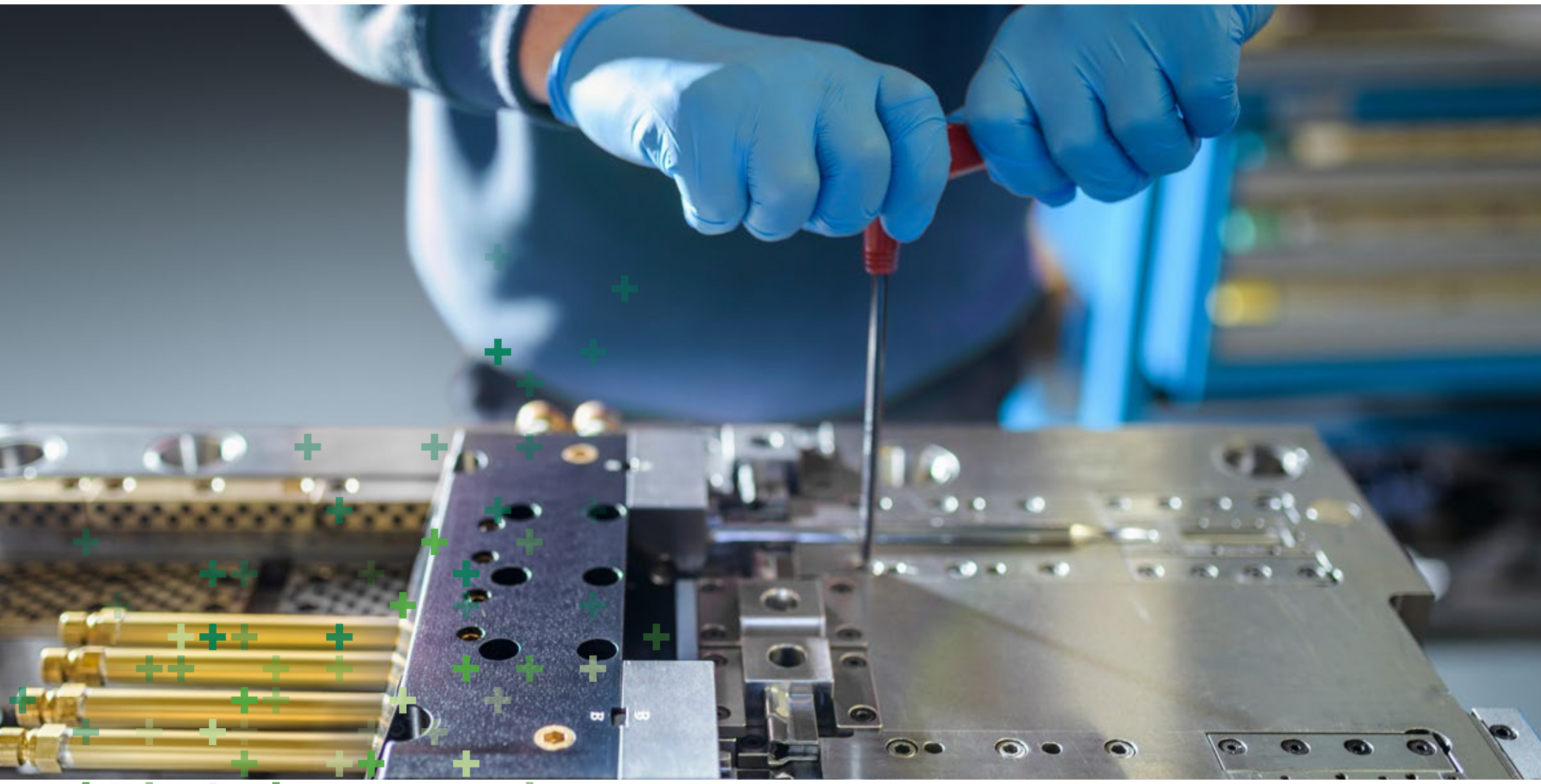
GF Machining Solutions

Additive Manufacturing

Metal AM for Mold and Die: Overcoming production challenges

Introduction

Mold and die manufacturing faces a unique combination of challenges, including working with tough alloys, achieving repeatable micron-level precision, creating complex part geometries, and meeting ever-growing demands for faster production at lower costs. As a result, many of these risk-averse manufacturers hesitate to invest in new production technologies. With potentially high initial costs and expected implementation difficulties, moldmakers take a conservative approach unless they can integrate new technologies with ease.



