EBOOK

Pathway to Metal AM Adoption: Overcoming Metal AM's Core Challenges

VELO 3D

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Introduction

Metal additive manufacturing (AM), despite being a revolutionary technology with tremendous potential, remains challenging to adopt. AM's historic challenges of complexity, cost, and quality are significant hurdles to mainstream usage.

However, these challenges, though substantial, are not insurmountable. The way forward starts with addressing these limitations and unlocking a cycle of technology adoption, advancement, and employment.

This eBook dives into these challenges and presents a straightforward outlook on how to overcome them for AM to gain wider adoption, enable innovation, and robustly bolster global supply chains.

> "The way forward starts with addressing the limitations of cost, lack of standardization, and quality control."

Cost Considerations

CHALLENGE:

Cost is among the first issues when considering AM. Not every part should be printed and it can be difficult to know whether a specific part is a good fit or not.

The final cost of a printed part has many variables. For example, the price of the metal powder can range between $50 and $300 / kg. However, this is only a portion of the total, representing between 20% and 50% of the total printed part cost. Producing parts that can reach value densities ($/kg) in the multiple hundreds of dollars per kilogram, AM can seem expensive but for the right application, this manufacturing process creates unmatchable value.

Metal 3D Printing

Metal AM Powder

$50-$300/Kg ~ 20-50% of
COMPLETE AM part cost

Metal AM Parts

$150-$1,000/Kg

One of the key questions to answer is "what is the value of 1%?" For example, if we could lower weight, improve performance, or decrease size, by 1%, how valuable would that be? By comparing the value density ($/kg) of the end market item to the printed part value density, we can start to see markets that are a clear fit for AM and markets where AM would potentially be too expensive. For example, a high-end car might see a value density of only $25/kg - a poor fit in general for AM. On the other hand, a commercial jet might be orders of magnitude higher and be a great fit for parts produced by AM. Cost is a key element that guides engineers to decide on a final manufacturing technology. While metal AM still exhibits one of the higher cost structures, there are many applications where the added value more than makes up for the high initial production expense.

Application Fit Requires Commercial Fit

Retail Price: $50,000
Weight: 2,000 kg

Value Density: ~ 25 $/Kg

Price: $100,000,000
Weight: 40,000 kg

Value Density: ~2,500 $/Kg

How do we overcome this challenge? Lowering costs is a primary step. This can be achieved by increasing throughput with higher-powered lasers, thicker layers, larger build volumes, and more streamlined workflows. Advances in technology are already leading in this direction.

For example, the Sapphire XC 1MZ metal AM printer from Velo3D is four times faster than its predecessor, with a print volume 10 times larger.

Larger printers also enable various industries to access the blue ocean of new-market parts that are bigger and that have previously only been achievable through more expensive means of production.

Pictured: Velo3D Sapphire XC 1MZ. The printer features 8 1kw lasers and build volume of Ø 600 mm x 1000 mm z.

Standardizing Qualification

CHALLENGE:

The second challenge is the ability to consistently generate parts with reproducible material properties and dimensional accuracy, irrespective of the machine used, the manufacturing year, or the supplier. The lack of standardization makes it extremely difficult to scale the supply chain, making qualification highly expensive.

In conventional CNC machining, it is common to achieve consistent and repeatable quality outcomes. However, this is not always the case in metal AM, due to the industry's fragmented nature. There are hundreds of service bureaus that offer AM services, and each bureau may have its own manufacturing processes and protocols. This can make it difficult to ensure that the quality of AM parts is consistent from one bureau to another.

Every new part requires process innovation, and every supplier has its own process variation. Each machine needs tuning and can have its process drift over time. This level of variation puts a significant strain on creating standardized design allowances in the industry.

Consequently, it is exceedingly challenging to standardize quality and create scalable supply chains from such an intricate network of independent operations.

A standardized, universal manufacturing process can enable machines to produce the same parts from a standard file, eliminating the need for customizing the process for each part.

For example, Velo3D's "Golden" Print file mirrors this capability. A print file is a set of digital instructions that tells a 3D printer how to create an object layer by layer. It contains information about the desired object's shape, structure, and dimensions. The printer reads this file and uses it as a guide to build the object from the bottom up.

