Design Best Practices For 3D Metal Powder-Bed Fusion

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Xact Metal
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SME's Additive Manufacturing Seminar Series
Juan Mario Gomez – CEO
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Customer Problem

“Pricing within the 3D printing industry needs to be ‘meaningfully lower’ than where it is today to drive adoption … In fact, pricing remains the most important factor which is holding back 3D printing adoption …”

- Matthew Cabral, Equity Research at Goldman Sachs

• Industrial and research customers who would like to enter metal 3D printing cannot do so profitably due to the high acquisition and usage costs

• A lower-priced unit, which does not sacrifice performance, would allow more customers to enter the metal AM space

• There is a segment of customers whose needs are unmet at these higher printer and powder prices.
Introducing Xact Metal

Xact Metal is taking the essential specs for metal powder-bed fusion and combining them with breakthrough technology to establish a new level of price and performance for additive manufacturing.

Xact Metal is dedicated to supporting the next generation of innovative manufacturing solutions powered by metal 3D printing.

Headquarter in State College, Pennsylvania at Penn State's Innovation Park, home to some of the leading tech companies in Pennsylvania.

Voted in the top 10 best small towns to live and in the top 10 for start-up businesses in the United States.
XM200C application demonstrations ongoing
Our Products

XM200C
The XM200C makes quality metal powder-bed fusion available for universities, labs and small-to-medium businesses who need prototyping, tooling capabilities, or low volume casting alternatives.

XM200S
The XM200S is ideal for printing of small parts where high-performance metal powder-bed fusion applications and print speed are critical.

XM300C
The XM300C offers an expanded print area for larger, industrial metal powder-bed fusion applications that need prototyping, tooling capabilities, or low volume casting alternatives.
The XM200C

- Large cubic build volume allows you to print multiple parts more efficiently and quickly.
- Patent-pending Xact Core™ high-speed scanner fuses at speeds up to 500 mm/sec. The beam is constantly orthogonal across the entire powder bed surface, which produces consistent fusing properties throughout the complete build area.
- 100W Yb fiber laser provides optimal power density and prints 20-100 μm layers with a spot size greater than 20 microns, providing precision to your build.
- Patent-pending recoater uses a unique “bulb” shape recoating element that spreads powder like a blade yet provides compaction similar to a rolling element. The recoater’s compliant design allows it to negotiate out-of-plane growth.
- Build chamber is easy to set up, quick to purge and simple to clean and maintain.
- Small printer footprint makes it easier to include additive manufacturing in your factory, lab or facility.
- Modern software architecture offers a streamlined, intuitive and functional platform that supports visual workflows and remote monitoring.
- Open platform provides qualified users the ability to develop their own printing parameters and use their own powder.

<table>
<thead>
<tr>
<th>Build Volume</th>
<th>125 in³ (5 x 5 x 5 in) 2,048 cc (127 x 127 x 127 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior Dimensions</td>
<td>Approx. 24 x 24 x 51 in³ - W x D x H (610 x 610 x 1,295 mm³)</td>
</tr>
<tr>
<td>Laser Type*</td>
<td>• 100W Yb fiber laser</td>
</tr>
<tr>
<td></td>
<td>• 200W available with optional kit</td>
</tr>
<tr>
<td>Precision Optics</td>
<td>Spot size greater than 20 microns</td>
</tr>
<tr>
<td>Scanner</td>
<td>• Fusing speed up to 500 mm/sec</td>
</tr>
<tr>
<td></td>
<td>• Orthogonal high-speed scanner</td>
</tr>
<tr>
<td>Electrical</td>
<td>• Power Supply 100-120/200-240 VAC Single Phase, 50/60 Hz</td>
</tr>
<tr>
<td></td>
<td>• 1.5 kW, 2.0 kW Peak</td>
</tr>
<tr>
<td>User Interface</td>
<td>7” intuitive user-friendly touch screen</td>
</tr>
<tr>
<td>Weight</td>
<td>Approximately 450 lbs (205 kgs)</td>
</tr>
<tr>
<td>Powder Options**</td>
<td>• Stainless Steel: 316L, 17-4 PH, 15-5, 400 Series</td>
</tr>
<tr>
<td></td>
<td>• Super Alloys: 718, 625, Cobalt Chrome F75, Hastelloy® X</td>
</tr>
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<tr>
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<td>• Bronze, Copper C18150</td>
</tr>
<tr>
<td></td>
<td>• Aluminum Si10Mg and Titanium Ti64 available with optional kit</td>
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</tbody>
</table>
Trusted Software Partners

The Xact Metal printer family relies on industry-leading software

- Autodesk Netfabb
- Materialise Magics 3D Print

Provides a complete workflow integration:

- Optimized support generation
- Slicing strategies
- Toolpath planning
- G-Code generation
- Printing execution
Available Powders include:

- Aluminum Si10Mg
- Bronze, Copper C18150
- Stainless Steel: 316L, 17-4 PH, 15-5, 400 Series
- Super Alloys: 718, 625, Cobalt Chrome F75, Hastelloy® X
- Titanium Ti64
- Tooling Steels: Maraging M300, H13
Customer Education

Design Guide Released to help engineers design for metal powder-bed fusion, including

• Applications
• Technical Capabilities
• Pre-Processing
• Process Flow
• Manufacturing Capabilities
• Manufacturing Considerations
• Design Guidelines
Manufacturing Capabilities

Build Tolerance*

- Part Dimensions <30 mm (1.18”): +/- 60 microns (+/- 0.0024”)
- Part Dimensions >30 mm (1.18”): +/- 0.2%

*Tolerances of 20 to 50 microns (0.001 to 0.002”) achievable after process optimization for a given geometry

Minimum Sizes

- Minimum practical wall thickness: 100 microns (0.004”)
- Minimum practical hole size: 200 microns (0.008”)

Feature Spacing

- Allow minimum of 0.5 mm (0.020”) between adjacent features

Flatness

- Dependent on thickness of additively manufactured component. Thin sections may distort on printing and require a thermal or mechanical stress relieving cycle

Surface Finish

- Dependent on build orientation and material; typically, better than as-cast

Mechanical Properties

- Tensile value, elongation, modulus of elasticity, and hardness properties comparable to forged or cast properties

Note: Features can be optimized by iteration of the build parameters
Design Guidelines

HEIGHT:WIDTH RATIO
Tall, narrow features should have a maximum height:width (aspect) ratio of 8:1. Features with greater aspect ratios risk damage by the recoater during powder application. Adding a gusset to the component design will strengthen the feature and minimize damage.

OVERHANGING SURFACES
- 0 to 30 degrees: Need supports
- 30 to 45 degrees: Supports not needed but part may have poor surface on down facing surfaces
- Greater than 45 degrees: Supports not needed; good quality surface finish
Design Guidelines
(continued)

FLAT CEILINGS
Flat ceilings larger than 1 mm (0.04 in.) will require a solid or mesh support. Fillets can also be added to prevent warpage out of the build plane.

GEOMETRY SUPPORT STRUCTURES
Solid or mesh mechanical supports can be added to optimize anchoring, minimize wall distortion from thermal gradients, support overhanging geometry, and provide solid anchoring between the component and the build plate to eliminate component movement during printing. The supports are easily removed after separation of the component from the build plate.
Design Guidelines
(continued)

HORIZONTAL HOLE SIZE AND SHAPE
Horizontal holes with diameters less than 5 mm (0.2 in.) can be printed reliably without internal support. Larger holes will require an internal mesh support or design change. Changing to a tear drop or square shape will eliminate the need for internal supports.

MINIMUM WALL THICKNESS
Typical minimum wall thicknesses range from 100 to 200 microns (0.004 to 0.008 in.).
Growth Operations On Plan

Shipments started December 2019
- Experienced VP Operations and techs in place
- Facility expanded to 4,000 ft²… 12,000 ft² late 2020
- BOM and documentation in place … standard products
- North America NRTL and CE certification completed
- Active Lean activities
- MRP upgrade January 2020
Leadership Team

JUAN MARIO GOMEZ
CHIEF EXECUTIVE OFFICER

Bringing over 25 years of business experience to the Xact Metal team, Juan Mario offers a seasoned executive’s perspective and guidance to Xact Metal. During his time at GE, he traveled the globe leading start-up units within the company and working in the aviation, energy, oil & gas and automotive industries. Juan Mario received bachelors and masters engineering degrees from Boston University and an MBA from The University of Chicago Booth School of Business.

MATT WOODS
CHIEF TECHNICAL OFFICER

Matt was born an innovator. With a mechanical engineering background, he’s used his inventive spirit and extensive technical expertise to develop new AM and rapid prototyping machines with Xact Metal. Matt honed his knowledge with experience at SpaceX and Penn State’s CIMP-3D, a leading additive manufacturing research facility. Matt received an engineering degree from Penn State University.

TIM SIMPSON
ADVISOR

Dr. Simpson is a Professor of Mechanical & Industrial Engineering at Penn State University with affiliate appointments in the School of Engineering Design, Technology, and Professional Programs and the College of Information Sciences & Technology. He has received numerous research and teaching awards, and is Co-Director of Penn State’s CIMP-3D.
Leading Technology

**Xact Core™**
Built on the patent-pending Xact Core, a high-speed gantry system platform that allows light, simple mirrors to move quickly and consistently above the powder bed on an X-Y axis.

