ACHIEVABLE INNOVATION

How Advanced Metal Additive Is Reshaping Manufacturing

Critical Insights from Benny Buller, Velo3D Founder & CEO

VELO3D

INTRODUCTION

Across industries, professionals are dealing with disruption and change from the effects of COVID-19, and nowhere is that more acute than in manufacturing. The increased dependence on technology has never been more essential than it is right now.

But in an environment where change is constant and unpredictable, how can we utilize the latest breakthroughs in manufacturing technology to address problems both old and new?

In this eBook, Benny Buller, Velo3D Founder and CEO, provides his insights about the ways in which advanced metal additive manufacturing can help companies overcome supply chain challenges while shining a light on the limitations inherent to conventional additive systems. Buller breaks down the difference between conventional and advanced additive manufacturing solutions, before going on to share the breakthroughs two companies, Hanwha Power Systems and Mohawk Innovative Technology, have achieved with Velo3D's advanced end-to-end metal 3D solution.

Crossover featuring complex, internal channels printed at low angles with a high-quality internal surface finish.

YOU'LL LEARN

- When to consider additive manufacturing
- The limitations of conventional metal additive
- How production-ready additive can transform the supply chain
- How advanced metal additive is helping organizations innovate

SECTION 1

ADDITIVE UPS THE ANTE

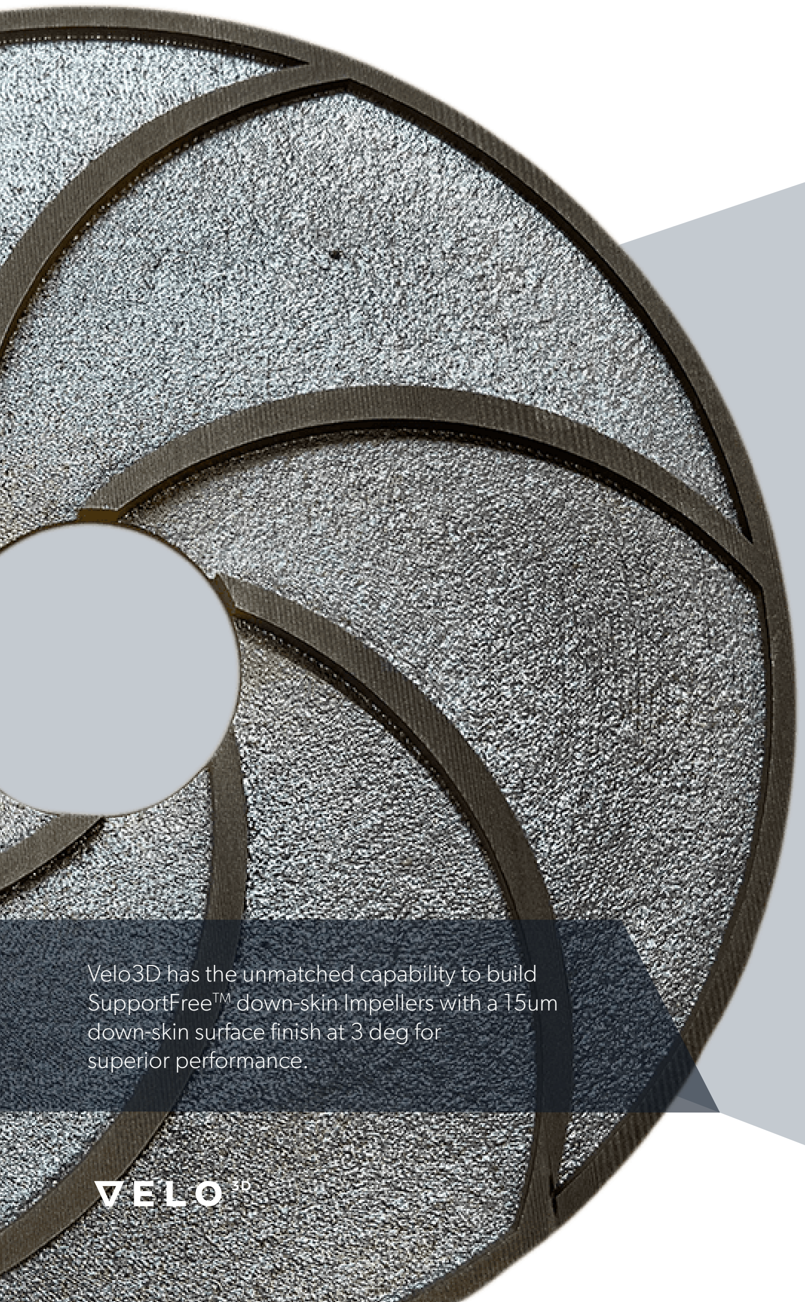
NEARLY ALL SUPPLY CHAINS ARE EXPERIENCING STRESS COMING OUT OF THE PANDEMIC

Shortages associated with labor, materials, capital, and strength of dependent networks are holding back many industries from meeting the surge in demand for goods and services.

As industrial supply chains look hard at their current production, shipping, and sourcing strategies, it's no surprise that some are reviewing their Just-in-Time (JIT) and inventory-on-hand practices.

While they handle more macro issues of working capital and orders on the horizon, these companies are also looking to tune their existing approaches.

A very real option, going forward, is to use additive manufacturing (3D printing) more aggressively to sharpen the agile and flexible manufacturing tactics already in place.



Velo3D has the unmatched capability to build SupportFree™ down-skin Impellers with a 15um down-skin surface finish at 3 deg for superior performance.

WHY IS IT TIME FOR ADDITIVE?

Additive is ideal for one-off parts, short production runs, and near on-demand fulfilment. The technology is quickly evolving from a prototyping and special applications manufacturing process to one that can authentically fit on many factory floors alongside CNC.

