WEBINAR

Sand Binder Jetting
How does it work?

Agenda

1. Who we are
2. Sand 3D printing Benefits
3. Speed 3D Mold Application Stories
4. Binder Jetting Production Ready
5. Process Furan
6. Q&A

Ben Leung

Regional Vice President Asia
ExOne

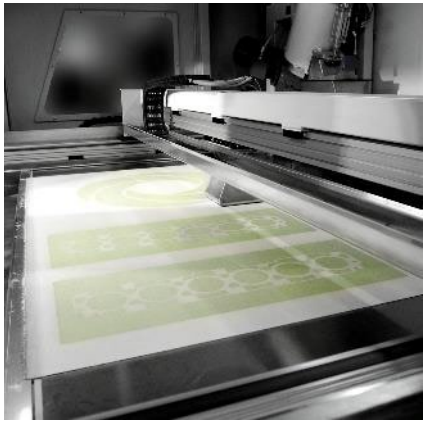
Nattinee Valun-araya

Head of Engineering
Speed 3D Mold

WHO WE ARE

About ExOne

As part of the Desktop Metal portfolio, ExOne is home to the world's leading team of sand binder jetting experts.Since 1995, we've been on a mission to deliver powerful 3D printers and today we're focused on helping foundries survive and thrive with more efficient and innovative production technology.



ExOne - A Desktop Metal Brand

We believe additive manufacturing 2.0 can change the world

OUR VISION

Sustainable manufacturing without limitations

OUR MISSION

To deliver powerful 3D printers that solve the toughest problems and enable world-changing innovations.

OUR VALUES

Customer-Focus. Collaboration. Innovation. Action-Oriented. Integrity. Caring. Positivity.

ExOne Overview

Global leaders supporting foundries with binder jet 3D printing for 20 + Years

Founded

- 20+ years' experience as global leaders with operations in Europe, Asia, and the US
- Acquired by Desktop Metal in 20 21 to advance mass adoption production tools

Machines & Services

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

High-Value Parts

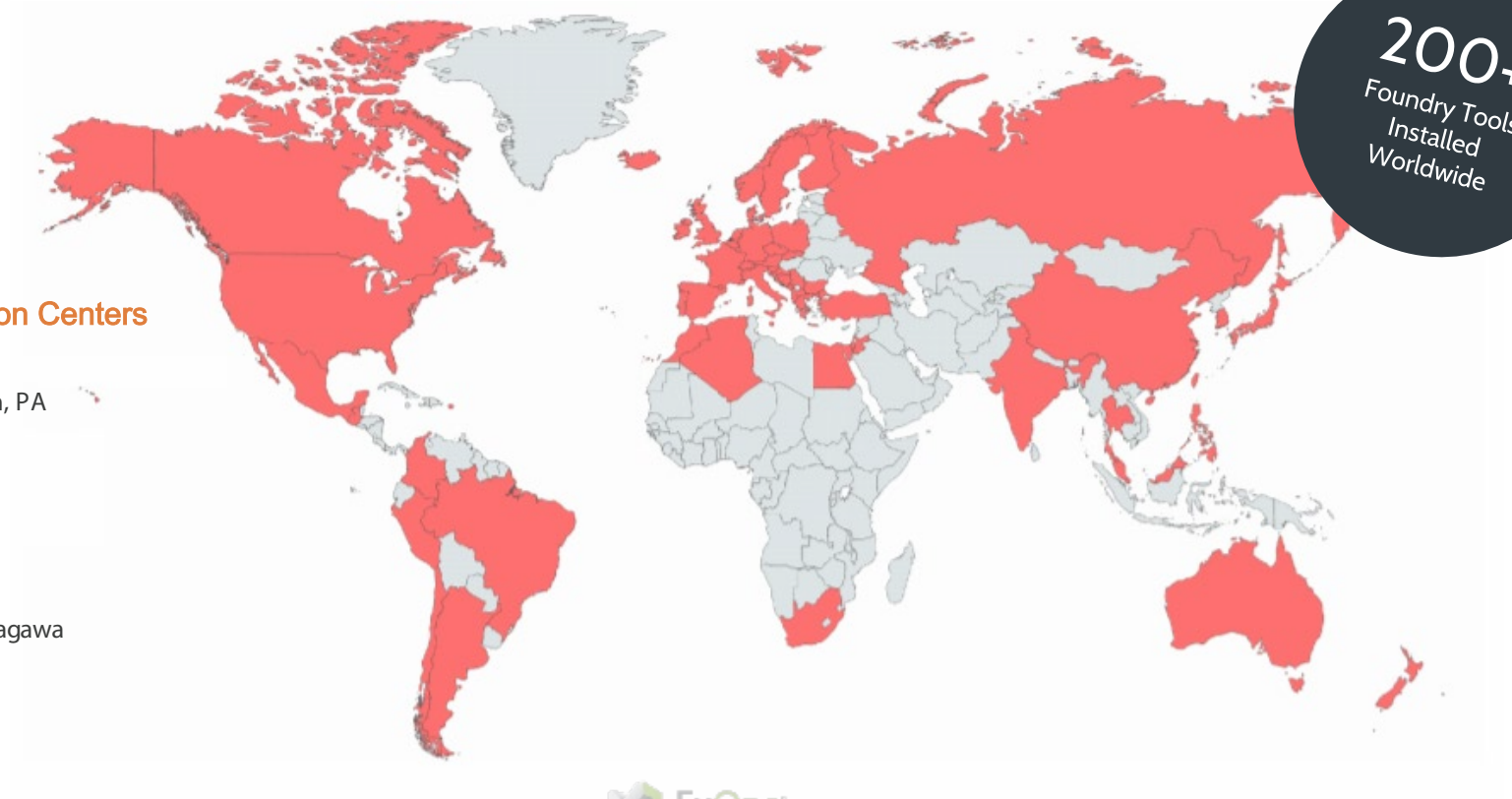
- Sand molds and cores
- 3D printed tooling solutions

