Technical white paper

HP Metal Jet technology

HP's digital printing technology for metals

Three-dimensional (3D) printing of complex applications and machine components is a reality. 3D printing offers the ability to produce rapidly and at low cost both industrial-scale runs of high-value parts and one-of-a-kind parts. Now, with an advanced technology for metal parts, HP continues to reinvent the design, production, and distribution of 3D-printed parts to drive the digital transformation of manufacturing with the most advanced 3D metals printing technology for mass production: HP Metal Jet.

Figure 1. HP Metal Jet S100 Printer[1]

Introduction

For more than 30 years, HP inkjet technologies have disrupted and led a broad range of printing markets. In 2014, HP introduced a revolutionary 3D printing technology for plastics: HP Multi Jet Fusion.[2] HP Multi Jet Fusion technology places drops of functional liquid agents onto a powder bed to control the physical properties and features of plastic parts point-by-point. It leverages HP's deep assets in imaging and printing to take the digital transformation of printing off the page and into a three-dimensional world of highly functional, high-value manufactured items. HP Metal Jet leverages and extends the workflows and technologies that HP developed for printing 3D plastics into metals with new functional agents, processes, and printing hardware.

HP Metal Jet technology offers high build quality and speed, at a low cost relative to competitive 3D printing solutions in the marketplace today. These breakthroughs in quality and speed will accelerate the adoption of metal 3D printing to create a digital transformation of manufacturing as widespread and profound as the way HP Thermal Inkjet changed the landscape of conventional printing markets and applications. As with other HP products, the HP Metal Jet S100 Printing Solution offers users HP's key values of reliability, ease of use, versatility, and an end-to-end digital workflow.

HP Metal Jet solutions break through the economic, design, and time constraints of traditional methods for metal part production while delivering quality, productivity, and cost advantages over existing 3D printing technologies for metals.[3]

Using HP Thermal Inkjet to precisely deliver HP Metal Jet binding agent to a powder metal bed and industry-standard metal injection molding (MIM) metal powders, the HP Metal Jet S100 Printer is a binder jet printer that features:

- Multiple parts produced at the same time, or large parts, with an effective build volume of 430 x 309 x 140 mm which meets MPIF standards for stainless steel with HP Metal Jet SS 316L and 17-4PH materials.
- Parts can be arranged freely in multiple levels in the powder bed to optimize packing density, productivity, and cost.
- No build plate required, compared with selective laser melting (SLM).
- 1200 x 1200 dpi addressability in a layer 35 to 140 microns thick.
- Finished parts with isotropic properties that meet ASTM and MPIF standards.[4]
- High material reusability reduces materials cost and waste without compromising part quality.[5]
- Density after sintering > 96%, similar to MIM.

With a design and technology foundation proven in generations of HP's commercial and industrial printing solutions, HP Metal Jet printers deliver industrial productivity with reliable, consistent, and repeatable results.

Note: parts are not shown at the same scale

Fixgure 2: Sample stainless steel parts made using HP Metal Jet technology (L-R top row: Lumenium, Schneider Electric, (2); L-R bottom row: Cobra, Legor, HP)

Figure 2 shows sample metal parts made from HP Metal Jet SS 316L and HP Metal Jet SS 17-4PH produced by an HP Metal Jet S100 Printer after sintering. Most of the parts are shown before post-processing (e.g., surface polishing, etc.), with the exception of the Cobra putter head and the Legor ring.

3D printing

While manufacturing by milling, grinding, and cutting removes material from a workpiece, additive manufacturing—"3D printing"—is a digital technology that creates parts by selective material addition. This allows each 3D-printed part to be unique in the same way that each page printed by an inkjet or laser printer can have unique content. 100% variable content page to page and part to part is a capability that digital technologies bring to 2D and 3D printing.

Prime applications for 3D-printed metal parts include the functional and aesthetic components for automotive, medical, industrial, and consumer goods. These parts—with complex internal and external geometries—can be produced in runs of 1000s or can be customized, high-value one-of-a-kind products. 3D metal printing is targeted to compete with metal injection molding, investment casting, and press and sinter processes.