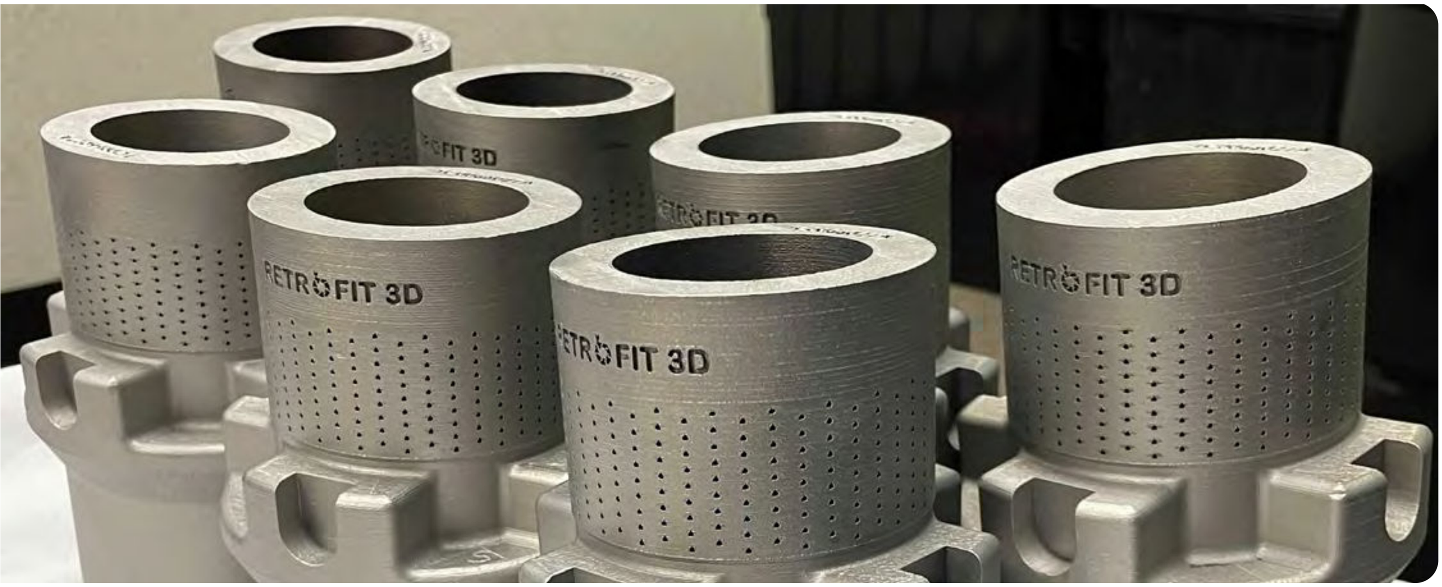
One Velo3D "Golden" Print file produces the same part on any Velo3D printer

*Distributor with printing capability only

The Velo3D "Golden" Print file is a highly optimized and refined version of a print file. It represents the ideal settings and parameters for producing the highest quality 3D printed objects using Velo3D's technology.

At Velo3D, we have spent significant time and effort developing this "Golden" Print file and fine-tuning it to achieve the best possible results.

Completed choke valve trims printed in Inconel® 718 on six separate Velo3D Sapphire printers across three continents.



By using the “Golden” Print file, we aim to ensure consistent and reliable production of high-quality 3D printed parts and serve as a standardized reference for achieving optimal printing outcomes, allowing users to replicate successful prints and maintain a high level of quality in their manufacturing process.

IMI Critical Engineering

PART NAME:	**MATERIAL:**
Choke Valve Trim	Inconel® 718
INDUSTRY SECTOR:	**ADDITIVE PROCESS USED:**
Oil & Gas	Laser powder bed fusion
PART DIMENSIONS:	
106 mm ø x 150 mm height	

