EXONE METAL BINDER JET 3D PRINTING

ABOUT EXONE

About ExOne

ExOne is the pioneer and global leader in binder jet 3D printing technology. Since 1995, we've been on a mission to deliver powerful 3D printers that solve the toughest problems and enable world-changing innovations. Our 3D printing systems quickly transform powders – including metals, ceramics, composites and sand – into precision parts, metalcasting molds and cores, and innovative tooling solutions.

Learn more about ExOne at www.exone.com or on Twitter at @ExOneCo. We invite you to join with us to #MakeMetalGreen™

The ExOne Company | Overview

The global leaders in binder jet 3D printing for 20+ Years

Founded

- Began in 1995 as the 3D division of Extrude Hone
- Around 270 employees worldwide
- NASDAQ listed since 2013

Machines & Services

- Industrial-grade binder jet 3D printing systems and services
- 3D printing solutions for sand, metal, ceramics and composites

High-Value Parts

- Sand molds and cores
- Direct metal 3D printing
- Direct ceramic 3D printing
- 3D printed tooling solutions

Industrial Markets

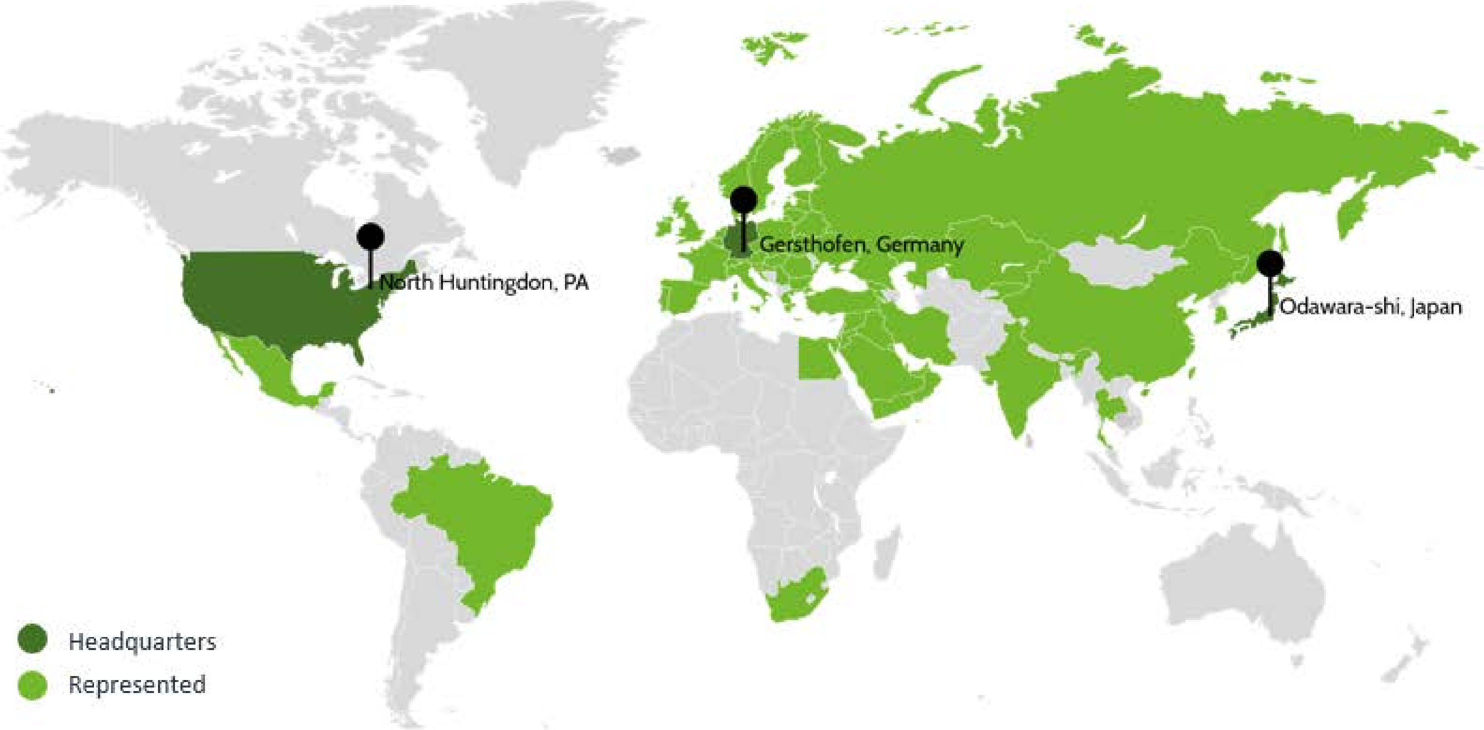
- Foundries | Automotive
  Aerospace | Defense | Medical
  Energy | Heavy Equipment
  Architecture | Construction

Rapid Growth

- 2018 Revenue: $65M
- 3-year annual growth: 17%
  Transitioning from R&D and prototyping to production

The ExOne Company | Locations

We are represented all over the world



Headquarters

The ExOne Company
127 Industry Boulevard
North Huntingdon, PA 15642
USA

ExOne GmbH
Daimlerstrasse 22
86368 Gersthofen
Germany

ExOne KK
161-5 Haneo
Odawara-shi, Kanagawa
Japan

The ExOne Company | Early Years

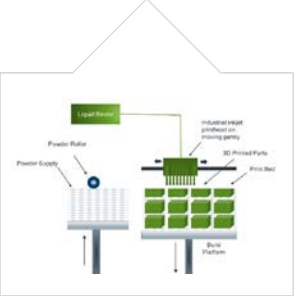
Highlights of an emerging technology leader

1995

The Vision
Extrude Hone creates the "ProMetal" division to develop 3D printing. Company founder Larry Rhoades sees the potential of the new technology.

1996

The Patent
Extrude Hone obtains exclusive field-of-use license for patented 3D printing processes developed at the Massachusetts Institute of Technology (MIT).



1998

The Pioneer
Launch of the ProMetal RTS-300, the first metal 3D printer using binder jetting technology and the commercial realization of MIT's invention.

2002

Entry into Sand
Extrude Hone launches the S15 sand printer using binder jet technology.

2003

A Workhorse
Extrude Hone launches the ProMetal R2, one of the company's most robust and successful direct metal 3D printers using binder jet technology.

2005

Year of the Spin-off
Extrude Hone launches two new printers, the S-Print sand printer and X1 Lab metal printer and is sold to Kennametal. The assets of the 3D printing business are transferred to a newly created entity: "The Ex One Company."

The ExOne Company | A New Era

Highlights of an emerging technology leader

2007

Unexpected Change

Rhoades dies unexpected and ExOne is purchased by a company wholly owned by S. Kent Rockwell, who has led the company ever since as Chairman of the Board of Directors.

2010-2013

The Printers

Launch of four all-new printers: the S-Max, a new version of the S-Print, now a staple portfolio product, and the M-Print and M-Flex metal printers.

2013

Breakthrough R&D

ExOne begins 3D printing full-density single alloy metals without infiltration – a game-changing technology breakthrough.

The XONE IPO

ExOne successfully completes its Initial Public Offering on Nasdaq, one of the most successful IPOs of the year. Shares of XONE begin trading.

2014

Waves of Sand

ExOne launches three new sand printers, including a new S-Max and S-Print models, continuing its market share gains in sand 3D printing.

2018

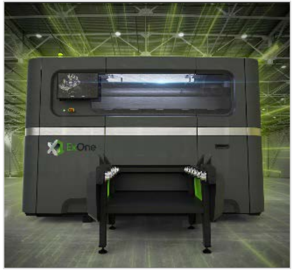
New Metal Era

ExOne launches the Innovent+ and X1 25PRO metal 3D printers for processing ultra-fine MIM metal powders into dense single alloy parts without infiltration.

2019

The Next Generation

ExOne launches the S-Max Pro production sand 3D printer and the X1 160PRO, the company's tenth metal printer and the industry's largest commercially available metal binder jetting system.



ExOne

ExOne Delivers

Experienced provider of metal binder jetting systems

SHIPPING SOON | The X1 160 Pro™

Our tenth and largest metal 3D printer
Build Dimensions: 800 x 500 x 400 mm
(31.5 x 19.7 x 15.8 in)

Announced: Formnext 2019 | Delivery: 2H 2020

ExOne Machine History

		Material Type				Build Area Dimensions*				Details	
		Sand	Metal	Ceramic	Composite	X	Y	Z	volume	Launch Year	Status
21	InnoventPro®		X			4.9 in (125 mm)	8.7 in (220 mm)	3.9 in / 7.9 (100/200 mm)	3L or 5L	2021	Coming Soon
20	X1 160Pro™		X	X	X	31.5 in (800 mm)	19.7 in (500 mm)	15.8 in (400 mm)	9,763 cu in (160 cu dm.)	2020	
19	S-Max Pro®	X				70.86 in (1800 mm)	39.37 in (1000 mm)	27.56 in (700 mm)*	76,886 cu in (1.26 cu m.)	2019	
18	X1 25Pro®		X	X	X	15.75 in (400 mm)	9.84 in (250 mm)	9.84 in (250 mm)	1,525 cu in (25 cu dm.)	2019	
17	Innovent+		X	X	X	6.3 in (160 mm)	2.56 in (65 mm)	2.56 in (65 mm)	41.3 cu in (676.8 cu cm.)	2018	
16	Innovent		X	X	X	6.3 in (160 mm)	2.56 in (65 mm)	2.56 in (65 mm)	41.3 cu in (676.8 cu cm.)	2016	
15	Exerial	X				86.61 in (2200 mm)	47.24 in (1200 mm)	27.56 in (700 mm)	112,760.5 cu in (1,848 cu m.)	2015	Discontinued
14	S-Max+Silicate	X				70.9 in (1800 mm)	39.37 in (1000 mm)	23.6 in (599 mm)	65,875.5 cu in (1.08 cu m.)	2014	Discontinued
13	S-Max+Phenolic	X				70.9 in (1800 mm)	39.37 in (1000 mm)	23.6 in (599 mm)	65,875.5 cu in (1.08 cu m.)	2014	Discontinued
12	S-Print Silicate	X				31.5 in (800 mm)	19.68 in (500 mm)	15.75 in (400 mm)	9,763.7 cu in (160 cu dm.)	2014	
11	M-Flex	X	X	X	X	15.75 in (400 mm)	9.84 in (250 mm)	9.84 in (250 mm)	1,525 cu in (25 cu dm.)	2013	
10	S-Print Phenol	X				31.5 in (800 mm)	19.68 in (500 mm)	15.75 in (400 mm)	9,763.7 cu in (160 cu dm.)	2012	
9	S-Print Furan	X				31.5 in (800 mm)	19.68 in (500 mm)	15.75 in (400 mm)	9,763.7 cu in (160 cu dm.)	2012	
8	M-Print	X	X			31.5 in (800 mm)	19.68 in (500 mm)	15.75 in (400 mm)	9,763.7 cu in (160 cu dm.)	2012	Discontinued
7	S-Max Furan	X				70.9 in (1800 mm)	39.37 in (1000 mm)	27.56 in (700 mm)	65,875.5 cu in (1.26 cu m.)	2010	
6	S-Print	X				31.5 in (800 mm)	19.68 in (500 mm)	15.75 in (400 mm)	9,763.7 cu in (160 cu dm.)	2005	
5	X1-Lab		X			1.5 in (38 mm)	2.3 in (58 mm)	1.3 in (33 mm)	4.5 cu in (73 cu cm.)	2005	Discontinued
4	R2		X	X		7 in (178 mm)	7 in (178 mm)	5 in (127 mm)	245 cu in (4 cu dm.)	2003	Discontinued; Still being used for production
3	S15	X				59 in (1499 mm)	30 in (762 mm)	28 in (711 mm)	49,560 cu in (812 cu dm.)	2002	Discontinued
2	R10		X			36 in (914 mm)	18 in (457 mm)	12 in (305 mm)	7,776 cu in (127 cu dm)	1999	Discontinued
1	RTS-300		X			11.8 in (300 mm)	11.8 in (300 mm)	9.8 in (249 mm)	1,364.6 cu in (22 cu dm.)	1998	Discontinued

Some systems may also have additional build box sizes and configurations.
**"Machine Results". Senvol. Retrieved 2019-06-26.*

ExOne™

The ExOne Company | Installed 3D Printers

Number of installed 3D printers worldwide

AMERICA

Country	Metal	Sand
United States	90	29
Canada	7	2
Mexico		5

ASIA

Country	Metal	Sand
Japan	10	32
China	4	21
India		7
Indonesia		1
Saudi Arabia	0	1
Singapore	3	
South Korea		3
Thailand		1

