box geometry. The maximum temperature for conventional cooling, at 62.8 °C, is about 14 K above the average temperature of the base surface. The maximum temperature can be significantly reduced by a highly thermally conductive mold material or a conformal cooling channel at the overheated edge of the mold core. With Contura cores it is 4.4 K and with Ampcoloy cores even 10.2 K lower than for conventional cooling.

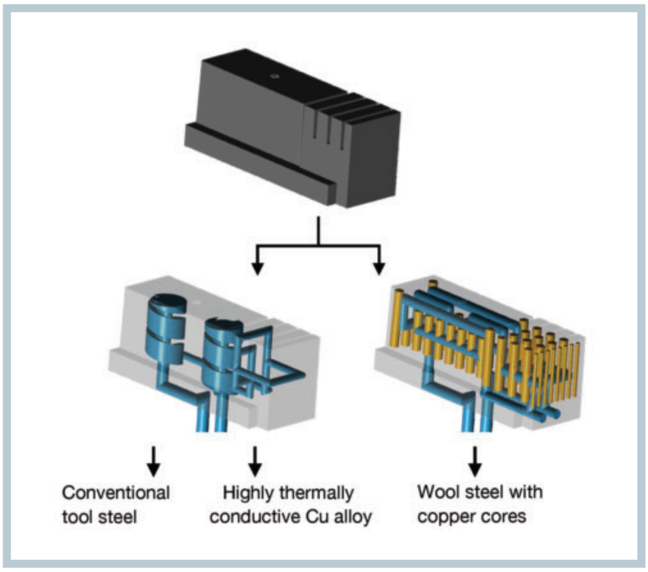

Fig. 3. The use of interchangeable cores allows different cooling concepts to be used

Since the heat is transferred to the cooling medium close below the surface, the effect of the interfaces of the core is less strongly pronounced than with other cooling concepts.

Thermal Boundary Conditions at the Sliding Core

The heat flow from the sliding core into the mold platen is particularly important when active cooling of the core is not feasible, i.e. when the cooling takes place solely by means of thermal conduction and convection. In a second series of experiments, the thermal boundary conditions at the interfaces of the sliding core are analyzed with the core cooling switched off.

In the trial mold, four sensors are arranged in a straight line, two of which lie in the sliding core and two in the nozzle-side mold platen **(Fig. 5)**. One measurement point in each case is located close to

	Temperature characteristics	Conventional	Ampcoloy	Contura
Fixed core	Average temperature	49.0	43.9	45.6
Fixed core	Maximum temperature	62.8	52.6	58.4
Sliding core	Average temperature	50.5	45.5	46.0
Sliding core	Maximum temperature	70.9	61.2	63.1

Table 1. The demolding temperature of the base surface of the box geometry can be characterized by means of characteristic values (in °C)

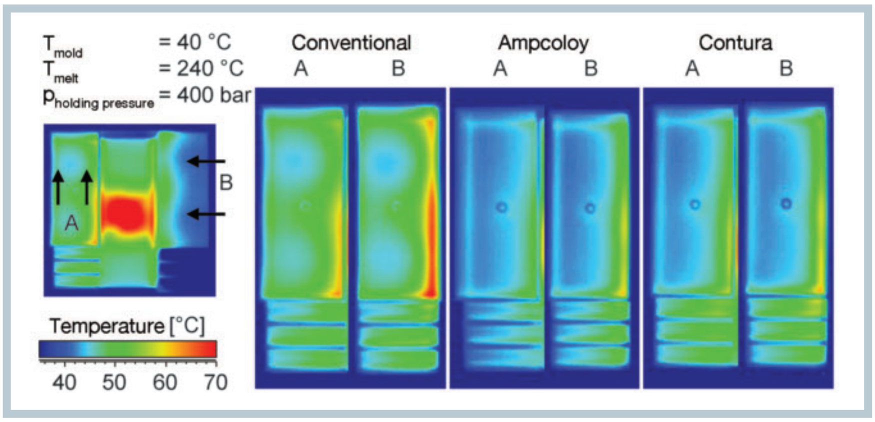

Fig. 4. The temperature distribution in the parts after demolding is determined using a thermal imaging camera. The parts were produced with a 240 °C melt temperature and a mold temperature of 40 °C

the interface and the second at a 10 mm distance from it. This allows a temperature gradient to be determined both in the sliding core and in the mold platen. By extrapolation to the interface, the temperature difference found there can be determined, which is in a direct relationship with the heat transfer taking place.

It is found that the temperature difference during mold opening rises, since the sliding core and stationary mold platen are not in contact, and the heat conducted to the surface of the sliding core is not sufficiently rapidly removed by convection. At the beginning of the cycle, the temperature difference at the interface is up to 4.4 K. As soon as the sliding core and mold platen come into contact, the temperatures of the two contact surfaces approach each other again. The heat is removed from the sliding core and the temperature difference decreases; in this process, the high cavity pressure during the holding pressure phase apparently improves the thermal contact of the two surfaces and speeds up the equalization process. During the holding pressure time, the temperature difference at the interface reaches its minimum value of 1.7 K.

Possibilities for Simulation

The knowledge of the temperatures at the interface offers the possibility of accurately modeling the thermal boundary conditions of the moving core in the injection molding simulation. The Sigmasoft simulation software from Sigma Engineering GmbH, Aachen, Germany, is used to generate a three-dimensional model of the trial mold. At the sliding core/mold platen interface, a constant estimated value of 200 W/(m²·K) based on empirical values is first assumed for the heat transfer coefficient. However, the simulated temperature difference at the interface in this case is a factor of 5 to 10 greater than that measured **(Fig. 6)**.