Industrial Markets

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

ExOne - A Desktop Metal Company

Part of #TeamDM advancing Additive Manufacturing 2.0 in 65+ countries



200+
Foundry Tools Installed Worldwide

ExOne Adoption Centers

Americas
North Huntingdon, PA
USA

Europe
Gersthofen
Germany

Asia
Odawara-shi, Kanagawa
Japan

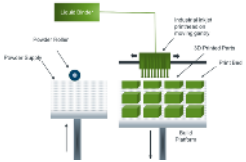
ExOne

History of Binder Jetting Leadership

Twenty years of being an emerging technology leader

1995
Extrude Hone creates the "ProMetal" division to develop 3D printing

1996
Extrude Hone obtains exclusive field-of-use license for patented 3D printing processes



1998
RTS-300, the first metal 3D printer

2002
S15, the first sand 3D printer

2005
The ExOne Company formed. Launch of S-Print® sand printer and X1-Lab® metal printer

2010 - 2013
Launch of four all-new 3D-printers: S-Max®, S-Print® 2.0, M-Flex® and M-Print®

2013
Initial public offering NASDAQ: XONE

2019
Launch of the S-Max® Pro sand production 3D printer

2021
Launch of X1 Tooling to deliver infiltrated sand 3D printed forming tools with fast turnarounds

2021
ExOne is acquired by Desktop Metal to advance the mission of Additive Manufacturing 2.0 across all materials

Desktop Metal

2022
Launch of the S-Max® Flex, the most affordable sand 3D printer ever offered combining the expertise of ExOne and Desktop Metal

ExOne

Our Collaboration Partners

Critical research and development network

ALTAIR
ANSYS
BMW GROUP
DOSIER PATTERN INC.
Humtown
KIMURA
NEXTEAM GROUP
OAK RIDGE National Laboratory
rexroth A Bosch Company
SIEMENS
VDMA

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

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BENEFITS OF SAND 3D PRINTING

When is Sand 3D Printing a Fit?

From rapid prototyping to production volume castings without conventional tooling

Sand 3D printing is another tool in the foundry toolbox. Taking advantage of digital manufacturing makes sense for:

- Quick-turn, tooling-less castings
- Low volume / small batch production
- Fast design iterations
- Complex assembled cores
- Organic geometries not possible with traditional methods

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Mold Production

Design freedom to create complex mold rigging

WATCH THE COMPLETE VIDEO
bit.ly/3DMoldVideo

When time is of the essence, complete mold packages can be 3D printed without traditional tooling.

