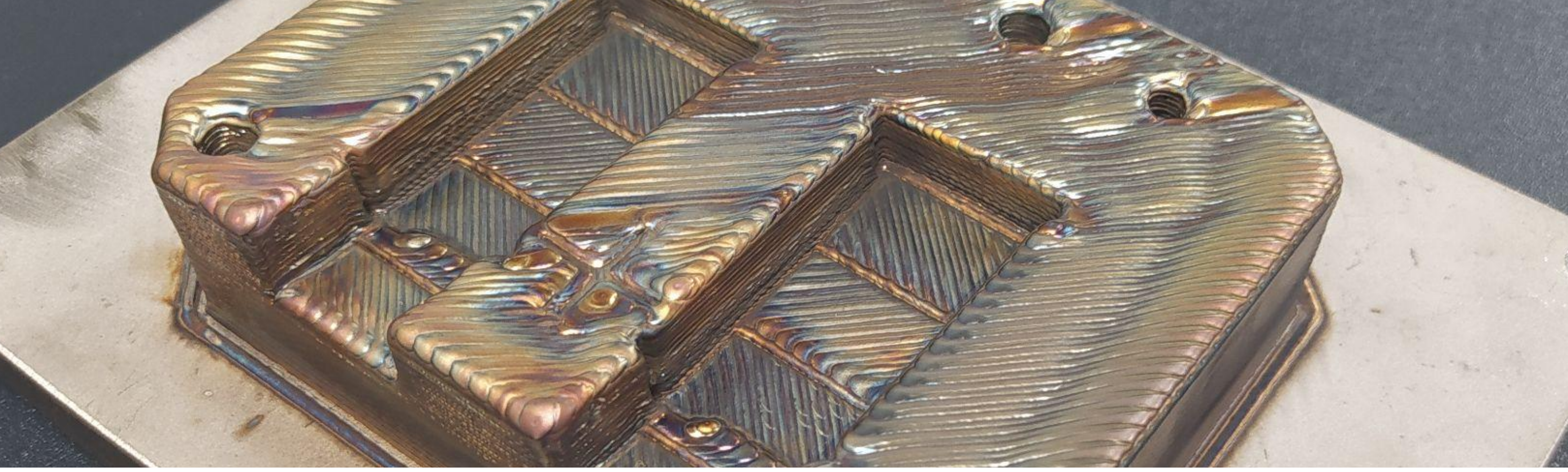
MELTIO

Q2 2023

Mold-Making with LMD and Dual Wire

Whitepaper



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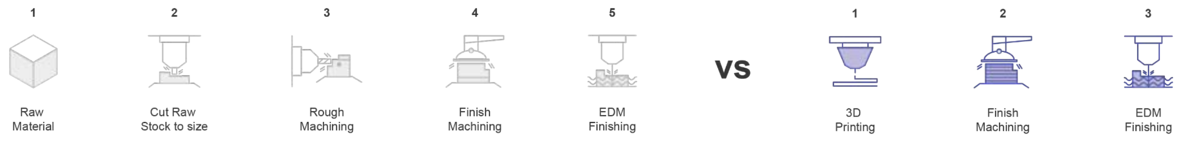
Summary

Mold and die manufacturing is an industrial sector, standing at the basis of a wide range of mass production processes.

Molds and dies are precision tools manufactured in durable materials, their performance requirements are increasing and this leads to higher complexity. All of the above translates into high cost and long lead times.



Standard manufacturing process vs MELTIO

Additive Manufacturing (AM), since its early developments with metals, has attempted to address the challenges of mold-making, with varied degrees of success. While performance improvements and flexibility were easily obtained, the range of applicability has remained fairly limited.

Meltio's Laser Metal Deposition (LMD), thanks to the use of readily available, inexpensive feedstock in the form of commodity welding wire, greatly expands the business case for AM in mold-making. The process enables the production of molds and dies, even with advanced features such as conformal cooling, without being impacted by issues such as de-powdering.

The advantages that can be leveraged are:

- Printing accurate near net shape parts;
- Saving on material and tool wear;
- Consolidation of assemblies;
- Cycle time optimization thanks to efficient cooling channels;
- Performance increase and lower cost using two materials;
- Repair of worn surfaces.

1. Introduction

The mold and die manufacturing market is a significant sector of the manufacturing industry. It involves the production of tools that are used in various industries such as automotive, aerospace, healthcare, consumer goods, and electronics. Molds and dies are critical elements in the mass production of parts, components, and products.

The mold manufacturing process involves designing and producing a mold that is used to create parts or products by injecting molten material into the mold cavity.

On the other hand, die manufacturing involves designing and producing a die that is used to shape and cut material, generally sheet metal, into a specific form.

The mold and die manufacturing market grows year over year due to the increasing demand for complex and precise components in various industries. The market is highly competitive, and manufacturers are constantly improving their processes and technologies to provide high-quality molds and dies at competitive prices.

The different types of molds and dies include plastic injection molds, die casting dies, stamping dies, and forging dies, among others.

The mold and die manufacturing market is expected to continue to grow in the coming years. This increasing demand requires manufacturers and operators alike to look at the most advanced and cost competitive technologies for tooling production.

1.1 Current Mold and Die Manufacturing Challenges

Mold-making is a complex and challenging process that involves creating precise and intricate components for a variety of industries. The following are some of the main challenges faced in traditional mold and die manufacturing.

1.1.1 Complexity

Molds and dies can be highly complex, with intricate geometries and small details. The complexity of external surfaces is frequently not as high as the one of internal cooling features, intrinsically harder to manufacture.

1.1.2 Materials

Choosing the right materials for the molds and dies is crucial for ensuring their performance and durability. A wide variety of tool steels are employed, each with different strengths, yet all sharing relatively high cost and low machinability.

1.1.3 Cost

Mold and die manufacturing can be expensive, particularly when creating custom or specialized components.

1.1.4 Delivery Times

Mold and die manufacturing may be subject to tight deadlines and turnaround times. Delays in the manufacturing process can lead to production delays, missed deadlines, and potentially lost revenue.

1.1.5 Maintenance

Molds and dies can be subject to wear and tear over time, requiring maintenance and repair. Cost effective molds and dies need to be capable of withstanding repair processes in order to offer a long and productive operational life.

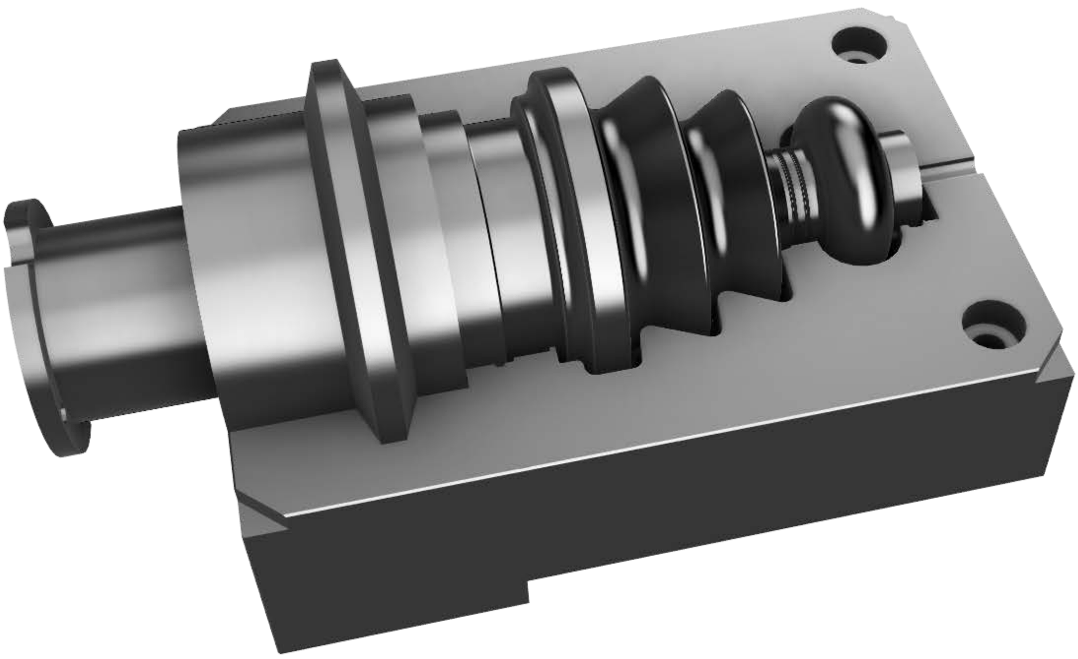


Fig. 1.1.1: Bottom half of a polymer injection mold, with insert.