- Avoids the use of complex galvanometer mirrors and F-theta lenses
- Maintains a constant laser angle across the whole build plate
- A simplified gas flow over the powder bed due to the smaller build chamber

**Patent-Pending Recoater**

- Unique “bulb” shape of the recoating element spreads powder like a blade, yet provides compaction similar to a rolling element
- Compliant design allows the recoater to negotiate out-of-plane growth and continue printing
- Mounting the recoater to the machine lid allows the entire recoating mechanism to be removed from the build chamber
- Easy access to the build chamber allows for simple recoater replacement and adjustments
Manufacturing Considerations

Manufacturing Quantity
Additive Manufacturing is typically a low-quantity process. Manufacturing components with established designs, in higher quantity, is more efficient and less costly with traditional processes like casting, machining, and assembly.

Two important exceptions where Metal PBF offers distinct advantages:

- Manufacturing of complex designs that incorporate difficult-to-machine features such as complex internal geometries or mesh structures
- Manufacturing of small run, custom parts

Build Sizes
Typical printer build volumes range from:

- 12.7 cm. cube (2048 cu-cm.) / 5-inch cube (125 cu-in)
- 25.4 cm. x 33 cm. x 33 cm. (27660 cu cm.) / 10 in x 13 in x 13 in (1690 cu-in.)

Reactive Metals
- Special handling and processing should be used when printing reactive metals such as titanium and aluminum.

Build Plate
- Metal PBF components are fused to a supporting build plate to prevent movement or warping during printing.
- Build plate material should be metallurgically compatible with the powder metal to minimize distortion during printing.
Manufacturing Considerations (Continued)

Post Processing (As Required Or Specified)

- Removal of the printed component from the build plate with a bandsaw, wire EDM, or flush cutting tools
- Removal of supports
- Traditional finishing processes such as grinding and polishing, finish machining, bead blasting, and abrasive slurry honing of internal channels
- Post treatment processes including heat treat annealing and Hipping
- Resurfacing of build plates
Target Customers

• Small-to-mid-size enterprises (SMEs), university labs, printing services labs who are focused on R&D, prototyping, tooling and low volume production

• Initial focus will be North America, followed by Europe and then Asia

• Target industries are aerospace, defense, automotive, universities, healthcare and engineering
Intuitive Touchscreen User Interface

The modern, interactive graphic user interface (GUI) for the XM300C makes loading files, setting up builds and monitoring the build process quick and easy.

- Home screen displays real-time build monitoring
- Chamber setup screen allows customer to optimize print parameters
- Build queue screen provides a description of all builds to be printed
- Monitoring screen shows behavior of important parameters such as bed temperature, chamber temperature and pressure and oxygen percentage
The XM200S

- Large cubic build volume allows you to print multiple parts more efficiently and quickly.
- 200W Yb fiber laser provides optimal power density and prints 20-100 μm layers with a spot size greater than 50 microns, providing precision to your build.
- Precision digital scanner includes active thermal and drift compensation that eliminates warm-up times and minimizes long-term drift.
- Patent-pending recoater uses a unique “bulb” shape recoating element that spreads powder like a blade yet provides compaction similar to a rolling element. The recoater’s compliant design allows it to negotiate out-of-plane growth.
- Build chamber is easy to set up and simple to clean and maintain.
- Easy user access to filters, particle collection and overflow container.
- Inert swap housing provides quick and safe filter changeovers.
- Small footprint makes it easier to include additive manufacturing in your factory, lab or facility.
- Modern software architecture offers a streamlined, intuitive and functional platform that supports visual workflows and remote monitoring.
- Open platform provides qualified users the ability to develop their own printing parameters and use their own powder.

**TECHNICAL DATA**

| Build Volume | 125 in³ (5 x 5 x 5 in) 2,048 cc (127 x 127 x 127 mm) |
| Exterior Dimensions | Approx. 37 x 24 x 67.5 in³ - W x D x H (940 x 610 x 1,715 mm³) |
| Laser Type* | 200W Yb fiber laser |
| Precision Optics | Spot size greater than 50 microns |
| Scanner | • High-performance galvanometric scanner • Scan speed up to 8 m/s |
| Electrical | • Power Supply 200-240 VAC Single Phase, 50/60 Hz • Consumption 2.9 kW |
| User Interface | 15” intuitive user-friendly touch screen |
| Weight | Approximately 600 lbs (272 kgs) |
| Powder Options** | • Aluminum Si10Mg • Bronze, Copper C18150 • Stainless Steel: 316L, 17-4 PH, 15-5, 400 Series • Super Alloys: 718, 625, Cobalt Chrome F75, Hastelloy® X • Titanium Ti64 • Tooling Steels: Maraging M300 |
Leading Technology

Precision Digital Scanner/Optics

• Active thermal drift compensation eliminates warm-up times and minimizes long-term drift during printing operations

