

Balancing the Speed and Technology of Additive Manufacturing with the Mature and Methodical Thermal Processing Industry

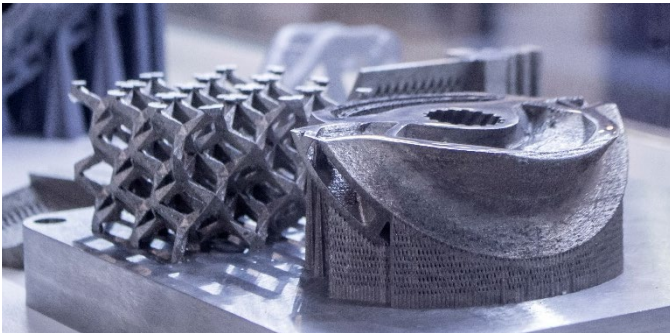
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Abstract

Additive manufacturing is a disruptive technology with the potential to lower cost, increase speed and create parts once thought to be too complex and intricate to manufacture by conventional methods. In addition, metal 3D printed parts are often lighter in weight and use fewer raw materials, making them more environmentally sustainable. For these reasons, companies of all sizes in many industries, as well as universities, R&D cooperatives, and governmental agencies, are investigating the possibilities for incorporating this advanced technology.



Manufacturers from aerospace and automotive, to medical devices, are now 3D printing production metal parts using a variety of processes. However, metal printed parts typically require post-processing operations in a furnace to bring components to their final dimensions and properties. Multiple variables must be considered when choosing a furnace, including the print technology, part design, size, material, and the volume of parts to be produced.

New 3D printing equipment companies looking to enter the metal additive industry may be unfamiliar with the science of heat treatment. Other manufacturing companies or commercial heat treaters may be experienced with heat treatment of metal parts but have no familiarity with 3D printing. This paper covers the relationship between the fast-moving industry that is 3D printing with the more mature and methodical industry of traditional thermal processing.

Bringing AM to a New Generation of Manufacturers

What does the widespread advance of additive manufacturing and 3D printing technology mean for the manufacturing industry as a whole? First, it has an immediate impact on companies that are looking to reduce costs and increase production. Second, we have the potential of using additive to build complex part designs that are not possible with traditional machining

methods. OEMs making their own parts, vendors that supply parts directly to industry, and third-party suppliers that produce parts for these vendors are seeing the benefit of this new process. The example below outlines an injection mold manufacturer that chose to bring printing in-house, purchasing a printer from industry-leader Desktop Metal.

Case Study:

Injection molding firm Built-Rite Tool & Die identified a 90% cost savings using Studio System™, a quick-turn mold application.

Small to mid-sized businesses like Build-Rite face increasing pressure from competitors as overseas manufacturers offer lower prices and domestic prototyping shops offer quick turnaround times for small quantities of parts. Built-Rite found that 3D printing introduced the ability to make quick-turn mold assembly components with a process that is far less labor-intensive than other equipment and more cost competitive than a third-party prototyping firm.

Ultimately, Built-Rite realized a 90% cost savings and 41% weight reduction using Studio System.

<i>Part Dimensions</i>	2.54 x 3.57 x 7.62 cm
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Studio System fabrication

<i>Technology</i>	Bound Metal Deposition™
<i>Material type</i>	AISI 4140 steel
<i>Infill spacing</i>	2.8 mm
<i>Part mass</i>	320 g
<i>Fabrication time</i>	50 hours
<i>Cost-per-part</i>	\$47

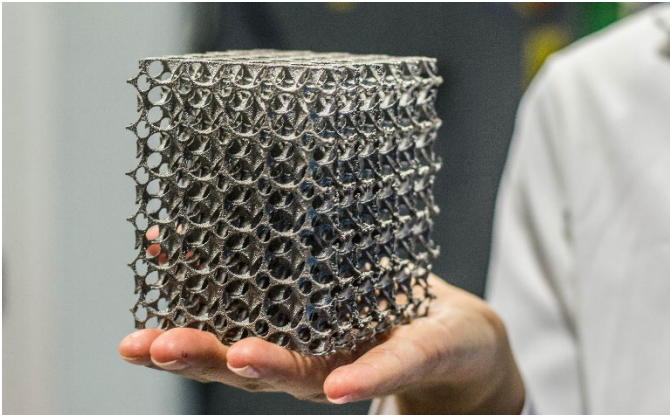
Third party prototyping firm

<i>Technology</i>	CNC machining from metal block
<i>Material type</i>	4140 steel
<i>Part mass</i>	545 g
<i>Lead time</i>	3 days
<i>Cost-per-part</i>	\$493

The explosion of novel 3D printing technologies has resulted in a whole new group of companies entering the marketplace to manufacture 3D printers and related equipment. These companies are employing scientists and engineers to design and build the equipment and create new processing methods. In addition, because the technology is relatively new, companies must navigate a steep learning curve for every aspect of the process, including the raw print stock, 3D printing method, and printer design, as well as methods for manufacturing the equipment. They must also plan for packing and

shipping the equipment, staging it, and educating customers on proper operation of the printer and its associated apparatus.