2. Opportunity of Additive Manufacturing for Mold and Die Production

2.1 Current Challenges that AM Can Address

Additive Manufacturing processes offer several strengths that can be leveraged in the production of molds and dies; some of these directly tackle the main challenges faced by conventional mold-making.

2.1.1 Design flexibility and Performance Improvement

Additive Manufacturing enables the creation of highly complex and intricate geometries that are difficult or impossible to produce with traditional manufacturing methods. This can result in more efficient and optimized designs for the molds and dies. An area of particular importance is the development of internal cooling features, a task where traditional technologies can only offer limited value.

2.1.2 Cost Savings

Additive Manufacturing can significantly reduce the cost of producing molds and dies. Traditional manufacturing methods often require expensive tooling and setup costs, summed to high levels of waste of stock material being removed during machining processes. The AM cost structure is more dependent on the cost of the raw material, with very limited waste, and the 3D printing equipment.

2.1.3 Faster lead times

Additive Manufacturing generally allows for faster production of molds and dies compared to traditional manufacturing methods. AM also lowers the barrier, for industrial final users, to the internalization of mold-making capabilities.

Overall, the use of additive manufacturing for molds and dies can lead to faster production times, cost savings, improved performance, and design flexibility, making it an attractive option for companies in a variety of industries.

2.2 New Challenges that AM May Bring to the Table

While Additive Manufacturing can offer tangible advantages over traditional technologies, its processes are not free of limitations.

The first metal AM processes that started successfully addressing mold-making needs focused on the use of fine metal powders. These processes, falling in the Powder Bed Fusion (PBF) category, grant the greatest level of accuracy and design freedom, however they may struggle to bring value to a large range of users.

There are several process related issues that the PBF technology may face.

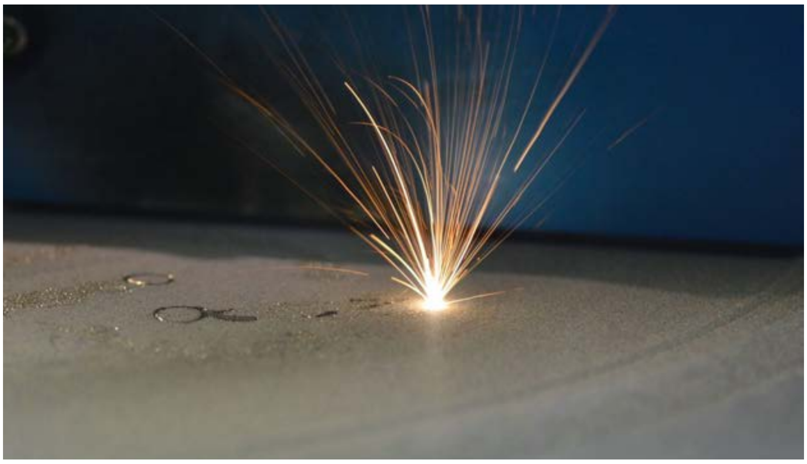
To begin with, as the process is fully developed for high value materials required for Aerospace and Medical applications, it has seen limited R&D focus towards Tool Steels common in mold-making.

Generally PBF systems are among the most expensive metal AM units and so is the powder feedstock. If the build volume utilization is not carefully optimized, the unit cost of the parts manufactured can be considerably higher than the value theoretically achievable.

With the exception of units mostly dedicated to Aerospace applications, PBF processes generally excel with complex parts of limited size and mass. Small mold inserts with intricate cooling can be a good fit, molds and dies weighing several kilograms may not fit in the build volume or fail to be cost-efficient.

All current commercial PBF technologies can only process a single alloy at any given time, with a quite lengthy deep cleaning process to be performed whenever the material is changed. This usually results in users dedicating units to specific materials to prevent risks of cross contamination. Indeed, powder handling is an added complexity in the ancillary operations to the process. The fine metal powders require careful storage, PPE for the personnel handling them and further safety considerations when processing waste (condensate), which in some cases is highly flammable.

Finally, and very relevant for mold-making purposes, while parts printed with PBF can theoretically feature highly intricate internal geometries, due to the nature of the process, any internal cavities get filled with loose powder while printing. This unwanted powder needs to be removed in a post-processing step in order to ensure the functionality of the part.



This process, at times, can be lengthy and costly in labor and machinery. Failure to successfully achieve full powder removal could result in scrap of the component and warrant a redesign.

2.3 Potential Beyond Powder Bed Fusion Metal AM Processes

Powder bed fusion processes, with rare exceptions, are developed with the intent of manufacturing parts starting from a build plate. This prevents the possibility of performing Feature Addition on pre-shaped substrates or repair of damaged tools.

Laser Metal Deposition processes do not rely on a bed sequentially filled with a layer of powder, the material is selectively deposited directly within the melt pool created by one or more lasers. This, with a 5-axis motion system, allows the deposition of material, Feature Addition, on non-planar surfaces. In the case of molds and dies, this may mean the manufacturing of tools starting from pre-machined bases or the repair of worn-out tools.

While LMD was first developed around the use of metal powders, its fundamentals can be applied to a different, easier to handle, feedstock: welding wire.

Fig. 2.3.1: LMD stock photo - Shutterstock

3. Wire - LMD Process

Meltio has revolutionized the metal 3D printing industry with its innovative laser wire process. While the company initially started as a provider of powder and wire metal LMD 3D printing technology, its focus has now shifted towards improving the laser wire process.

With Meltio's wire-LMD process, users can expect better microstructure, improved control, and minimal extra material to be machined. The heat-affected zone is extremely compact, reducing heat transfer to the layers below and the vicinity of the melt pool. This results in a more stable process that produces consistent, high-quality results.

The printing process has the wire (0.8 to 1.2 mm in diameter) entering the melt pool coaxially with the deposition head, melting at the point of contact with the substrate, in the focal point of six converging laser beams. The independence from energy input and material flow allows Meltio to use a sophisticated feedback system, leading to a stable process.

Fig. 3.0.1: Meltio's deposition head, sectioned to show the laser path through the collimator and to the focal point on the tip of the wire, fed coaxially.

The process delivers high resolution Near Net Shape parts (NNS), i.e. raw parts requiring a finishing process to reach their final, net, geometry. The extra material present on the NNS compared to the net shape is known as over thickness. One of the most significant advantages of Meltio's laser wire process is the minimal over thickness required. Thanks to the lower heat input and controlled wire-laser process, the surface rivals that of powder-based processes, with the required over thickness ranging from a maximum of 1.5mm to a few hundred micrometers.

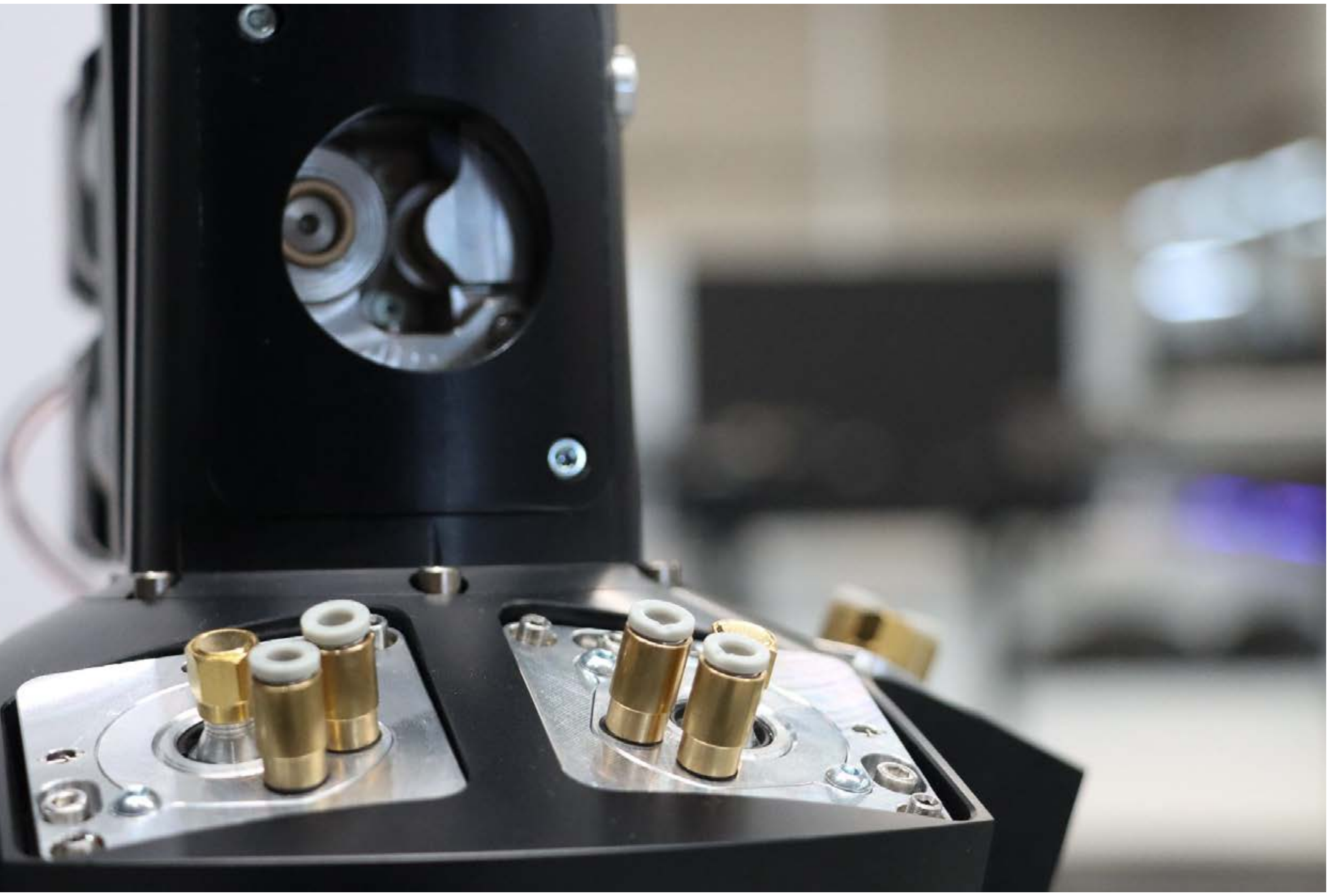
Fig. 3.0.2: Meltio's welding wire spools