But when considering the economics of additive, manufacturers of all stripes should consider the cost of tooling, along with volume and time requirements.

Shorter product lifecycles tend to favor additive for agile production. Moreover, parts may be scaled-up or down in production to address unstable demand. Additive in many cases also has superior metallurgical traits.

Additive is a powerful technology designed to overcome many traditional manufacturing constraints, but there are concerns one must understand before using additive to supplement their supply chain.

ADDRESSING THE CONCERNS OF ADDITIVE

We have long preached about the possibilities of additive for mass customization and fast production. Yet leaders in aerospace and energy, for example, have been skeptical about additive quality and production repeatability.

Early adopters turned away because additive could not meet the most innovative and demanding requirements—if at all—without redesign and compromise, exhaustive parameter experiments and calibration, poor early yields, individual-part monitoring, and repeated testing.

This continues with many legacy additive systems trying to produce high-value, high-performance components, and assemblies.

OPPORTUNITIES AHEAD

Thankfully, more advanced additive systems, such as Velo3D's end-to-end solution, can now achieve desirable outcomes through optimized build-chamber dynamics and user-friendly automation.

Velo3D's Assure™ Quality Control Software

Advanced additive systems now conduct real-time, in-situ, process monitoring and control—delivering critical quality and repeatability for novel designs that simply couldn’t be achieved in the past.

OEMs: Because of their size, complexity, and supply chain structures, OEMs often move at slower speeds and depend on traditional manufacturing techniques, with the only option of amortizing the cost over large production volumes. With additive manufacturing, OEMs can better manage low volumes across complex supply chains at a reduced investment.

Contract manufacturers: Contract manufacturers often have flexible, agile manufacturing practices in place to utilize the capabilities that additive can provide for direct-part replacements. In the supply crisis, for example, long-order cast components for the aviation industry could be delivered rapidly, allowing that industry to regain some footing and cut costs. What’s more, little to no design adjustment is needed to adapt additive for these products.

Existing parts: Existing parts—where assembly and finishing costs, along with quality, have been an issue — can use additive for transforming single-part assemblies into efficient, multi-functional components. This has been proven to dramatically shrink supply chain strings, reduce costs, and cut production time. It’s also ideal for the scalable, order-to-demand tactics needed for our current, and future economy.