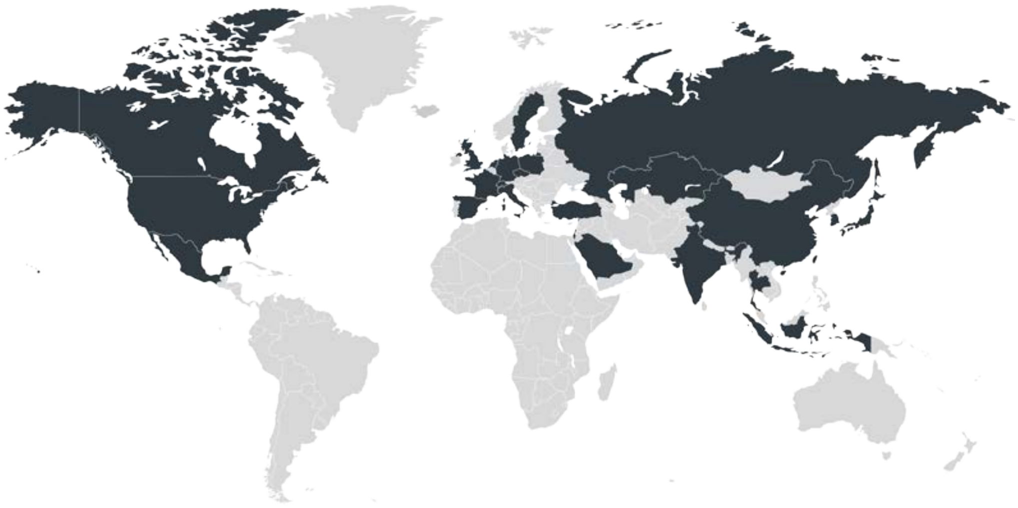
EUROPE

Country	Metal	Sand
Germany	12	20
Czech Republic	2	2
France	2	4
Great Britain	1	8
Israel	1	
Italy	1	8
Kazakhstan		1
Liechtenstein	1	
Netherlands		1
Spain	3	1
Sweden	5	2
Switzerland		4
Turkey		3
Russia	1	11
Poland	2	0

167 Sand

145 Metal

312 * MACHINES WORLDWIDE



* sold machines as of Q2 2020

ExOne | Our Collaboration Partners

Critical research and development network

Amy Elliott, PhD Research Scientist, Oak Ridge National Laboratory ORNL

Altair

ANSYS

ELNIK SYSTEMS

KENNAMETAL

OAK RIDGE National Laboratory

SANDVIK

SIEMENS

ExOne has a growing number of collaborations that enable us to develop binder jet technology faster.

These relationships, often made with customers, help us develop faster by working with us in a variety of areas:

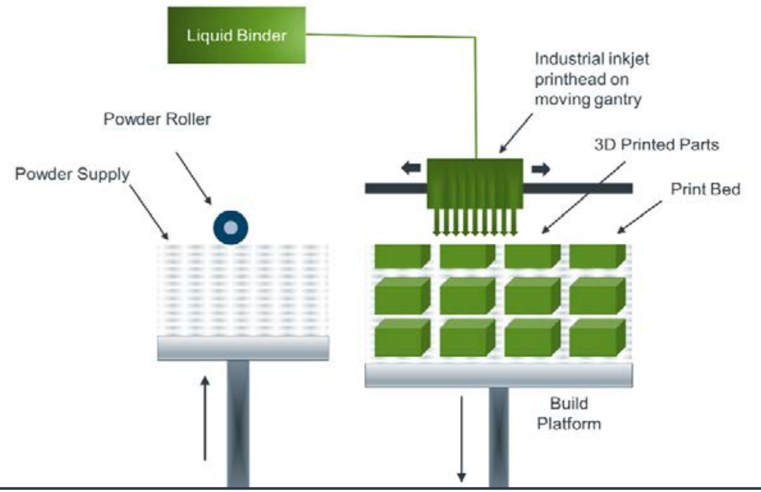
- Materials
- Software
- All-New Applications
- Optimizing Applications
- Research Studies
- Binder Jetting Processes
- Binder Jetting Accessories

ExOne

OUR CORE TECHNOLOGY

ExOne | Our Core Binder Jetting Technology

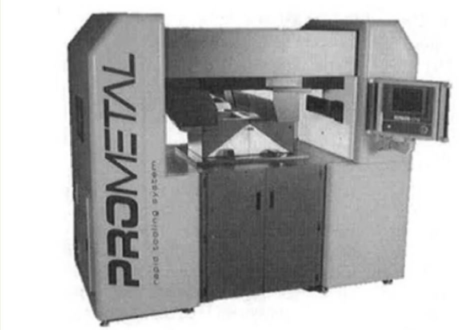
Binder Jet 3D Printing Leadership for 20+ Years



Definition: A method of 3D printing in which an inkjet print head quickly deposits a bonding agent onto a thin layer of powdered particles, either metal, sand, ceramics or composites. This process is repeated, layer-by-layer, using a map from a digital design file, until the object is complete.

For metals, this process creates a "green" part that is then cured, or dried, in an oven. The part is then "depowdered" or removed from the powder bed and cleaned before final sintering in a high-temperature furnace, where the particles fuse together.

Initially developed at the Massachusetts Institute of Technology in the early 1990s, ExOne obtained the exclusive license to this inkjet-in-powder-bed approach in 1996. **Two years later, in 1998, ExOne launched the market's first commercial binder jet metal 3D printer, the RTS-300.**



Binder Jetting | Overview

Patented in 1993 by Massachusetts Institute of Technology

POWDER

Sand, Metal, Ceramics, Composites

BINDER

Liquid binder adheres powder and layers together

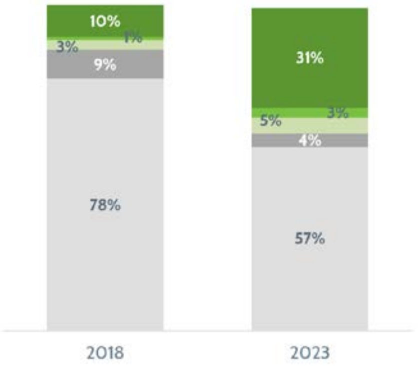
PRINT EACH LAYER

- Layer of powder is spread into the print bed
- Industrial printhead lays down binder fast sweeps.
- Recoater dries layer and lays down fresh powder
- Process is repeated until the part is complete and ready for post-processing.

CORE BENEFITS

- High processing speeds
- Scalable, large systems
- Small or large parts
- Many materials
- Low operating cost
- Easy to operate

AM Power Forecast



- Binder Jetting Technology
- Metal Fused Deposition Modeling
- Directed Energy Deposition
- Electron Beam Powder Bed Fusion
- Laser-based Powder Bed Fusion

Binder Jetting | 3D Printing Process Overview

Liquid binder is applied to a layer of powder to form high-value parts and tooling

Digital File Prep → Machine & Material Prep → 3D Printing

3D Printing

1 Powder is deposited.
2 Inkjet applies binder.
3 Each layer is printed fast.
4 Powder is recoated.
5 The process repeats.
6 3D printing is complete.

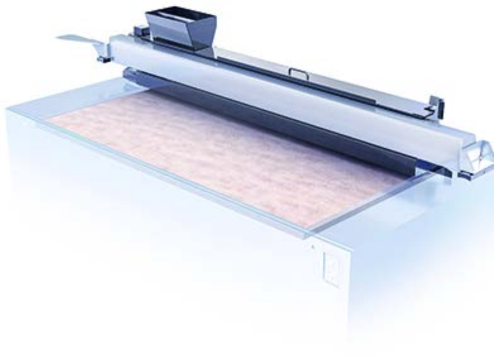
Next Steps Depend on Application and Specific Materials →

- Sand molds & cores → Depowder → Cure optional
- NEW Sand tooling → Depowder → Coat or Infiltrate
- Metal and ceramics → Cure → Depowder → Debind & Sinter

ITERATIVE PROCESS WITH BIG PAYOFFS

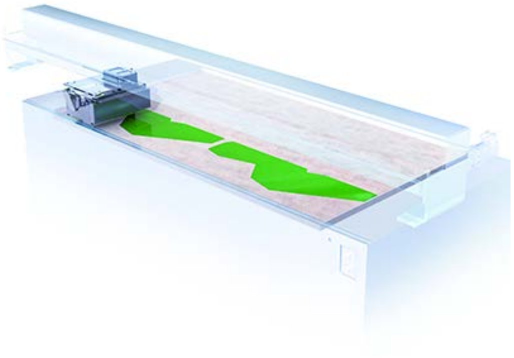
ExOne | Binder Jetting Technology

Binder is selectively applied to a thin layer of sand, layer by layer, to form parts



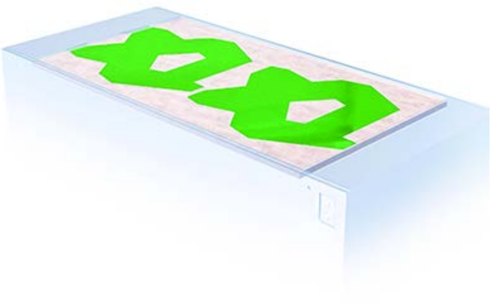
START LAYER

The recoater applies the first thin layer of powder – either sand, metal, ceramics or another material – into the print area or job box.



INKJET BINDER

A gantry of industrial print heads selectively applies binder to the powder to bind particles together where desired.

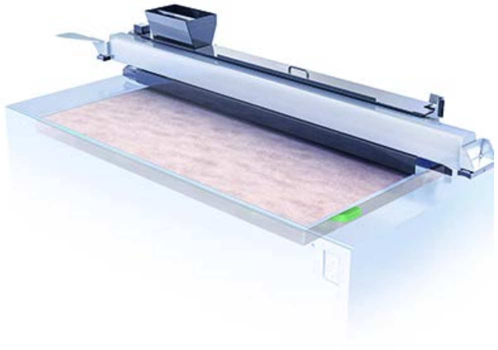


FAST LAYER SPEEDS

With a full sweep of print heads, a binder jet 3D printer can complete a full layer very quickly. This is one of the core benefits of binder jetting compared to other 3D printing methods.

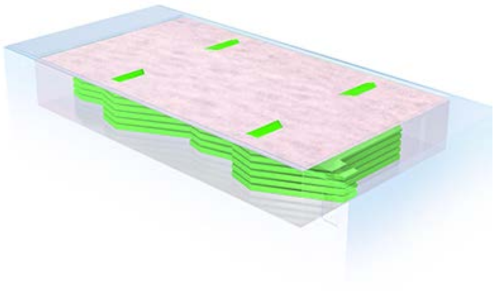
ExOne | Binder Jetting Technology

Precise recoating of sand, and application of binder, are key for quality parts



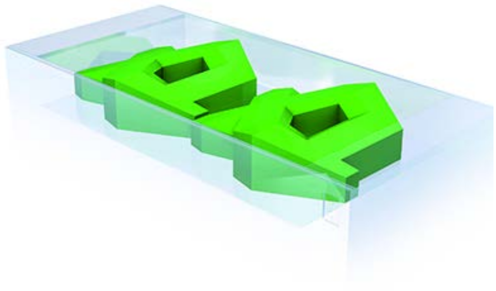
RECOATING

This is a critical step in the binder jetting process, when the recoater lays down the next layer of powder. It must be precisely and compactly applied to deliver a high-qualify precision part.



RINSE AND REPEAT

Once the next powder layer has been applied to the print area, the stage has been set for the next layer of binder. This recoating-and-binding sequence is repeated until the part is complete.



POST PROCESSING

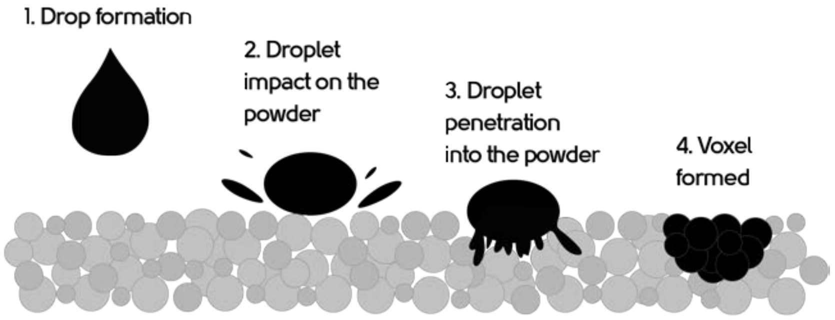
Once the job is complete, the part is removed from the bed of sand and may need to be cured in an oven or microwave, depending on the sand and binder selected. Metal parts need an additional step of sintering to fuse the particles together.