The process capabilities, coupled with the low variable cost obtainable with the use of commodity welding wire as feedstock, make Meltio's system an ideal candidate for the manufacturing of tooling such as molds and dies.

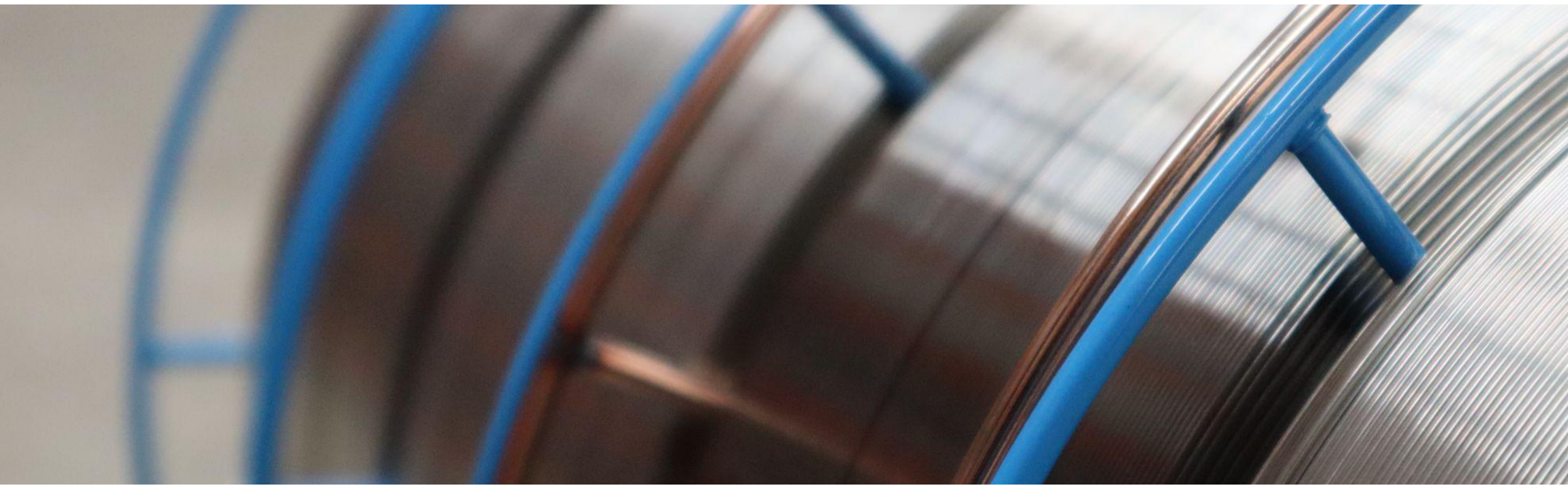
3.1 From Basic to Advanced Process Capabilities

The basic capabilities of the system, fully outlined in Meltio's Design Guidelines, are under constant development with the focus of expanding the range of applicability. Specifically, current software updates provide improved capabilities in the manufacturing of internal features.

In the Meltio M450 platform, Meltio Horizon slicer offers a new Infill strategy for Gyroid Lattice infill to generate parts with defined open cell porosity. This is particularly suitable for the manufacturing of cooling channels. In combination with the Object modifiers it is easy to define a central region of the build and apply different hatching strategies based on model overlap, achieving shapes once thought impossible with LMD.



4. Materials & Mechanical Properties



4.1 Hot Work Tool Steels

Hot work tool steels are used in the manufacturing of molds and dies that are exposed to high temperatures, heavy loads, and abrasive forces. The typical features required by these metals for this application include:

- High hot hardness: The ability to maintain hardness and strength at elevated temperatures is critical for hot work tool steels.
- High wear resistance: The steel should resist wear and deformation caused by abrasive forces during use.
- High toughness: The steel should be able to withstand shock loading and resist cracking or breaking during use.
- Good thermal conductivity: The ability to conduct heat away from the mold or die is important to prevent overheating and premature failure.
- Resistance to thermal fatigue: The steel should resist cracking and failure due to cyclic heating and cooling.
- Good machinability: The steel should be easy to machine and shape to the desired form.

- Good polishability: The surface finish of the mold or die is important for the final product, so the steel should be capable of achieving a good surface finish.
- Corrosion resistance: The steel should resist corrosion from the environment, such as oxidation or rusting, to maintain the integrity of the mold or die.

Overall, hot work tool steels should have a combination of high temperature strength, wear resistance, toughness, and machinability to perform well in the demanding environment of mold and die manufacturing.

4.2 Commodity Welding Wire as AM Feedstock

Hot work tool steels are readily available as welding wire, as they've long been developed for traditional welding processes, for either repair and hard-facing.

The possibility of using a feedstock familiar to any industrial environment lowers the barrier to the acquisition of the Meltio LMD process. Meltio's strategy revolves around an Open Materials platform: all users can 3D print with wires from any manufacturer.

AM process development for any given alloy, however, requires iterative steps focused on obtaining the desired final density and mechanical properties. Meltio's Materials and Process Development department already performed this task for a range of ready-to-print materials, offered under Meltio's brand. Among these, mold-makers will primarily focus on Meltio Tool Steel H11.

4.3 Meltio Tool Steel H11

Meltio's first Tool Steel is the common H11 (1.2343), obtainable in welding wire form in its original composition, the same one already well known to tool makers.

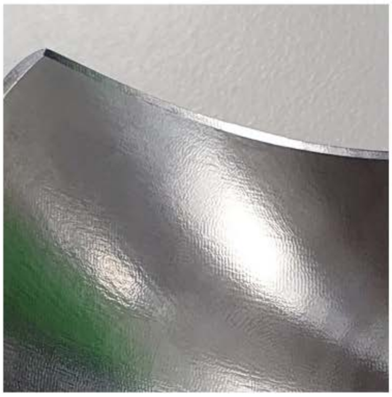
Tool Steel H11 is an Air-Hardening tool steel which during 3D printing reaches its hardened state. As 3D printed H11 displays tempered and fresh martensite, retained austenite, and columnar grain morphology aligned with the solidification front. Heat treatment reduces retained austenite and refines the grain to a primarily equiaxed shape, converting most of the martensite. Trace amounts of austenite may remain undetectable with light microscopy.

In as 3D printed state machinability is affected and there is a higher risk of cracking during operation, due to the reduced ductility. Consequently, a traditional heat-treatment cycle is typically necessary, except potentially for cladding applications or small feature addition.

Fig. 4.3.1: Meltio Tool Steel H11 spool with sample part, a dual material Press Brake Tool with surfaces in Tool STeel H11 and core printed in Mild steel.

The ideal cycle should begin with an Annealing step prior to removing the part from the build plate. The material will be softened and free of internal stresses, making it easy to machine. After machining, the part should then undergo Hardening and a suitable Tempering cycle to achieve the desired hardness.

Machined - hard machining on as-printed part



Polished and textured

Fig. 4.3.2: Polishability of Tool Steel H11, index of high density.