Why does it matter? We’re starting to witness the limitations of traditional manufacturing techniques to where additive is needed to achieve the performance we’ve come to expect from jet engines, power-generation impellers and other aerospace components, oil & gas, and alternative-energy products.

We are seeing additive radically move the performance markers in these industries—and quickly.

Early additive manufacturing alliances and contract manufacturer networks are beginning to make realistic contributions to distributed manufacturing, scalable, on-demand product delivery, and repeatable production.

SECTION 2

REDEFINING EXISTING MARKETS, CREATING NEW PRODUCT CATEGORIES

THE MANUFACTURING INFRASTRUCTURE IS POSITIONED, HUNGRY, AND READY TO GO.

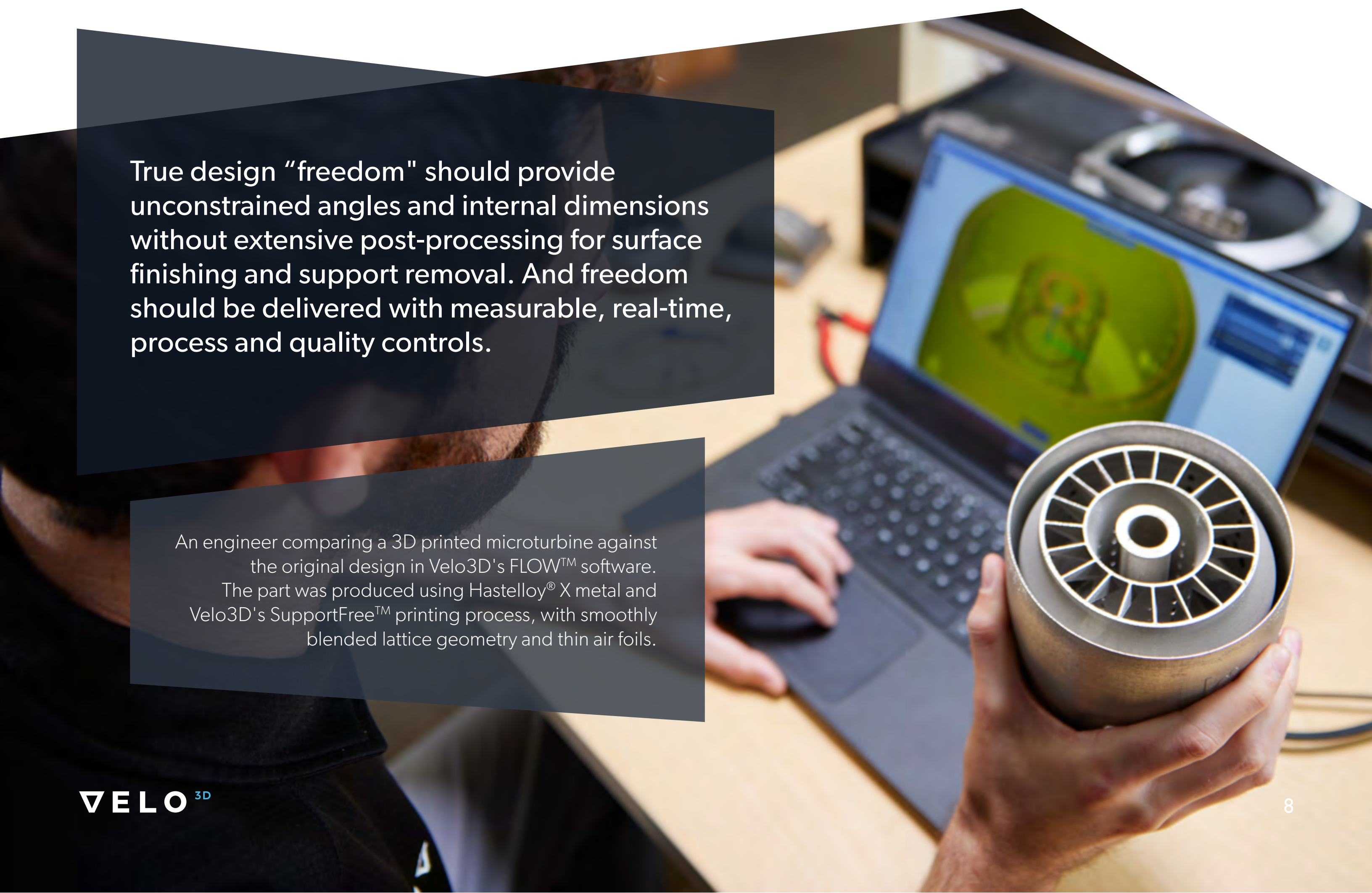
The most forward-thinking of this group are reaping the benefits of high-value, production-ready, advanced metal additive manufacturing (AM).