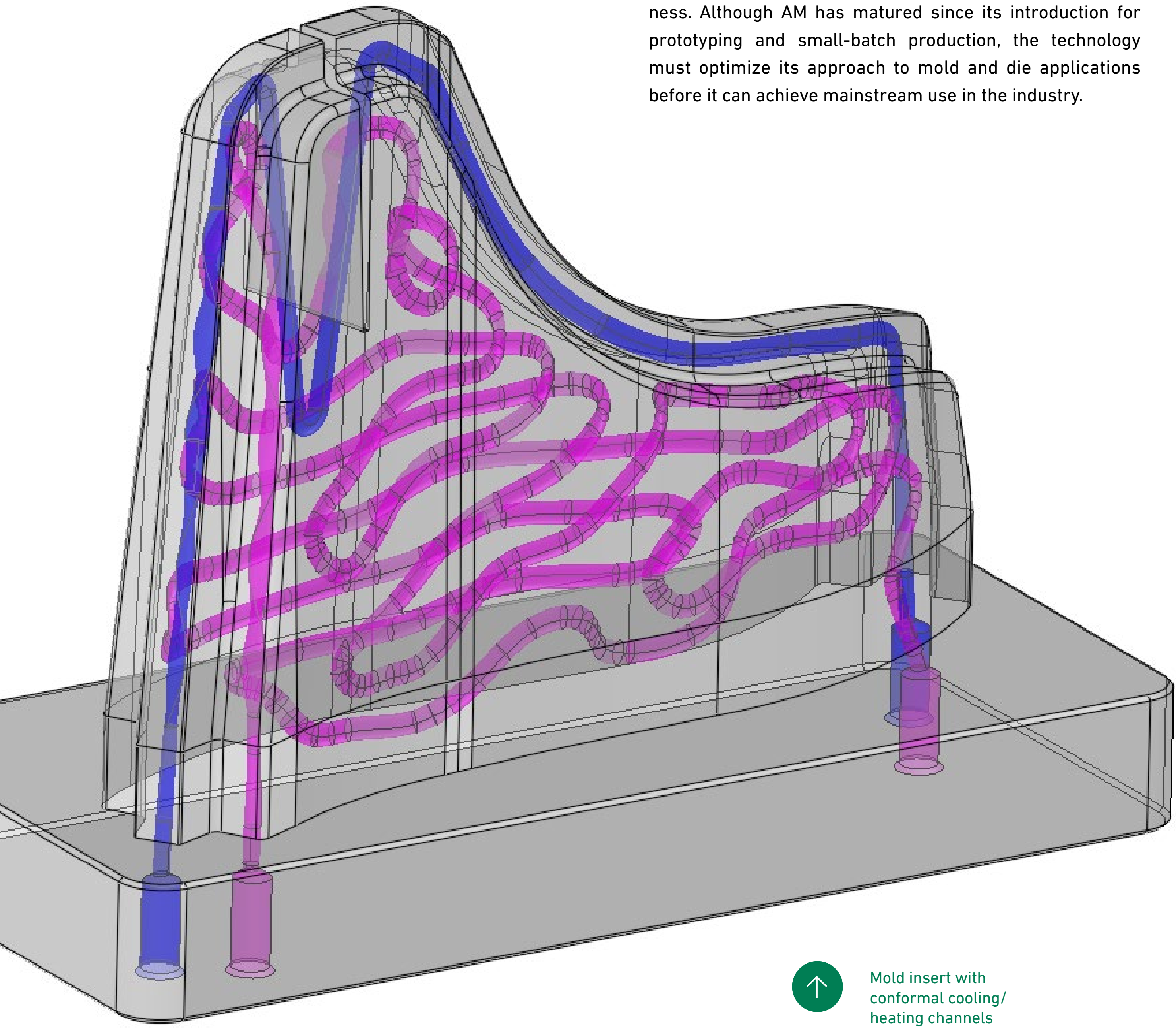
Mold assembly

For more than a decade,

manufacturers have relied on GF Machining Solutions to tackle the unique production challenges of moldmaking and deliver solutions to effectively mill, erode, engrave, and texture products for demanding industries such as packaging, medical, or automotive. Now, GF Machining Solutions has expanded that expertise to offer metal Additive Manufacturing (AM) to address the mold and die industry's needs with refined solutions.

Challenges

The costs of implementing metal AM have kept adoption rates low in the mold and die industry. The well-known advantages of conformal cooling in the production of molded plastic or metal die-cast components, combined with the unique ability of AM to create mold inserts with optimized thermal management, increase the technology's attractiveness. Although AM has matured since its introduction for prototyping and small-batch production, the technology must optimize its approach to mold and die applications before it can achieve mainstream use in the industry.



Mold insert with conformal cooling/ heating channels

The mold and die industry relies on a relatively finite list of alloys for part production, and expects its production technologies to accommodate those materials. Therefore, AM material manufacturers must work to recreate mold and die's familiar alloys in powdered form.

Metal AM powder

The risk aversion that such industry displays toward new technologies and materials also extends to retraining and learning new methodologies.

It indeed expects new technologies to integrate seamlessly with its traditional applications and minimize secondary processes for cost efficiency. In addition to the right hardware and software solutions and the availability of suitable materials, mold and die manufacturers need dedicated training and support to prepare their teams for new manufacturing methodologies—all challenges that are best addressed through a single-source approach.

Likewise, any process that cannot achieve surface requirements fails to meet mold and die manufacturers' needs. In fact, a defective mold or die transfers its flaw to every part it produces. Along with flaws that originate on the surface, areas of subsurface porous metal typically create critical problems because they can emerge during post-processing as surface defects or shorten the life of the insert through thermal fatigue. To avoid these problems during AM production, manufacturers need process stability, one of the main challenges of metal 3D printing, especially in producing parts with large, bulky sections.

Mirror surface finish after 5-axis milling of solid block

Automation process of finishing operations of 3D printed mold inserts

Once optimized for the demands of mold and die production, AM can create a wide variety of parts beyond the complex conformal inserts that first brought the technology to the industry's attention. The keys to success in AM implementation lie in taking a systematic approach to integration, which becomes much easier with the support of a technology partner that also offers experience in the mold and die industry itself. GF Machining Solutions knows the industry, develops the AM technology, and combines these areas of expertise to create productive applications of the technology.