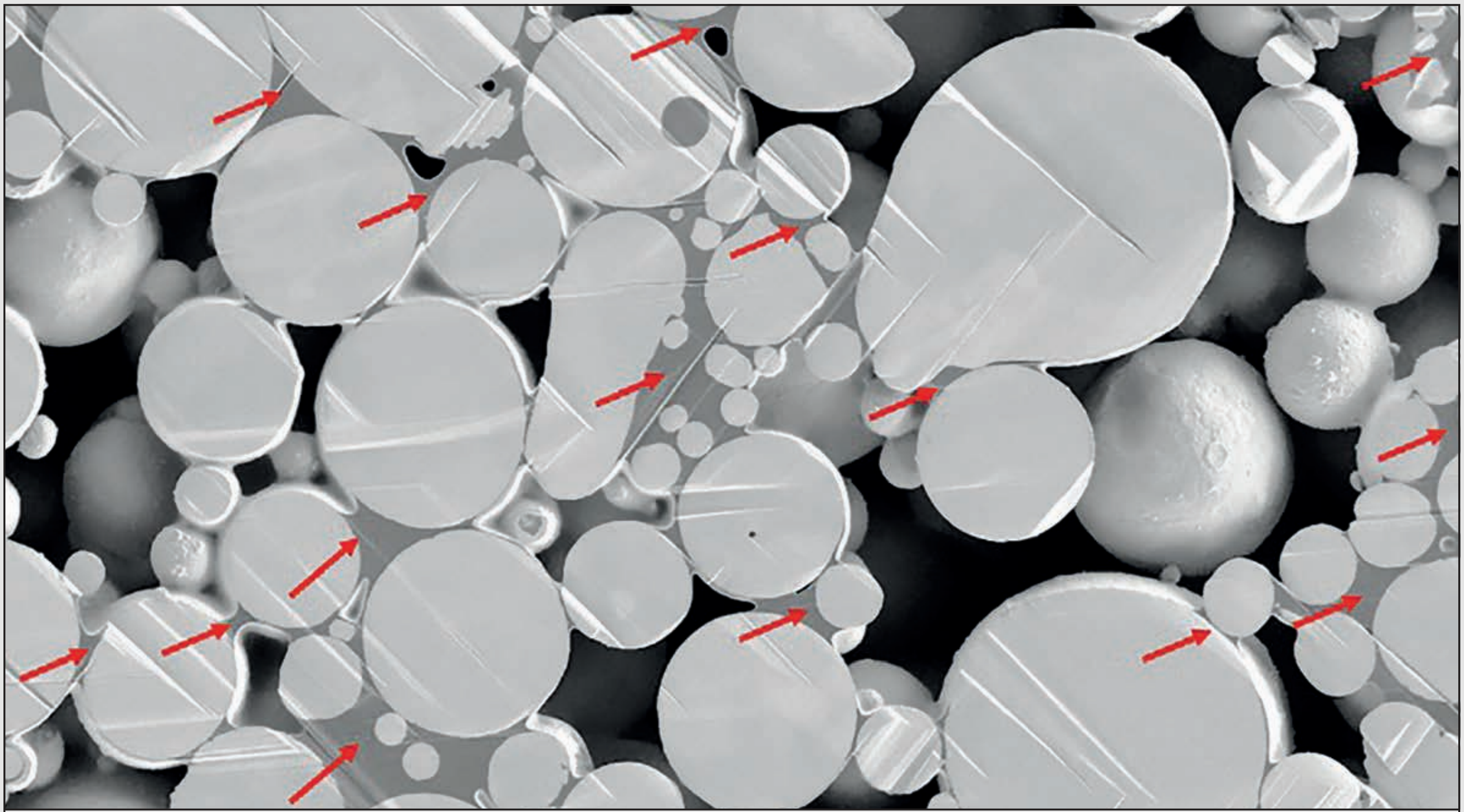
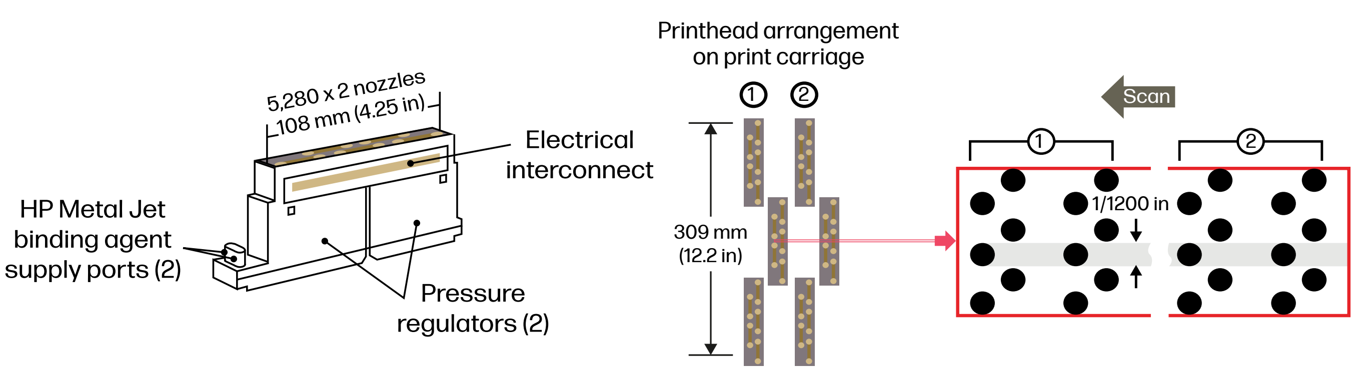


