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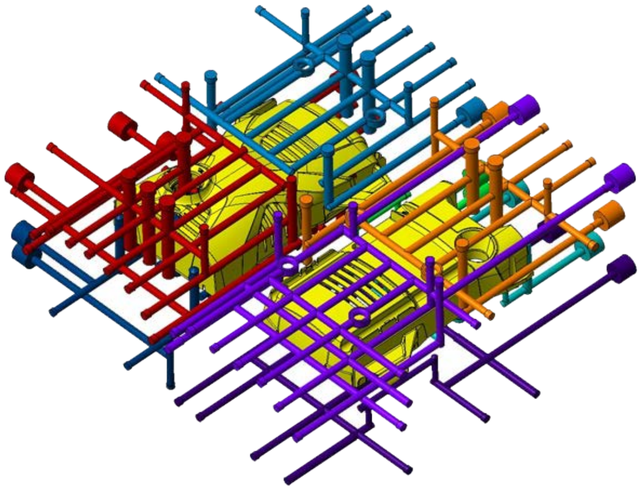
Conformal-cooled mould tools - how to cut cycle times and boost part quality



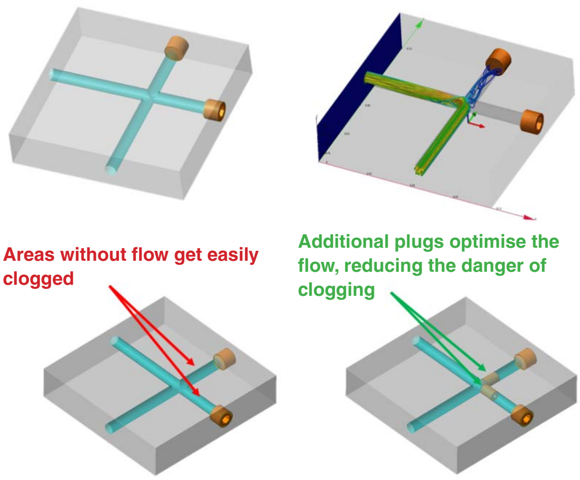
Injection moulding allows plastic products to be produced in complex and intricate detail, often in sizeable batches, with repeatable tolerances and high surface quality.

For mould-makers, this means providing their customers with tools that can produce parts that perfectly replicate the 3D design in the minimum cycle time. Cooling of the plastic part as it solidifies within the mould tool is a critical factor, affecting both the cycle time and the quality of the part.

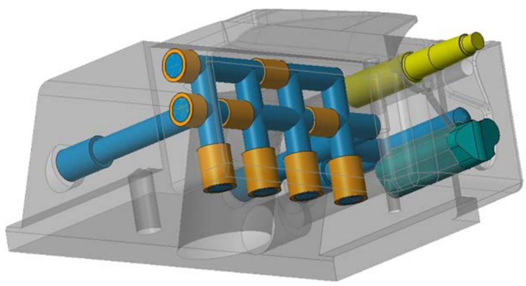
The principle of conformal cooling is to reduce the temperature of the plastic part rapidly and in a uniform manner. The part cannot be removed from the tool until is has cooled sufficiently to detach from the mould. Any hot spots will delay part release, may lead to warping and sink marks after removal, and may compromise the quality of the component surface.

Rapid cooling is achieved by passing a fluid through channels inside the mould tool so that the heat is conducted out of the plastic part, through the metal tool, and away in the fluid. The speed and evenness of this cooling effect is driven by how closely the fluid channel tracks the surface of the tool, and the rate at which cooling fluid passes through it.

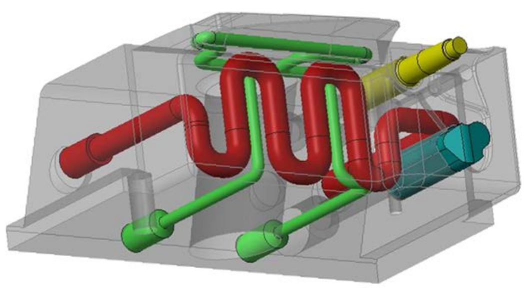
The conventional way to make cooling channels in a mould tool is via secondary machining operations. As I mentioned in my post Minimal manifolds - how to shed weight and boost performance, such channels are produced by cross drilling to create a rectilinear internal network of tubes, with plugs used to limit the fluid flow:



This approach has its limitations when we are designing a conformal-cooled slider, as shown below. The channel network is limited in its shape so that it sits deeper below the surface of the tool, making cooling less efficient. Not only that, but we also have to deal with additional machining and assembly time, as well as dead-spots in the channel network that may clog up over time. In complex cases, conformal cooling channels can only be inserted by producing the tool in sections, resulting in extra joints that can shorten the life of the tool.



Additive manufacturing (AM) frees us from the constraints of cross drilling. Now we can design internal channels that follow the surface of the tool, and which have smooth corners for faster flow, increasing the heat transfer into the coolant. In the example below, we have separate cooling circuits for different areas of the slider, designed to carry the heat away at a consistent rate to promote even cooling.