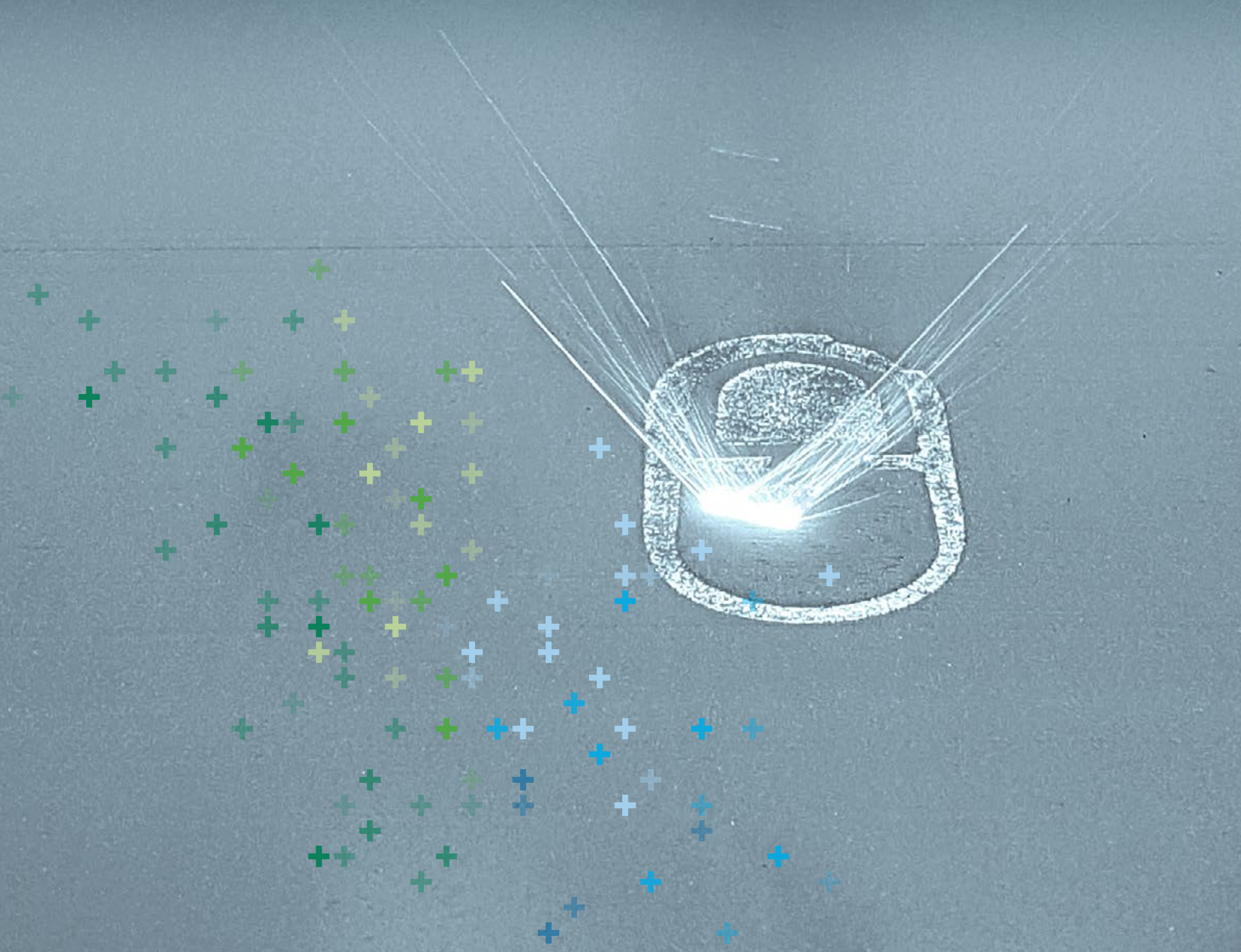
Solutions

Equipment

DMP Flex 350

With a build volume of 317,625 cm3 and a printing environment, that constantly maintains less than 25 ppm oxygen, the DMP Flex 350 metal 3D printer produces precise parts with maximum powder usage and minimal user intervention. Oxygen reduction in the vacuum chamber improves part quality and reduces oxidation, especially in reactive materials such as titanium and aluminum, while the finely tuned laminar argon flow efficiently eliminates fumes and spatters that may cause porosities. With a 60 µm repeatability on all three axes, this high-throughput machine generates features as small as 200 µm and produces outstanding density steadily from batch to batch and machine to machine. Specifically, its consistent performance ensures appropriately thin mold-insert walls for excellent conformal cooling.

Finally, a modular, removable print module adds multiple levels of flexibility to this system. Such modules enable shops to run a high-mix workflow that requires them to switch from one build material to another in rapid succession, from steel to aluminum for instance.



Equipment

Tooling for AM

The complete GF Machining Solutions AM ecosystem includes exclusive System 3R tooling for AM and secondary processes, optimized to provide the best technological approach to an AM-based mold and die workflow. From clamping and automation to printing substrates, tabletop chucks and other hardware, this modular solution eases the transfer of workpieces from one step to the next. This integrated approach is key for mold manufacturers in order to optimize their complete manufacturing chain and reduce the cost per part.

3D printed dies built on printed on System 3R Tooling for AM solutions

Milling and EDM

Post-processing workflows can include various manufacturing steps, including part separation and milling, which shape and refine part features to achieve the final part geometry and surface finish. The CUT AM 500, a new dedicated wire EDM solution, separates completed parts from build plates with greater speed and precision than a bandsaw or standard EDM. A comprehensive, holistic production solution unifies this step with the AM process that precedes it and the secondary subtractive processes that follow it.

