Simply print mold inserts - rethinking conformal cooling

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Justifying additive manufacturing with simulation?

Additive manufacturing has been on everyone's lips for more than a decade and 3D printing has now arrived in everyday production. In addition to prototypes and small series, the focus is now also on the opportunities that this manufacturing technology offers through completely new possibilities in design and shaping.

In modern injection molding, stable mould temperature control is the basic prerequisite for a robust process and high component quality. Precise and local temperature control not only influences the cycle time, but also shrinkage and warpage. The design of the temperature control channels must therefore be carefully planned in terms of arrangement and flow rate. Cooling close to the contour is an option for uniform temperature control, but this can be complex.

Modern simulation such as SIGMASOFT Virtual Molding is indispensable for the detailed and reliable design of injection molds and processes. Here, the mold including all heating areas, cooling channels and insulation materials are operated virtually with the selected plastic in the computer with cycle accuracy. Defects and quality problems are detected before they occur. Changes and optimizations can be tested virtually before they are implemented. This is important if additional costs are to be recovered through better results in production. The following example from connector expert H&B Electronic demonstrates the possibilities of simulation in the development of an optimized, new type of conformal cooling for a connector housing (Figure 1).

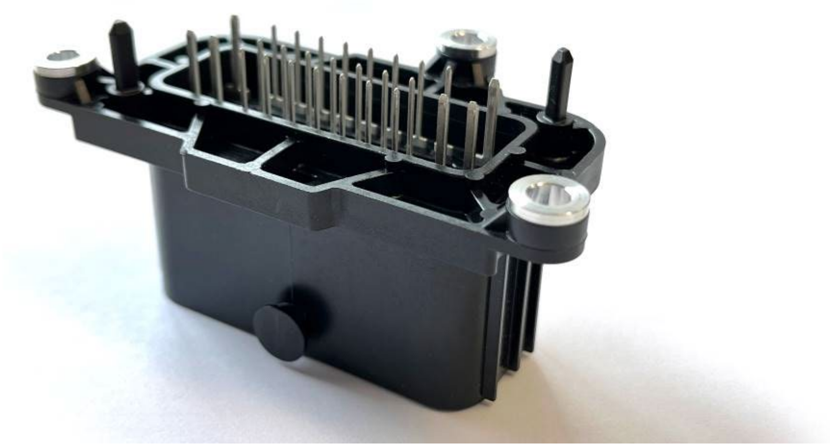

Figure 1: Plug with overmolded pins and sockets (source: H&B Electronic)

Where does the heat go?

In plastic injection molding, the melt is injected into a comparatively cold injection mold made of steel (e.g. 90 °C) at a material-specific temperature (for a PA 66, for example, approx. 290 °C). During injection, the molten plastic begins to release heat into the injection mold on contact with the mold wall. This process continues until the melt has solidified into a solid body and can be removed from the mold. The injection mold must continue to dissipate the heat supplied to it. This is usually done via temperature control channels, holes in the mold that are flushed with liquid.

The heat flow within the mold is significantly influenced by two effects. Firstly, the amount of heat to be dissipated depends on the geometry of the molded part. Less heat needs to be extracted from thin-walled component areas than from thick-walled areas, the so-called hotspots. On the other hand, the drilled temperature control channels cannot be positioned in the mold in such a way that they ensure the same heat dissipation at all points in the cavity. This results in an inhomogeneous temperature distribution in the conventionally cooled mold (Figure 2, left). The red areas of the mold insert shown have a temperature of over 150 °C, whereas the blue areas are around 100 °C. Accordingly, there is a temperature difference of around 50 °C within the shaping area at the time under consideration.

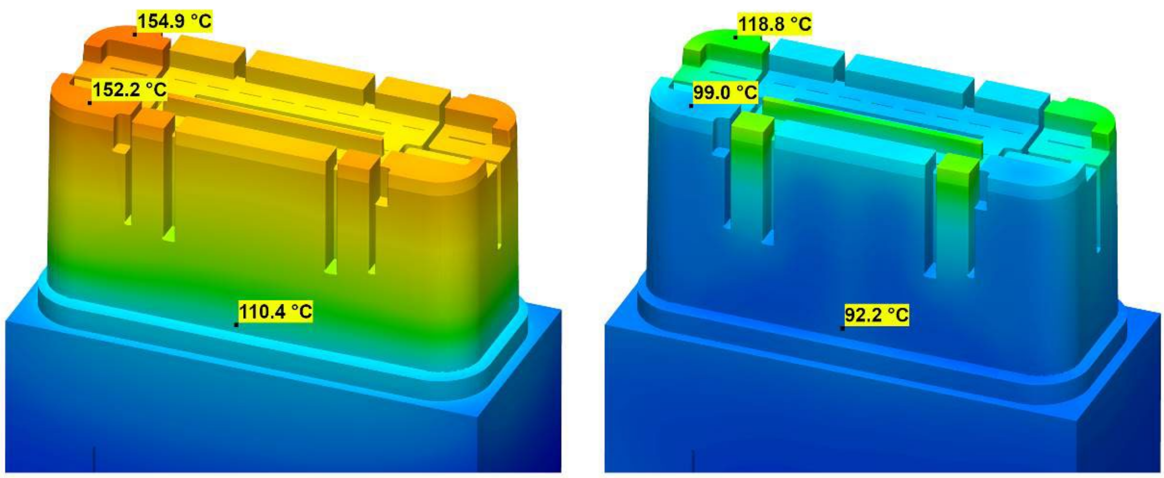

Figure 2: Temperature distribution of a mold insert in the cooling phase. Conventional temperature control on the left, near-contour temperature control on the right.