The most industrial-focused and impactful segment of metal AM is Laser Powder Bed Fusion (L-PBF). But progress toward mainstream performance has been anything but steady and inspiring.

Yes, there have been more lasers added and more choices provided in powder materials. But design freedom has stalled around old rules, limits, and costs. The above limitations were simply unavoidable until now.

REPEATABILITY

True reliability and production repeatability translate as: first part, tenth part, hundredth part. That means the same geometry and material characteristics outcomes regardless of whether a part is printed in Oklahoma or Ohio, Seville or Seoul, on separate self-calibrating machines. This is what's needed for innovation-based market growth.



True design “freedom" should provide unconstrained angles and internal dimensions without extensive post-processing for surface finishing and support removal. And freedom should be delivered with measurable, real-time, process and quality controls.

An engineer comparing a 3D printed microturbine against the original design in Velo3D's FLOW™ software. The part was produced using Hastelloy® X metal and Velo3D's SupportFree™ printing process, with smoothly blended lattice geometry and thin air foils.

Real growth – that flourishes out of invention and creates new, unique, expansive applications that are paradigm-breaking — can't be accomplished without repeatable production outcomes of the highest industrial quality.

TO DATE, THIS DYNAMIC HAS BEEN LARGELY MISSING FROM COMMODITY AM

It's a hard truth to hear. But there has been progress. Yet, until AM performs more daringly, predictably, and as easily as CNC operations, the true potential of AM will be reached far too slowly — even as markets in aerospace, oil & gas, power generation, and heavy industry clamor for a full-production approach.

HOW WILL PRODUCTION-READY AM TRANSFORM THE SUPPLY CHAIN?

There are three key areas where metal L-PBF can benefit a company's manufacturing agility and capacity for product-design innovation.

They are:

- Direct-part replacement of legacy designs without need for DfAM (an "as-is" design)
- Part consolidation of existing designs into single, more multi-functional components and assemblies
- Blank-slate, novel and fully optimized AM product design

These three design-engineering markets cover all AM-specific manufacturing. Each can be functionally improved by advanced AM with a corresponding boost to product economics.

DIRECT-PART REPLACEMENT IS WITHIN REACH, WORTH THE INVESTMENT

Direct-part replacement is an area where certified AM processes (along with approved-material guidelines) can have an immediate impact. Take commercial aviation. The industry is in crisis today, not just from pandemic-caused drops in passenger travel but from the inability to affordably replace worn components.

Velo3D printed parts from left to right: Titanium diffuser, sCO2 impeller, radial heat exchanger, microturbine, oil/water heat exchanger.

With advanced AM, manufacturers can create new products that have higher acceptance, end-use benefits, and profits.

The health of the industry strongly depends on a more financially viable and agile parts supply stream. That means avoiding large, upfront investments in tooling when part stocks decline, and demand is uncertain or falling.

Fleets holding older aircraft are often unwilling or unable to invest in hard tooling for a multitude of part types that have volumes of only five to 30 per year. Such low inventory turns don't justify the high, disproportionate capital tooling expenses for new products.

As a result, still-valuable aircrafts remain parked for lack of high-quality, cost-effective cast replacements for landing gears, engine components, and more.