5-axis milling operation of 3D printed mold insert

Material

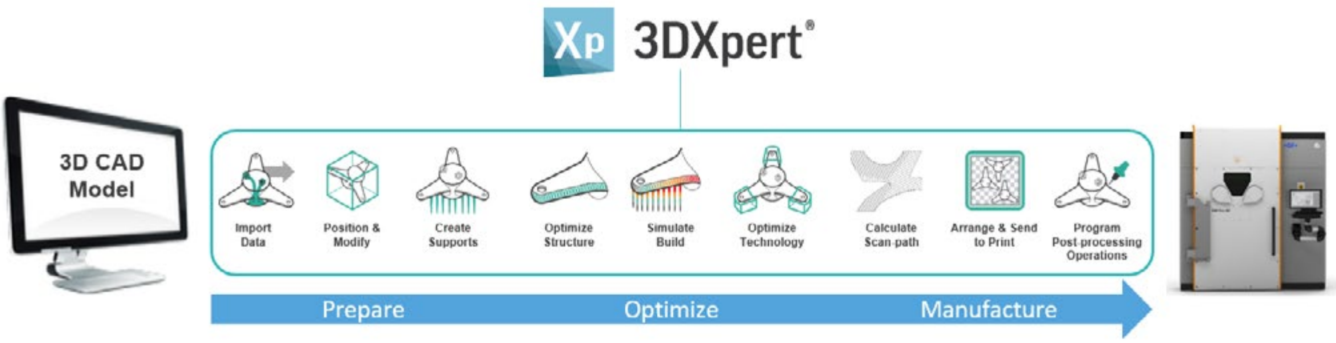
Laser powder bed fusion (LPBF) applies hundreds or even thousands of layers of metal powder and melts them with a laser, in what essentially amounts to an ultra-precise, incremental welding process.

The quality of a 3D-printed metal part greatly depends on the quality of the feedstock material used. For AM productions with metal alloys suitable for mold and die applications, the DMP Flex 350 offers compatibility with LaserForm® materials developed for fine-tuned AM performance. For instance, LaserForm® Maraging Steel is optimized for printing inserts with conformal cooling and other advanced applications, as along with high wear resistance; it also provides excellent hardness and strength.

Mold and die typically relies on quenching to harden its production metals, but quenchable materials lack optimal AM suitability because they weld poorly. Moreover, many moldmakers tend to privilege corrosion-resistant materials in order to avoid expensive surface-treatment processes to protect the active surfaces of molds from corrosion, a phenomenon definitely not admissible for applications in regulated sectors such as the medical one.

Instead of regular tool steels, mold and die makers can now use Bölher AMPO M789–a high-strength and -hardness, corrosion-resistant steel–to produce their parts with the AM process. Metallurgy created this new alloy specifically to serve the needs of mold and die customers through the AM technology, and through its expertise in serving these customers' needs, GF Machining Solutions recognized the importance of M789 in meeting the challenges of their applications.

Software



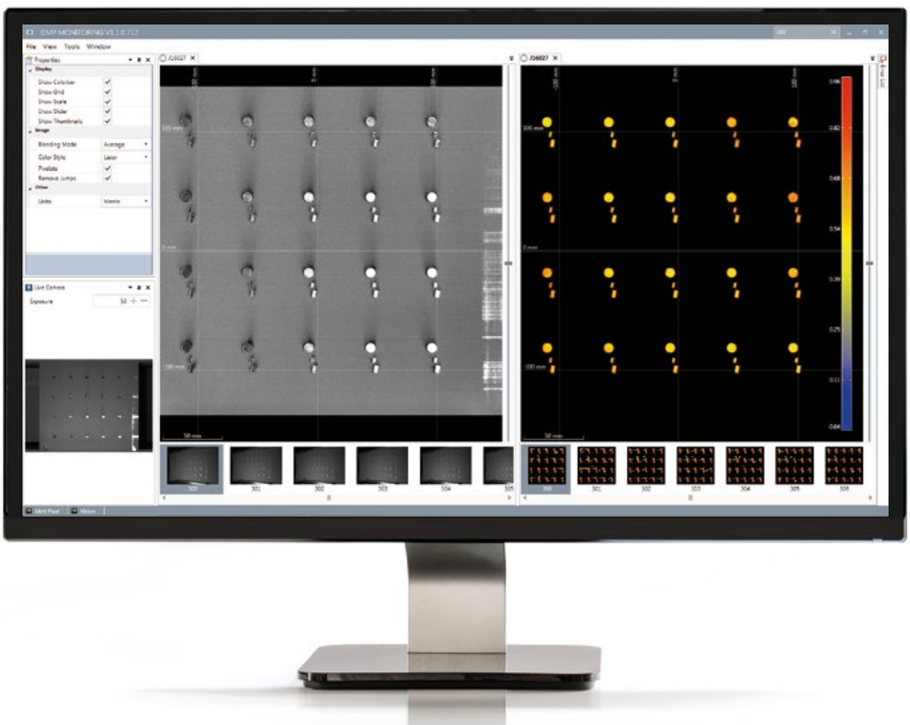
DMP Flex 350 operators use 3D Systems 3DXpert™ all-in-one integrated software to prepare, optimize, and manufacture AM parts. This advanced software suite handles the entire workflow from 3D model through part production and secondary processing, meeting the unique requirements of this production technology with full user control on every parameter. Its compatibility with all native CAD and 3D file formats enables mold and die manufacturers to produce parts from new and existing part models and maintain compatibility with mesh and parametric features.

Beyond file support, 3DXpert™ also optimizes 3D models for the specific demands of metal 3D printing, positioning and orienting them on the printer tray, and applying scaling to account for in-build part shrinkage.

Before the build, simulations enable shops to maximize repeatability and minimize faults without wasteful tryouts. Post-processing tools then make it simple to finalize parts with templates for subtractive machining.

