Conformal Cooling Using DMLS

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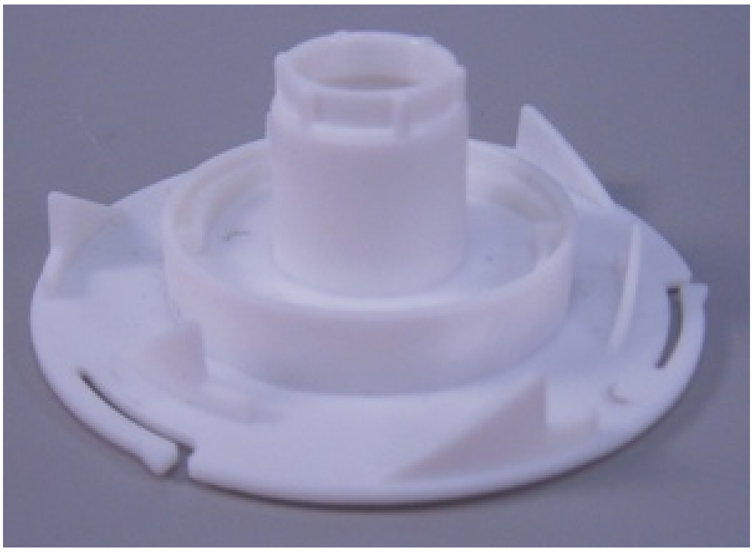
Conformal cooling in tool design is a concept that's fundamentally sound. The trouble lies in the mechanics. Design obstacles imposed by performance boundaries in available machining processes often put its merits out of practical reach. The emergence and attainability of DMLS technology gives toolmakers the design latitude to make conformal cooling a profitable reality.



This was the actual part produced from the conformal cooling insert provided to Phillips Plastics.

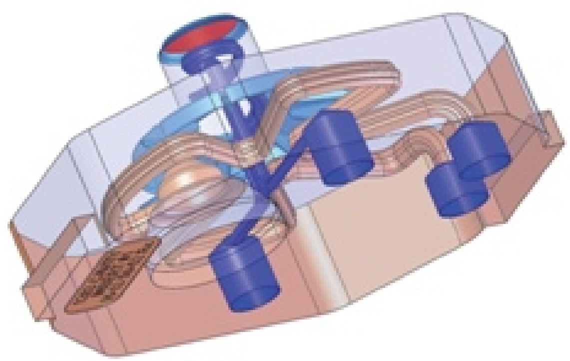
Conformal cooling is the holy grail of injection mold temperature systems. It's the most effective means for maximizing tool performance. But, implementation has been historically problematic with straight line methods or time/cost consuming secondary operations. DMLS gives the current state of conformal cooling a technological upgrade that can create tools and inserts with precisely placed and seamless channels.

What is DMLS?
Direct Metal Laser Sintering (DMLS), developed by EOS GmbH, is an additive metal technology that builds directly from 3D CAD files. The technology takes a CAD file and slices the object into thin 20 or 40 micron layers. The machine then uses those layers to build the part using a 200 watt fiber optic laser. This locally melts each metal powder layer onto the previous layer, eliminating the need for a binder. The result is a fully dense metal part.

The build envelope size of DMLS machines vary, but can be as large as 9.5 × 9.5 × 12 in. It is possible to orient diagonally to build certain “good candidate” parts that are longer than the machine’s base dimensions. Another option is to build in segments and weld parts together.

Typical tolerances as built in DMLS are 0.005 in. on the first inch and an additional 0.002 in. each inch thereafter, but with some fine-tuning respective to individual projects, certain machines are capable of tighter tolerances. These parts are usually post machined for tight tolerances and surface finish, in which case the customer would add about 0.02 to 0.04 in. of material per side.

DMLS Materials



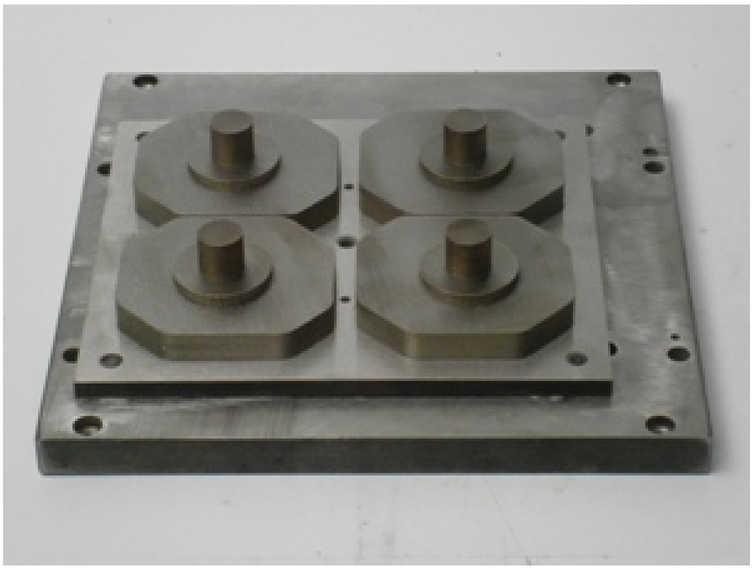
Design of tool insert showing conformal cooling channels

- DM20 bronze alloy
- PH1 stainless steel 15-5—meets materials specification ASTM A564-04 (XM12) and ASTM A693-06 (XM12)
- GP1 Stainless Steel 17-4—fulfills the requirements of AMS 5643
- MP1 Cobalt Chrome alloy—conforms to the composition UNS R31538
- MS1 Maraging Steel—conforms to US classification 18% Ni Maraging 300
- AlSi10Mg Aluminum
- Nickel Alloy IN718—composition corresponding to UNS N07718, AMS 5662, AMS 5664, W.Nr 2.4668, and DIN NiCr19Fe19NbMo3
- Ti64 Titanium Ti64—fulfills the requirements of ASTM F1472

Secondary Processes
The inherent design freedom of DMLS often reduces the need for secondary processes. For example, text may be incorporated into a CAD file to build an engraved part. However, when desired or needed, parts built on a DMLS machine are secondary-process friendly. The options include machining, tapping, welding, coating, plating and/or texturing, EDM, and engraving.