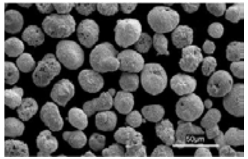
ExOne | The Binder Jetting Process

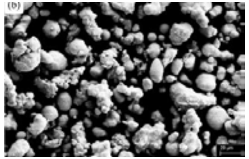
Dropping inkjet into a bed of powder takes extreme engineering and experience to control

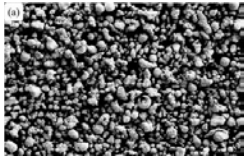
Among the Challenges

- Precisely jetting fine droplets of binder fluid into a bed of powder where particles are not necessarily the same size and shape (not perfect rounds, D50 variations) is challenging in X, Y and Z
- Ink must be dropped precisely in the X and Y directions and not bleed in the powder
- Ink must seep vertically around various particle sizes and shapes (depending on material) to a controlled Z-depth
- Powder must be spread on top of existing print layers to a controlled depth across the entire build area and compacted tightly for green-part density
- Binder must cure between layers to prevent spreading new particles on wet particles
- The process must be repeatable and deliver consistent results across the entire build area









Learn More
www.exone.com/binderjetting

ExOne | We Turn Powder into Parts

Binder jetting a wide range of powder materials

POWDER MATERIALS WE PROCESS

SAND	METAL	CERAMICS	COMPOSITES
Industrial Sands for metal casting	Ultra-fine metal MIM powders	Wide variety of ceramic powders	Industrial-grade composites
EX: Silica sand, ceramic sands, and more ...	EX: 316L, 304L, 17-4PH, and more ...	EX: Silicon carbide and more ...	EX: Tungsten Carbide Cobalt and more ...

ExOne™

ExOne | Binder Jetting Materials

20+ qualified 3D printing powders plus another 25 R&D materials

ExOne Binder Jet 3D Printing Materials

Q4 2020

3D Printers	sands	ceramics	composites	100% metals	build volume	applications
X1 160Pro		✓	✓	✓ >97% Density with TRIPLE ACT	XL	• Serial Production Low or High Volumes • MIM-Like Parts • Prototypes • R&D
X1 25Pro		✓	✓	✓	L	
Innovent+ or Pro	✓	✓	✓	✓	S/M	
M-Flex	✓	✓	✓	✓	L	• Metalcasting Molds & Cores • Sustainable Tooling • Production Low or High Volumes • Prototypes • R&D
S-Print	✓	✓			XL	
S-Max	✓	✓			XXL	
S-Max Pro	✓	✓			XXL	
TWENTY+ QUALIFIED 3D PRINTING POWDERS	2 SAND TYPES Natural and Synthetic Sands	4 CERAMICS Alumina, Carbon, Silicon Carbide, Tungsten Carbide Cobalt	5 COMPOSITES 316 w/Bronze, 420 w/Bronze, Boron Carbide w/Aluminum, Silicon Carbide w/Silicon, Tungsten with Bronze	11 METALS 17-4PH, 304L, 316L, Cobalt Chrome, Copper, H13 Tool Steel, Inconel 718, Inconel 625, M2 Tool Steel, Titanium, Tungsten Heavy Alloy	SUSTAINABLE MANUFACTURING TECHNOLOGY	

The twenty+ materials listed above have been qualified for use on ExOne machines by ExOne, our customers and independent third parties.

Plus, another 25 R&D materials – including aluminum and more

Binder Jetting | Print, Pour and Produce

A flexible array of materials for direct printing complex, high-value parts and tooling

Binder Jetting | Four Primary Application Categories

Binder Jetting delivers complex, high-value parts faster, with a dramatic reduction in waste

3D sand molds and cores for metal casting

Complex molds and cores in days instead of weeks and months. Pattern-less production for sandcasting.

Direct metal 3D printing

Custom or mass production of complex single-alloy metal parts in hours versus weeks or months.

Direct ceramic 3D printing

3D printing greatly simplifies production of difficult to produce ceramic materials, such as silicon carbide.

Innovative 3D printed tooling solutions

Affordable, time-saving 3D printed tooling solutions for complex sacrificial, vacuum- and hydro-forming.

ExOne

Binder Jetting | Transformational Benefits

Faster delivery, done-in-one pieces, new design freedoms and business flexibility

While all forms of 3D printing deliver some of these benefits, **only binder jetting** can deliver the throughput necessary to drive high-volume transformation.

SPEED

- **High volumes at high speeds**
- Hours and days versus weeks and months
- Rapid design iterations without $$ hard tooling
- Beat competitors to market

WASTE REDUCTION

- Reduce or eliminates a wide range of wastes
  - Material waste
  - Hard tooling
  - Excess mfg processes
  - Inventory
  - Labor (reduce or eliminate excess assembly)

SAVINGS

- Saves costs by streamlining many forms of wastes
  - Waiting
  - Defects
  - Over-processing
  - Overproduction (no min. volumes)
  - Transportation and storage of parts to assemble

DESIGN FREEDOM

- Sustainable manufacturing without traditional limitations
- **Consolidate parts** into monolithic parts
- **Lightweight** part designs in trusted materials
- New rigging, riser and other designs for metalcasting molds for **done-in-one pours**
- All new innovative products not previously possible
- Easy to iterate designs

FLEXIBILITY

- Some binder jet systems can print **many different materials** (industrial-grade or MIM powders)
- Print or Pour: Binder jetting systems can **direct print final parts and tooling** for metalcasting & more
- From prototyping to production: Binder jetting is currently **best suited for production volumes** and can also accommodate tooling
- Enables decentralized manufacturing

ExOne | Eliminating Costly Waste

3D printing eliminates wasted time and resources, improving profitability

改善 Kaizen

The ultimate lean tool

Binder Jet 3D printing addresses all of the eight types of waste recognized in lean business principles.

Waste is the root of all unprofitable activity, according to Kaizen lean philosophy.

Lean production is focused on reducing and eliminating waste.

Waiting
No waiting for patterns, molds, pours or parts

Overproduction
No minimum volume requirements

Overprocessing
Reduce processing and assembly steps

Defects
Eliminate stack-up errors, reduce defects

Motion
Reduce unnecessary movement (assembly)

Inventory
Eliminate many forms of inventory

Transportation
Reduce shipping materials and parts

Skills
Inefficient use of people doing low-value task

ExOne

Metal 3D Printing | Exceptional Design Freedoms

Complexity achievable in final part as well as rigging and riser design

ExOne and Altair worked with a global automotive manufacturer to lightweight an existing structural truck part that holds cruise control sensors.

The existing part was redesigned with Altair Inspire and 3D printed with ExOne binder jetting in 316L stainless steel.

BENEFITS

- More than 45% lighter
- Fewer manufacturing processes to make
- Reduced the amount of welding required to affix the part to the vehicle structure

BINDER JETTING CONSIDERATIONS

Binder Jetting | A Simple Process with Interdependency

Dropping inkjet into a bed of powder takes extreme engineering and experience to control

PRINTHEAD

- Binder must be dropped precisely in the X and Y directions, with controlled levels of bleeding and saturation in Z

POWDER

- Powder particles vary in size and shape (not perfect rounds, particle size variations), and oxidation sensitivity, so powder needs to be characterized and conditioned prior to printing

BINDER

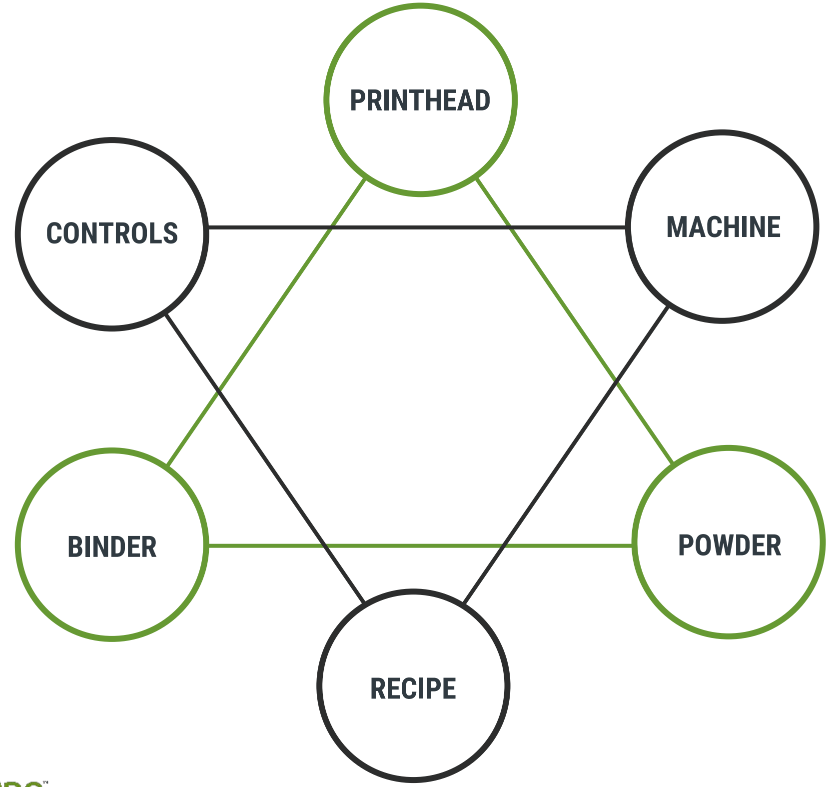
- Droplet size and properties (chemistry, rheology, ink, glue and coating properties) must adapt to material characteristics. Must be able to "dry" quickly between layers for quick binding and application of next layers without wet powder smearing

CONTROLS & MACHINE

- Tight controls of the mechanicals necessary to ensure precise powder dispensing, spreading and compact, as well as printing

RECIPE

- Process must be optimized for all powder-binder combinations and deliver consistent and repeatable results across the entire build area



ExOne

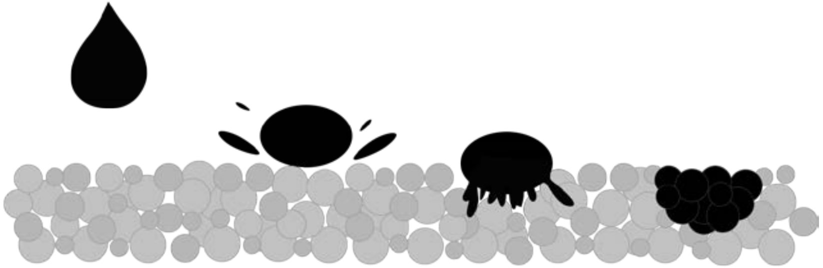
Binder Jetting | Powder Characterization

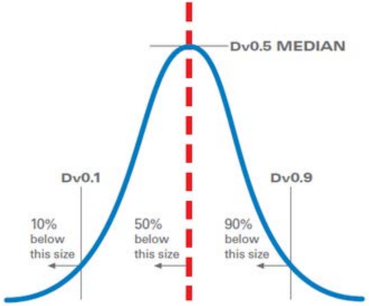
Powder must be characterized and conditioned and work well with selected binder

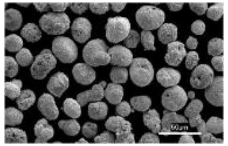
Large Particle Powders (60 microns) → Finer Particle Powders (30 microns) → MIM Powders (<30 microns) → Multiple MIM Powders

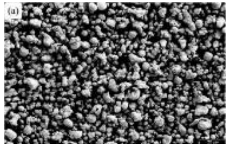
UNDERSTANDING POWDER CHARACTERIZATION

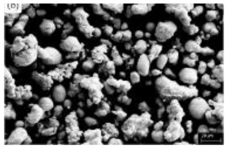
- Important to understand the powder on which you're printing for successful outcome
- While high-density metal is achievable today, you may want bonded, partially sintered, or infiltrated parts for some applications
- Particle size distribution D50 is also known as the median diameter of the particle size distribution. It is the value of the particle diameter at 50% in the cumulative distribution. It is one of the most important features of characterizing powder.
- Particle shape and surface textures
- Bulk and tap densities of the powder
- Rheology characteristics such as powder cohesiveness











Metal 3D Printing | Applications by Porosity

From large particles to infiltrated materials to dense, single-alloy, ultra-fine powders

Coarse Powders

Product Forms

Materials (D50>20μ):
Minerals, Ceramic, Carbon, Glass, Ceramic, Metal

Markets:

- Sand casts molds
- Low density single-alloy parts < 90%, Filters
- Metal and ceramic matrix
- Other course powder non-metallics
- Castings - high density single-alloy
- Tooling

Fine Powders

Product Forms

Materials (D50 <20μ):
Minerals, Ceramic, Glass, MIM, CIM powders

Markets:

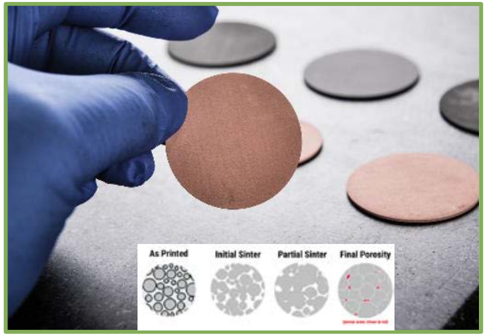
- MIM
- CIM
- Investment castings
- Machined parts
- PM parts
- Ceramic matrix
- Cutting tools
- Wear parts

Bonded

Partially Sintered

Infiltrated

Highly Sintered



Binder Jetting | Binder Considerations

Many binders are proprietary to manufacturers and play a critical role

CHEMISTRY REQUIREMENTS

- Compatible with jetting module
- Compatible with powder
  - Must wet powder while limiting bleeding and seeping to desired depth for stitching
  - Must not ruin powder (like acid/rust)