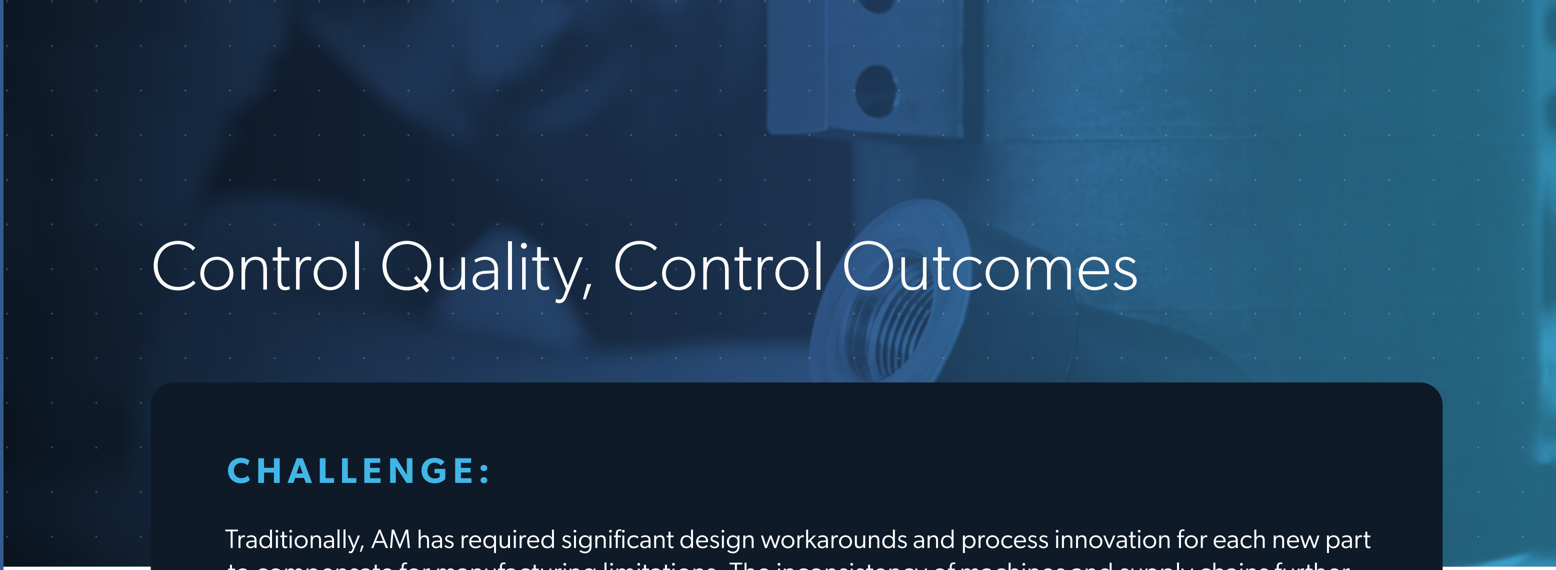
In November 2020, IMI Critical Engineering successfully qualified and fielded a printed choke valve trim for an O&G Operator. The parts were printed on a Velo3D Sapphire metal 3D printer operated by contract manufacturer Knust-Godwin.

BENEFITS OF AM TECHNOLOGY

- DRAG™-optimized legacy valve part
- Improved maintenance and supply chain scalability
- Automated logging of essential variables layer-by-layer to meet API20S requirements

IMI Critical, a company that makes flow control solutions, worked with a major oil & gas operator to test metal AM for reducing lead time in making critical parts, especially choke valve cages, for difficult-to-reach places. IMI worked with Velo3D to design an improved choke valve cage. This design improvement was captured in a “Golden” Print File, a set of universal printing instructions that can be used on any Velo3D Sapphire printer anywhere in the world.

IMI used the “Golden” Print File to work with Velo3D’s global network of contract manufacturers to successfully print the same design in six different locations around the world. The resulting parts were of identical quality and performance. This shows that metal AM can drastically reduce lead time in producing core parts and can also be scaled as needed.



Control Quality, Control Outcomes

CHALLENGE:

Traditionally, AM has required significant design workarounds and process innovation for each new part to compensate for manufacturing limitations. The inconsistency of machines and supply chains further complicates this development process, requiring constant adaptations to meet minimum consistency requirements. The need for constant reinvention adds to the burden of creating an educated workforce capable of leveraging AM technology.

Built-in metrology within the machine and software can ensure consistent quality. This approach makes the printing process more transparent and qualification more straightforward and scalable.

To ensure consistent outcomes, the Velo3D metal AM solution includes Assure, a quality control software enabling visibility into every build layer through real-time, multi-sensor monitoring. Assure tracks and reports Sapphire's 'pre-flight' check before each build, ensuring that performance is within specification.