4.3.1 Heat Treatments

Annealing	**HT.1:** Inert atmosphere - Heat up to 820°C	Slow Cooling in oven to RT
Hardening	**HT.2:** Inert atmosphere - Heat up to 1025°C	Hold for 2h Forced Air-cooling to RT
Tempering	**HT.3** (Example)**:** Inert atmosphere -Heat up to 550°C	Hold for 1h Slow Cooling to RT (Repeat 2x)

**Typical Parameters for a Sample of 160x60x30 mm*

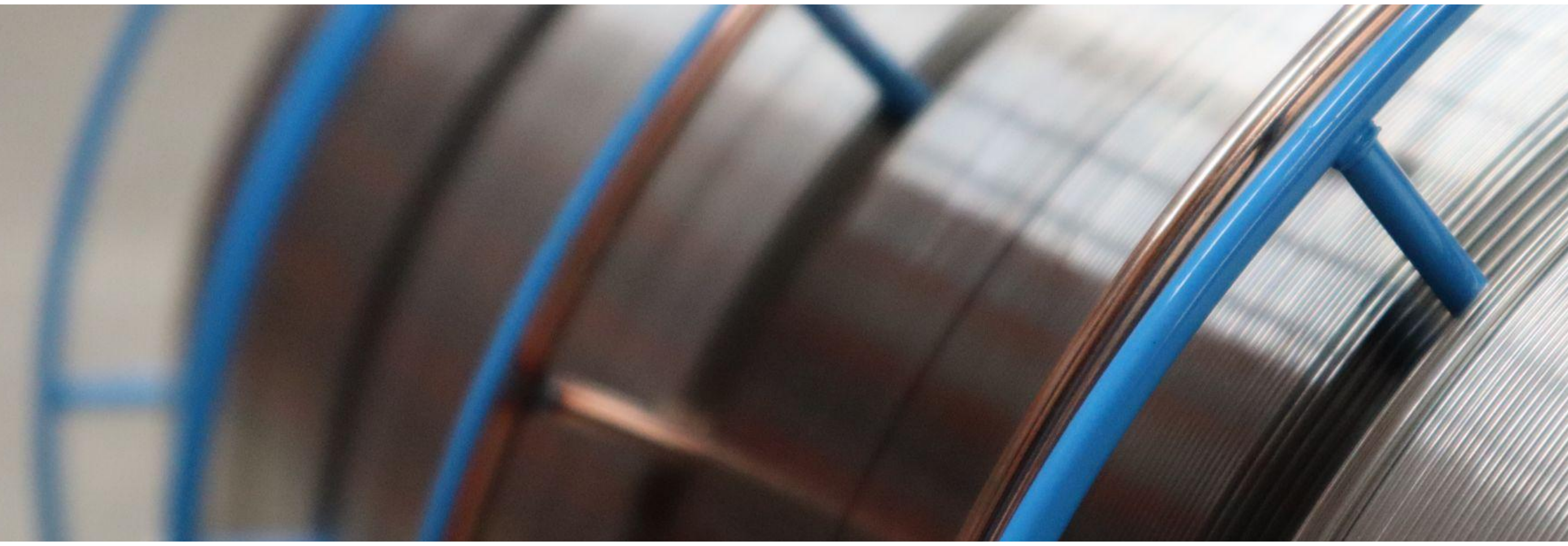
4.3.2 Density

Relative density as 3D printed	**99.89%**

4.3.3 Mechanical Properties

	UNE EN ISO 6892-1	
	Meltio XZ Properties (HT.1 + HT.2 + HT.3)	**Meltio XZ Properties (As Printed)**
Ultimate Tensile strength (UTS) [MPa]	2087 ± 2	1830 ± 105
Yield strength [MPa]	1735 ± 101	1170 ± 90
Elongation [%]	12.18 ± 0.19	3.46 ± 0.36
	*Tests Carried Out In IDONIAL *info@idonial.com*	

5. How to add Conformal Cooling features with LMD



5.1 Conformal Cooling introduction

Molds and dies operating with hot materials, whether polymers or metals, require cooling to increase their longevity and reduce the cycle time, therefore increasing productivity.

Conventionally manufactured molds and dies typically employ cooling channels made by straight lines with a circular section, as this geometry can be obtained easily and reliably through drilling processes. This approach however is chosen as a consequence of the limitations of the manufacturing technologies and it is generally somewhat far from the ideal cooling performance that can be achieved on the molding tool.

Improved cooling features can be obtained by adopting, thanks to Additive Manufacturing, a “Conformal Cooling” approach, i.e. internal channels designed to broadly follow the shape of the external surface in order to provide the most efficient thermal exchange between the hot surface and the cooling fluid.

The benefits of conformal cooling are significant. By reducing cooling time, cycle times can be decreased, which increases productivity and lowers production costs. Additionally, parts produced with conformal cooling have fewer defects, resulting in higher-quality products.

Conformal cooling also allows for more complex part designs, as traditional cooling channels can limit the geometry of the part. The ability to place cooling channels closer to the surface of the part can reduce the amount of warpage, distortion, and residual stresses in the part, resulting in better part quality.

Overall, conformal cooling is a valuable tool for the mold-making industry, allowing for faster production times, improved part quality, and more design freedom.

5.2 Basic designs: teardrop and house-shaped channels

Several Additive Manufacturing technologies allow the production of conformally cooled mold inserts and dies. Curved paths are fully achievable,and printability can be obtained by including some design changes compared to conventional shapes.

The most common design shift is converting channels not perpendicular to the build plate from a circular section into a teardrop-shaped one. This is required in order to provide a self-supporting geometry on the top of the channel, compared to a curved top which would require supporting material to be printed correctly.Teardrop shape

Teardrop Shape

Teardrop-shaped cooling channels are typically wider at the bottom and narrower at the top, with a rounded edge at the wider end and a pointed edge at the narrower end. This shape allows for a large surface area for heat transfer while maintaining a thin wall thickness and minimizing the amount of material used.

Designing a teardrop shape that can be printed effectively requires careful consideration of its angle relative to the central vertical axis. In order to ensure proper printability, the teardrop shape should have an angle of 25 degrees or less with respect to the central vertical axis that coincides with its midline. When considering the horizontal axis, the angle should be 65 degrees or greater.

A teardrop shape with an angle greater than 25 degrees from the vertical axis may be difficult to print or may require additional support structures. In general, a smaller angle will result in a more easily printable shape.

It is also important to consider other design factors when using teardrop-shaped cooling channels, such as the spacing between channels, the thickness of the walls which should be at least 2.0 mm (the minimum wall thickness printable with Meltio's technology). These factors can all impact the performance of the cooling system and the manufacturability of the part.

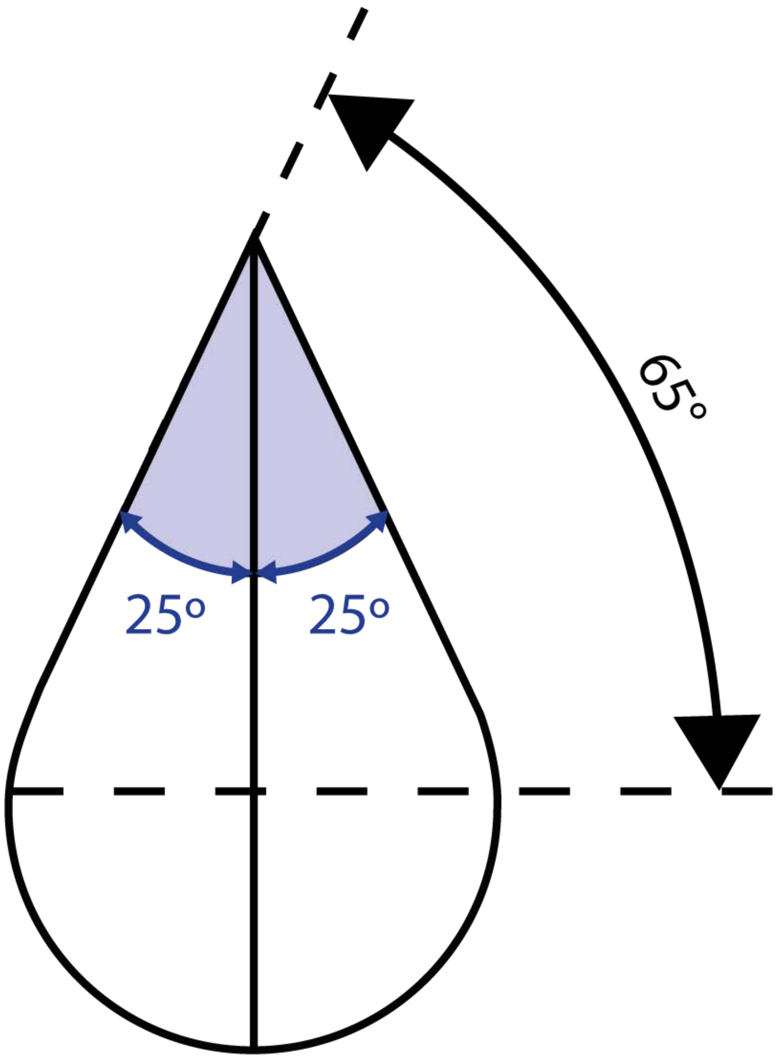


Fig. 4.3.2: Polishability of Tool Steel H11, index of high density.