Polishing requires some pre-build planning. DMLS parts can be polished to a mirror finish, but the size of the part must be altered in the CAD file (0.008 in. up to 0.03

in., depending upon desired finish) to account for material removed during the polishing process.



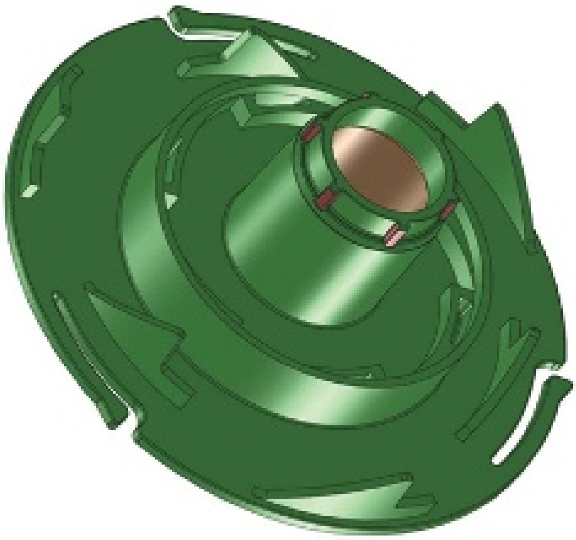
Completed build of tool inserts on build plate

Conformal Cooling: It’s in the Channels
An effective temperature control system saves time and costs in the process of injection molding. Conventional cooling relies on factors such as the conductivity of the mold material and straight line drilled channels. Its focus is mold cooling. Costly inserts made with alloys that have higher conductive properties aid the process. Conformal cooling uses strategic channels concentrated around the product. Its focus is on cooling the injected melt.

When plastic melt cools evenly, internal stress is minimized. This results in a higher quality part with little to no warping or sink marks. An added bonus comes in the form of drastically diminished scrap rates. Productivity gained in upgrading from a conventional tool to a tool with conformal cooling channels can be upwards of 30% to 60%.

Properly maintained mold temperature also tends to improve tool life and the high costs associated with replacement tools. DMLS builds conformal cooling channels into the tool as part of the tool. Channel geometries around the cavity can be fluid and controlled for optimal cooling. Even combined systems with separated cooling and heating channels are possible or the split between main systems (for the control of the global temperature) and specific systems (for the handling of close to cavity critical temperatures) can be performed with DMLS. This opens up potential for future applications.

Guidelines for Conformal Cooling with DMLS
The recommended material for tooling is MS1 Maraging Steel. It is the hardest, most durable material and is used in 95% of all DMLS tooling. It can be post-hardened to 54 Rockwell and withstand temperatures of up to 750°F before yielding.



DMLS can build channels down to 1.0-mm diameter; however, channels this fine can only be put into service with specially treated fluids to avoid clogging. Simulation software helps find the right layout in such critical cases.

According to experience, the optimal diameter should be chosen between 4 to 12 mm (depending on the design of the product). This range is preferred, to be used in ideal cases, as in practice, tool inserts may be too slim to make it possible to follow this rule exactly (e.g., a closely placed pair of ejector pins, thin walls, etc.). In cases of complex geometrical conditions, it can be necessary to design much smaller diameters (e.g., when eliminating a hot spot).

In addition to circular cooling channels, designers can use more complex shapes in order to reach greater cooling performance. The feasibility criterion supposes a cross section, which is self supporting. This means the angle of overhanging areas should be above 40° to horizontal.

Some overhanging angles require support during the build process. Supports cannot be removed in channels. A DMLS operator should be able to help identify suspect angles prior to building.

Case in Point: Phillips Plastics
Phillips Plastics came to GPI Prototype [1] with a design for an insert that was to be part of a four-cavity mold to replace the one-cavity conventional mold currently in operation.

GPI used an H13 tool steel plate and built DMLS tool inserts with conformal cooling channels incorporated onto the plate. The plate was sent with the completed build to Philips Plastics for them to post machine and wire cut the inserts off.

Phillips Plastics confirmed that conformal cooling using DMLS allowed for a shorter cycle time. It also produced a higher quality part (flatness and dimensionally correct). The cycle time with the one cavity conventional tooling was 16.78 seconds. With four cavity DMLS conformal cooling, the cycle time improved to 13.02 seconds, a savings of 22.4%. Additionally, the flatness spec with conventional tooling was 0.25 mm, 0.15 min, and 0.223 max. The flatness spec with DMLS conformal cooling was 0.2 mm, 0.08 min, and 0.161 max, for a quantifiable part feature improvement of 20%.

Conclusion

Conformal cooling in many applications was considered a lost cause due to the problems faced in execution. DMLS reopens the door for tool designers and mold makers to effectively design high performance, high efficiency conformal cooling tools. DMLS technology has consistently proven to create tools that categorically improve productivity. The drawbacks are size limitations imposed by the build envelope and gaps in designer/operator communication. The results and returns seen by Phillips Plastics in the case study are evidence of the practicality in conformal cooling using DMLS.

References

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