Assure – Quality Control Software

Factory Monitoring

- Real-time machine fleet tracking
- Live build progress monitoring

Printer Health

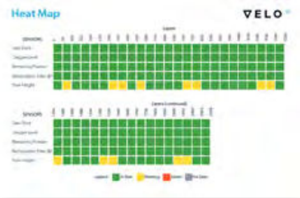
- Automated system calibration

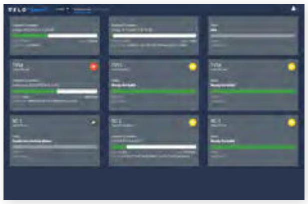
In-process monitoring

- Optical health
- Powder bed quality
- Build chamber environment

Build report

- Build information summary
- Tool and build data documentation





During a build, the system validates critical parameters such as powder bed health, consumables, chamber atmosphere, and optics, which monitor nearly 1,000 different readings. These checks validate that a Sapphire printer is ready to print and stays within specification during a print.

Each build includes a detailed build report that contains part quality data and printer health results for the part. With this information, Velo3D is making it easier to qualify parts with less effort and move AM into production. With this automatically generated report, engineers gain insight into the AM process that can form the foundation of knowledge for AM compliance requirements for many industries. This report offers full traceability of system performance and provides detailed information on interruptions and deviations observed during a print.

Development Complexity

CHALLENGE:

The challenge of making parts manufacturable adds another level of complexity. Engineers have to learn to apply workarounds due to manufacturing limitations to each part they design. The variability in conventional AM machines and lack of standardization causes inconsistent quality and prevents the formation of a strong supply chain.

Addressing the development challenge requires flipping the design approach on its head. Instead of designing for additive manufacturing (DfAM), manufacturers need to make AM more serviceable. This paradigm shift involves developing a standardized manufacturing process that can be applied to various parts without requiring specialized skills or constant re-invention of the wheel. As a result, AM becomes a dependable tool akin to a CNC machine, paving the way for more widespread use in volume manufacturing.

Critical Feature: Part Consolidation

The uniqueness of the design lies in how much functionality just one part serves. Building a system like this with traditional manufacturing methods can take months to years of development along with hundreds of individual components that would require brazing or welding. This component consolidates an inlet spike, heat exchanger, flame holder, struts, and fuel injectors into one-piece. It was printed in just eight days without supports.

Critical Feature: Perforated Boundary Layer Bleed

Velo3D technology made it possible for overall engine efficiency with a consistent perforated array of 500 µm holes. With this consistency and remarkable circularity, it minimizes the thermoacoustic instabilities and diffuses supersonic flow regimes caused in the inlet spike.

Critical Feature: Flow Channels

Velo3D's ability to produce parts with thin walls, lattice structures, and complex internal channels such as the flow channels of this ramjet. This can prove exceptionally valuable in supersonic and hypersonic systems.

Critical Feature: Bleed Air-Injected Flame Holder

Due to Velo3D's non-contact recoater, the flame holder of this ramjet was printed completely without supports. As air flows inside, it is then ejected out of the wake of the flame holder, helping to maintain combustion and reduce some of the parasitic drag on the engine.

This ramjet engine was developed in partnership with Lockheed Martin. It is designed for small unmanned reusable or non-reusable aircrafts flying at supersonic speeds. This display piece was printed on a 1-meter-tall Sapphire XC 1MZ in Inconel® 718 as a solid piece without supports. It was made possible with funding through LIFT, the Detroit-based national manufacturing innovation institute, in partnership with the Department of Defense.

Remember that this manufacturing technology aims to facilitate the production of parts that customers genuinely need without making them compromise their designs or enforce choices they don't want to make.

In addition, training engineers about design for AM and training process technologists constitutes a massive education effort, further slowed by the current limited technology adoption.

In contrast, the operators of Velo3D machines at our contract manufacturing locations are experienced machinists, not PhDs or scientists. This allows additive manufacturing to become a standard, reliable tool for large-scale manufacturing, like a CNC machine.

This removes the need for continuous reeducation of both the design and manufacturing technology workforce and enables the creation of a skilled, scalable supply chain that takes advantage of established manufacturing and machining manufacturers and the machinists operating CNC machines.

By extending the technology's capability limits, costs can be reduced, qualification processes simplified, development streamlined, and the human skills required minimized. This strategy will enable the AM industry to scale up and speed up adoption, unlocking its full potential.

Ready to Learn More About Velo3D?

Let us help you with your most challenging and innovative projects.

Contact us today to schedule a consultation or to learn more about our fully integrated metal AM solution.

Without Compromise

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