Once the model with the cooling channels is designed, it needs to be imported as a mesh file into the slicing software. All the features of the channels will be in this single file.

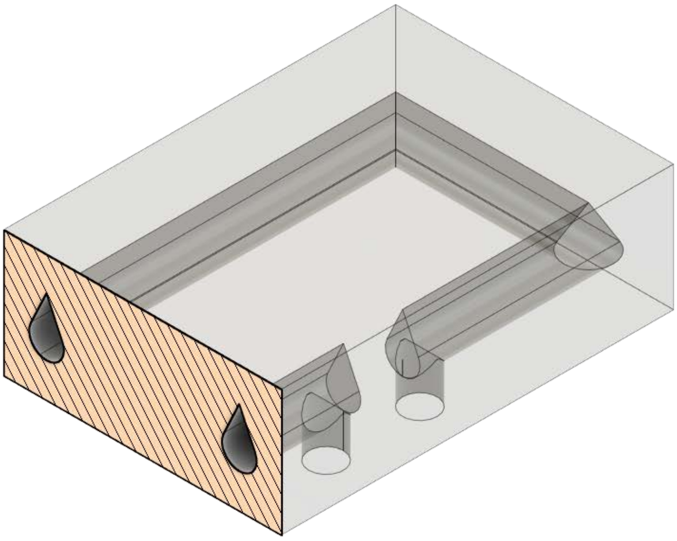


Fig.5.2.2: Cross section of the part with the teardrop shaped cooling channel

Fig.5.2.3: photo of a sectioned sample with teardrop-shaped cooling channels

House shape

As the name suggests, these channels have a cross-sectional shape that resembles a house, with a peaked roof and angled walls.

The house-shaped cooling channel design can be effective because the angled walls create turbulence in the coolant flow, increasing heat transfer efficiency. The peaked roof of the channel also provides additional surface area for heat transfer. Nonetheless, an improper design or printing parameters can result in reduced cooling efficiency or other defects in the final part.

The house-shaped cooling channels may be more difficult to print than simpler shapes like teardrop-shaped channels. The angled walls and peaked roof of the channels can create overhangs and therefore, the same consideration for the teardrop section should be taken into account : an angle from the vertical middle axis of 25 degrees or less in order to preserve printability. [For further guidance refer to Meltio Technical Resource "Printing cooling channels using Meltio AM"]

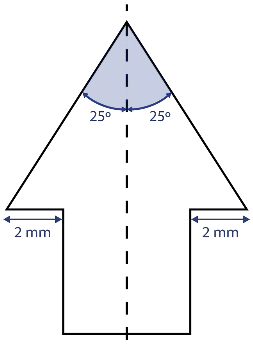


Fig.5.2.4: Internal angle to the house shape cross section with 2.0 mm distance between the vertical walls and the lower corners of the "roof"

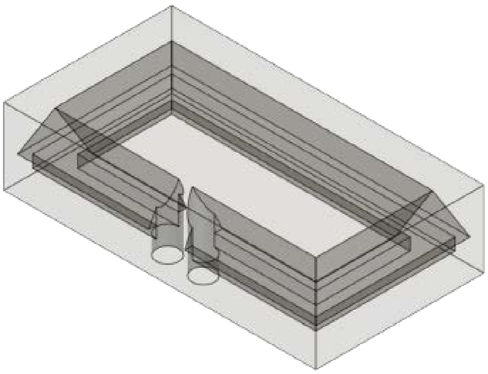


Fig.5.2.5: Part with the cooling channel cavity (darker gray)

5.3 Advanced designs: channel bridging and gyroid infills

While the teardrop shape is still a common choice for molds and dies manufactured with Meltio LMD, the latest developments in slicing strategy open up to more possibilities. Dedicated printing parameters on the top surface of the channels allow the achievement of short bridges and therefore square holes. Full redesign of the cooling features can allow the use of gyroid infills.

Squared shape

Square-shaped cooling channels are often used in cooling systems for various applications, including electronic devices, engines and industrial machinery.

One advantage of using square-shaped channels is that they can provide more surface area for heat transfer compared to circular or other shapes. However, there are also some drawbacks to using square-shaped channels since they can be more difficult to manufacture than circular channels, and they may be more prone to developing stress concentrations at the corners, which can lead to cracking or failure over time.

To have a squared shaped cooling channel, the most complex step is to print the top face of the square since it consists of a bridge between two walls. Therefore, it is necessary to design the top face in a specific way to guarantee its printability. [For further guidance refer to Meltio Technical Resource “Printing cooling channels using Meltio AM”]

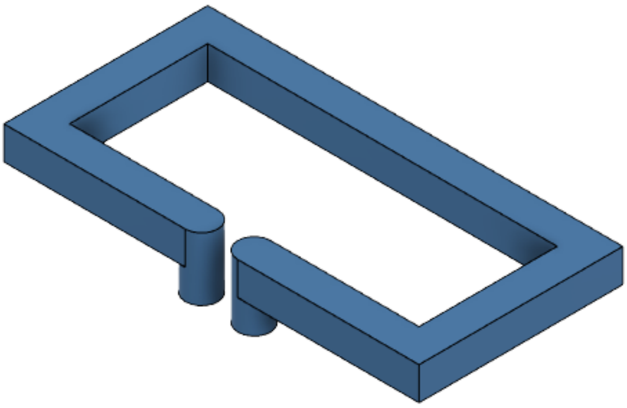


Fig.5.3.1: CAD model of the square shaped cooling channel

Fig.5.3.2: photo of a sectioned sample with square cooling channels

Gyroidal lattice infill

Gyroidal lattice infill is a type of 3D printing infill pattern that consists of a repeating, porous lattice structure. This lattice structure can be used to create conformal cooling channels in 3D printed parts.

The gyroidal lattice infill pattern is particularly well-suited for use in conformal cooling channels because of its ability to create a complex, interconnected network of channels that can efficiently remove heat from the part. The lattice structure is made up of interlocking, curved channels that provide a large surface area for heat transfer while maintaining structural integrity.

Using a gyroidal lattice infill for cooling channels can provide a lot of flexibility in terms of the geometry and shape of the channels. By incorporating a gyroidal lattice infill into the design of a cooling channel, it is possible to create channels with complex, unconventional shapes. Thus, a cooling channel using a gyroidal lattice infill can match the part’s shape without any issues and follow its contours, without the need for additional support structures.

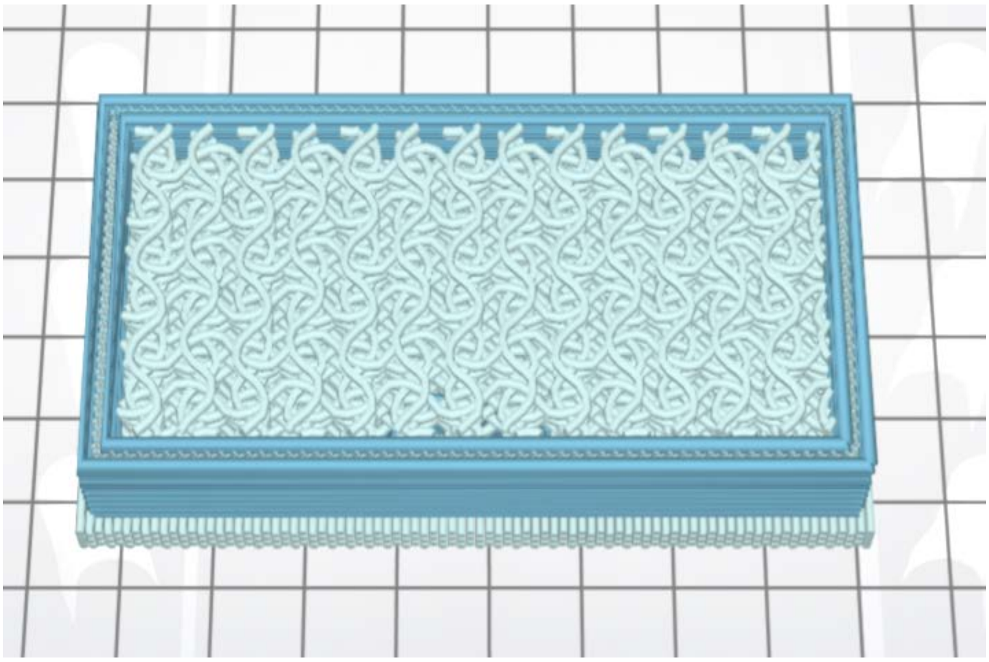


Fig.5.3.3: Meltio Horizon's print simulation showing the cooling channel with a gyroidal lattice infill

Fig.5.3.4: photo of a sectioned sample with gyroidal cooling channels

5.4 Why Meltio Wire - LMD for Conformal Cooling

Meltio's wire LMD process offers competitive advantages over conventional processes, by reducing the number of manufacturing steps and optimizing material utilization.