The existing temperature distribution indicates that there are local areas in the component that cool down at different rates. The resulting residual stresses within the component ultimately cause warping after demolding. In addition, inhomogeneous cooling behavior also extends the cycle time.

It can be even better....
When designing the mold temperature control, the aim is therefore to keep the temperature differences within the mold, especially in the cavity, as low as possible and to ensure homogeneous heat dissipation. The hotspots can be precisely determined by simulation (Figure 3).

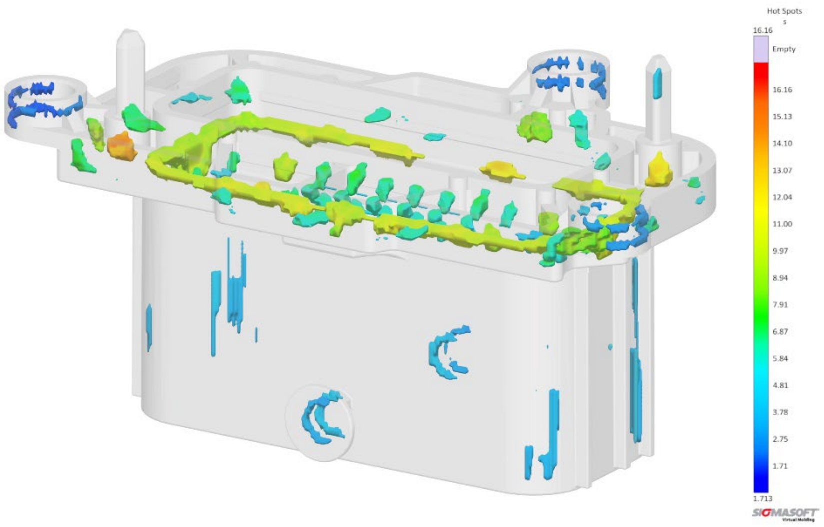

Figure 3: Hotspots in the component

If the critical points on the component are known, the design of the channels in the tool can be specifically adapted to these. H&B Electronic relies on metal 3D printing to realize almost freely selectable, near-contour channels - more on this later.

Figure 4 shows such a design of a near-contour temperature control channel, as it was ultimately actually implemented in the series mold. The result of the Reynolds number is shown. As a reminder: turbulent flow, if this is greater than 2300 - this is desirable for cooling; laminar flow, if less, for good fluid transport. To be on the safe side, H&B has set the limit value at 10,000.

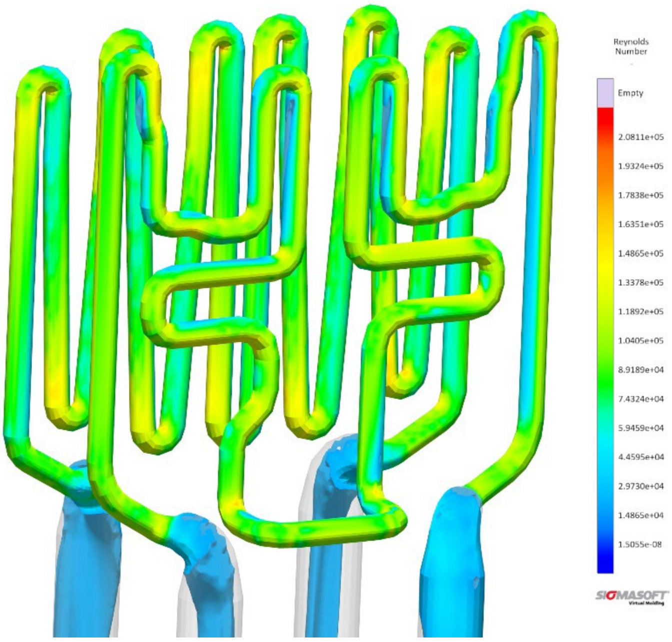

Figure 4: Reynolds numbers >10,000. The transparent areas are laminar flows or the transition phase.

The flow calculation in SIGMASOFT is carried out by taking into account the following influencing parameters, among others:

- Viscosity of the temperature control medium
- defined volume flow in l/min and
- geometric progression and surface roughness of the tempering channels.