• 24-bit command resolution gives industry-leading positional accuracy

Patent-Pending Recoater

Unique “bulb” shape of the recoating element spreads powder like a blade, yet provides compaction similar to a rolling element

Compliant design allows the recoater to negotiate out-of-plane growth and continue printing

User-Friendly Modern Design

• System is designed to allow ease of operations and minimize changeover times and has a small footprint

• Easy access to filters, particle collection and overflow container

• Quick filter changeover times using an inert swap housing
The XM300C

- Large build volume provides flexibility in development and manufacturing applications.
- Two or four independent Yb fiber laser scanners reduce build time and increase productivity.
- The patent-pending Xact Core™ high-speed scanner fuses at speeds up to 500 mm/sec. The beam is constantly orthogonal across the entire powder bed surface, which produces consistent fusing properties throughout the complete build area.
- Twin feed cylinders lower build time and increase throughput.
- Accessible build chamber is easy to set up, quick to purge and simple to clean and maintain.
- Small footprint reduces overall space requirements.
- Modern software architecture offers a streamlined, intuitive and functional platform that supports visual workflows and remote monitoring.
- Open platform provides qualified users the ability to develop their own printing parameters and use their own powder.

### TECHNICAL DATA

| Build Volume       | 1,690 in³ (10 x 13 x 13 in)  
|                    | 27,661 cc (254 x 330 x 330 mm) |
| Exterior Dimensions| Approx. 44 x 28 x 55 in² - W x D x H  
|                    | (1,118 x 711 x 1,397 mm³) |
| Laser Type         | 2 or 4 independent 100W Yb fiber lasers |
| Precision Optics   | Spot size greater than 20 microns |
| Scanner            | - Fusing speed up to 500 mm/sec  
|                    | - Orthogonal high-speed scanner |
| Electrical         | Power Supply 220V (50-60 Hz) |
| User Interface     | 15.6" intuitive user-friendly touch screen |
| Powder Options     | - Stainless Steel: 316L, 17-4 PH, 15-15, 400 Series  
|                    | - Super Alloys: 718, 625, Cobalt Chrome F75, Hastelloy® X  
|                    | - Tooling Steels: Maraging M300, H13  
|                    | - Bronze |
Metal Powder-Bed Fusion Build Process

**POWDER FEED**
Feed cylinder increments up placing powder in front of the recoater.

**ADDING POWDER LAYER**
Recoater moves across the feed cylinder delivering powder to the build cylinder.

**FUSION**
Laser fuses the cross section of the part.

**BUILD CYLINDER**
Build cylinder increments down one thickness layer.

**COMPLETING THE BUILD**
The process is repeated until the volume of the part is fully built.

**BUILD PLATE AND PART REMOVAL**
The build cylinder raises up and the build plate is removed.
Technical Capabilities

Metal Powder-Bed Fusion enables manufacturing of complex geometries with many features not readily obtainable by conventional subtractive manufacturing processes such as machining and casting.
Printing of complex 3D parts with metal powder bed fusion is a straightforward process with total build and processing times of 4 to 36 hours.

1. PRE-PROCESSING
   - Optimizing CAD build file for additive manufacturing
   - Support generation and parameter optimization
   - Slicing strategies

2. BUILD PREPARATION
   - Loading build file
   - Preparing build volume and adding metal powder

3. BUILDING
   - Precision controlled fusion of the metal powder into layers that form the desired shape and volume

4. SEPARATION OF PART FROM BUILD PLATE
   - Removal of part from build plate with wire EDM, bandsaw, or flush cutting tool

5. POST PROCESSING
   - Removal of supports
   - Final surface finishing
   - Heat treating for mechanical properties
Segments and Applications

- Aerospace
- Defense
- Automotive
- Universities
- Healthcare
- Engineering

- Rapid design prototyping
- Tooling
- One-off and small volume manufacturing
- Complex designs
- All-in-one assemblies
- Remote manufacturing
- Inventory Reduction
Typical Metals Used In Metal Powder-Bed Fusion Applications

- Stainless Steels: 316L, 17-4 PH, 15-5 and 400 series
- Super Alloys: 625, 718, Cobalt Chrome F75, and other Nickel, Chromium & Molybdenum based alloys
- Tooling Steels: Maraging M300
- Bronze and Copper C18150
- Aluminum AlSi10Mg
- Titanium Ti 64
- Precious metals: gold, silver
Design Guidelines
(continued)

POWDER ESCAPE
Holes are required to allow powder to escape from enclosed printed structures. A minimum hole diameter of 3.0 mm (0.12 in.) is recommended. Multiple or larger holes will increase the speed of powder removal.

OTHER RECOMMENDATIONS
- Add fillets to decrease stresses at geometry changes
- Minimize unnecessary blocks of printed material
- If practical, print internal holes parallel to the build direction (Z-axis)