The good news is that the direct-part replacement market, in aviation and beyond, is ripe for high-quality AM.

AM enables agile manufacturing and digital inventory replenishment that ensure adequate stock while avoiding the shortfalls and panics of Just-In-Time.

Moreover, AM metals are metallurgically superior to casted metals, making them an excellent performance stand-in and supply chain solution.

In the total-cost picture of keeping aging planes flying, or legacy oil rigs drilling, AM provides the necessary speed, flexibility, and performance to avoid costly downtime.

THE HEALTH OF THE INDUSTRY STRONGLY DEPENDS ON A MORE FINANCIALLY VIABLE AND AGILE PARTS SUPPLY STREAM

PART CONSOLIDATION OF EXISTING DESIGNS IS A GOOD FIT

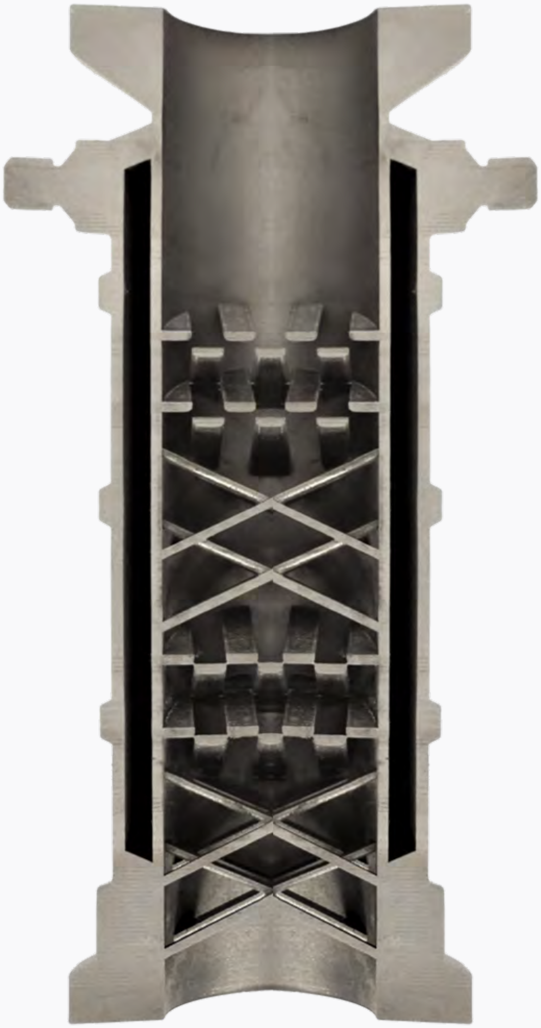
The benefits of direct-part replacement also factor into lowering the cost of manufacturing established designs. An aging design has often stood the test of time. It's reliable, desired by customers and has a stable business ecosystem around it.

So, why consolidate its separate parts?

When one considers how much of the cost of producing parts goes into the perfection of the surfaces where they interface — both in terms of dimensional accuracy and surface finish — eliminating multiple interfaces is a smart path to cost reduction.

In addition, the manufacturing flow that produces the assembly in a single print is dramatically simpler and shorter than that of creating the assembly from individual parts. This leads to an extreme reduction in production times.

The consolidation of an assembly into one "elegant," AM produced part is not only an attractive path for cost reduction but with reduced production times — coupled with relatively light engineering investment and risk mitigation — the benefits of AM solutions are clear.



Internal view of a next generation static mixer - printed without supports, even on low angle vanes and manifolding. Surface finish shown as printed with no post-processing.

AM IS THE PERFECT PART-CONSOLIDATION PROCESS

Even more so than casting and molding, no other method can build more features and behaviors into fewer parts.

Take, for example, the redesign of a popular jet engine. The manufacturer decided to reduce its production cost burden by consolidating more than 100 parts down to one, using an earlier-generation AM machine. While they succeeded dramatically in this — reducing cost by 50% and lead time by 90% — they also lost 30% of the engine performance.

