CASE STUDY

Print and Repeat:
Validating Metal AM Part Repeatability & Scalability

Overview

The ability to produce a new part design is common to additive manufacturing (AM). What holds AM back is the technology's inability to reproduce the **same part, system to system, site to site, year after year without requalification.**

To help overcome these shortcomings, Velo3D developed a solution designed for scalable, global production. This unique approach provides customers with a scalable, persistent supply chain that delivers identical geometric accuracy and material properties site to site, year after year.

In this case study, we examine:

- How a choke valve trim printed on a Velo3D Sapphire metal AM printer for IMI Critical Engineering—used in mid and upstream oil and gas applications—**was successfully reproduced one year after its initial qualification** using the same print instruction file (Velo3D "Golden Print File") across a global network of independent contract manufacturers without requalification.
- Why this has traditionally proved challenging for other metal AM technology.
- How the Velo3D fully integrated metal AM solution enables true distributed supply chain capability with its ability to print parts with the same material properties in different locations around the world.

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 printed choke valve trim using the Velo3D fully integrated metal additive manufacturing solution. The parts were printed on a Velo3D Sapphire® metal 3D printer operated by contract manufacturer Knust-Godwin. With Velo3D, the part was successfully printed with no design, quality, or performance compromise.

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

Challenge

IMI Critical Engineering is recognized as a world leader in flow control solutions. Its products help vital industries operate smoothly to provide the world with energy, resources, and other essential materials.

In our previous case study, the company was approached by a major oil & gas operator to conduct a pilot program to meet API20S requirements for additively manufactured mission critical upstream oil & gas components.

The original pilot program successfully validated the use of metal AM, specifically, the Velo3D fully integrated metal AM solution's ability to provide its customers with significantly shorter lead times and a simplified supply chain for critical oil & gas field service applications.

Velo3D's quality validation software, Assure, simplified the requirements to meet API20S standards for the printer parts, it also featured IMI's DRAG™ technology, resulting in optimized performance, including DRAG™-optimization of the legacy design. What's more, it achieved this without requiring part redesign or site-specific development to achieve a consistent level of geometric accuracy and material properties.

The original results proved so encouraging, IMI set out to conduct another analysis of Velo3D technology for its Retrofit3D business, which uses AM in place of traditional manufacturing methods to provide customers with high performance valve trim upgrade solutions for increased reliability and performance.

The goal of this test was to validate the Velo3D "Golden Print" file's capability to produce parts with consistent geometric accuracy and material properties and help overcome ongoing supply chain scalability challenges.

Why choke valve trims are ideal for metal AM

- Low volume/high mix
- Complex internal passages
- Traditional brazing, manufacturing process can introduce too much variation

One of the most frustrating challenges facing oil & gas organizations is the inability to quickly and reliably sourcing critical replacement parts. Often, there is no good path forward. One approach is to order more parts than you need, warehouse them, and deal with the cost and logistical headaches. Another approach is to simply endure long lead times for replacement parts. But this too is not ideal, especially if the part needed is no longer supported by a part OEM.

For IMI Critical Engineering to adopt the Velo3D fully integrated solution to scale their global supply chain, it needed to ensure that the previously printed choke valve trim could be produced at scale and meet the following success criteria:

- Consistent material properties
- Validated within specified performance envelope (in this case flow testing characteristics)