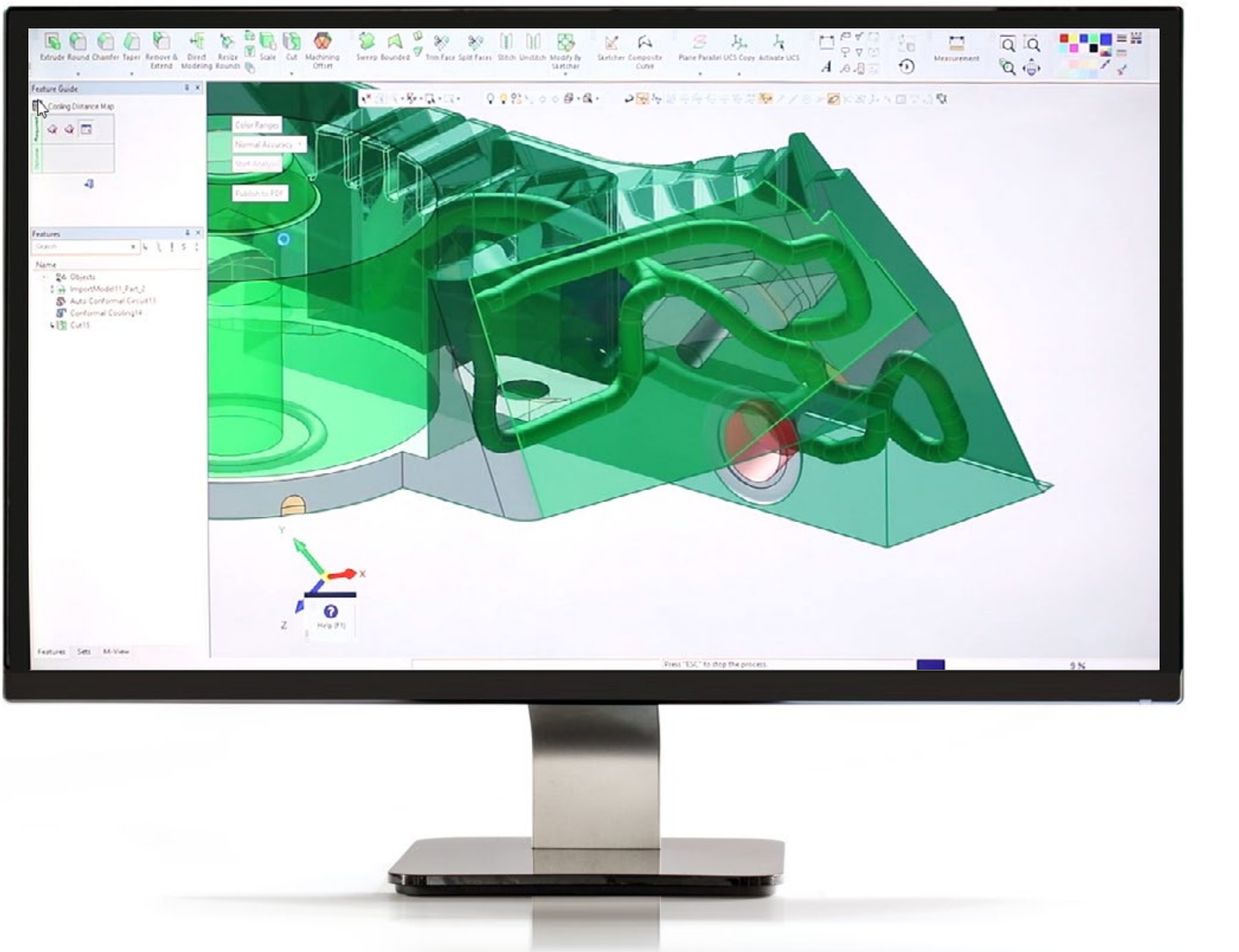
The software suite also comprehends an innovative solution to tap into the power of the melt-pool monitoring hardware available on the DMP series of metal AM machines. In fact, an optional real-time process monitoring tool, DMP Monitoring, allows enhancing quality control with synchronized, whole-layer images of the laser melt pool signature. These can also be post-analyzed by a further offline software tool, DMP Inspection, which detects differences in melt-pool emission, and thus predicts material porosities and disuniformities in the built parts. Being based on in-process data collection, such toolset also contributes to build-parameter optimization.

Figure 2: The DMP Monitoring interface as seen by the user during the manufacturing process. The far left window displays a live imaging of the printing process while central windows display the powder bed imaging (left) and meltpool imaging (right).



Because traditional CAD programs struggle to create the conformal cooling paths that molds and dies require, 3DXpert™ incorporates an Additive Molding Add-On that quickly optimizes insert designs to minimize the cost of design and manufacturing. This add-on can save many hours of design work and enables the designer to combine traditional and conformal cooling. It can generate a conformal cooling path automatically from user input or provide manual layout capabilities. Additionally, its analytical features map and optimize channel/part-wall distances, check channel overhangs, and simplify the quick creation of channel geometries. Lastly, its heat-map tool shows how homogeneously and efficiently a specific design will cool.

