Metal 3D Printed Conformally-Cooled Injection Mold Increases Production Rate by 30%

Metal 3D printed conformal cooling lines reduced temperature variation by 86% compared to conventional straight line channels

3D Systems' metal additive manufacturing and Cimatron mold design software deliver mold inserts that dramatically reduce cooling cycles

Large temperature variations in an injection molding cooling cycle can dramatically increase the risk of parts warping. When tests of a conventionally designed and manufactured injection molded automotive duct yielded temperature fluctuations of 132˚C throughout the process, B & J Specialty, Inc. recommended conformally-cooled mold inserts to its client for more even cooling. To achieve this, B & J Specialty engineers relied on 3D Systems' Cimatron® software to design the molds and conform the internal cooling channels parallel to the part's surface. To accurately deliver these complex internal channels, metal additive manufacturing on 3D Systems ProX® DMP 300 was used for production. The new conformally-cooled mold insert reduced temperature variation throughout cooling to 18˚C, and shrank cycle time on the mold from 1 minute to 40 seconds, an overall productivity improvement of 30%.

CHALLENGE:
Increase productivity of injection molding for an automotive duct that required a long cooling cycle to avoid warpage.

SOLUTION:
3D Systems' Cimatron® software to design conformal cooling lines within the mold insert for production on 3D Systems ProX® DMP 300 metal 3D printer

RESULTS:

- Accelerated cycle cooling time from 1 minute to 40 seconds
- Increased duct production rate by 30%
- Reduced temperature variation across cooling 86%
- Extended lifetime of mold from reduced molding pressure
- Produced parts that consistently meet tough quality requirements
- More efficient cooling delivers higher quality parts to enable time and cost savings for tool builders and mold operators

The ProX® DMP 300 can hold tolerances of three or four thousandths of an inch according to Jarod Rauch

Sub-Optimal Cooling Lines Lead to High Temperature Variations

Conformally-cooled molds take advantage of modern technology to solve an age-old problem. Many injection molded parts have curved surfaces, yet the drills used to create cooling channels only produce straight lines. In most cases this means it is impossible to match cooling lines to part geometry. Conventionally-produced straight cooling lines have to run beyond the outermost features of the part to avoid interfering with the cavity, which means that features closer to the part's center are typically far from the nearest cooling line. This often results in significant temperature variations over the volume of the part at the start of the cooling process.

The automotive duct B & J Specialty redesigned for more efficient cooling features multiple irregular and curved surfaces. In the original mold design, straight cooling lines were drilled through a hub and stator block that were used to adjust the mold geometry to account for warpage. As is often the case with irregular shapes, several key features of the duct were distanced from the cooling lines due to the limitation of the straight channels. The resulting temperature variations generated various residual stresses that tended to bend the part as it cooled. In the past this problem was addressed by extending the cooling cycle to ensure the part was fully solidified before removing it from the mold and adjusting the inserts to account for any remaining warpage. The problem with this approach was that lengthening the cooling cycle reduced productivity and increased the cost of making the part.

Updating the Mold with Conformal Cooling Channels

According to Jarod Rauch, Information Technology and 3D Printing Manager at B & J Specialty, Inc., the automotive duct appeared to be a strong candidate for a modified conformal cooling design, which would help to improve final part quality, reduce scrap, and shrink the cooling cycle. B & J Specialty proposed this solution to their client, an automotive supplier, who agreed to test the new methodology. Provided with the CAD file of the original geometry, B & J engineers got to work using 3D Systems' Cimatron Mold Design software. "Cimatron is pretty much a one-stop-shop software that allows us to have full CAD functionality for designing and gives us the option to roll right into build preparation from the same package."