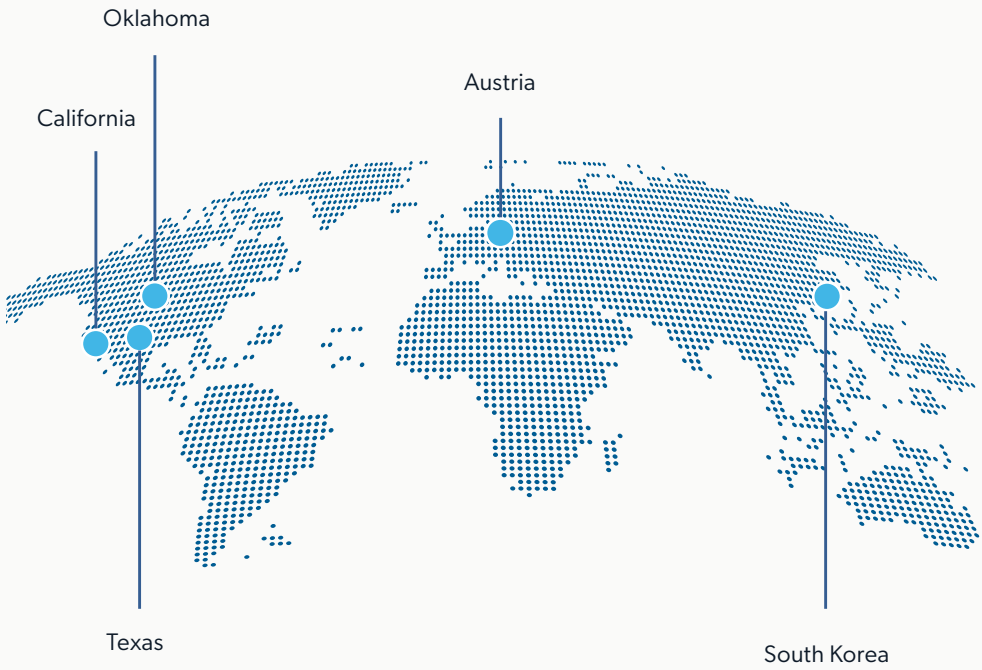
Solution

To achieve the scale, quality, and repeatability required, IMI Critical Engineering worked with Velo3D and a global network of independent contract manufacturers within the Velo3D contract manufacturing (CM) network. The collaboration involved **taking the same print file from the original production qualification completed in Q4 2020** and printing it in six separate locations (four in the US as well as manufacturing facilities in Austria and Korea).

With Velo3D, parts can be easily replicated on any Sapphire printer thanks to Velo3D's "Golden Print" file technology, which is a set of proprietary print instructions that can be used to repeatedly print a part, at multiple sites, year-after-year, on any Velo3D Sapphire printer, anywhere in the world loaded with the same print material.

Flow, Velo3D's print-preparation software, outputs an encrypted and immutable set of self-contained locked in print instructions while Assure, the solution's quality control software, allows you to check calibrations before each build to verify machine health.

The above was critical to achieving the predictable, consistent, and scalable parts production required for IMI Critical Engineering's Retrofit3D business.



Tool Health

Beam Stability	Value	Status	Timestamp
Optics Box + Window			
Laser 1	-30.982	✓	2022/03/08 at 14:32
Laser 2	-24.703	✓	2022/03/08 at 14:32
Optics Box			
Laser 1	2.722	✓	2022/03/08 at 14:32
Laser 2	2.303	✓	2022/03/08 at 14:32

Laser Alignment	Value	Status	Timestamp
Overlay Variation - *x* direction	25	✓	2022/03/08 at 14:52
Overlay Variation - *y* direction	29	✓	2022/03/08 at 14:52
Laser Overlay - *x* direction	2	✓	2022/03/08 at 14:52
Laser Overlay - *y* direction	-12	✓	2022/03/08 at 14:52
Laser Mapping Accuracy - *x* direction	76	✓	2022/03/08 at 14:52
Laser Mapping Accuracy - *y* direction	75	✓	2022/03/08 at 14:52

Thermal Sensor Alignment	Value	Status	Timestamp
Offset - x direction			
Laser 1	-0.007	✓	2022/03/08 at 14:40
Laser 2	-0.103	✓	2022/03/08 at 14:40
Offset - y direction			
Laser 1	0.083	✓	2022/03/08 at 14:40
Laser 2	0.04	✓	2022/03/08 at 14:40

Laser Focus	Value	Status	Timestamp
Spot Size Center Focus			
Laser 1	6.802	✓	2022/03/08 at 18:31
Laser 2	-2.025	✓	2022/03/08 at 18:55
Spot Size Focus Across Build Plate			
Laser 1	19.204	✓	2022/03/08 at 18:31
Laser 2	19.15	✓	2022/03/08 at 18:55

Legend: ✓ In Spec ✗ Out of Spec ! In Spec older than 7 days – No Data

Assure software calibration information. The tool health checklist signifies all calibrations were performed and under defined control limits. This is a key enabler to the Golden Print file because it eliminates machine to machine variability.

Results

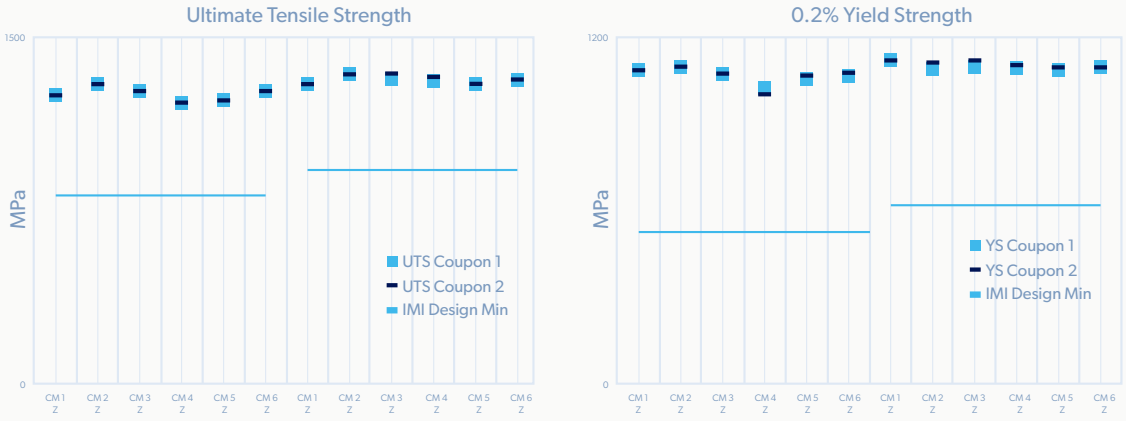
By leveraging the Velo3D fully integrated metal AM solution, Golden Print file, and Velo3D's network of contract manufacturers, IMI Critical successfully printed each build six times with two choke valve trims per build with acceptable material properties to IMI specifications in six separate locations around the world a year after the initial pilot program.