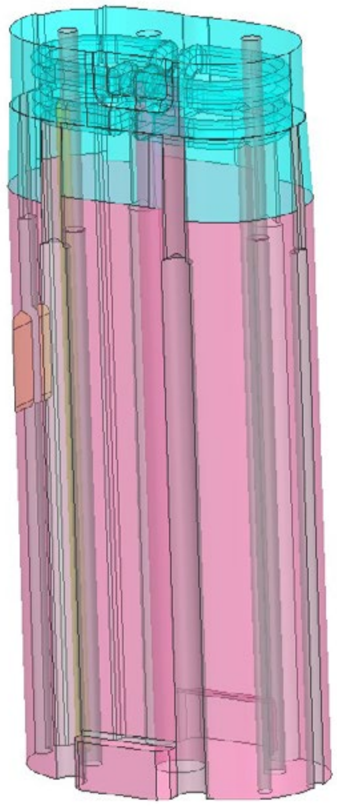
Conformal cooling design with 3DXpert™ Additive Molding Add-On



Hybrid printing

Mold and die makers face intense cost pressure from their customers, along with demands for quick production of high-quality parts. Although metal 3D printing can shorten lead times, increase part quality, and produce inserts that enable customers to cut their own production costs, it can raise manufacturing costs for mold inserts and force mold-makers to justify their pricing. Moreover, the intrinsic competitiveness of the mold and die industry includes intense sensitivity to any considerations that increase price.

Because AM production costs rise as the amount of material increases, larger parts cost more to manufacture through metal 3D printing. Instead of approaching every mold or die as a completely 3D-printed part, hybrid printing reduces production costs and leverages the best attributes of additive and subtractive processes. By limiting the AM production to creating the complex elements of a mold insert rather than the easily machined features of its geometry, mold and die makers can obtain complex parts more efficiently.

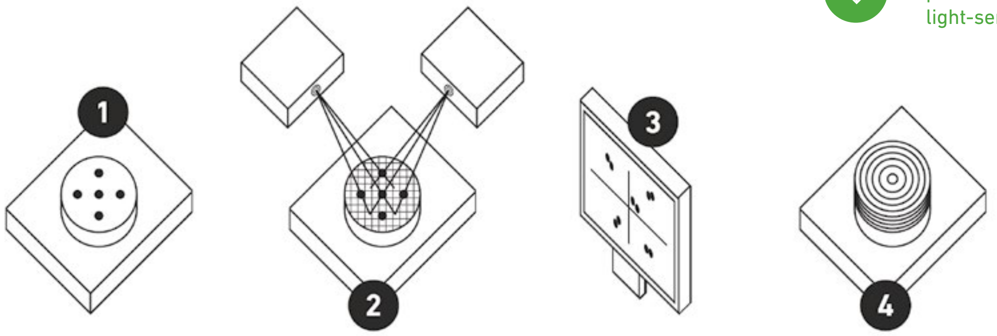


Hybrid mold insert rendering

For example, shops can build mold cavities much more quickly with subtractive than with additive processes.

When a fully AM approach would require too many build supports or large amounts of expensive metal powder, a pre-machined preform becomes the "host" for AM-created mold features. This hybridized production style requires an automated AM system capable of precisely referencing the existing workpiece. This is possible thanks to a use of the capabilities of DMP Monitoring. GF Machining Solutions applied the expertise developed through years of experience with mold and die customers to develop a hybrid process that minimizes per-part costs while maximizing the efficiency of AM processes in mold and die applications.

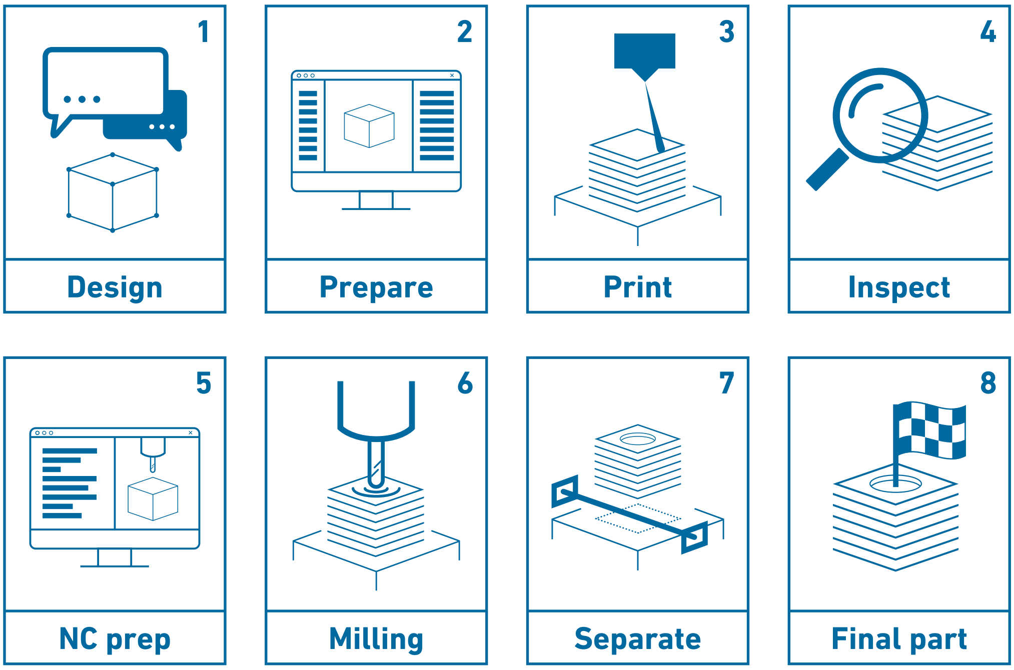
Effective referencing process: data from light-sensing hardware



Workflow summary

GF Machining Solutions delivers the experience, technology, and support required to help customers in seamlessly integrate the AM technology.

From part design to finished part, a holistic approach to the AM workflow gives customers the confidence to take their manufacturing processes to the next level.