SAFETY

- Safe to handle, ship and dispose of or recycle
- Pure or clean.
  - Filtered below 3 microns
  - DI / Distilled Water

BINDER RHEOLOGY

- Viscosity
- Surface Tension

BINDER PROPERTIES

- Open Time
- Droplet Formation Time
- Stability (doesn't change over time)
- Low or no foam

COATING PROPERTIES

- Film Former
- Matrix Former

INK PROPERTIES

- Detergency
- Adhesive to Surface
- Cohesive to Self
- High-Temperature Functioning

ExOne

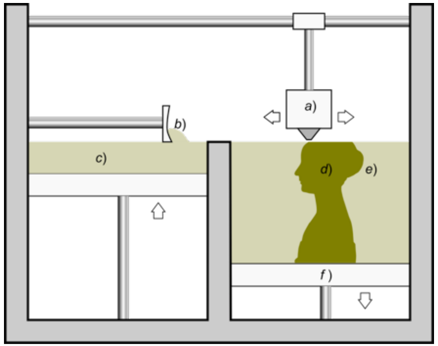
Binder Jetting | Machine Design & Control System

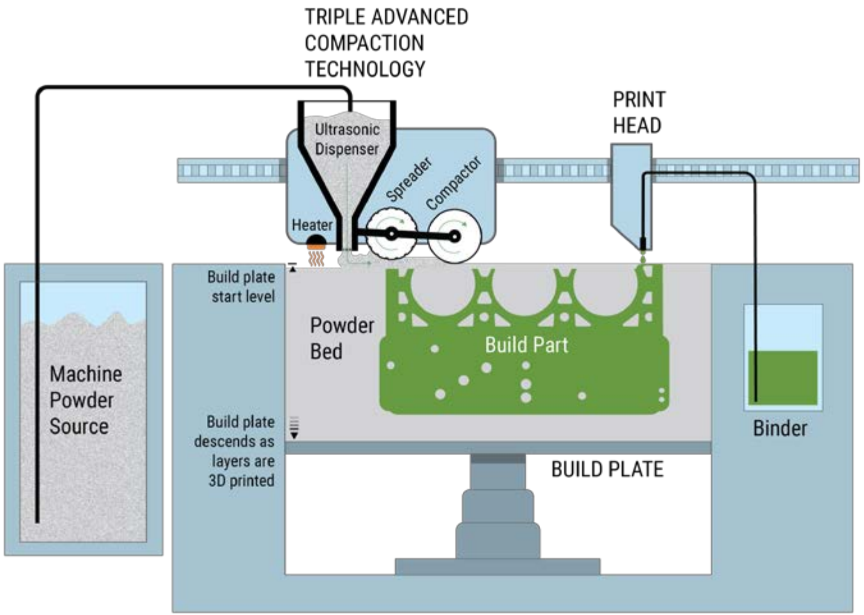
Different binder jet approaches to powder and binder management

Original Approach

New Approach

- Important to understand different designs and how they impact powder management, cleanliness (a serious consideration with powder) as well as impact on speed and other factors
- Important to consider control systems, sensors, part wear, waste management, recyclability features, accessibility/greenhouse and more





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Binder Jetting | Recipes & Optimizing with Iteration

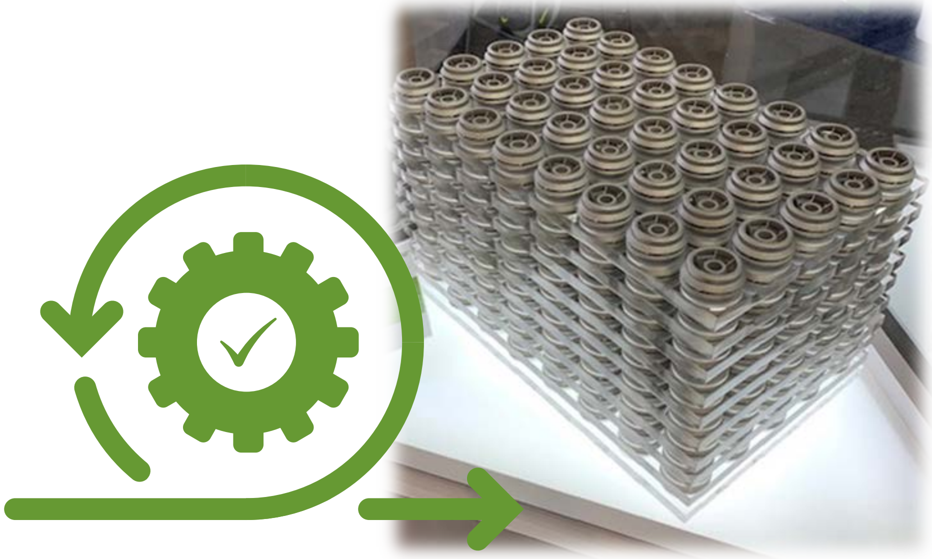
Users can tap high-throughput 3D printing benefits with binder jetting

SAND BINDER JET 3D PRINTING

- The sand printing process and recipes are highly plug and play with little adjustment required
- This process is ready for volume production

METAL BINDER JET 3D PRINTING

- Currently, binder jetting for metals is an iterative design process, where 2-3 prints may be necessary to dial in the parameters. This is largely due to sintering dynamics.
- However, after the iterative process is complete, you can tap the benefits of extremely high throughput and low cost binder jet 3D printing at scale
- Software companies such as ANSYS and Materialise are working to develop software that predicts sintering characteristics and automatically scales and makes recommendations for quality results with less or no iteration



Part: Impeller
Quantity: 400
Build time: 24 hours
Material: 316L

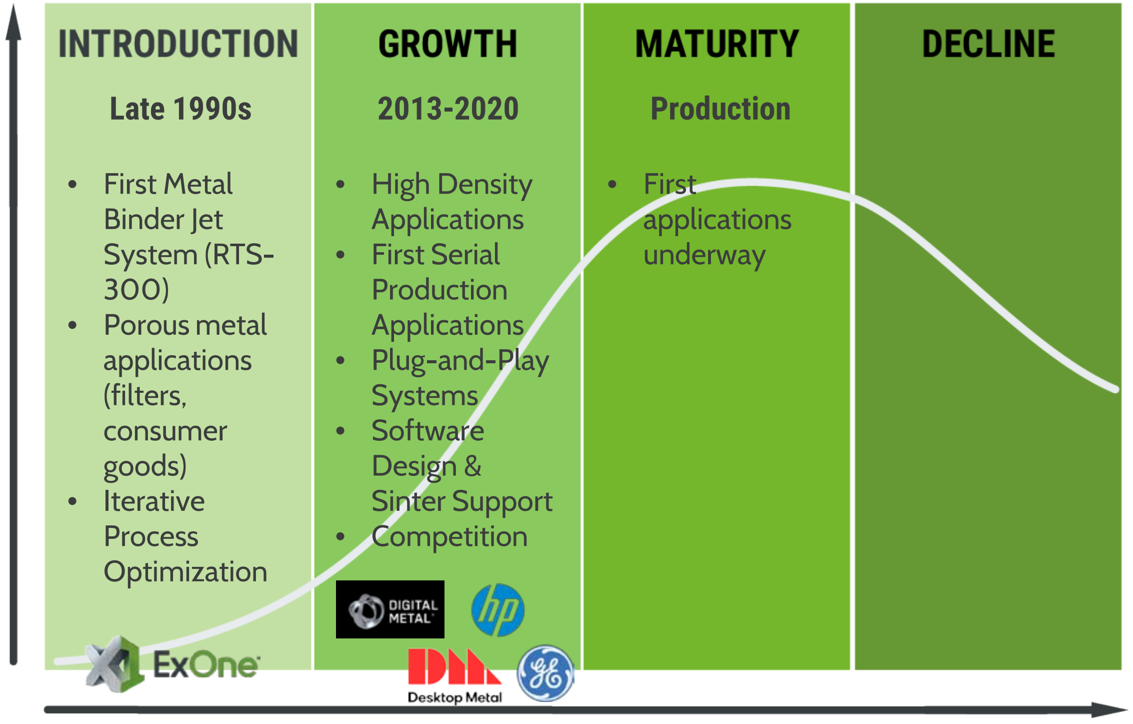
ExOne

METAL 3D PRINTING

Metal 3D Printing | History

Transitioning from first serial applications to industrial use

- Started with larger particle sizes and porous/infiltrated parts
- Growth has occurred as densities have increased and manufacturers take advantage of BJT for problem-solving
- Today final part density is now more than 97% dense, in line with MIM and better than investment castings
  - Maturity for production coming fast as software solutions enable BJT design and sintering support



ExOne

Metal 3D Printing | ExOne Leadership

We are the market share leader in binder jet 3D printers for metals and ceramics

Binder Jet 3D Printers

- Innovent+, a reliable entry-level model
- M-Flex, an affordable, large and reliable model
- X1 25Pro, a cutting-edge large production system
- X1 160Pro, our largest and smartest production system

APPLICATIONS

- Direct 3D printing of metal parts in a variety of alloys
- Direct 3D printing of ceramics
- Direct 3D printing of composites

SUPPORT SERVICES

- Comprehensive implementation and training
- 3D printed parts on demand
- Design for Additive Manufacturing (DfAM) services
- Custom development for special manufacturing programs, including custom metal development

DIRECT METAL 3D PRINTING

Custom or mass production of complex single-alloy metal parts in hours versus weeks or months.

DIRECT CERAMIC 3D PRINTING

3D printing greatly simplifies production of difficult to produce ceramic materials, such as silicon carbide.

ExOne

Metal 3D Printing | Transformational Benefits

Faster delivery times and new design freedoms

Quick delivery of accurate and dense metal parts. Process and material waste efficiencies over traditional methods. New design and lightweighting opportunities.

SPEED

Fast Delivery Times

FLEXIBILITY

Print a wide variety of metal powders on the same machine

WASTE REDUCTION

Consolidate parts, process steps and save on material costs

RAPID DESIGN CHANGES

Improve designs without a cost penalty

EXCEPTIONAL DESIGN FREEDOM

Consolidate parts, reduce weight, deliver all-new designs without traditional limitations

Metal 3D Printing | Iterative Design with Big Payoff

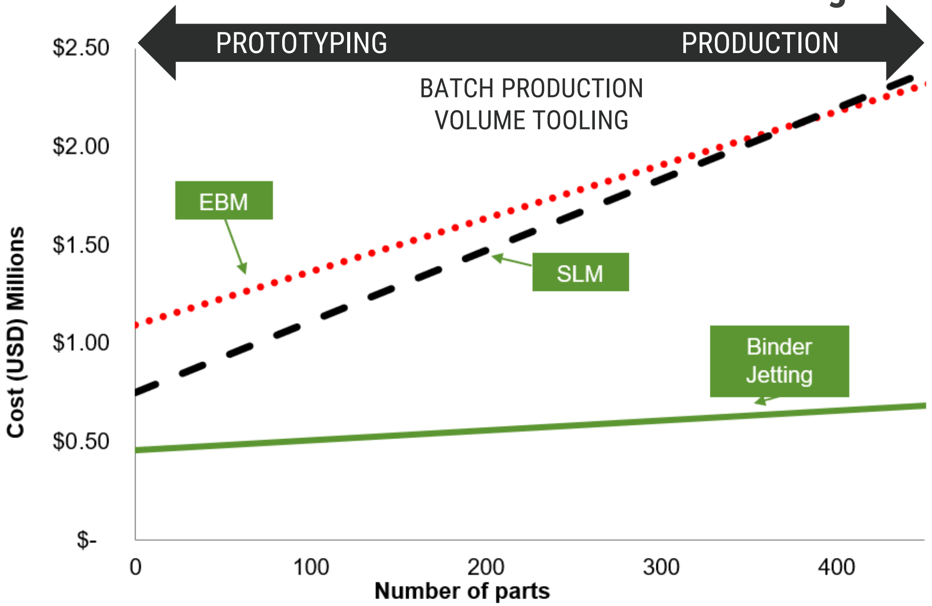
The 3D printing technology that is best suited for mass production

Currently, we can binder jet to 1-3% dimensional tolerance on a first effort. Improving to below 1% requires about 3 iterations of printing and sintering. However, the benefits can be quite meaningful as unit volume increases.

"Binder jetting exhibits lower capital and operating costs when compared to similar direct metal technologies. The fast manufacturing speeds make binder jetting a scalable process and well suited for mass production. For these reasons, binder jetting is the best possible future investment for a mass production setting."

Philip Morton, Manager
W.M. Keck Center for 3D Innovation
The University of Texas at El Paso

The "No-Scale" Effect of Binder Jetting



Metal 3D Printing | Successful Sintering

Predictable process with uniform densities. Sintering exposes microscopic quality of the print.