The heat transfer coefficient is then adjusted until the measured and simulated temperatures at the interface show a similar profile. The maximum values of up to 4,000 W/(m²·K) are used during the holding pressure phase. The good agreement at the interface also improves the prediction accuracy of the simulation regarding the temperature distribution in the part, as is made clear by the comparison with the thermal images **(Fig. 7)**.

Contact

Institut für Kunststoffverarbeitung IKV
RWTH Aachen
D-52056 Aachen
Germany
TEL +49 241 80-93806
→ www.ikv-aachen.de

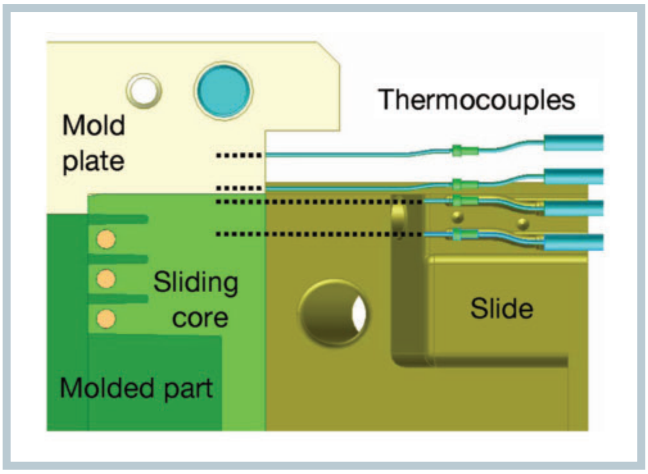

Fig. 5. Four temperature measurement points are located in the direct vicinity of the sliding core/mold platen interface

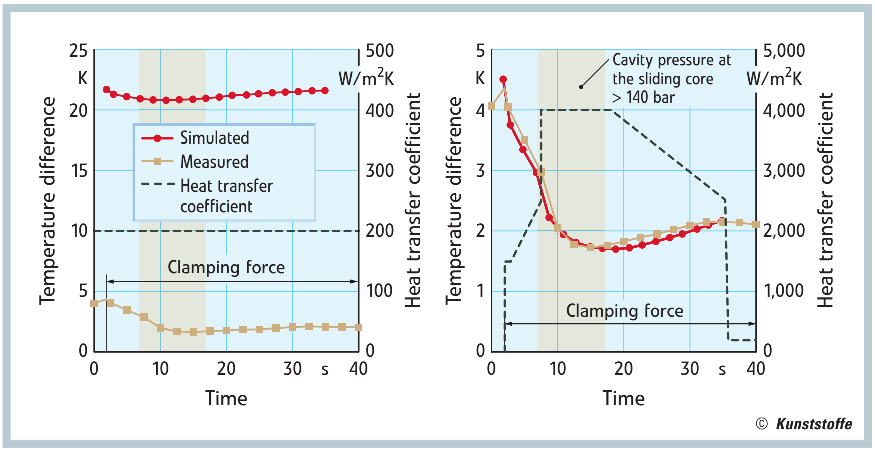

Fig. 6. A time-dependent heat transfer coefficient (right) allows the temperature difference at the sliding core/mold platen interface to be accurately displayed

Summary

The installation position of a mold core only has a small influence on the average temperatures in adequately cooled regions of the part. However, because of the increased thermal resistances at the interfaces in moving cores, higher maximum temperatures can be expected at the hotspots than in fixed cores. For mold cores in a movable position, intensive →

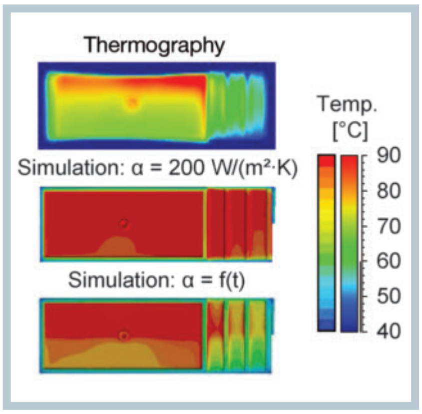

Fig. 7. The prediction accuracy of the simulation is improved by using an adjusted heat-transfer coefficient

cooling of critical regions is therefore all the more important. The use of highly thermally conductive mold materials can therefore compensate for a temperature rise due to additional parting lines. On the other hand, the thermal boundary conditions of the movable installation position are less significant with conformal core cooling than with other cooling concepts. The differences between fixed and moving cores are minimized by the rapid heat removal to the cooling system.

In the simulation-aided design of moving cores, it has been found appropriate to take into account both the restricted heat transfer at the sliding core/mold platen interface during mold opening, as well as the intensified thermal contact at high cavity pressure. Correct representation of thermal boundary conditions can improve the accuracy of simulation in the region of moving mold cores. For cores that are cooled by thermal conduction and convection alone, this approach is unavoidable for a reliable design. ■

ACKNOWLEDGMENT

The above described research project 15004 N of the plastics processing research association was financed as part of the Joint Industrial Research project (IGF) by the Federal German Ministry of Economics and Technology, via the German Federation of Industrial Research Associations (AiF). The authors expressly thank both institutions.

The Institute for Plastics Processing (IKV) will present the latest findings on the topic at the 25th International Colloquium of Plastics Technology on March 3/4, 2010.
www.ikv-kolloquium.de

REFERENCES

Our readers can find the references list at www.kunststoffe-international.com/A016

THE AUTHORS

PROF. DR.-ING. DR.-ING. E.H. WALTER MICHAELI, born in 1946, holds the chair of plastics processing at the RWTH Aachen University and is head of the Institute of Plastics Processing (IKV).

DIPL.-ING. SILKE ALLERT, born in 1981, has been a research assistant at the IKV since 2007. She works on different cooling processes for injection molds and heads the mold technology work group.