Figure 3. Optical micrograph of cross-section of an HP Metal Jet green part showing metal particles and cured binder (red arrows).

HP Thermal Inkjet printheads provide precise placement of drops of HP Metal Jet binding agent in the powder bed. The printhead for HP Metal Jet printers is based on a design that has been proven in-service in HP's PageWide Web Presses, HP Latex printers, and HP Jet Fusion 3D printers. Internal architecture to HP Metal Jet printheads has been further adapted to improve robustness to metal powder particle ingestion. Each printhead produces a 108-mm (4.25-inch) print swath with two independent columns of 5,280 nozzles that are spaced 1200/inch in each column. The printhead is shown on the left in Figure 4. There are two independent supply ports for HP Binding Agent and two built-in pressure regulators.

A key feature of HP printheads is quick and easy replacement by the operator. No tools, handling fluid or electrical connections, orx manual alignment are required.



Figxure 4. HP Thermal Inkjet printhead for HP Metal Jet printers, printbars, and details of nozzle arrangement.

HP Metal Jet printers employ multiple printbars for high productivity and nozzle redundancy. As shown schematically in Figure 4, two printbars (1 and 2) on the print carriage, each with three 108-mm (4.25-inch) printheads in a staggered and overlapping configuration, produce a print swath 309-mm (12.2-in) wide.

Voxel resolution

A voxel—"volume element"—is the 3D equivalent of a 2D pixel in digital printing. Voxel resolution is a planar grid in the powder bed with a depth corresponding to the thickness of each printed layer. HP Metal Jet printers address a 1200 x 1200 dpi grid with a layer typically between 35 and 140 microns thick. HP Metal Jet's high voxel resolution produces fine details and precision definition of edges and surfaces both inside and outside the part.

Redundant nozzles

A group of nozzles across printbars 1 and 2 is shown on the right in Figure 4. The two columns of nozzles on each printhead are shown as well. The nozzles are aligned so that four nozzles print in the same 1/1200-inch dot row (gray highlight) in the powder bed. This means that up to four different nozzles can print HP Metal Jet binding agent in the same 1200 dpi grid point. This is called 4-times nozzle redundancy, and nozzle controllers leverage this redundancy to reliably print HP Metal Jet binding agent in each voxel.