From this exercise, IMI successfully qualified Velo3D technology and validated three critical benefits of the Velo3D solution, including:

- The ability to print on any Velo3D system with consistent part performance and material properties as validated by IMI's internal material and testing specifications.
- The ability to take a previously created print file (in this case a print file from more than one year ago) and print it successfully without requalifying the process, incurring delays, or additional financial expense due to calibration shifts over time.
- The flexibility of a Velo3D contract manufacturing network to utilize existing print files and replicate the parts successfully in separate facilities around the world.

Static Mechanicals

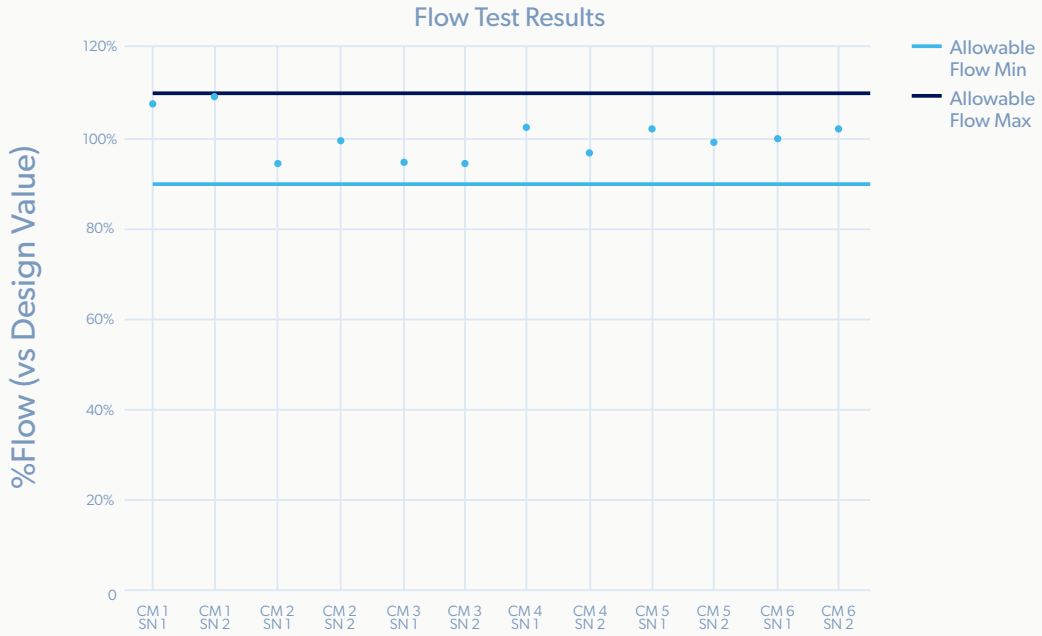
IMI Golden Print File: Tensile Results



The plot shows how the static mechanical properties for the builds maintained an acceptable spread and met IMI specifications. For reference, each build was tested twice in XY and twice in Z directions for UTS and Yield strength, per APO20S AMSL Level 3.

Flow

IMI Golden Print File: Flow Results



Contract Manufacturer 1-6
Serial Number 1/2

Flow test results demonstrating the consistent part performance for the test choke valve trims. The upper/lower flow criteria implies a dimensional accuracy of the internal channels which are +/- 0.002" (50 microns). These results underscore the quality and repeatability achievable with the Velo3D solution when working with CMs who are knowledgeable about the metal AM process.

The Importance of OEM and Industry Standards for Post-Processing

Post processing is critical to realizing the final quality of a part in any manufacturing process. This is also why industry specifications such as API20S are critical to enforcing standard operating procedures.

IMI Critical validated the technology's ability to produce its components via the global Velo3D network of contract manufacturers. This capability frees IMI from being locked into a single supplier and provides a true global supply chain for Retrofit3D to reliably provide customers with critical parts. The ability to create a bill of material, lock it in for later use, and return to that digital inventory, without any re-engineering effort, years later will help Retrofit3D to better meet the needs of its customers and scale its addressable market.

WITHOUT COMPROMISE

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