Green density target: 50-60% for most metals

- High green density = less shrinkage
- High green density = less distortion
- High green density = tight tolerances

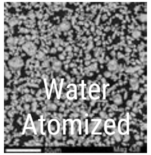
Sintering time, temperatures (often in excess of 2000° F) and conditions must be tailored to the precise part to achieve target part density.

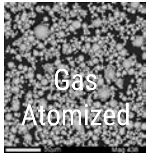
Sintering Considerations

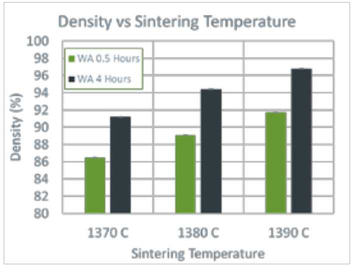
- Quality 3d Print In > Quality Sinter Out
- Shrinkage
- Gravity
- Setters
- High-quality heat profiles
- Final metallurgy

Right: ExOne has a patented process to 3D print ceramic setting devices for use in the sintering process to support green parts during sintering.

Water Atomized and Gas Atomized 316L







Powder	D_{10} D_{50} D_{90} (µm)	Apparent, Tap Density	Green Density, Std Dev
WA 316L	2.5, 6.2, 12.9	37%, 53.7%	54.1% , 0.65%
GA 316L	3.6, 8.3, 15.6	42%, 56.9%	55.6%, 0.58%

- Green densities are high and variabilities are low
- Triple ACT delivers sintered density of 98-99%.

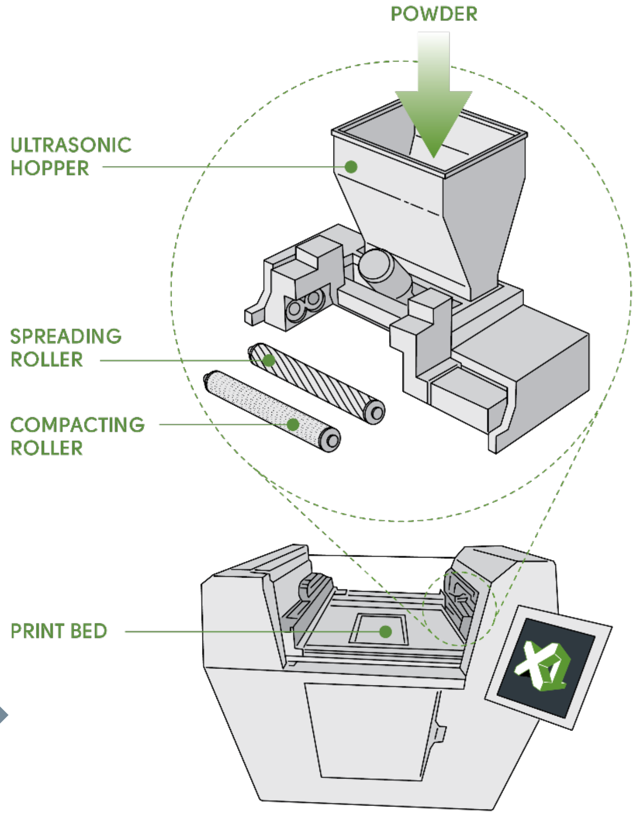
Metal 3D Printing | Critical Powder Management Features

Delivering high-density green parts is essential for high-quality results

Exclusive, patented system for dispensing, spreading and compacting the finest powders for high green strength

- Delivering Fast, High-Quality Parts
- Patented ultrasonic dispensing system of the finest powders.
- Patented spreading roller system
- Counter-rolling spreader and compactor
- Works in conjunction with patented compacting roller featuring unique design
- Complete system works together to deliver green-part density standard deviation of <1% at print speeds of over 150 mm/sec
- Adjustable roller spacing provides controlled densities that approach or exceed tap densities

Delivers industry-leading part density and repeatability
Learn More: www.exone.com/tripleact



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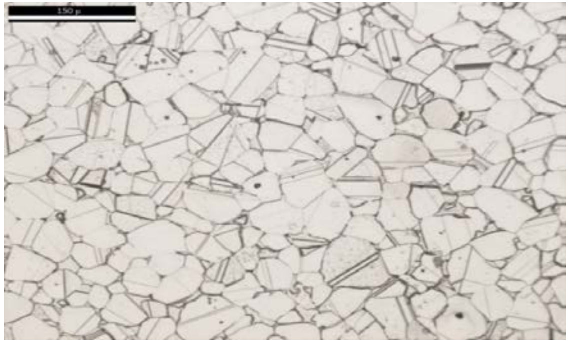
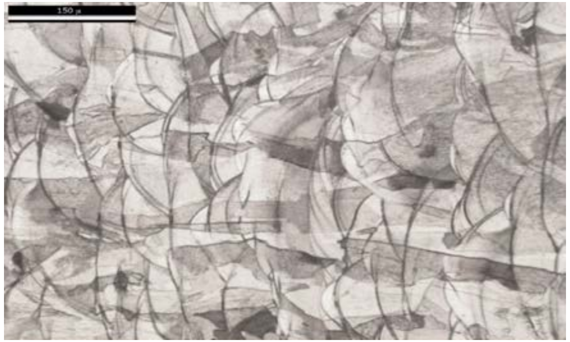
Metal 3D Printing | High Density, Superior 3D Microstructures

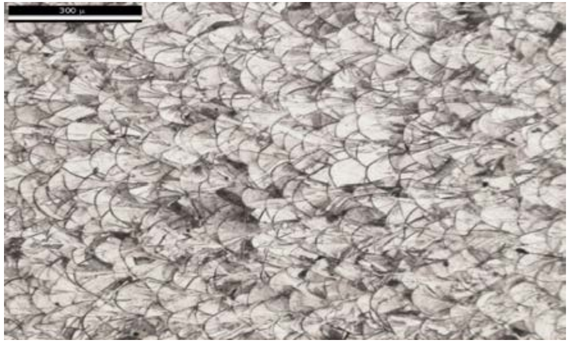
Why? Binder jetting 3D prints parts without particle fusion until final sintering



Binder Jetting



EBM



DMLS

- Equiaxed grain structure for binder jetting leads to isotropic material properties (30 to 60μm grain size)
- Tiered, columnar grain structure for EBM and DMLS (80 to 400μm grain size)
- Minimal chemical segregation at grain boundary in binder jetting parts due to room temperature processing
- Binder jetting microstructure closely resembles microstructure for standard PM parts

Metal 3D Printing | Material Flexibility & Qualification

3D print more than twenty metal, ceramic and composites – plus R&D

R&D QUALIFIED: Have passed a preliminary qualification phase by ExOne and are deemed printable, supported by ongoing development.

CUSTOMER-QUALIFIED: Qualified by customers with their own standards and being successfully 3D printed for their own applications.

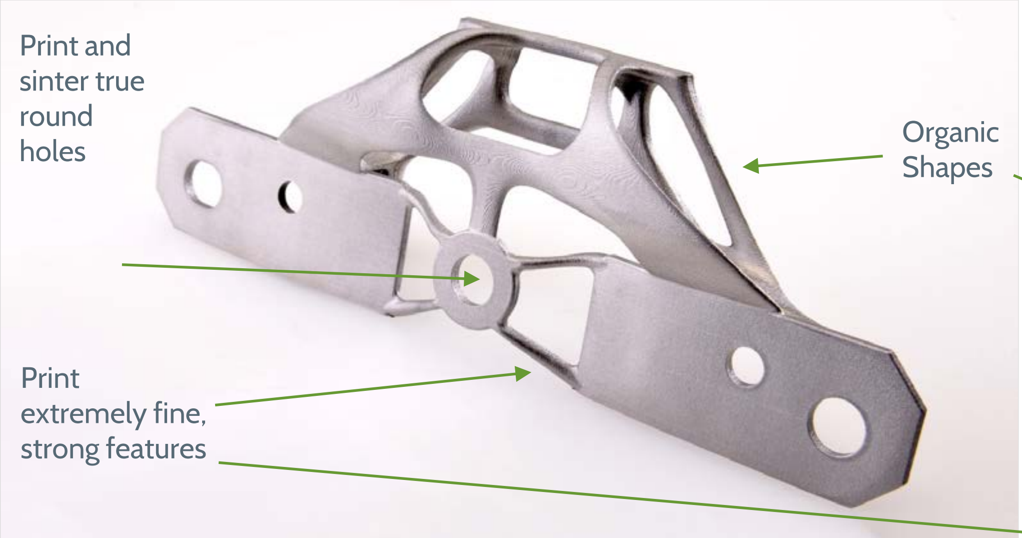
THIRD-PARTY QUALIFIED: Have passed rigorous tests over multiple builds and have verified material property data from an independent third party. General marketplace readiness.

ExOne

Metal 3D Printing | Rethink What's Possible

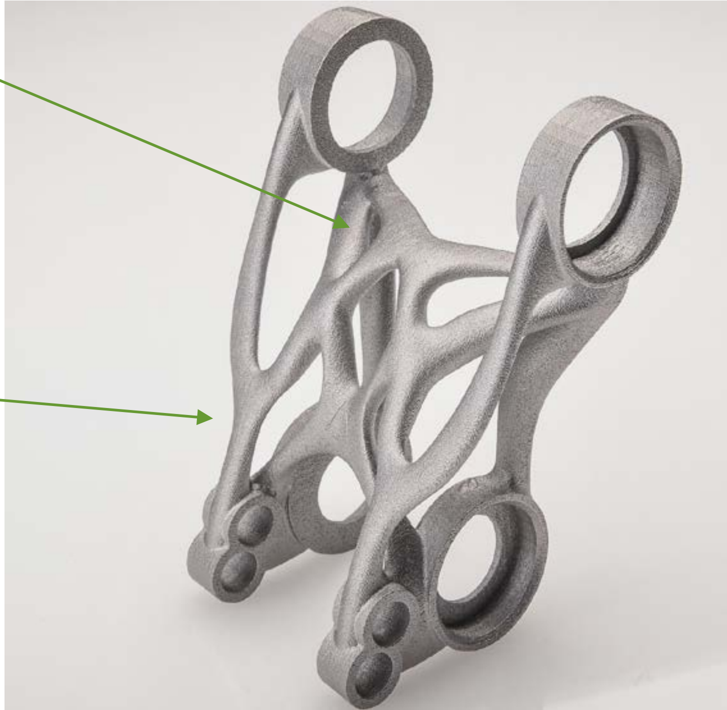
Dense and strong single alloys parts with complex geometries

Binder jetting makes impossible parts possible. It also makes them faster with less waste.



Automotive Sensor Bracket 3D Printed in 316L

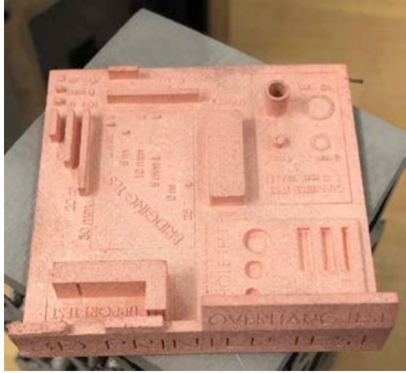
Altair bike pivot in 316L



ExOne™

Binder Jetting | Metal Design Guidelines

Part size, wall thickness, minimum feature size, and aspect ratio



- Scaling up for most metals:
  - 19% in X and Y
  - 21% in Z
- Shrinkage of green part is typically 16%
- Iterative process for dimensional tolerances
  - +/- 1-3% on first print and sinter
  - Usually 3-4 iterations for <1%
- Minimum wall thicknesses varies with geometry and part size. Generally:

Part Size	Min. Wall Thickness
3-75 mm (0.12-3 in)	1 mm (0.04 in)
75-150 mm (3-6 in)	1.5 mm (0.06 in)
150-200 mm (6-8 in)	2 mm (0.08 in)
200-300 mm (8-12 in)	3 mm (0.13 in)

XY: 19%
Z: 21%

- Inside corners and sharp intersections should have a filleted edge, with the fillet radius approximately equal to the connecting wall thickness
- Consistent cross sections recommended
- Cavities require drain holes and should be placed centrally to each pocket for depowdering
- For "dumbbell" designs with a thin connection between thick walls or masses, maintain consistent wall thickness as much as possible
- Aspect ratio recommendation: 15-20:1

ExOne

METAL 3D PRINTERS

Metal 3D Printing | Product Overview

Binder jetting for metals, ceramics and composite powders.

Innovent+

TRIPLE ACT INSIDE

- ✓ Research
- ✓ Prototyping
- ✓ Rapid product development
- ✓ Short-run production

An affordable, compact and reliable 3D printer for metal, ceramic or composite. Since 2018.

MAIN SPECIFICATIONS
Build envelope: 160 x 65 x 65 mm (6.3 x 2.5 x 2.5 in)
Volume: 676 cc
Max throughput: 166 cc/h
Min layer height: 30-200 µm
Min powder size: 2 µm (d50)

M-Flex

- ✓ Research
- ✓ Prototyping
- ✓ Rapid product development
- ✓ Short-run production

An affordable, large and reliable 3D printer for metal, ceramic or composite powders. Since 2013.