Moreover, from small inserts to larger molds and dies, Meltio's wire LMD process also offers the following economical advantages over competing powder-based AM processes:

- **Direct process:** there is no sintering required, therefore no extra heat treatment cycles compared to billet material;

- **High density:** there is no risk of having the coolant leak and the working surfaces can be polished to high shine;

- **Lower cost feedstock:** welding wires can be up to 10 times cheaper than powder;

- **No de-powdering requirements:** while powder based processes allow great design flexibility, internal channels thus manufactured require to be cleaned of unused powder, a process that at times can be lengthy, costly and potentially leading to redesign; with wire-LMD there is no such need and the channels are usable as-printed;

- **Dual material readiness:** Meltio wire-LMD process can offer novel approaches to potential reduction and performance improvement, thanks to the capability of using two materials in the same print;

- **Capability of 3D printing on existing components:** when employed in a 5 axis platform, Meltio wire-LMD process enables the capability of depositing material over shaped substrates, such as pre-machined mold bases or tools requiring repair.

6. Dual Wire Capabilities

Meltio's printhead is equipped with two independent wire feeders allowing the use of two compatible metals within the same print, with no limits on the number of times the active material switches to the other.

On material switch-over one material is retracted, by just 50mm. Once it reaches its final position the second material is pushed through the same nozzle and the printing process continues. This happens in less than 5 seconds. Both feeders are equal in performance, therefore there is no preferred material.

Thanks to the use of wire feedstock, there is no cross contamination between the materials, each alloy is deposited exactly where it is needed and the unused feedstock is not affected.

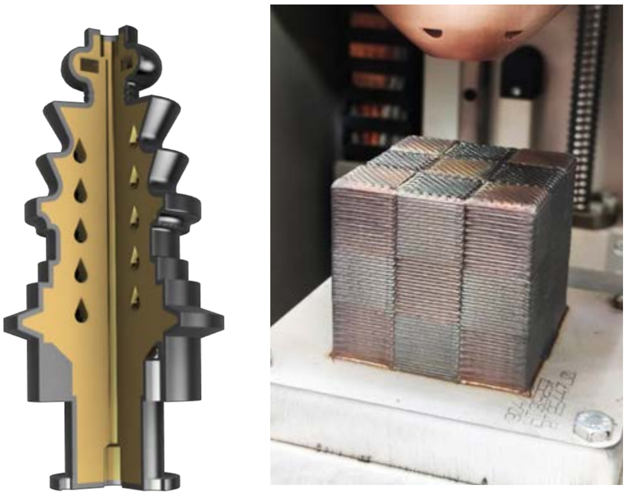


Fig. 6.0.1: mold insert design with core printed in a different material than the tool steel surface
Meltio's Rubik Cube showing hundreds of material changes

The potential advantages for mold-making are the following:

- Printing easily machinable supports (e.g. in Mild Steel) for Tool Steel components; this saves cost by directly reducing the waste of the more valuable materials and by indirectly increasing tool life in the machining steps;
- Reducing cost by depositing Tool Steel only in the areas where its mechanical properties are required, while keeping the bulk of the mold in a less expensive steel;
- Printing cooling channels in a corrosion resistant metal to increase the durability of the component;
- Printing cooling channels in a more conductive metal to improve thermal transfer.

7. Examples of Molds and Dies

Meltio performed and is constantly engaged in trials with mold-makers and final users.Meltio 3D printed samples successfully proved the viability of the technology: performance in line with fully machined components, yet employing more advanced, leak free, cooling channels.

The high density achieved with the wire LMD process leads to high mechanical properties and highly polishable surfaces, resulting in flawless injection.

Case Study:
Conify and Modular Molds for Polymer Medical Items

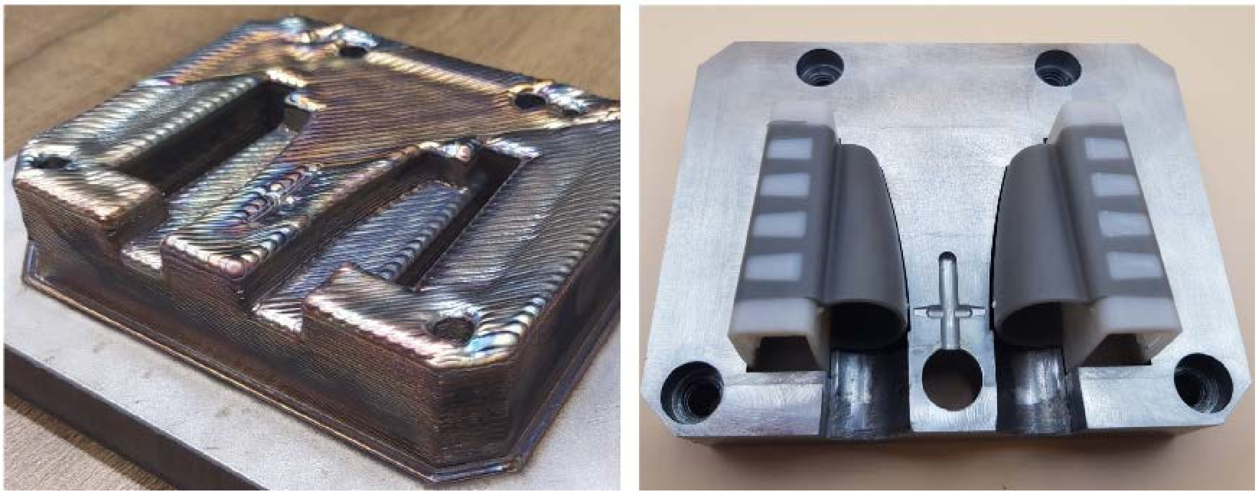


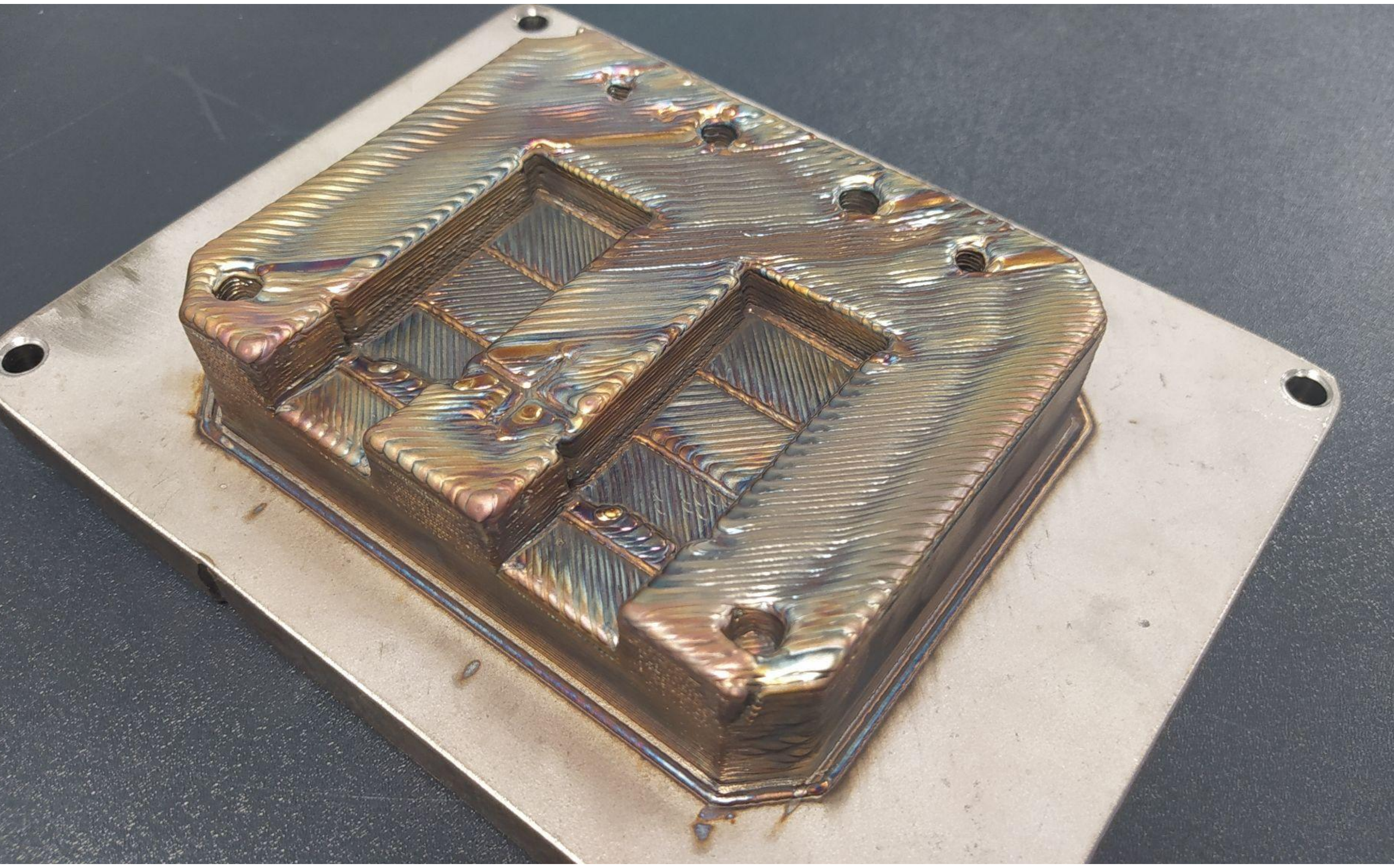
Fig. 7.0.1: Conify mold as printed and as operational