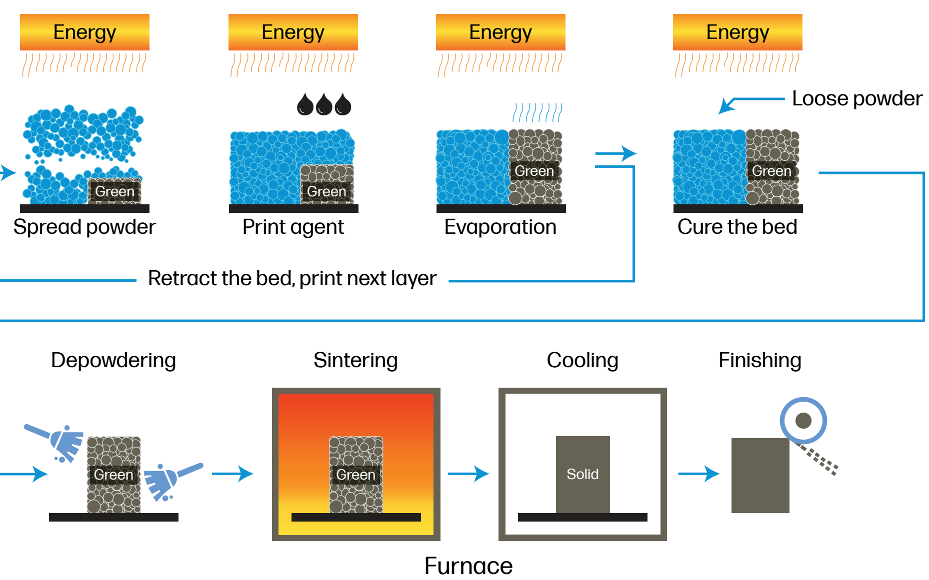
Printhead service station

A printhead service station uses HP's optical drop detector technology to quickly determine the health of each nozzle before, after, and during printhead recovery operations. This process identifies nozzles that are not performing within specifications. An automatic service cycle can recover nozzle function.

HP Metal Jet process

The process of building a metal part by HP Metal Jet is described schematically in Figure 5. A detachable build unit, containing the powder bed and powder supplies, is rolled into the HP Metal Jet printer for part production.

Note that throughout the printing process, the powder bed may be heated—shown by the "Energy" element—to evapxorate volatile components of HP Metal Jet binding agent.



Fixgure 5. Schematic of HP Metal Jet printing process.

Spread powder

The build begins with a scanning recoater laying down a uniform, thin layer of powdered metal across the working area. The recoater is refilled from supply bins of metal powder located at each end of the scan. This enables bi-directional recoating for increased productivity.

Print agent

HP printheads jet HP Metal Jet binding agent at precise locations onto the powder bed to define the geometry of single or multiple parts. At one end of the scan, a printhead service station tests, cleans, and services the printheads for reliable operation.

Evaporation

The liquid components of HP Metal Jet binding agent evaporate.

Retract the bed, print next layer

The powder bed is retracted the thickness of the printed layer, and the process repeats until the build is completed.

Cure the bed

The powder bed with its printed parts is heated to complete the evaporation of liquid components from HP binding agent and to cure the polymers to achieve high strength in the green part(s).

Depowdering

The powder bed is now cooled, and parts can be removed. Depowdering is the process of removing loose powder from around the parts and from the surfaces of the part. Once the loose powder has been removed from the parts, the remaining powder can be processed and reused for economical consumables management.

Sintering

The green parts are now moved into a furnace. At sintering temperatures, atomic diffusion at the surfaces of the metal particles binds them in a matrix that can exceed 96% solid density.[8] The polymer from the HP Metal Jet binding agent decomposes.

Finishing

The part(s) may now undergo post-processing to meet dimensional and surface finish requirements.

Metal materials for the HP Metal Jet S100 Printing Solution

The HP Metal Jet S100 Printer uses industry-standard stainless steel materials developed for metal injection molding (MIM). HP will work with customers to extend HP Metal Jet technology to process additional metal materials commonly used in MIM or those specific to customer applications.

The grain structure in a test specimen produced using HP Metal Jet technology is visible in the photomicrograph of Figure 6. The section was processed by a 10% oxalic acid - electrolytic etch.[9] The microstructure is typical of Type 316L stainless steel in the annealed condition, and consists of austenite grains and annealing twins.[9] This sample shows superior grain isotropy compared to most competitive 3D metal printing technologies. For example, a cross-section of a part produced using selective laser melting (SLM) is shown for comparison in Figure 7. Notice the anisotropic grain structure, which will introduce orientation-dependence in physical properties (e.g., tensile strength may be different along X and Y axes in the powder bed and along the Z axis).