MAIN SPECIFICATIONS
Build envelope: 400 x 250 x 250 mm (15.75 x 9.84 x 9.84 in)
Volume: 25L
Max throughput 1,600 cc/h
Min layer height 50-200 µm
Min powder size: 15 µm (d50)

X1 25Pro

TRIPLE ACT INSIDE

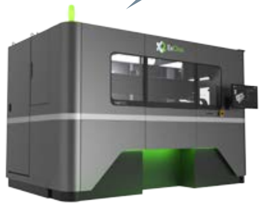
- ✓ Research
- ✓ Prototyping
- ✓ Rapid product development
- ✓ Short-run production
- ✓ Continuous 24/7 production
- ✓ Serial production

A large, smart 3D printer for high-quality serial production of metal, ceramic or composite parts. 2019.

MAIN SPECIFICATIONS
Build envelope: 400 x 250 x 250 mm (15.75 x 9.84 x 9.84 in)
Volume: 25L
Max throughput: 3,600 cc/h
Min layer height: 30-200 µm
Min powder size: 5 µm (d50)

NEW

X1 160Pro



TRIPLE ACT INSIDE

- ✓ Research
- ✓ Prototyping
- ✓ Rapid product development
- ✓ Short-run production
- ✓ Continuous 24/7 production
- ✓ Serial production

The largest and most advanced 3D printer for production of metal, ceramic or composite parts. 2020.

MAIN SPECIFICATIONS
Build envelope: 800 x 500 x 400 mm (31.5 x 19.7 x 15.8 in)
Volume: 160L
Est. throughput: 10,000+ cm3/hour
Est. layer height: 30-200 µm
Est. Min powder size: 5 µm (d50)

Specifications are subject to change without notice. Some data may depend on the size and characteristics of the powder being processed.

ExOne | Innovent+®

An affordable, compact and reliable 3D printer for metal, ceramic or composite. Since 2018.

- Research
- Prototyping
- Rapid product development
- Short-run production

DETAILS

- Build envelope: 160 x 65 x 65 mm (6.3 x 2.5 x 2.5 in)
- Volume: 676 cc
- Max throughput: 166 cc/h
- Min layer height: 30-200 µm
- Min powder size: 2 µm (d50)
- Binder systems: AquaFuse™, CleanFuse™, FluidFuse™, PhenolFuse™
- Process options enabled by various printhead sizes, including; 80, 30, or 10 picoliter printhead
- Print resolution: >30 µm voxels
- Operator interface: Full HD multi-touch display, On-board Wi-fi, USB input
  Software: Model review, rescaling technology, check customizable, print parameters
- Improved print speed control

Specifications are subject to change without notice. Some data may depend on the size and characteristics of the powder being processed.

ExOne | M-Flex®

An affordable, large and reliable 3D printer for metal, ceramic or composite powders. Since 2013.

- Research
- Prototyping
- Rapid product development
- Short-run production

DETAILS

- Build envelope: 400 x 250 x 250 mm (15.75 x 9.84 x 9.84 in)
- Volume: 25L
- Max throughput 1,600 cc/h
- Min layer height 50-200 µm
- Min powder size: 15 µm (d50)
- Print resolution: >50 µm voxels
- Binder systems: AquaFuse™, CleanFuse™, FluidFuse™, PhenolFuse™
- 3D prints metal, ceramic, sand, and composite powders

Specifications are subject to change without notice. Some data may depend on the size and characteristics of the powder being processed.

ExOne | X1 25Pro®

A large, smart 3D printer for high-quality serial production of metal, ceramic or composite parts. Since 2019.

- Research
- Prototyping
- Rapid product development
- Short-run production
- Continuous 24/7 production
- Serial production

DETAILS

- Build envelope: 400 x 250 x 250 mm (15.75 x 9.84 x 9.84 in)
- Volume: 25L
- Max throughput: 3,600 cc/h
- Min layer height: 30-200 µm
- Min powder size: 5 µm (d50)
- Printhead options: 10, 30 or 80 picoliter printhead
- Print resolution: >30 µm voxels
- Binder systems: AquaFuse™, CleanFuse™, FluidFuse™, PhenolFuse™
- 3D prints metal, ceramic, sand, and composite powders

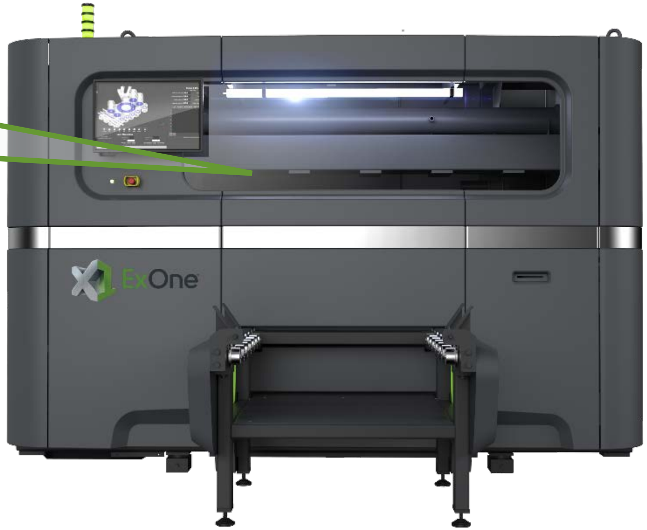
Specifications are subject to change without notice. Some data may depend on the size and characteristics of the powder being processed.

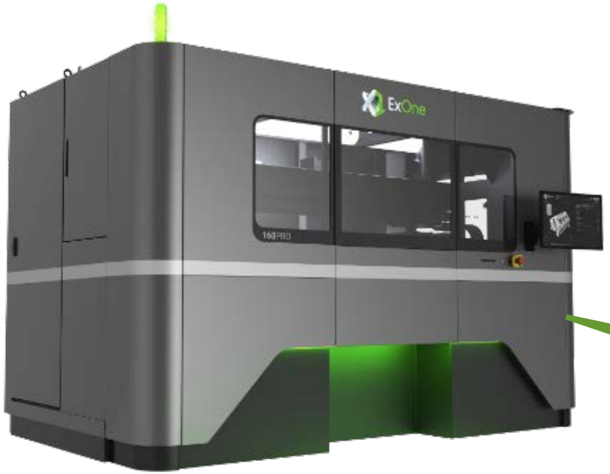
ExOne | X1 160Pro™

The largest and most advanced 3D printer for production of metal, ceramic or composite parts. 2020.

- Research
- Prototyping
- Rapid product development
- Short-run production
- Continuous 24/7 production
- Serial production

Triple ACT included





New conveyor system for continuous, serial production

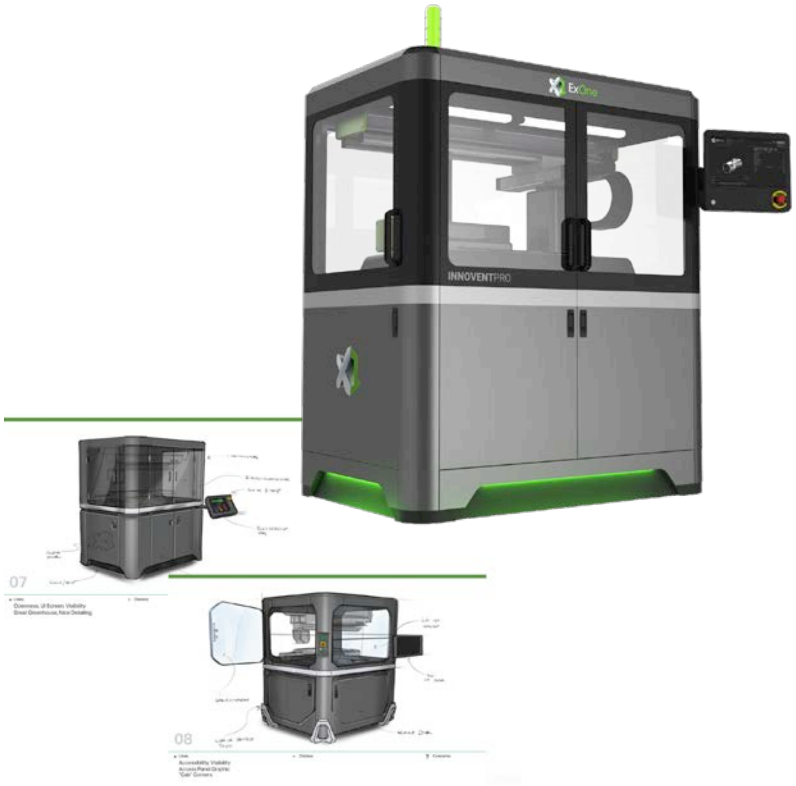
DETAILS

- Build envelope: 800 x 500 x 400 mm (31.5 x 19.7 x 15.8 in)
- Volume: 160L
- Est. throughput: 10,000+ cm3/hour
- Est. layer height: 30-200 µm
- Est. Min powder size: 5 µm (d50)
- Printhead options: 10 picoliter printhead
- Print resolution: >30 µm voxels
- Binder systems: AquaFuse™, CleanFuse™, FluidFuse™, PhenolFuse™
- 3D prints metal, ceramic, sand, and composite powders
- Siemens MindSphere optional

Specifications are subject to change without notice. Some data may depend on the size and characteristics of the powder being processed.

The InnoventPro

A vision for the future



ENTRY-LEVEL BINDER JETTING JUST GOT BETTER

We've taken the world's best-selling metal binder jetting system, the Innovent, and reimagined our entry-level system to deliver an even bigger bang that takes your work further than ever. The new InnoventPro, offered in 3L and 5L options, combines the ease of use of the Innovent+ with the robust X1 25Pro production capabilities, using the same piezoelectric printhead modules across the lineup.

The Innovent Pro delivers 3X the build area, faster throughput, and even more reliability from the most trusted name in metal binder jetting, ExOne. Suitable for R&D, prototyping and precision manufacturing, the Innovent Pro features ExOne's industry-leading Triple ACT. This patented advanced compaction technology quickly transforms more than 20 metal and ceramic powders into high-density parts (>97%) with industry-leading dimensional tolerance (<1-+/-2.5%), with final results dependent on material selection.

A complement to any metal injection molding or shop-floor operation, the ExOne Innovent Pro allows manufacturers to affordably offer low- or mid-volume production runs. For our faithful R&D customers, the InnoventPro will continue to offer easy material changeover.

Even better, when your project is ready for high-volume production, you can simply scale up to one of ExOne's larger binder jet systems, the X1 25Pro or X1 160Pro, minimizing or eliminating the re-engineering often needed to take a prototype to full production.

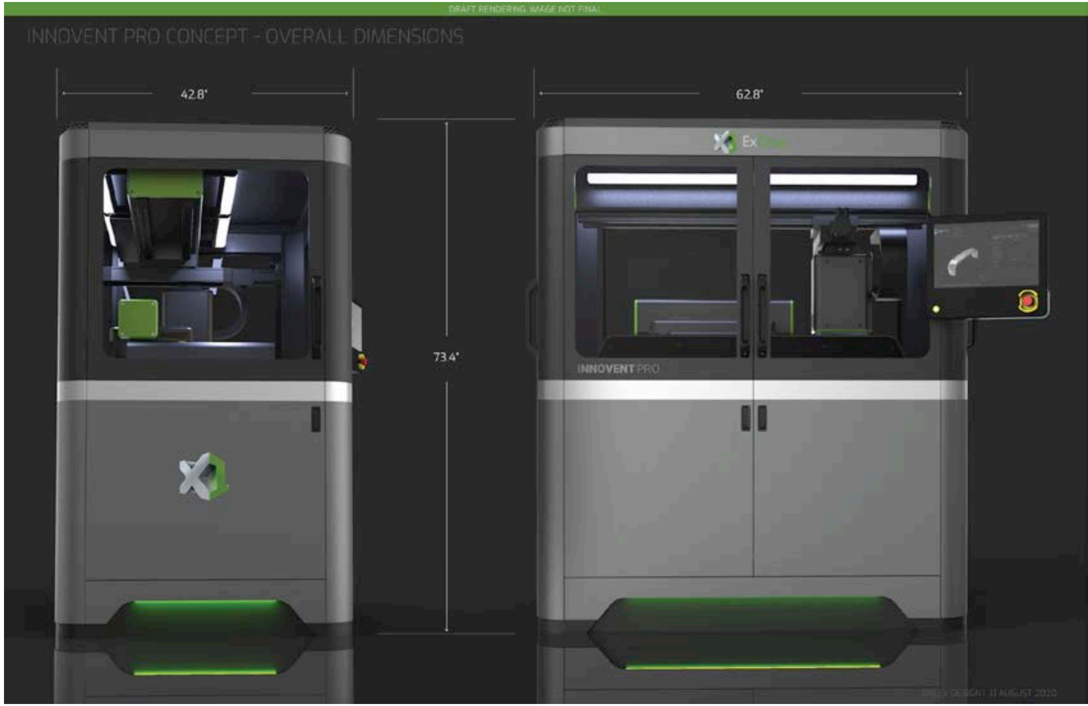
ExOne

InnoventPro 3L and 5L

Preliminary machine specifications, subject to change

The InnoventPro will combine the ease of use and low cost of the Innovent+ with the production capabilities of the X1 25Pro. The InnoventPro will be capable of producing parts up to 100x180x80 mm (3L) or 100x180x80 mm (5L) using MIM-sized powders in a variety of alloys