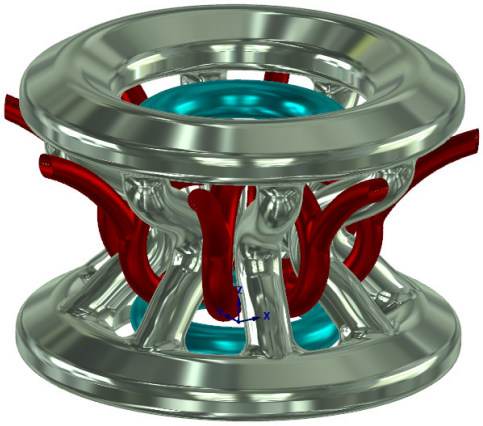
Rauch says B & J Specialty discovered Cimatron while researching metal 3D printers for conformal cooling applications. "We saw that 3D Systems provides a complete end-to-end solution including mold design software, build preparation software and 3D printers, and that's what got me excited about this solution," says Rauch. "3D Systems not only focuses on the machine, it also focuses on how engineers design for additive."

Working within Cimatron, B & J engineers removed the original straight cooling lines and replaced them with conformal ones that maintained a consistent distance from the part's surface. Final mold production with metal 3D printing allowed the engineers to design complex channels with improved cross-sections and interface surfaces. These features help ensure turbulent flow, which further increases

the amount of heat transferred from the mold to the coolant to assist in efficient cooling. The ability to cool molded parts more efficiently also helps ensure part quality by reducing the occurrence of part defects such as warping and sink marks. A direct path to higher quality parts saves time and money for both the tool builder and the mold operator by limiting the amount of corrections, trials and sampling required to achieve the desired results.

Setting Expectations with Accurate Simulation

B & J engineers then exported the mold file from Cimatron to Moldex3D, an injection molding simulation software for integrated cooling simulation. "The integration between Cimatron and Moldex3D makes it easy to simulate the complete injection molding cycle and map temperatures across the mold and part to identify hot and cold spots, and simulate the effect of different cooling times," says Rauch. The simulation also helps highlight areas where redesign may improve the overall cooling strategy before any investment is made in a physical part. Comparative simulations between the original mold design and the new design with conformal cooling lines showed a dramatic improvement in temperature distribution for the new part, reducing temperature variation by 86%.



Integration between Cimatron and Moldex3D make it easy to simulate the injection molding cycle to evaluate designs digitally

3D Printing Mold Inserts with Conformal Cooling Lines

B & J engineers then used 3D Systems 3DXpert™ metal additive manufacturing software to prepare the mold insert designs for production. They imported the part data, optimized the geometry, calculated the scan-path, arranged the build platform, and sent the job to their in-house 3D Systems ProX DMP 300 metal 3D printer directly from the 3DXpert software.

B & J Specialty has increased productivity throughput by 30% using conformal cooling channels delivered with direct metal 3D printing

The ProX DMP 300 directs a high precision laser to selectively build up metal powder particles in thin horizontal layers, one after the other using 3D Systems LaserForm® material. For this automotive duct mold, B & J Specialty used 3D Systems' maraging steel material. "The ProX DMP 300 is ideal for producing conformal cooling lines because of its extraordinary accuracy," Rauch said. "We can hold tolerances of three or four thousandths of an inch." 3D Systems' patented Direct Metal Printing (DMP) technology enables smaller material particles to generate the finest feature detail and thinnest wall thicknesses. A surface finish quality of up to 5 Ra µm (200 Ra micro inches) is achievable, and requires less post-processing.

Substantial Gains in Productivity

When printing was complete, B & J Specialty scanned the inserts into 3D Systems Geomagic® Control X™ inspection and metrology software using a blue laser line 3D scanner and overlaid the mesh on the as-designed geometry to validate the metal 3D printed mold inserts. The inserts were shipped to the automotive supplier who installed them on its molding machine. "Benchmark testing demonstrated that the more even cooling provided by the conformal lines made it possible to reduce the cycle time and increase productivity throughput by 30%," Rauch said. "The life of the mold is also expected to be substantially higher since the cycle time reductions provided by conformal cooling make it possible to reduce the injection pressure, which in turn reduces wear on the parting line and intricate details of the mold."

Interested in learning more about conformal cooling?
Download the conformal cooling white paper today.

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