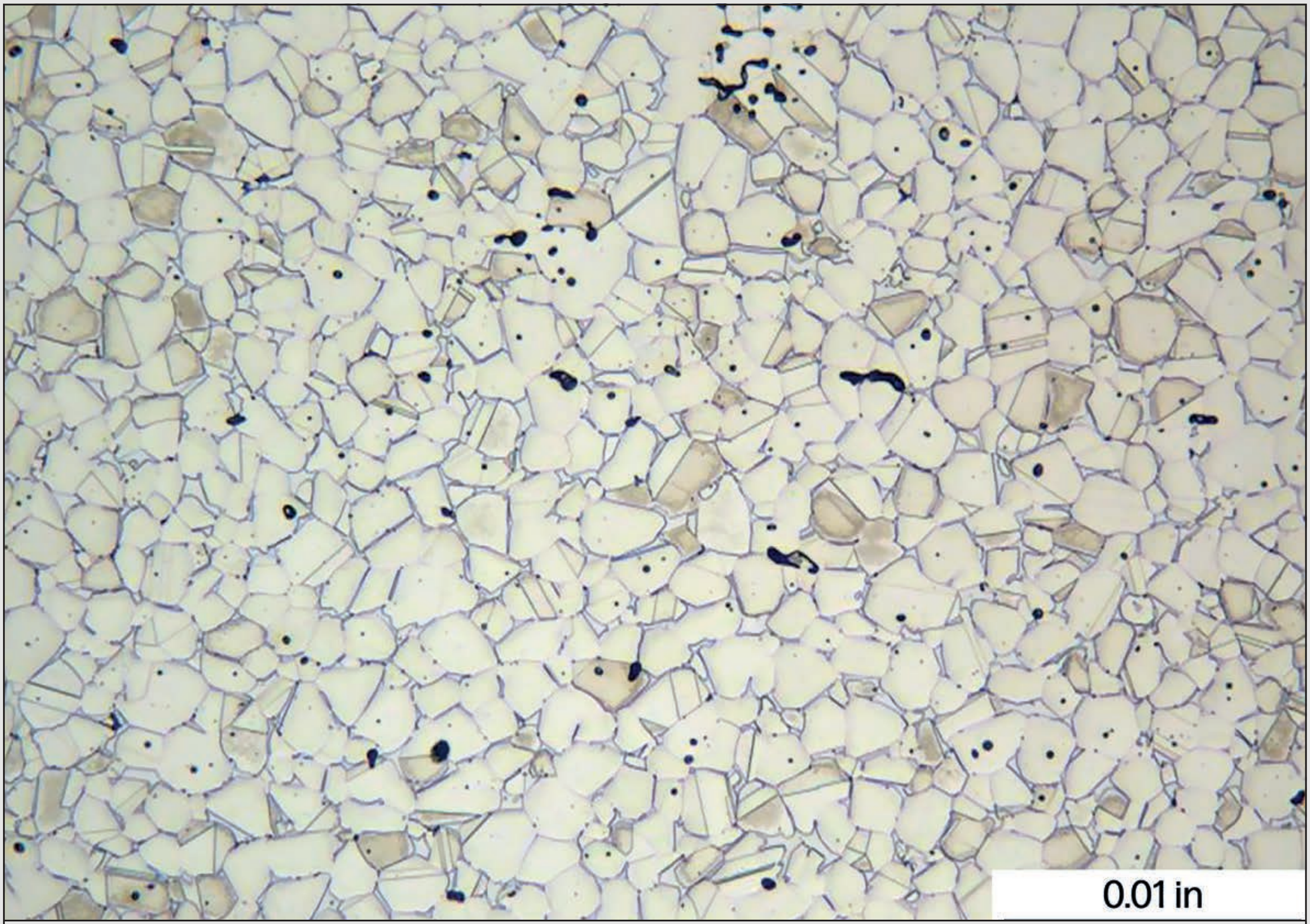


Figure 6. Optical micrograph of cross-section of a 316L stainless steel test specimen produced by an HP Metal Jet printer.[9]