- 3L build box: 125 x 220 x 100 mm (2.75L)
- 5L build box: 125 x 220 x 200 mm (5.5 L)
- Triple ACT recoating system
  - <1% green part-to-part uniformity
- Same exact printhead as used in the X1 25Pro
- Both use same printhead modules as 160Pro
- Print speeds will be at least 700 cc/hour
- Standard MIM powders (Min. Powder Size: 5 µm (d50)
- Improved powder management and handling
  - Near net zero emissions
  - Easy to clean, change out powders
- Serial build boxes with covers
- In-situ process monitoring
  - Temperature, humidity, camera, internals
- Siemens controllers and MindSphere with ExOne Scout App
- *NOTE: 3L size is maximum to still carry a box full of metal powder under most US guidelines without assistive device*



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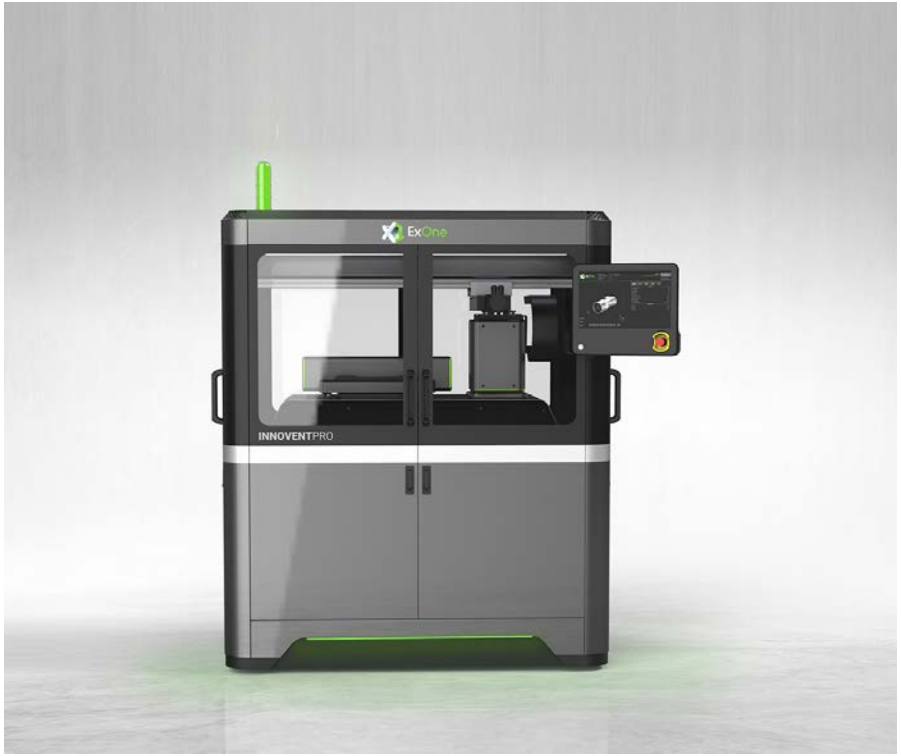
InnoventPro Ideal for R&D, Smaller Part Production

Your path to scale up to high-volume serial production for full range of part sizes



Preliminary InnoventPro Timeline

A plan for the future

2020 | 1H 2021 | 2H 2021 | 1H 2022 | 2H 2022 | 1H 2023

FORMNEXT '21
3L
PRODUCTION
LAUNCH

InnoventPro 3L
AVAILABILITY
Limited: Q4 2021
Volume: Q1/2
2022

RAPID '22
5L
PRODUCTION
LAUNCH

InnoventPro 5L
AVAILABILITY:
Q2/3 2022

METAL MATERIALS AND BINDERS

Metal 3D Printing | Material Qualification Process

ExOne systems print more than two dozen metal, ceramic and composite powders

R&D Qualified

- Verifies printability
- Powder characterization
- Powder conditioning
- Sieve test
- Print trials
- Sintering trials
- Material Testing - Mechanical, Microscopy & Chemistry

\+ 24+ Materials

Customer-Qualified

These materials are routinely being 3D printed by ExOne customers prior to readiness qualification for the broad marketplace.

\+ 14 Materials

Third-Party Qualified

- Uniformity testing
- Test powder rheology & PSD after multiple builds
- Print and sinter multiple builds
- Full third-party qualification

\+ 8 Materials

ExOne's tiered, multistep qualification process to ensure materials will deliver consistent, high-quality results – from the 3D printing process through final sintering

Full Third-Party Qualification

- Tensile X, Y, Z
- Poisson Ratio
- Hardness
- Impact
- Surface Roughness
- Chemistry
- Machinability (Option)
- Weldability (Option)
- Thermal Conductivity (Option)
- Specific Heat (Option)
- Corrosion (Option)

All tested against MPIF standards

ExOne

Third-Party Qualified Materials

Have passed rigorous ExOne tests over multiple builds and have verified material property data from an independent third party. General marketplace readiness.

Single Alloy Metals

1. 17-4PH SS
2. 304L SS
3. 316L SS
4. M2 Tool Steel
5. Inconel 718

Metal Composites

1. 316 SS i/w Bronze
2. 420 SS i/w Bronze
3. Tungsten i/w Bronze

ExOne

Customer-Qualified Materials

Have been qualified by ExOne customers with their own standards and are being successfully printed for their own applications.

Single Alloy Metals

1. 17-4PH SS*
2. 304L SS*
3. 316L SS*
4. Cobalt Chrome
5. Copper
6. H13 Tool Steel
7. Inconel 625
8. Titanium
9. Tungsten Heavy Alloy

Ceramics

1. Alumina
2. Carbon
3. Natural Sands
4. Synthetic Sands
5. Silicon Carbide
6. Tungsten Carbide Cobalt

Ceramic-Metal Composites

1. Boron Carbide i/w Aluminum
2. Silicon Carbide w/Silicon

Metal Composites

1. 316 SS i/w Bronze*
2. 420 SS i/w Bronze*
3. Tungsten w/w Bronze*

**This material is also a third-party qualified material*

R&D Materials

Have passed a preliminary qualification phase by ExOne and are deemed printable, supported by ongoing development.

Single Alloy Metals

1. 17-4PH SS**
2. 304L SS**
3. 316L SS**
4. 4140
5. 420
6. 4340
7. 4605
8. Aluminum
9. Bronze
10. Cobalt Chrome**
11. Copper*
12. H11 Tool Steel
13. H13 Tool Steel**
14. Hastelloy
15. Haynes 230
16. Inconel 625**
17. Inconel 718
18. Iron-Chrome-Aluminum
19. M2 Tool Steel**
20. Panacea
21. Titanium**
22. Tungsten (bonded or green)
23. Tungsten Heavy Alloy**
24. TZM Molybdenum

Ceramics

1. Alumina**
2. Aluminum Nitride
3. Barium Titanate
4. Boron Carbide
5. Carbon**
6. Glass
7. Lead Zirconate Titanate (PZT)
8. Natural Sands**
9. Silicon Carbide**
10. Silicon Nitride
11. Synthetic Sands**
12. Tungsten Carbide
13. Tungsten Carbide-Cobalt**
14. Zirconia
15. Zirconium Carbide

Ceramic-Metal Composites

1. Boron Carbide i/w Aluminum**
2. Silicon Carbide w/Silicon**

Metal Composites

1. 316 SS i/w Bronze**
2. 420 SS i/w Bronze**
3. Iron i/w Bronze
4. Tungsten i/w Bronze**
5. Tungsten i/w Copper
6. Tungsten i/w Invar

Metal 3D Printing | ExOne Fuse™ Binders

Our growing portfolio of innovative metal binders

One of the reasons ExOne metal binder jet systems can print such a diversity of powdered materials is our portfolio of specialty Fuse™ binders, which deliver unique benefits for the material being 3D printed.

BINDER CONSIDERATIONS

- Viscosity
- Saturation
- Bleeding X/Y
- Debinding

CleanFuse™
A premium, clean-burning binder that leaves behind no carbon residue and works well with metallic materials negatively affected by carbon

FluidFuse™
A versatile solvent-based binder with low viscosity that works well with a variety of metallic and non-metallic materials, including ceramics

AquaFuse™
A water-based binder that works well with a variety of metallic material

PhenolFuse™
A phenolic binder best suited for printing high-temperature materials, including non-metallics such as carbon, tungsten carbide (WC), silicon carbide (SiC), and other ceramics

COMING SOON: NanoFuse™
A new line of groundbreaking binders featuring suspended nanoparticles to improve the quality of binder jetting results with certain materials, such as copper and aluminum

METAL 3D PRINTING SERVICES

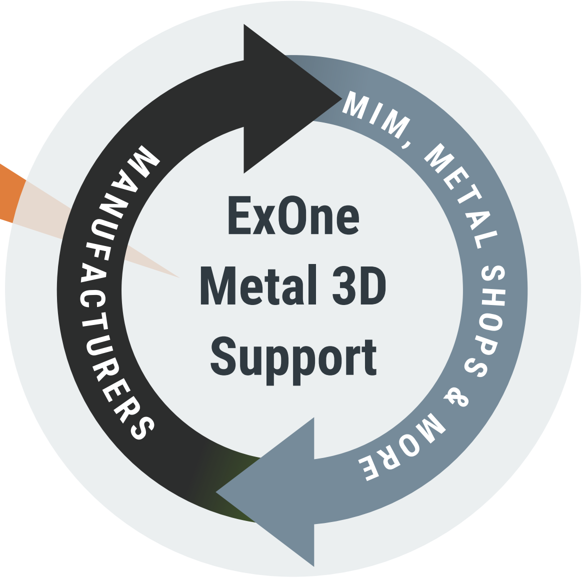
ExOne | Metal 3D Printing Solutions

Full support for sand casting with 3D printing technology

The ExOne Metal3D Team has world-class knowledge of metal AM designs and processes for binder jetting

360° SUPPORT

- Manufacturers
- Machine Shops
- Researchers
- Educators
- Designers



ExOne Metal 3D Services

- Printed Metal Parts on Demand
- Design and Engineering Service
  - Requirements assessment
  - Experienced 3D design services
  - Final part printing and finishing
  - Custom material development
  - Part qualification services
  - Full Inspection Services
- Training
  - Full implementation and design training

CERAMIC 3D PRINTING

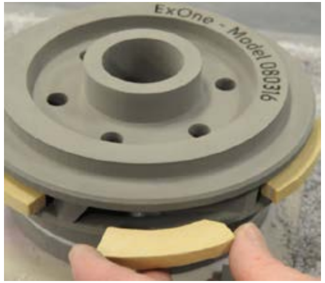
Ceramic 3D Printing

Software being developed to codify and streamline design for binder jetting

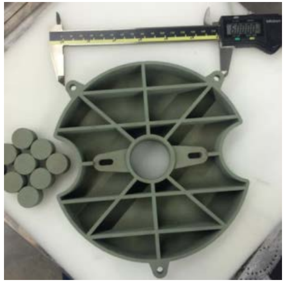
- Inherent advantages for ceramics:
    - Print speed, print size, material choices and flexibility

- Application in many ceramic materials markets:
    - Reaction bonded / Siliconized Silicon Carbide (SiC) for optics, automotive, chemical, and high-temperature material industries
    - Tungsten Carbide / Cobalt (WC/Co) for wear parts and cutting tool industries
    - Oxide based ceramics for filters, electronics packaging, etc.
    - Prototyping and low quantity runs of CIM parts

- As binder jetting further develops for ceramics, enhancements for printing small particle size, sinterable ceramic powders will continue to create broader adoption. Published material property characterization data from large industrial players will also drive adoption throughout the industry.