In the case of metal 3D, almost every printed part will require post-processing heat treatment to bring it to final specification. Manufacturers of 3D printers that want to provide their customers with a complete solution must consider several factors, including post-treatment processes such as debinding and sintering, and any additional heat-treatment processes that will be required for the printing method used.



Companies using traditional machining methods or metal-injection molding (MIM) typically have accumulated a large library of known factors about their heat-treatment processes over time. These knowns help them refine their processes to efficiently produce a product that meets requirements for part geometry, tolerances, metallurgical quality, and industry standards.

In contrast, companies using 3D printing to create parts of the same quality may need to review and educate themselves on several topics, including the debinding, sintering and heat-treatment processes. As the additive industry grows rapidly, companies are scrambling to understand all the steps required in order to give them the final part quality they need.

A Quick Look at the Technology Today

Multiple technologies are now available for metal 3D printing, including direct metal laser sintering (DMLS), binder jetting, and electron beam additive manufacturing (EBAM), to name a few. This technology is used in industrial applications to create end-use dense metal engineered products. Build orientation, part support, build time and material waste are all considerations to keep in mind. The selection of the printer is just part of the process—a multitude of auxiliary equipment may be needed, including curing stations, de-powdering stations, transfer carts, build boxes, gas and powder management system, and of course the debinding, sintering and heat-treatment furnace.

A mature furnace industry means that several types of furnace technology are available today for the debinding, sintering and heat-treatment steps. These include a simple air furnace for debinding, a vacuum furnace with either graphite or metal hot zone, and a walking beam furnace for very high throughput, or a hot isostatic pressing (HIP) furnace for full part density. Furnace and atmosphere selection are of course based on several factors, including material, size, and throughput. All designs offer their own advantages, with a vacuum solution providing the cleanest atmosphere and highest sintering temperatures.

Many of the companies that build these furnaces understand the nuances of heat treatment, materials, and the processes required to manufacture a viable product. However, in an industry that is moving at such a rapid pace, lots of financial backing, and a drive to be technically flawless, one of the most important factors will be partnerships. Not just in the science of heat treatment and furnace technology, but also in a partner who sees potential and collaborates with the company to design a furnace that meets the high standards the industry requires. This means that suppliers in the thermal processing industry that are used to a more methodical pace must change their mindset and move swiftly to keep up.

Finding the Right Furnace Solution for 3D Printing

For any business considering 3D printing, finding the right furnace technology and the right partner starts with a series of questions designed to get enough information to devise a path forward on design recommendations. Questions to ask include:

- What is the material composition, binder composition and content, and is it compatible with vacuum furnace processing?
- What is the part size and volume?
- Will it undergo a first stage debinding process?
- What are the industry standards that parts need to meet?
- Are there part density requirements that must be met?
- Will the furnace be used strictly for material commonly used for production 3D applications, such as stainless steel and aluminum, or is there a possibility of a broader range of material such as tool steel, high-speed steel, exotic metals or materials, including titanium?
- What are the final property requirements and what is the end use?

During the consulting process, many of the questions a customer may have for a furnace supplier will center around the material to be used. So, for example, they

might want to print a certain part using 17-4 PH stainless and need to know the right furnace features to ensure that part quality, performance and repeatability is maintained.

Because 3D printing is rapidly evolving, the process, technology and print speed will continue to change. Learning together is required when there are not decades of history to look back on—when testing new things, it takes some time to get it right. Therefore, furnace suppliers must be nimble to meet their customers' ideas and requirements. With so many knowns in the heat-treatment industry and so many potential unknowns with 3D printed parts, there is a blue ocean ahead.



