Building Industry-Ready 3D Metal Printers

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Are metal additive machines ready to meet industrial demands?

— Customer-centric innovation
— Validation
— Industrial grade

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While early laser-based metal 3D printers were first commercialized over two decades ago, it is only in recent years that experienced users of additive manufacturing have begun to deploy additive technology for industrial-scale production.

Today's laser-based metal 3D-printing systems come in a variety of technologies and sizes, each with its own range of capabilities, speeds and price points. With so many different printers across the laser powder-bed fusion (L-PBF) category, it might be easy to think they have become a commodity. This is far from the truth. While most L-PBF printers have grown faster and more affordable, until recently only a very few have demonstrated the ability to handle the demands of production at scale.

Today's machines are an intricate combination of precision hardware and advanced software capable of transforming metal powders, as thin as ~10 microns, into fully dense parts with properties equivalent to wrought metals. To do this, they must orchestrate the interaction of many complex subsystems, from precision lasers and thermal management to powder handling and advanced software.

Yet, for an industrial-ready system, putting these subsystems together is merely the start. To convince technical and business decision makers that L-PBF is ready for their factory, the system must produce precision parts with geometries, properties and metallurgies that are consistent from part to part, machine to machine, and even from factory to factory. And they must do it day in and day out while operating with minimum disruption.

Building industry-ready laser printers is an imposing task. I know this from personal experience, having led a team at GE Additive that has spent the last four years continuously improving our M2 Series 5 and getting the M Line system commercially ready. By describing the steps our team took to ensure our M Line system meets industrial standards out of the box, we hope to demonstrate why we believe L-PBF printing is ready for production at scale today.

Customer-Centric Innovation

Since its formation six years ago, GE Additive has been in the unique position of working closely with GE Aviation, an early proponent and now super user of metal additive technologies, creating flight-critical parts and systems of parts within a highly regulated industry.

With well over a decade working with additive technology, GE Aviation continues to set the bar high for the entire additive community. One example is in the field of materials science. GE Aviation's materials team has decades of expertise in everything from alloy development to the analysis of finished part microstructure. That experience and insight has proven invaluable to our team in creating additive manufacturing systems that print parts across the entire build plate using robust and stable parameter sets.

Both GE Additive and GE Aviation also leverage Lean Manufacturing and a Six Sigma quality infrastructure. This involves extensive testing of multiple runs on multiple machines to ensure that we can print parts within specification and that any variations in those parts are not statistically significant.

Validation

To develop the M Line system (as well as the M2 Series 5), GE Additive leveraged GE Aviation's formal new-product-introduction process, which ensures we understand our goals and line up resources early, go through several rounds of engineering refinement and ultimately validate products in ways that ensure they are ready for factory floor production.

Development starts with a consensus design review, during which we lay out our broad objectives, make sure they align with the needs of our customers and target critical-to-quality parameters our printers must meet. This is followed by conceptual, preliminary, and detailed design reviews. During each of these stages, we narrow down and model possible solutions, build subsystem test rigs, and eventually create prototypes that demonstrate how we will meet customer requirements.

Then comes the real work: validation. It ensures that our L-PBF machines meet their specification goals and operate reliably. The process may take one year or longer.

For the M Line, this involved measuring more than 2,000 different variables on at least three individual machines during runs of increasingly complex parts over a period of one year, collecting over nine million data points on the performance of the machine systems. We also monitor other systems that have been operating for several years to understand how wear conditions arise, so we can either prevent them or compensate for them with software.

Since additive printers are actually a collection of subsystems, that is where we start. With sophisticated sensors, we monitor subsystem components and behavior. Some are obvious, like how precisely the build plate lowers itself in 30- to 50-micron increments during the build.

Others seem obvious on the surface, but we dive deep into the details. Take, for example, the speed and temperature of gas flowing into the build chamber. We monitor it at different heights and locations to ensure consistent temperatures—and parts—up to the edges of the build plate. We also monitor the temperatures within the lasers and mirrors and the housings that hold them. We measure laser stability, wavelength and spot size, then double-check how well two or more lasers work together to create a single, seamless, monolithic part.

Our goal is to eliminate subsystem variations. After doing that, we integrated those subsystems into three M Line prototypes for system-level testing. We had several goals in mind. First, we wanted to make sure that each module continued to achieve consistent results while interacting with the printer's other subsystems. Second, we needed to demonstrate that they all worked together to print parts with build-to-build consistency over time, so that the 1,000th build has exactly the same physical and metallurgical properties and geometries as the first.

Finally, we needed to demonstrate that our subsystems and system would provide consistent performance with little variation over the printer's or system's lifespan. This is incredibly important to existing and potential customers, especially those making demanding products for aerospace, medical and other industrial applications. While every L-PBF machine manufacturer, including GE Additive, uses software to compensate for small drifts in processing parameters, software should never be used as a band-aid for an unstable printer.

Industrial grade

Innovation in additive manufacturing is difficult and costly. At GE Additive, our formal process is more than just a set of guidelines we follow internally. We are able to tap into knowledge and additive infrastructure across the wider GE network. We also include customers at every stage of our development process, as well as outside experts to evaluate potential solutions. We do thousands of tests and analyze every statistically significant variance and failure mode.

We began this process as soon as we acquired Concept Laser in 2016. Since then, we have completely reengineered our portfolio of printers to turn them into reliable industrial assets. They produce parts safely with the right quality, scale and cost to compete with conventional machining in applications that place a premium on complexity, weight and durability.

Like other manufacturers, we provide services that help customers get the most out of their investment in additive manufacturing. For many companies, this involves answering engineers' questions about software and machine parameters. For others, it extends to in-depth technical support to help select the right material for an application or to design or redesign parts and components to maximize the value of their L-PBF printers. Most companies offer similar services, but they cannot call on the immense library of knowledge we share with GE Aviation.

Engineers should continue to question any machine manufacturers' claims that seem too good to be true, especially when it comes to achieving industrial scale performance. I regularly see certain manufacturers over-selling the promise of additive technology, while struggling to provide cost-effective capabilities. This is the primary reason there are so many 3D printers gathering dust in the corners of factories around the world.

To avoid that fate, keep asking questions about the cost, speed and capabilities of additive manufacturing. Demand proof. The best way to evaluate an industrial-ready machine is to see it in action. Visit one or more factories running dozens of printers. Look at the parts they make and ask about variation. Check financial models to see why it makes sense to make that part additively. Ask about reliability. And—this is important—talk with customers who have used printed parts and ask about their quality and durability.

At GE Additive, we have hundreds of L-PBF, Electron Beam Melting (E-PBF) and increasingly Binder Jet printers in operation. Our L-PBF machines have made hundreds of thousands of complex parts, and our customers plan to make hundreds of thousands more in the near future.

We are proud of what we have accomplished. That is why we invite your skepticism. Seeing is believing, and we want you to see for yourself that our L-PBF machines are industrial-ready for your most demanding applications.


Concept Laser
M Line