The question then becomes: Can advanced AM fix the specific performance areas where conventional AM processes and design for additive manufacturing (DfAM) fall short?

THE CONSTRAINTS OF CONVENTIONAL AM

The central problem is that adapting and redesigning around the DfAM limits of conventional AM reduces the effectiveness of the original consolidated design. In the jet engine example above, performance was directly compromised to enable AM manufacturability of the consolidated assembly.

Meanwhile, an advanced L-PBF printer could fully deliver the novel design in question, continue the savings, and restore the engine performance to its original metrics. While this is a commercial-aviation example, it applies to other industries, too.

Part consolidation in legacy products — which removes costs in the supply chain, factory, ERP and MES systems, and through avoiding quality failures in mating surfaces — is critical to part excellence and profitability. As engineers have realized, and some are still learning, costs (and quality) are locked into a design early on.

Each individual part in a product — that could otherwise have been incorporated into a single, multifunctional component — has a separate part number and existence. These unnecessary parts and their numbers will travel through numerous engineering, accounting, purchasing, and manufacturing and scheduling systems toward final assembly, packaging, and shipping.

There are added material and production costs accumulated along the way, too, and extraneous suppliers to manage. Big savings always start in design and move downstream.

Today, advanced AM can eliminate part proliferation and make those high-value, consolidated designs. It has proven to reduce accumulated manufacturing and supply chain burdens, and positively influence costs.

BLANK-SLATE AM DESIGNS ARE NO LONGER A DREAM

Conceptual design distilled from bold core requirements has never been more achievable than today.

When we start from a pure thermodynamic, fluid, energy or structural goal, a design can realistically take shape around a deeply sought-after performance metric rather than the constraints of either the CAD system or manufacturing method.

Shrouded impeller printed down to zero degrees without supports using Velo3D Intelligent Fusion® technology.

This is only a recent reality.
The interdependent disciplines of design and advanced AM are now allowing for complex, finely detailed products to emerge that are optimized around physics that affect performance.

As we hit a new apex for modeling and simulation, AM, as a category of manufacturing, must become as internally automated, predictable, easy-to-use, and production-ready as its factory-floor companion, CNC.

The old rules of DfAM that have literally propped up first-and-current-generation AM part structures need to be discarded — and AM systems reengineered.

To overcome the limitations of conventional metal 3D printers, such as tilting the build plate and the use of supports, critical components of the E2 rocket, including the inducer impeller, were printed in Inconel 718 using a Velo3D Sapphire®.

SECTION 3

REDEFINE INNOVATION: BREAKING FREE OF DFAM

Today, advanced metal L-PBF AM is here to help aging aircraft, imaginative aerospace projects, critical oil and gas operations, alternative-energy ventures — and every high-performance-focused area of general industry — reach greater heights.

> “Whether duplicating a legacy design or making breakthrough innovations, advanced AM is performing new feats of engineering and creating vastly better production economics via scalable and distributed manufacturing strategies.”
>
> Benny Buller, Founder & CEO of Velo3D

With this flexible capability comes greater opportunity to redefine existing markets, create entirely new product categories, and develop quality products that have higher acceptance, end-use benefits, and profits.

Take, for example, Hanwha Power Systems and Mohawk Innovative Technology. Each company stepped out on the edge and, in pursuing their best, most aggressive designs, chose to break free of the conventions and limits of DfAM.

While AM is meant to break paradigms, the real-world constraints on AM are being downplayed for what the technology can do against machining, casting and other methods.

AM has made a significant impact on how we think about the possibilities of design and manufacturing. Yet much more development must take place for metal AM to align with high-performance, conceptual design.

There’s a reason we must call out DfAM and not the broader industrial category of Design for Manufacturing (DfM). In the semiconductor industry, rule-based and then model-based DfM went together with a relentless drive to expand the limits of the manufacturing technology. DfM was not a replacement for advances in manufacturing technology; instead, it complemented it.

DfAM today is mostly a construct to compensate for the weaknesses of L-PBF. Weaknesses that were set in the last century and stand today.