Creating a Solution for the Future

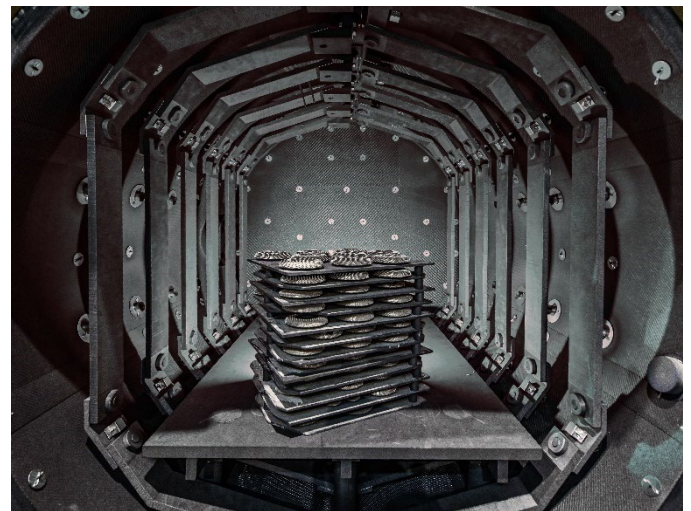
There is no crystal ball to tell us all the technology we are going to need to keep up with 3D, but we do know that the 3D industry is both proactive and reactive. It is testing, trialing, investing, and pushing to get better every day, and both learning from its mistakes while simultaneously pushing the technology to expand its limits. To keep pace, we must learn to move at a speed outside the industry norm. So, what are the questions we now have to ask in order to use existing technology and new methods in a meaningful way to help build the next generation of furnaces and partnerships that will prove we can keep up with their speed?

- Is there a furnace design that allows ultimate flexibility for running the knowns now and the unknowns later?
- If the printed parts have a high level of binder content, how do we capture and dispose of that binder in the simplest, cleanest, and most environmentally friendly manner?
- What is the most precise, accurate and repeatable method for flowing gas through the furnace to ensure uniform part quality?
- In a vacuum application, can we design a unit with ultimate flexibility and interchangeability to provide a global platform that meets the customer needs no matter where it ships?

- How do we make the perfect furnace for not only the debinding and sintering processes, but also the post heat-treatment process? Can one furnace capture all processes?
- How do we make a robust retort and fixture model for ease of use and ultimate durability?
- What is the design for not only a broad range of temperature capabilities, but also the best possible temperature uniformity?

Additive is a Global Industry

Following along with the shift from analog to digital manufacturing and the Industrial Internet of Things (IIoT), 3D printing has gone fully global. Almost daily, announcements of new research funding and joint projects in additive manufacturing emanate from places like India, Dubai, and South Korea, as well as the U.S., China, and Europe. R&D labs and public and private consortia are discovering breakthroughs in technology, expanding 3D printing from prototyping to large-scale metal parts production. Many U.S.-based corporations moving into full-scale additive also run operations in Asia, Europe, Canada, and Mexico. These organizations need support for post-processing of metal 3D printed parts from a vacuum furnace company with a global footprint.



Conclusion

Additive manufacturing, often referred to as 3D printing, is a fast-growing, emerging industrial technology. 3D printed parts require subsequent thermal processing to achieve properties competitive with those produced via traditional manufacturing methods. There are often several thermal processing steps in producing a high-quality 3D printed part with different process goals and requirements. It would be desirable to have one furnace perform various thermal processes for 3D printed parts.

3D printing is a global trend requiring a global furnace – **one that can ship anywhere with a short lead-time, be compatible with local standards, and includes interfaces in multiple languages.** Other requirements for a truly global furnace include:

- Quick delivery
- Competitive pricing
- Developed specifically for, and continuously improved for, the 3D industry, with important changes made based on customer feedback
- Depending on the customers' material needs, available for use with graphite and all-metal hot zone design
- Precise gas flow design for part quality and flexibility
- The ability to use with or without a retort
- An inline filter system for the binder material
- Built as a sintering furnace but could be used for other heat-treatment processes (hardening, stress relief, tempering, and aging)
- Build for robust quality

A full-solutions provider can recommend the right furnace – whether it be custom, semi-custom, standard, or a global platform product.

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Desktop Metal. (2017). *Case Study: Built-Rite Tool & Die*. Retrieved from https://www.objective3d.com.au/wp-content/uploads/2018/03/Case_Study_Built-Rite_v2.pdf.

About Ipsen

Ipsen designs and manufactures industrial vacuum and atmosphere heat-treating systems, supervisory controls and predictive maintenance software for many industries including Aerospace, Automotive, Commercial Heat Treating, Energy and Medical. Leading the industry with more than 10,000 furnaces installed worldwide, with production locations on three continents and representation in 34 countries, Ipsen is committed to providing 360° support for customers.

Ipsen Customer Service provides aftermarket support for any brand of vacuum furnace through process development, factory layout planning, installation and start-up assistance, training, replacement parts, hot zones, controls and instrumentation upgrades, mechanical retrofits and furnace refurbishments. With a global team of more than 120 field service technicians, Ipsen employs the largest and most skilled aftermarket team in the business providing quick and easy access to troubleshooting, maintenance, repairs, instrument calibrations and temperature uniformity surveys. Ipsen's aftermarket support helpline also provides remote assistance for customers in any location.

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