The EU Project imPURE managed to develop a methodology to reuse existing pilot lines for manufacturing medical materials through design and development of modular molds for injection molding. An Additive Manufacturing-enabled approach for fast repurposing of industrial IM lines was established and validated. A base master die was adapted to receive, align, clamp and release inserts of standard dimensions so that different dies could be quickly changed, thus reducing cost per die and setup time of each product.

CONIFY selected AISI-420 martensitic stainless steel for manufacturing mold inserts for oximeters, due to good corrosion and wear resistance. Poor ductility and toughness, together with AM-induced anisotropy, were the main challenges to address. CONIFY defined a multi-step methodology, combined with CFD simulation, to study the effect of different process parameters, validated through printing trials, to identify the process window in MELTIO M450 multi-material wire-laser metal 3D printer.

During 9-hour full scale printing of modified 3D models, to account for post-processing, the fine tuning of optimum parameters was selected as the approach for fast on-demand manufacturing. Raw material cost was another key-factor for assessing the value of the processes, where the cost for powder was at least 5-8 times higher than the commodity welding wire employed in the Meltio M450. Post AM Annealing heat treatments were necessary to reduce HRC values from 57 to 28.

The annealed inserts were subsequently machined to achieve the desired design features. For the final post-processing stage, CNC and die-sinking EDM and tool finishing were employed (Ra = 0.025 μm). The dimensional accuracy of the as-printed inserts was evaluated through 3D scanning to perform Digital Geometric Dimensioning and Tolerancing analysis. It was observed that the resulting average deviation between the as-deposited part and model was approximately 0.38 μm. The manufacturing IM trials successfully produced 1,000 sets of oximeters, verifying the quality of the DED molds and the overall methodology for rapid IM tooling manufacturing.



Development Project:
Polymer Injection Molding Insert - Consumer Product

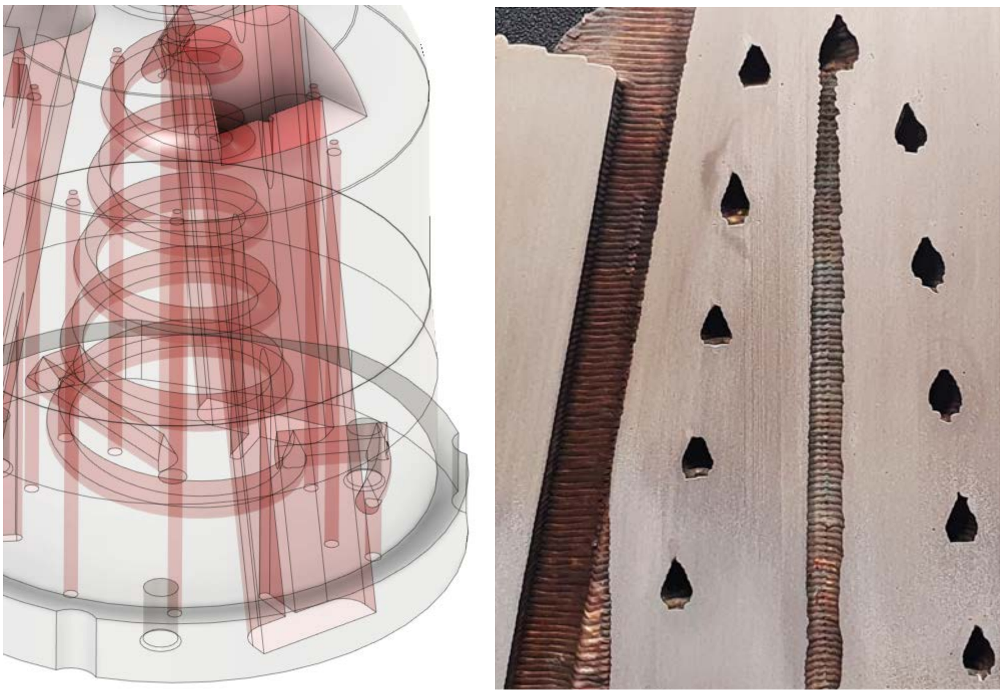


Fig. 7.0.2: overview of the complex cooling channels in this project
CAD model and sectioned printed sample

A large size (about 15.0 kg) polymer injection molding insert was printed on the Meltio M450 unit, with limited DfAM converting the cooling channels section to teardrop shape. The cooling channels follow a spiral path along the main axis of the part starting from the bottom face.

After printing the insert underwent heat treatment, machining and EDM post processing in order to achieve the surface finish and dimensional accuracy required by the process.

Development Project:
Polymer Injection Molding Insert - Automotive Optical Component

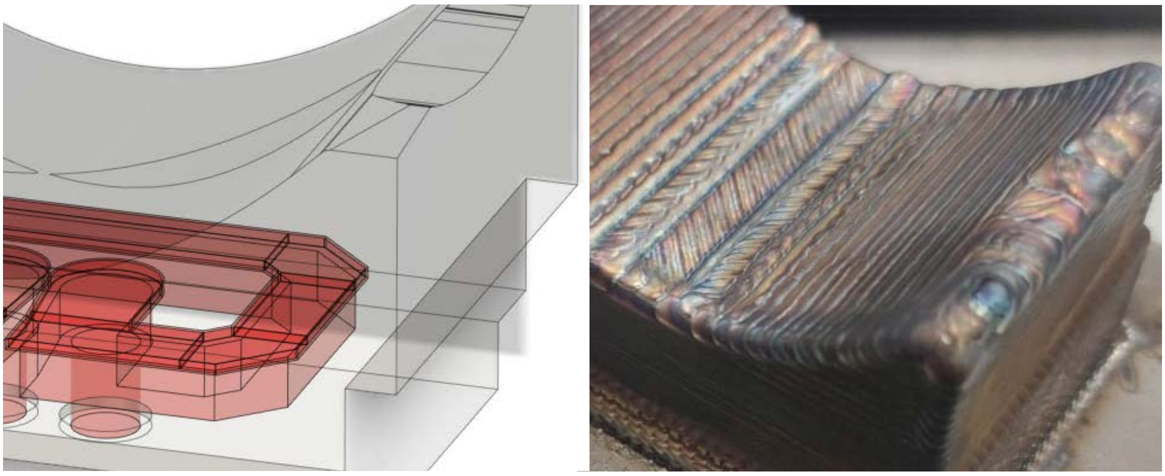


Fig. 7.0.3: overview of the project with its square-section cooling channels - CAD model and printed sample

A small (about 1.0 kg) polymer injection molding insert was printed on the Meltio M450 unit, in several iterations: replicating the original, with no cooling, and with cooling channels with a rectangular section. This was made possible with careful parameter development, allowing the possibility of adding conformal cooling to an existing design not yet cooled.

The printed part underwent machining, polishing and laser texturing of its active surface, showing excellent density and surface quality, a requirement of utmost importance for a tool to manufacture optical components.