Metal AM workflow

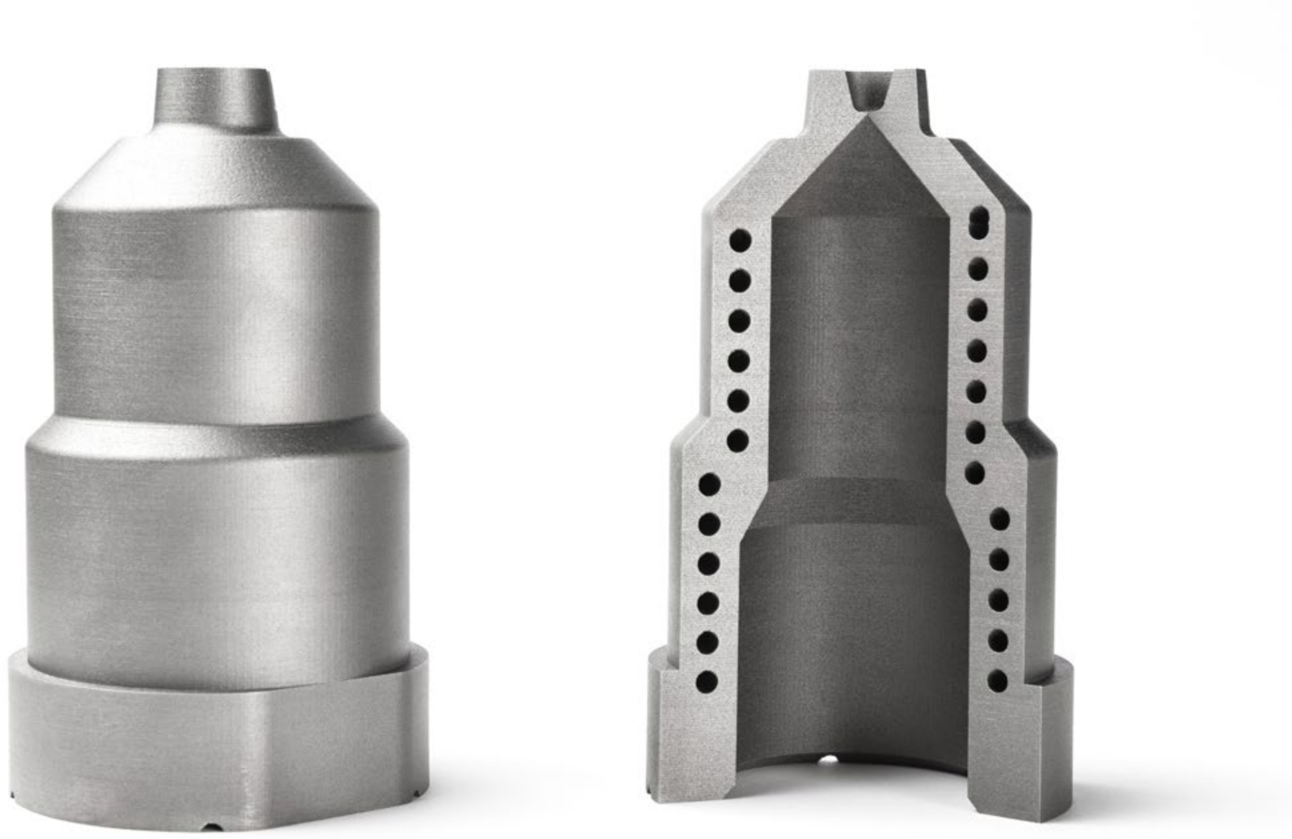
Conclusion

The unique challenges of the mold and die industry have resulted in a rightfully cautious approach toward improving on reliable processes. Moreover, despite enhanced design capabilities, shorter production cycles, better inserts, and reduced overall costs, mold and die makers have still hesitated to make the investment in the AM technology.

AM, however, dramatically enhances the range of parts mold and die manufacturers can create.

If they look at metal 3D printing as merely another way to create the same parts they have always made, they lose out on the technology's greater design freedom. With comprehensive and integrated production technologies from GF Machining Solutions, mold and die makers can opt for turnkey additive solutions with transformative potential for their workflow and business potential.

Hotrunners with conformal channels



Appendix 1: Case study: Hybrid inserts for packaging mold

TK Mold of Shenzhen, China, produces plastic molds and parts for industries ranging from healthcare to consumer goods. With 37 years of experience designing and fabricating molds with traditional insert production strategies, the company immediately saw the advantages of using AM to create inserts with optimized conformal cooling channels. It now applies AM where subtractive processes fail to achieve the desired results at a reasonable cost.

In the production of packaging for a smartwatch, TK Mold created the plastic support that held the watch in place inside its box. Both high-volume production and high-value aesthetics provided demanding–and common–molding challenges. Conventionally produced mold inserts could not reach the company's productivity and cost-per-part targets. Non-conformal cooling channels failed to provide optimal thermal regulation, and only costly assembly of insert components could overcome these limitations.

To attain the necessary insert performance, TK Mold used a hybrid approach, starting with preforms produced through wire EDM. Clamped onto a System 3R AM Carrier mounting system, the preforms were mated with a DMP Flex 350 metal 3D printer and referenced using the DMP Calibration tool based on the identification of locating holes. Finally, the AM process added features using highly wear-resistant LaserForm® Maraging Steel. Following the AM process, TK Mold used a GF Machining Solutions Mikron MILL S 400 U milling machine to achieve a perfectly homogeneous final active surface. Additional milling and grinding completed the production process.

This optimized insert enabled TK Mold to cut the injection cycle time by almost five seconds, from 21.70-21.79 seconds with a traditionally fabricated insert to 16.98-17.01 seconds. The company also raised its monthly production from 189,788 to 242,250 pieces and its revenue by RMB 92,871, or approximately €12,000. Thermal performance and repeatability climbed, customer satisfaction rose, and waste virtually disappeared from the veteran moldmaker's process with conformally cooled inserts built through an optimized hybrid AM production.