Metal materials for the HP Metal Jet S100 Printing Solution

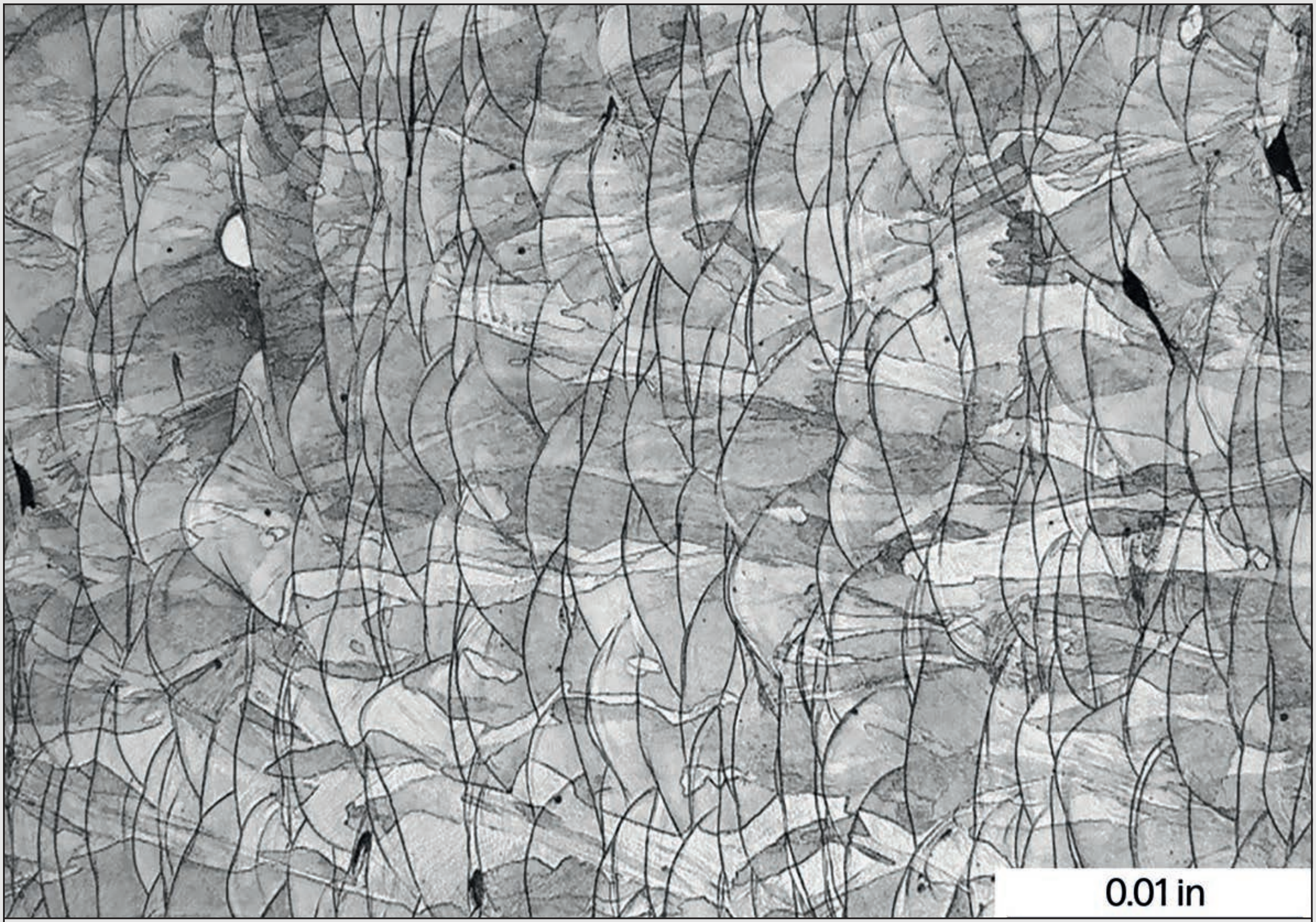


Figure 7. Optical micrograph of a cross-section of a 316L stainless steel sample produced by selective laser melting (SLM).[9]

Clearly visible in Figure 7 are the microscopic pools of melt and the weld lines between them. Elongated grains—showing distinctive anisotropy—are visible as the gray shapes extending across weld lines.

