VELO 3D

Additive Manufacturing Solutions

Intelligent Fusion

Executive Summary

Intelligent Fusion optimizes the additive manufacturing (AM) process by combining thermal process simulation, print prediction, and closed-loop control during print execution. It's a first-of-its-kind innovative approach that sets the stage for a next-generation additive manufacturing solution.

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Background

Metal additive manufacturing is moving beyond prototyping and proving to be a viable production method for some higher value end-use parts. There is still, however, quite a bit that stands in the way of widespread adoption. Throughout the entire workflow of producing a part, from the design to quality assurance of the final part, metal AM, in particular powder-bed fusion systems in their present capabilities, have many unresolved shortcomings. These constraints are preventing metal additive manufacturing from living up to its promises to enable the impossible and to prove that it could produce dimensionally accurate, production-quality parts.

Thus, engineers are still held back by design constraints, inconsistent idea-to-build success, deformations, inconsistent material properties, poor surface quality, poor dimensional accuracy, and low yield.

Velo3D invented Intelligent Fusion technology to overcome these limitations and usher in new capabilities in additive manufacturing.

What and How

There are three aspects of the Intelligent Fusion process that define the breakthrough of this new approach:

Process Simulation

The Velo3D approach to optimizing the AM process relies on a deep understanding of the relevant physics and on a proprietary physical simulation capability developed in-house.

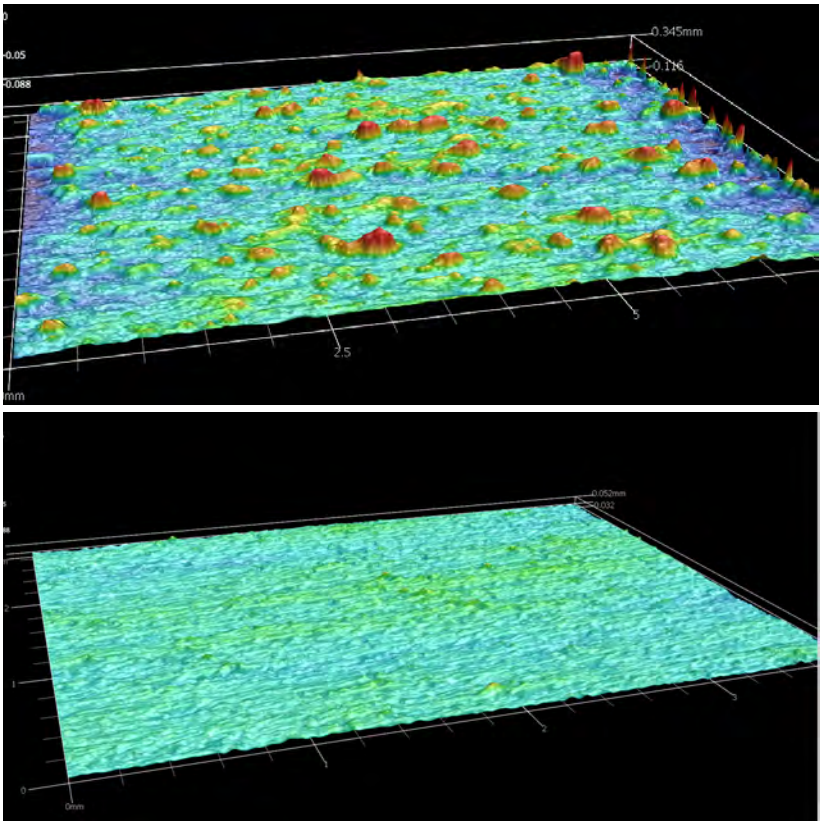
The **Velo3D simulator** takes the approach of a **deep understanding of physics fundamentals** so that one can explore a wide range of new, enabling physical processes. It predicts a print outcome by simulating a full print deformation of complex parts. This in turn informs an **Object Pre-print Correction (OPC)** utility that counter-deforms a part, assuring dimensional accuracy of the final part that inevitably will undergo deformation during printing.

The Velo3D simulation engine generates approximate simulation / data-driven parametric models that are used as sophisticated Feedforward instructions for the printer and work in conjunction with the real-time Closed-Loop Control (CLC) capability.

The extensive real-time metrology of process data during a build provides a rich source of data that can be used to refine the approximate parametric models used in the Velo3D control systems. This capability coupled with powerful machine learning techniques allows for **iterative refinement** of the AM process by **fleet learning**.

Figure 1.

Surface Roughness scans: Left: Roughness of 60 degree overhang on conventional AM machine Right: same geometry on Velo3D Sapphire system. The color scale is the same for both images



Geometry-Based Detection

Intelligent Fusion enables printing at low angles without the use of print supports. Specialized processes were designed to minimize thermo-mechanical distortions and ensure high-quality surfaces at build angles as low as five degrees.

Highly intelligent and sophisticated software, developed in-house, uses geometric feature detection to apply the optimal physical processes to the appropriate features. To be able to do that, each geometric model is decomposed into various distinct geometric features and the appropriate optimal process is then applied automatically.

Additionally, the geometric feature detection algorithms use information from multiple layers, leveraging information from previous layers to define the print strategy for the next layer.

The software is capable of modifying or adjusting parameters of the Feedforward model and passing them on as instruction sets to the printer.

Closed-Loop Control

To achieve consistent material properties across a printed part and reduce print variability from build to build, the Velo3D system ensures that every relevant build parameter is monitored and controlled throughout the build process. This is done by applying **real-time process control** during the build, a key component of the success of the Velo3D solution.

Natural process instabilities caused by minute hardware and powder variations as well as the uncertainties in the Feedforward simulation model can cause the process to drift outside the acceptable range, thereby affecting the final part outcome. Intelligent Fusion solves this problem by measuring in real time the melt pool thermal signal and using that as real-time feedback for a Closed-Loop Control system. The CLC system then adjusts process parameters in-situ to ensure consistent outcomes.

Thermal sensors perform in-situ real-time monitoring of the melt pool to ensure that the thermal signals remain within an acceptable range, thereby ensuring that the process is successfully applied.

A major factor in enabling sophisticated real-time process control, and Intelligent Fusion in general, is Velo3D's development of **proprietary controller hardware and software**, giving us the ability to control and coordinate every aspect of the build execution. This level of control is key to consistent outcomes and reduced variability.

The Velo3D solution is focused on **outcomes, not actions**.

Intelligent Fusion Deliverables

By combining science, industry knowledge, smart process control and powerful, integrated hardware and software systems, Intelligent Fusion offers an innovative solution that delivers on some of the not-yet-resolved promises of metal AM:

- Parts that meet dimensions and specification and that are consistent across builds, thanks to a system that predicts, instructs, and self-corrects.
- Shorter development process time in which one arrives faster to first articles and in which time and cost of post-production is reduced, thanks to the unique ability of free float printing or to the smart processes that require minimal supports.
- Unleashing of design freedom by enabling building of complex geometries — extending the range of applications for metal additive manufacturing.