Appendix 1:
Case study: Hybrid inserts for packaging mold

TK mold

Technology	DMP Flex 350 3DXpert™ DMP Monitoring System 3R AM Carrier Milling MIKRON MILL S 400 U
Market Segment	Packaging (Mold and Die)
Material	LaserForm® Maraging Steel
Build Time	4.7 hours
Layer Thickness	30 µm

Key advantages

+ Optimized mold insert with enhanced thermal management
+ Reduced injection's cycle time and production costs
+ Reduced inserts manufacturing lead time thanks to dedicated software tools
+ Reduced inserts manufacturing costs thanks to hybrid approach
+ Integrated approach with unique GF Machining Solutions' AM ecosystem and expertise

Machined and cut preforms before printing process

Appendix 2:
M789 medical pipette mold

A German manufacturer of medical pipettes sought to optimize a multi-cavity injection mold insert for greater productivity and better thermal performance. Produced as a conventionally manufactured insert core, the 109 mm x 109 mm x 60 mm product incorporated 38 coolant holes and eight mold cavities, which required two sets of processes. The first set included five days of manufacturing and consisted of milling, drilling, and grinding. The second spanned an additional six manufacturing days that included turning, grinding, die-sinking EDM, wire cutting, milling, and assembly.

Application optimization with a metal 3D-printed solution in Bölher AMPO M789 material transformed the insert into a 100 mm x 100mm x 50 mm 12-cavity core with optimized 6+6 inlet/outlet cooling channels, all produced in a five-day process that begins with AM and includes grinding, wire EDM separation, milling, and die-sinking EDM. The result saved the medical products manufacturer 50% of the labor resources it formerly needed to devote to moldmaking for this pipette product.

Original 8 cavities core

Blank core
Cutting / Saw
Milling / Drilling
Hardening

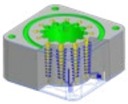
Core
Grinding
Milling
Die-sinking EDM

Blanks inserts
Cutting / Saw
Turning
Hardening

Inserts
Grinding
Wire cutting EDM
Die-sinking EDM

Assembly
Adjustment of inserts
Manual and grinding

Estimated manufacturing load: 11 days



GF Machining Solutions 12 cavity core

Blank core
Printing
Separation
Hardening

Core
Grinding
Milling / Boring
Die-sinking EDM

Estimated manufacturing load: 5 days

Conclusion
> 50% labour resources saved

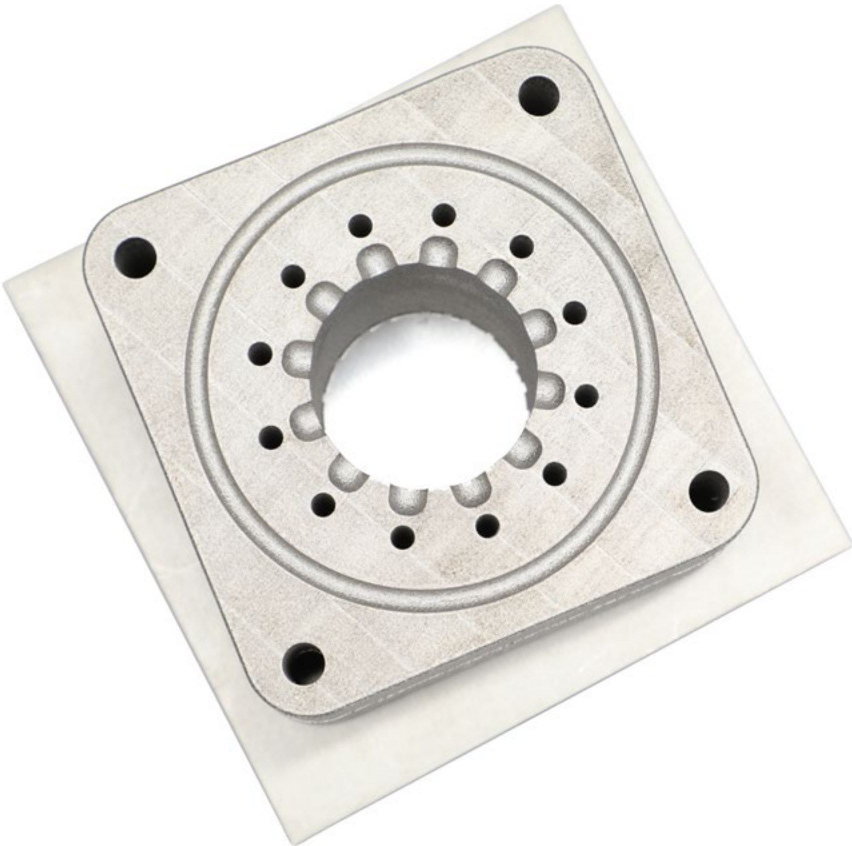
Appendix 2:
M789 medical pipette mold

M789 medical pipette mold

Technology	DMP Flex 350 System 3R AM Carrier and BuildPal 126 AgieCharmilles FORM X 400 Milling MIKRON MILL S 400 U AgieCharmilles CUT AM 500
Market Segment	Medical (Mold and Die)
Material	Böhler AMPO M789
Build Time	40.6 hours
Layer Thickness	30 µm

Key advantages

+ Optimized mold insert with enhanced thermal management
+ Increased plastic injection molding's productivity
+ Integrated approach with unique GF Machining Solutions' AM ecosystem and expertise
+ Benefit from a material in line with the needs of moldmakers



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