High-density alumina sintering setters printed in 99% purity alumina



SiC optical structure 3D printed preform

3D printed 8” graphite impeller core

ExOne

NEW OPPORTUNITIES
3D PRINTED TOOLING

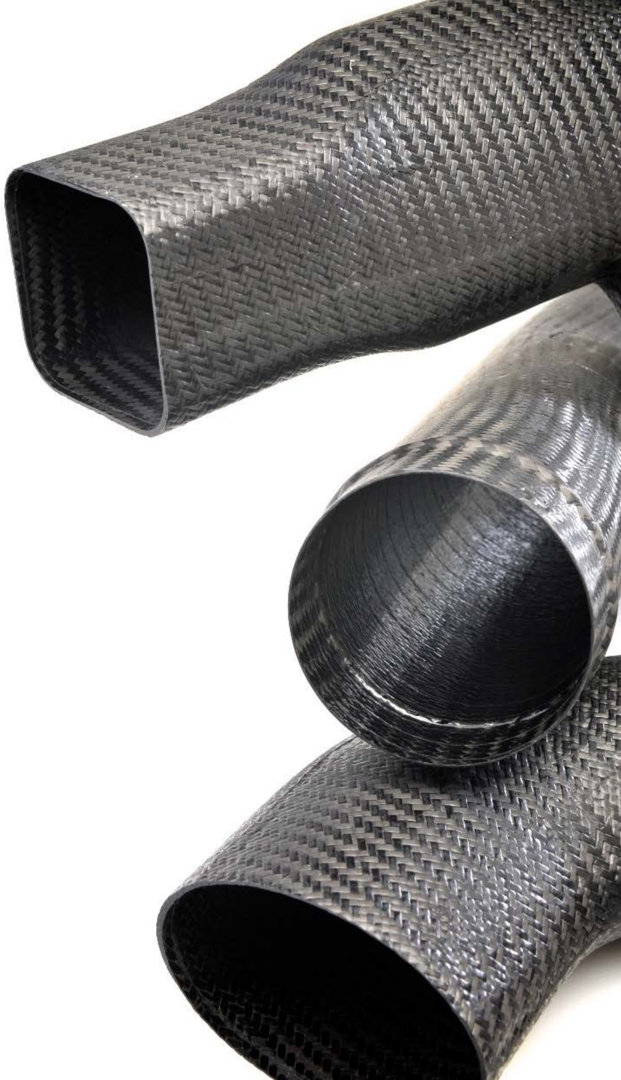
What is Washout Tooling?

A new form of 3D printed sacrificial tooling

A new and sustainable method of creating lightweight parts with trapped geometries, such as ducting, tanks, struts, mandrels and rocket shrouds.

With this ExOne-exclusive form of sacrificial tooling, a tool is 3D printed in sand or ceramic sand and then coated with a proprietary spray or a Teflon tape so that it can be used for layup of carbon- or glass-fiber thermoset composites.

After autoclaving, the tool can simply be washed out with tap water. This is possible because the binder used in the 3D printing process remains water soluble up to 180° Celsius or 356° Fahrenheit throughout the process.



The Core Benefits of Washout Tooling

A fast, easy-to-use, affordable form of sacrificial tooling

FAST

Eliminates long lead times needed for most other forms of sacrificial tooling. Quick removal of tool.

EASY

Washes out with tap water. No need for hot solvents, detergents, deflatable tools and complex tool removal.

PRECISE

Expansion of the tool is completely isotropic and controlled by the print media. Low or high CTE available.

SUSTAINABLE

The sand or ceramic sand media used in the process is reusable, making this tooling process sustainable.

ExOne™

Washout Tooling Industries

Choose a low or high CTE to manage expansion

Aerospace

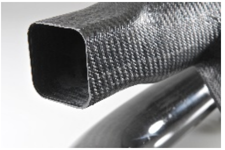
We serve a wide range of customers in this market, including makers of UAVs, with tooling for parts.

- Ducting
- Engines
- Structural composites (Stiffeners, fly-away foam replacement, etc.)
- Pressure tanks

Automotive

We serve the NASCAR, Performance and Luxury automotive markets with tooling for a variety of parts.

- Ducting
- Tanks
- Structural composites



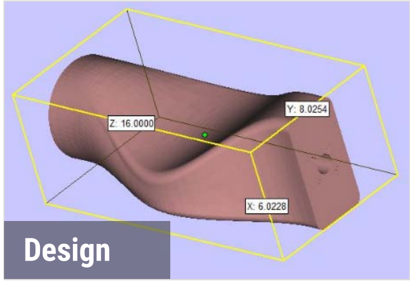
WASHOUT TOOLING PROCESS

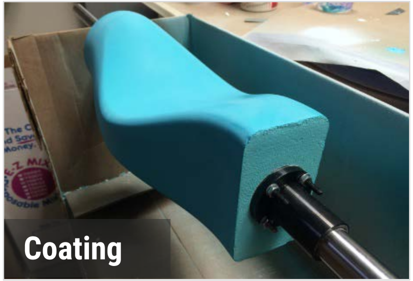
Washout Tooling Process

Design › 3D Print › Coating › Layup › Autoclave …

Processes supported by washout tooling include:

- Hand/wet layup
- Pre-preg layup
- Filament winding
- Tape or fiber placement





ExOne

Washout Tooling Process

Simple Water Washout › Final Part

Remove Tool with Tap Water

Recover and Reuse Sand Media

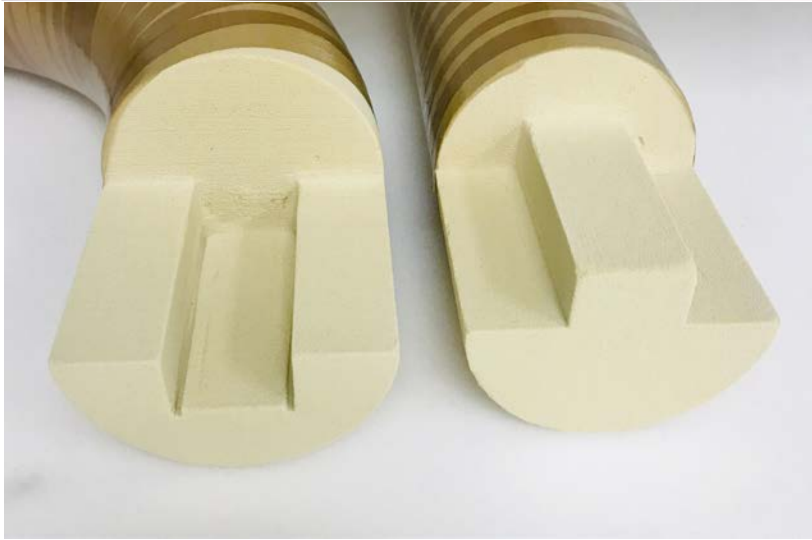
Final Fiberglass Part

ExOne

Extreme Design Benefits

Choose a low or high CTE to manage expansion

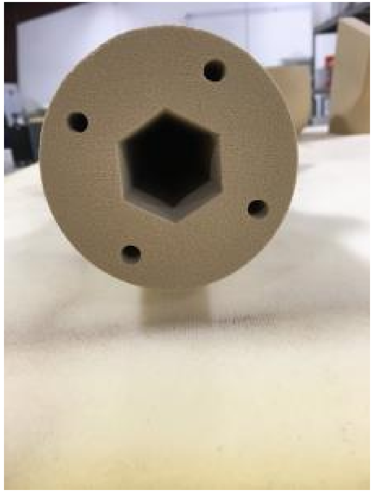
- Novel designs printed in ends of mandrels to create longer mandrels
- Creates ability to manufacturer parts longer than the build volume (L > 800 mm)
- Minimizes shipping issues and potential damage to shipping long mandrels
- A lot of unexplored design possibilities

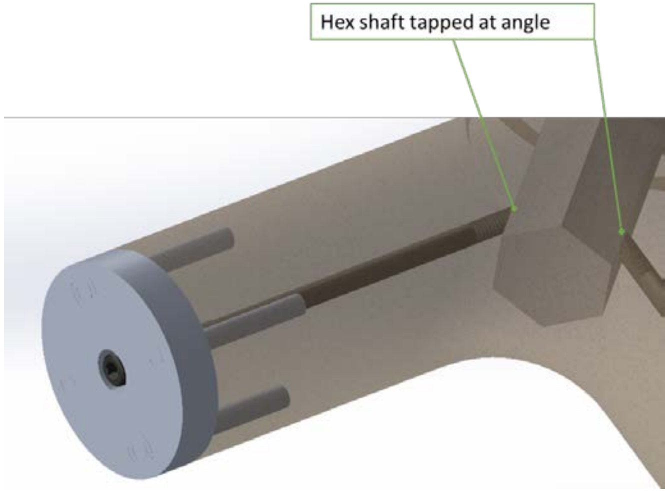


ExOne

Integration with Metallic Hardware

Printed Cerabeads washout mandrel (Teflon wrapped) with integrated hardware





Comparing Washout Tooling Methods

High-quality manufacturing in our Saint Clairsville, Ohio, facility

Technology	NRE Cost	Build Cost	Build Time	Tooling Req'd	Use Temp	Removal	CTE	Use Driver
Binder Jetting	$	$	Low	No	180° C	Tap water	Low or High	New technology
FDM (SSYS)	$	$$	Med	No	180° C	Hot solvent	High	New technology
Plaster / Castable Media	$$	$	Low*	Yes	120° C	Breakout	Med	High Quantity, Legacy, inexpensive
Bladder Molding	$$$	$$$	High	Yes	>180° C	Deflate	High	High quantity, OML & IML control
Breakdown Tooling	$$$	$$$	High	Yes	>180° C	Multi-pc	High	High quantity

Washout Tooling Print Media

Choose a low or high CTE to manage expansion

ExOne binder jet machines 3D print traditional sand and ceramic sand media into a tool with a binder that remains water soluble up to 180° Celsius or 356° Fahrenheit throughout the process. Expansion is driven by the media, not the binder, and it's isotropic (XYZ), resulting in high-quality results.

Silica Sand
CTE
20 ppm/°C
(11 ppm/°F)

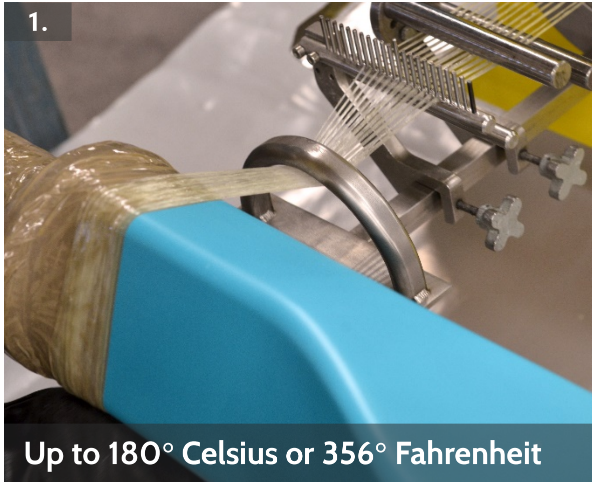
Ceramic Sand
CTE
3 ppm/°C
(2 ppm/°F)

3D Printed Form
Before Coating

Washout Tooling Coating Options

Prevent resin migration into the porous 3D printed tool form

ExOne offers two forms of proprietary spray coatings for its 3D printed tooling, in addition to Teflon tape wrapping. The blue coating remains water soluble up to 180° Celsius or 356° Fahrenheit while the green coating remains water soluble up to 132° Celsius or 270° Fahrenheit.



Up to 180° Celsius or 356° Fahrenheit

Up to 132° Celsius or 270° Fahrenheit

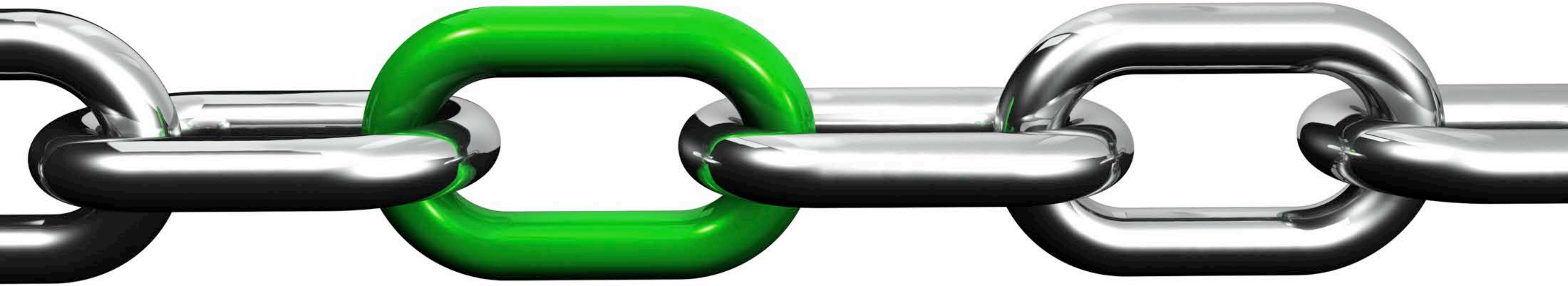
Teflon Tape

A PROMISING FUTURE
BINDER JET 3D PRINTING

Enabling Smarter, Sustainable Supply Chains

Binder Jet 3D is a serious tool to lightweight and consolidate parts, de-risk supply chains

- Fabricates objects with little to no waste, a dramatic improvement over traditional technologies
- Enables all-new lightweight designs that are not possible or affordable with traditional technologies
- Enables part consolidation that eliminates manufacturing processes and reduces energy consumption
- Eliminates need for hard tooling, enabling distributed manufacturing that shortens supply chains



Thank you!

The ExOne Company

127 Industry Boulevard, North Huntingdon, PA 15642

1-877-773-9663

www.exone.com