HP Metal Jet vs. metal injection molding

In MIM, a slurry of metal particles, wax, and polymers is injected under high pressure into a mold. MIM green parts are typically less than 93% metal powder by weight[10] versus up to 98%-99% for HP Metal Jet printing.

MIM requires a debinding process to remove the wax, and this can add up to 20 hours to the MIM workflow. Unlike MIM, a time-consuming wax debinding process is not part of the HP Metal Jet process.

In both processes, the binding polymer decomposes under sintering. The polymer in HP Metal Jet technology is used at a lower weight fraction compared with MIM, and this facilitates the decomposition and evacuation of polymer residue during sintering. This is important to obtain high productivity of thick-walled parts.

Software for HP Metal Jet

The HP Metal Jet S100 Printer accelerates process development and scales production with HP Metal Jet Software Solutions, which provide end-to-end automation from installation to process development to production workflow management built on an extensible API platform.

Additional hardware and offerings

The HP Metal Jet S100 Printing Solution consists of the HP Metal Jet S100 Powder Management Station, the HP Metal Jet S100 Powder Removal Station, HP Metal Jet S100 Curing Station, and HP Metal Jet S100 Build Unit, which are designed to be deployed with the HP Metal Jet S100 Printer. Additionally, HP Metal Jet Solution Services provide businesses with a comprehensive suite of onboarding, maintenance, and professional services to help create the most value with HP Metal Jet technology.

Availability

The HP Metal Jet S100 Printing Solution is expected to be widely available during the first half of 2023. New customers can evaluate HP Metal Jet technology by requesting test prints of applications. Visit hp.com/go/3Dmetals for more information.

Summary

HP's metal 3D printing technology is built on HP's core competencies in precision low-cost mechanics, precision metering and placement of liquid functional agents, high-volume manufacturing, material science, and imaging. Compared with other commercially available 3D printing technologies, HP Metal Jet printers will define new levels of part quality, part functionality, productivity, and production economy.

HP Metal Jet—initially using stainless steels (17-4 PH and 316L) with industry-wide applications—opens new markets for high-quality, high-strength metal parts for automotive, medical, industrial, and consumer goods. Unique designs for one-of-a-kind applications as well as industrial-scale runs of high-value parts can be produced economically using the unique features of HP digital 3D printing workflows. This capability enables a host of new possibilities in the design and function of parts that are not well-suited to traditional manufacturing methods or other 3D printing solutions.

HP's 3D printing products will drive the digital transformation of manufacturing with a 3D printing ecosystem including software for 3D part creation and production, industry-standard metal powders, robust, industrial-grade 3D printers, powder handling equipment, and ancillary hardware optimized to deliver end-to-end productivity and economy.

Learn more at
hp.com/go/3Dprint
hp.com/go/3Dmetals

1. Imxage shown may differ from actual product.
2. For more information and detailed claims, see the HP Technical White Paper "HP Multi Jet Fusion Technology", 4AA5-5472EEW, March 2018 and current specifications for HP Jet Fusion 3D Printers at https://www.hp.com/go/MJFWhitepaper .
3. Productivity based on print speed for serial production up to 100,000 parts compared to competitive binder jetting and selective laser melting (SLM) metals 3D printing solutions available as of July 31, 2022.
4. Specifically, ASTM/MPIF standards for tensile strength, yield strength, and elongation.
5. Compared to selective laser melting (SLM) and based on internal testing of HP Metal Jet technology as of September 2022.
6. For example: gears, sliders, rotating joints, and other kinematic elements.
7. "Green" refers to a part made of metal powder and stabilized by binders before sintering.
8. Solid densities greater than 96%, similar to MIM, can be achieved using HP Metal Jet technology.
9. Source: Element Materials Technology Report to HP Inc.: "Metallurgical Evaluation of Type 316L Stainless Steel Specimens".
10. See http://www.pim-international.com/metal-injection-molding/sintering-in-the-metal-injection-moulding-process/.

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4AA7-3333ENW, April 2023