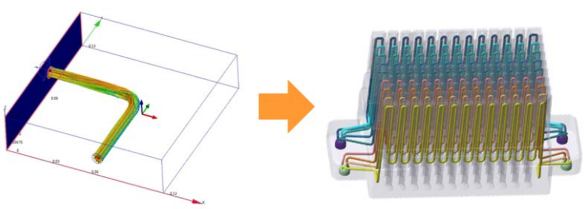
Maximising and equalising flow

Coolant flow rates through the tool are critical to increase the rate of cooling. Fluid channels must therefore be designed with smooth corners to minimise the pressure loss along the channel. Using AM, channels as small as 1.4 mm in diameter and over 1,100 mm in length can be produced.

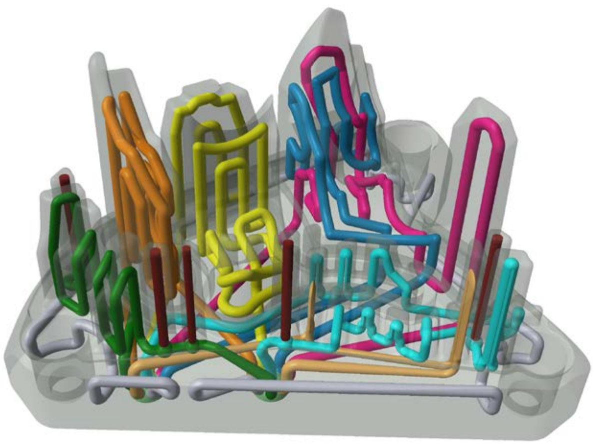
One useful benefit of additive layer manufacturing is that the surfaces of the cooling channels are slightly textured. This texture increases the surface area inside the channel for better heat transfer, and also promotes self-cleaning turbulent flow inside the channel.

Application examples

In the example below, a complex tool with numerous thin ‘fingers’ in nine rows is cooled by a network of channels that reach up inside each finger. To promote even and rapid cooling, two inlet manifolds split the flow into five and four parallel channels of equal diameter and length. The total cooling channel length in this case is over twelve metres!



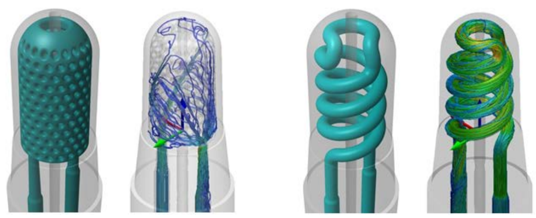
An irregularly shaped mould tool can also be cooled using multiple channels of equal diameter and length. In this instance, eight cooling channels, each 3 mm in diameter and of equal length, have been built into the mould tool. All eight channels are connected to 10 mm diameter inlet and outlet ports to guarantee equalised flow.



Net and channel cooling techniques

Another consideration is the design of the internal structures through which coolant will be passed. A common technique is to design a mesh network of channels with single inlet and outlet pipes, with the coolant free to flow where it wants to within the mesh. When we look at the simulated flow through such networks, however, we see that it is low and irregular, reducing the rate of coolant flow and thus the rate of cooling that can be achieved, and raising the risk of deposits in low flow regions.

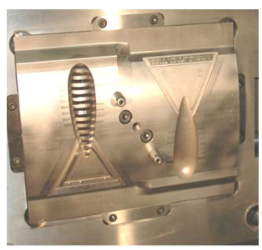
The pictures below contrast a mesh network channel with an optimised continuous channel. The left hand pair of images show the mesh design and the simulated flow through the network - lots of low speed flow, unevenly distributed. The right hand pair of images show a continuous cooling channel, with high and consistent flow throughout. For the same size input and output channels, the coolant flow rate is over 50% higher for the continuous channel, resulting in significantly faster cooling.



Additive impact on cycle times

The impact of this improved cooling on moulding cycle times varies from application to application, but can be as much as 70%. In the example below, the AM insert for a two-cavity mould tool for an ice scraper reduced the moulding time from 80 to 40 seconds, enabling parts to be produced at twice the rate.

Other key advantages of conformal cooling include the production of more homogeneous parts, with zero defects and avoidance of sink marks caused by uneven cooling rates. Greater dimensional stability also helps to adjust and debug new designs in fewer iterations. Plus, of course, AM enables even complex mould tools to be designed and built on short lead-times.



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It should be noted that an AM process will not produce surfaces of sufficient quality for many moulding applications. Most AM moulds are finish machined and polished to produce the desired surface precision.

Summary

AM gives mould designers the freedom to create tools with complex internal cooling channels, which can be designed to maximise heat transfer to produce a rapid and uniform cooling effect. This leads to production cost savings in terms of cycle time, reduced scrap and longer mould life, and also to improved product quality.

About the author

Marc Saunders, Director of AM Applications

Marc Saunders has over 25 years' experience in high tech manufacturing. In previous positions at Renishaw, he played a key role in developing the company award-winning RAMTIC automated machining platform, and has also delivered turnkey metrology solutions to customers in the aerospace sector.

Marc manages Renishaw's global network of Additive Manufacturing Solutions Centres, enabling customers who are considering deploying AM as a production process to gain hands-on experience with the technology before committing to a new facility.

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