Development Project:
Sector of a Die for Hot Stamping of steel sheets

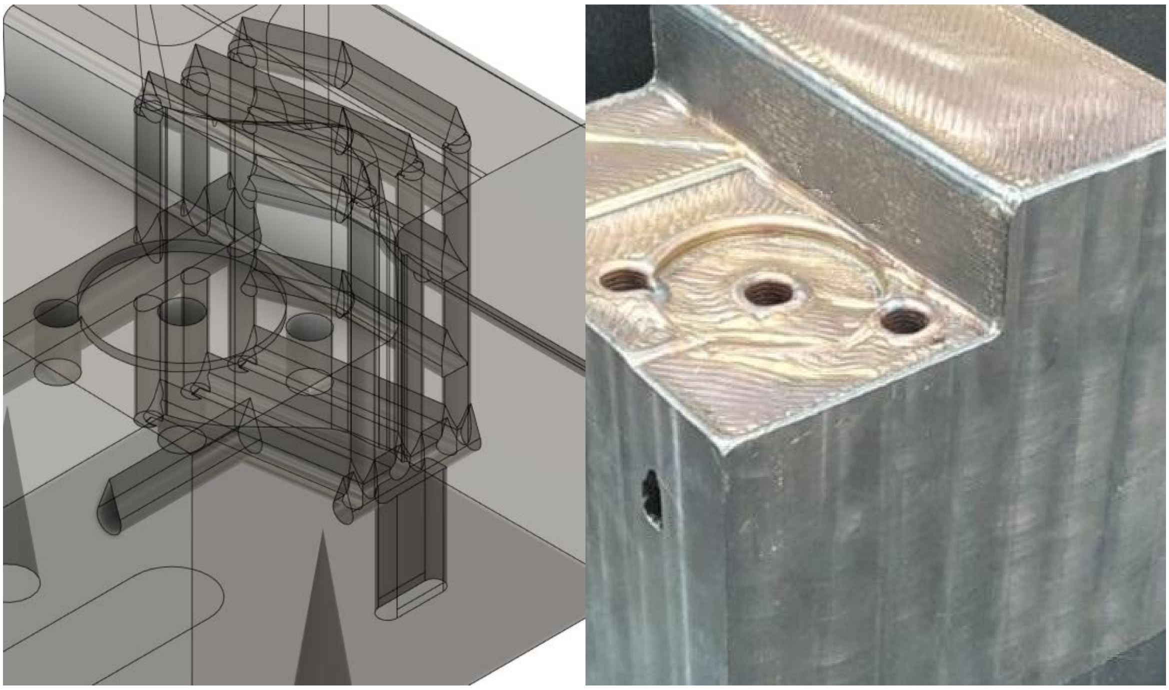


Fig. 7.0.: overview of the project - CAD model and printed sample

A large size (about 15.0 kg) hot stamping die was printed on the Meltio M450 unit, a replacement part of an existing tool, adapted with limited Design for Additive Manufacturing to convert the cooling channels section to teardrop shape.

Heat treated, machined and set in operation, the die has logged over 17,000 cycles at the time of writing, with no noticeable signs of wear.

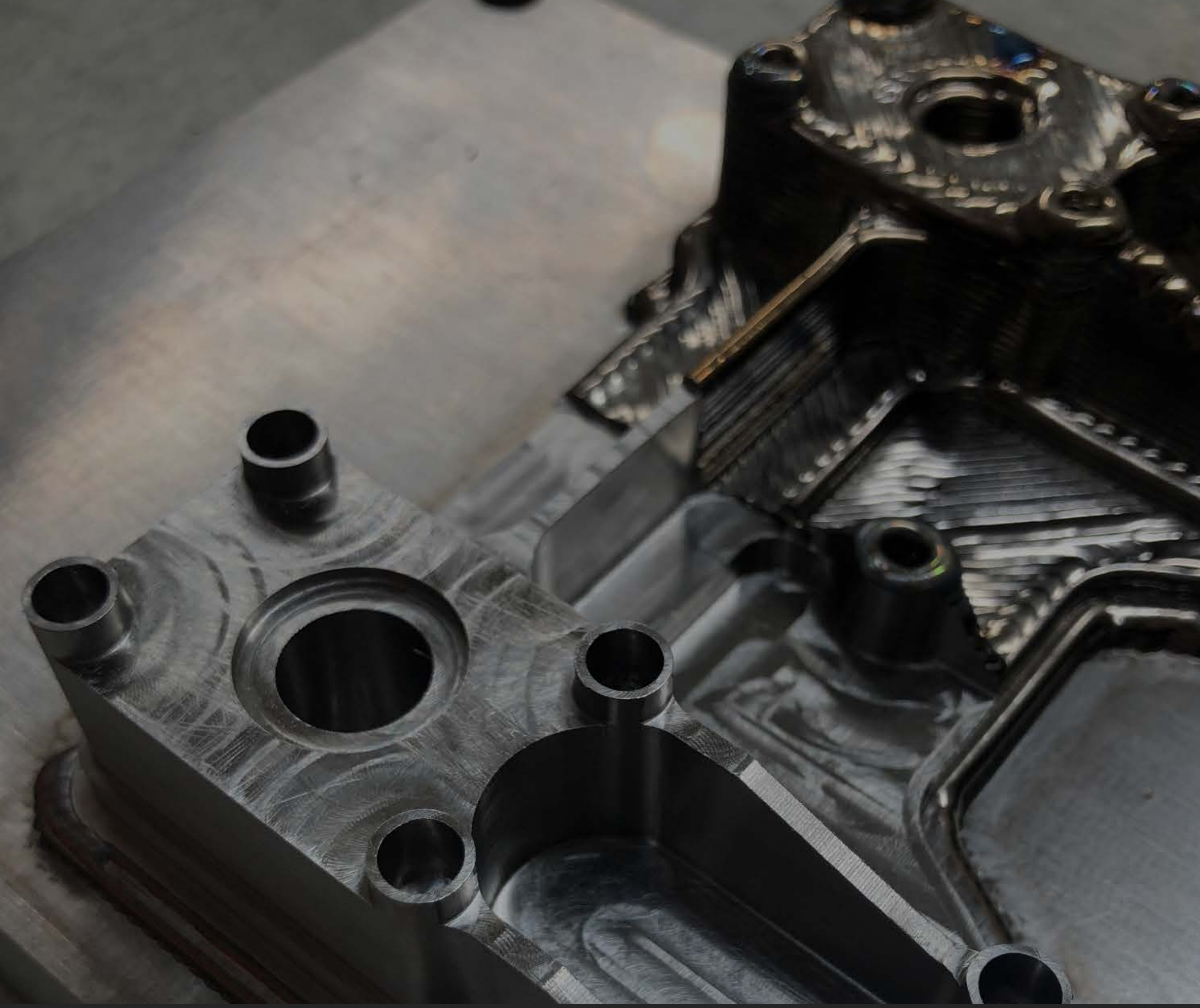
8.Conclusions

In conclusion, the Meltio wire Laser Metal Deposition (LMD) process emerges as a transformative solution for the manufacturing of molds and dies, surpassing conventional processes in both performance and efficiency. With the ability to meet the density standards of wrought stock while optimizing material utilization and offering conformal cooling capabilities, Meltio's wire LMD process enables advancement in mold-making.

One of the key advantages of the Meltio system lies in its flexibility. The Meltio M450 and Meltio Engine offer size ranges suitable for molds and dies weighing up to 15 kg / 33 lbs and 50 kg / 110 lbs respectively. Moreover, the system has been successfully tested with various Tool Steels, with an initial focus on Hot Work steels. Thanks to Meltio's Open Materials strategy and dedicated parameterization process, any steel available in wire form can be utilized, providing unparalleled versatility.Meltio's wire LMD process also brings notable economic advantages over competing powder-based additive manufacturing (AM) processes. With a direct process that eliminates extra heat treatment cycles and offers high density, highly polishable surfaces, Meltio reduces manufacturing steps and optimizes material utilization. Additionally, welding wires used in the Meltio system can be up to 10 times cheaper than powder, minimizing cost without compromising quality. Furthermore, the absence of de-powdering requirements and the readiness for dual material usage further contribute to cost reduction and performance enhancement.

The process benefits extend beyond direct cost savings in the printing process. By enabling high-resolution near net shapes and incorporating Design for Additive Manufacturing (DfAM) principles, material waste can be significantly reduced. Moreover, by transferring the roughing step from CNC machining to the additive step, more CNC machine capacity is made available, reducing CNC machine time and increasing efficiency, this also leads to a drastic decrease in CNC tool usage and wear, lowering tool costs and extending their lifetime. Furthermore, assembly consolidation is made possible, ensuring airtightness and avoiding potential leakages from cooling channels.

In summary, Meltio's wire LMD process offers an innovative and cost-effective solution for the production of molds and dies. Its ability to combine high density, optimized cooling, and material utilization with economic advantages and improved performance sets it apart from conventional and competing AM processes. With Meltio, the future of additive manufacturing in the molds and dies industry has arrived.



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