Designing the flow using simulation

The general requirements for a temperature control system consist of good heat dissipation with the lowest possible pressure loss within the duct and a resulting homogeneous temperature distribution in the component at a given flow rate.

In addition to the Reynolds number, the pressure requirement of the temperature control channel is an important quality criterion (Figure 5). Even if the pressure requirement does not reach a critical value in this example, such simulations provide valuable assistance in the selection of the temperature control unit and the feasibility assessment. Last but not least, a low delivery pressure also means an improvement in the energy requirement of the temperature control unit.

A reduction in printing requirements was achieved over three iteration loops through the following measures:

- Diameters at the inlet and outlet area have been greatly increased

- Increasing the diameter of the entire temperature control channel
- Reduction or "softer" design of the deflections.

During optimization, the pressure loss was reduced from the original 4.5 to 1.8 bar (Figure 5).

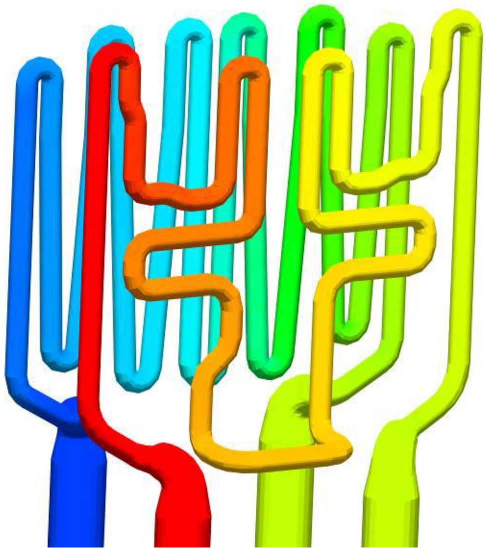

Figure 5: Pressure requirement inlet to outlet (blue to red) approx. 1.8 bar

The images do not show a pipeline, but channels within a block of tool steel. In the computer, this looks like a perfect solution, but in terms of production technology, 3D printing is used here due to its feasibility (Figure 6).

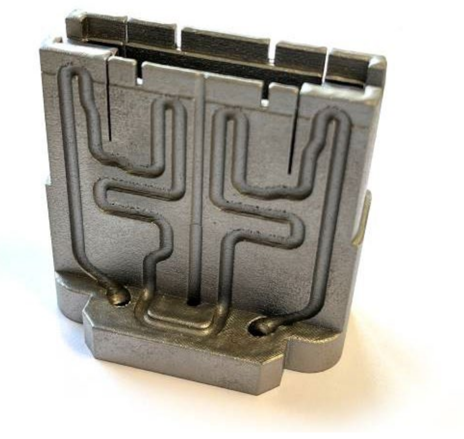

Figure 6: Section through a near-contour temperature-controlled insert - can only be produced with a metal 3D printer (source: H&B Electronic)

Practical 3D printing in toolmaking

Metal 3D printing used to be limited to the ageing steel 1.2709. This material tends not to be used for mold inserts in conventional production due to its disadvantages in terms of thermal properties (e.g. hot hardness) and corrosion resistance. The hot-work tool steel

1.2343 is one of the most popular materials for many tool and mold makers when it comes to the production of mold inserts for plastic injection molds, for example. It enables the reliable processing of technical plastics in large quantities to produce, for example, sophisticated connectors. H&B is one of the few service providers able to reliably manufacture components from this high-carbon tool steel using the laser melting process (LPBF). In terms of material properties such as strength and hardness, the printed components achieve values comparable to those of conventionally manufactured components.

What happens next?

With the help of conformal temperature control, it was possible to achieve more homogeneous and faster heat dissipation (Figure 1, right). Simulation with SIGMASOFT enabled the advantages of the cooling concept for this and similar tools to be calculated to such an extent that H&B decided to purchase the TruPrint 5000 from TRUMPF. This is also available for customer projects together with the in-house expertise in tool design through simulation. The production of hybrid components, printed on conventionally manufactured steel structures, is just as possible as the production of larger components (up to 270 mm in diameter and 300 mm high). The production of these 3D printed structures is not cheap, but generally pays off in series production thanks to reduced cycle times and improved quality. Thanks to SIGMASOFT, the associated cost and sustainability benefits can be quantified in advance.

H&B will be exhibiting the component and models of near-contour cooling at Fakuma 2023 at the SIGMA Engineering stand in Hall A5, Stand 5110, where further information material and videos from the simulation will also be on display.

Info box

In the laser melting process (LPBF), metal powder is melted layer by layer using a laser beam. In addition, the locally applied thermal energy causes the immediately adjacent areas that have already been produced to melt again. The resulting partial melt pool ensures a similarly homogeneous and fine-grained microstructure to that of the hot-work tool steel 1.2343 (H11) produced conventionally by electroslag remelting (ESR). H&B Electronic prints exclusively with 1.2343 (H11) and a preheating of the build platform of 500 °C. This reduces the tendency to microcracks and ultimately enables the printed components to be polished.