DFAM OFTEN INVOLVES DESIGNING THE PART IN WAYS THAT WILL ALLEVIATE THE NEED FOR SUPPORTS IN PLACES THAT THOSE SUPPORTS WOULD NOT BE PRACTICAL TO REMOVE OR PREVENT ACCEPTABLE SURFACE QUALITY.

Now, imagine a world where walls and internal channels include a design space from zero to 180 degrees instead of stopping at 45-degree angles like DfAM tells us we must.

The companies mentioned above used Velo3D’s end-to-end AM solution to produce remarkable product advances and far-reaching end benefits.

For the U.S. Department of Energy (DoE), Hanwha developed a shrouded impeller utilizing supercritical carbon dioxide (sCO_2) to drive an advanced Concentrated Solar Power Array.

Hanwha's shrouded impeller produced using Velo3D's AM solution in high-temperature nickel alloy (718). Compared to legacy metal AM solutions, the part required 90% fewer support structures and was printed in a fraction of the time.

What they called "huge geometric freedom" was made possible by the capabilities of the Velo3D solution, with its end-to-end process and quality controls.

This enabled engineers to imagine and deliver fully enclosed, low-angle, sweeping blades, made from a challenging-to-work-with, high-performance nickel alloy—3D printed completely without supports.

Mohawk, working on a different type of sCO2 system for a DoE solar-power project, used Velo3D to achieve what they themselves called a "pretty strange" solution, with complex geometries that addressed different fluid-flow and temperature forces inside the curved channels of volutes.

The support-free interior walls were printed at such high quality that performance was greatly enhanced, and at a cost savings of two-and-a-half times that of making such a component using traditional methods.
In both cases, engineers were able to realize the innovative solutions they imagined, rather than workarounds based on what they'd previously been able to achieve.

Velo3D helps redefine legacy AM and circumvents DfAM by virtue of its advanced L-PBF systems. With Velo3D, we can now look ahead with the same dedication and determination that the semiconductor industry used to better our lives.

Whether it's redefining existing markets, creating new product categories, or simply trying to overcome the stress of the Covid-19 pandemic, manufacturing is facing many challenges ahead. To navigate this complex landscape, organizations must utilize the best-suited, most advanced manufacturing technologies available. Velo3D is one such solution. Our end-to-end metal 3D AM solution is designed and assembled in California, and solves manufacturing needs for existing and newly created parts.

Our technologies enable innovators to control every step of the manufacturing process while delivering the necessary support to build the most challenging parts possible. We've simplified complications that have made legacy AM systems inefficient and non-repeatable, creating conditions for a more agile, less costly supply chain to revolutionize the parts production process.

Our end-to-end solution represents a paradigm shift that optimized every aspect of complex, high-value parts manufacturing through:

Design Freedom

- *Design the best part you need, without compromise.*

Agility

- *Rapidly respond to changing demand, product, and go-to-market development requirements.*

Quality Assurance by Design

- *The gold standard in quality for advanced AM technology, verifiable layer-by-layer.*

Efficiency

- *Empowering engineers to optimize parts, save time, lower costs, and reduce risk.*

Interested to learn more about how Velo3D advanced metal AM can transform your manufacturing process?

Get in touch with one of our expert engineers today

VELO 3D

ABOUT US

Velo3D, one of Fast Company's 2021 World's Most Innovative Companies, empowers engineers and designers to imagine more and additively manufacture nearly anything with a fully integrated patented solution of software, hardware, and process-control featuring Flow™ print preparation software, Assure™ quality assurance software and the Sapphire® family of laser powder bed 3D printers. Velo3D additive manufacturing solutions for 3D-printing high-value metal parts allow for previously impossible geometries, so businesses can make the mission-critical parts they need without compromise. Customers include some of the world's most visionary companies, such as Aerojet Rocketdyne, Chromalloy, Honeywell, LAM Research and Raytheon Technologies.
For more information, follow Velo3D on LinkedIn or visit velo3d.com.