Done-in-one pours are also enabled with the design freedoms that provide the ability to throttle the velocity of the pour and achieve the optimal feeding distance to reduce casting defects.

- Eliminate the need for drafts
- New design options for rigging, risers, gates
  - Optimized cross sections for runners and gating
  - Hyperbolic and conical helix sprues
  - Spherical risers to guide flow of liquid metal

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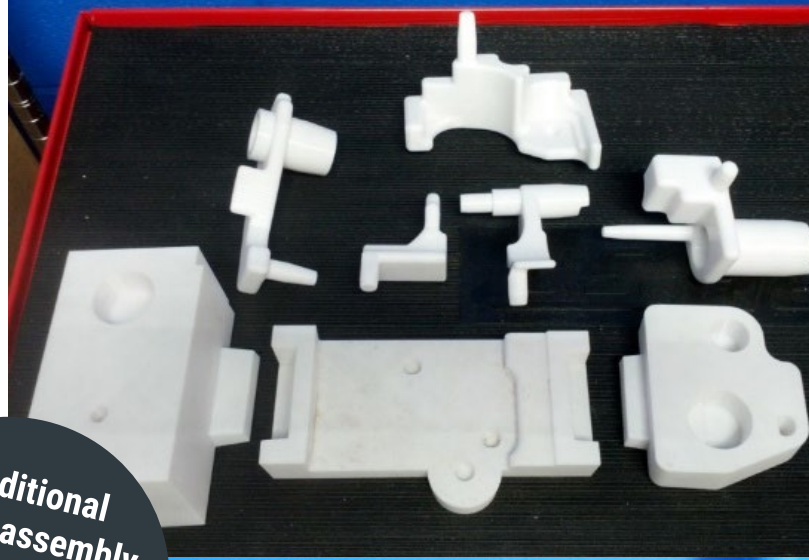
Core Production

Complex designs that lead to core consolidation

When expensive tooling is required, 3D printing is advantageous for low quantity production.

For highly complex parts, sand 3D printing may be cost effective, even if tooling exists or for high quantity production, especially in situations where core assembly can be reduced.

- Eliminate the need for assembly labor and increase productivity
- Removal of stacking tolerances
- Increased accuracy and decreased scrap rates from core shift



Traditional 8 core assembly reduced to one 3D printed core at Humtown

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Sand 3D Printing Speed & Quality Improvements

New designs are now possible for metalcast products as well as sand molds and cores

Digital Technology Drives out Defects Faster

Analog Process

Time to First Pour | Time to Delivered Part

Digital Process

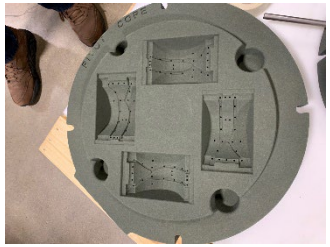
Time to First Pour | Time to Delivered Part

SIKORSKY
A LOCKHEED MARTIN COMPANY

Main Gear Box Transmission
First Pour = No defects, part delivered

Done-in-One Pour (Aluminum)

Altair



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Sand 3D Printing Transformational Benefits

Faster delivery times, done-in-one pours, and new design freedoms

OEMs and foundries optimize business with binder jetting to deliver castings with complex designs and fast turnarounds, while saving money on patterns, molds, and labor.

SPEED

Reduce delivery times

- Regardless of complexity, deliver molds and cores within hours or days, not the weeks and months needed for traditionally manufactured patterns

SAVINGS

Eliminate patterns, molds, and labor

- Eliminate the added time, labor, and expense of mold creation, extraction, repair, and assembly and deliver complex cores at a lower total cost than core shooters

NO PATTERN STORAGE

Replace physical inventory with digital storage

- Print direct from CAD files without the need to store patterns or molds for core shooters while removing the risk of lost patterns or repair for degraded molds

RAPID DESIGN CHANGES

Improve designs without a cost penalty

- Save time and money while reducing waste and optimizing designs by iterating instantly without scrapping existing or creating new patterns and molds for core shooters

EXCEPTIONAL DESIGN FREEDOM

Optimize final parts and mold package design

- Complex and organic geometries for both final parts and rigging and riser design deliver higher-quality castings and enable low-pressure pouring at no extra cost

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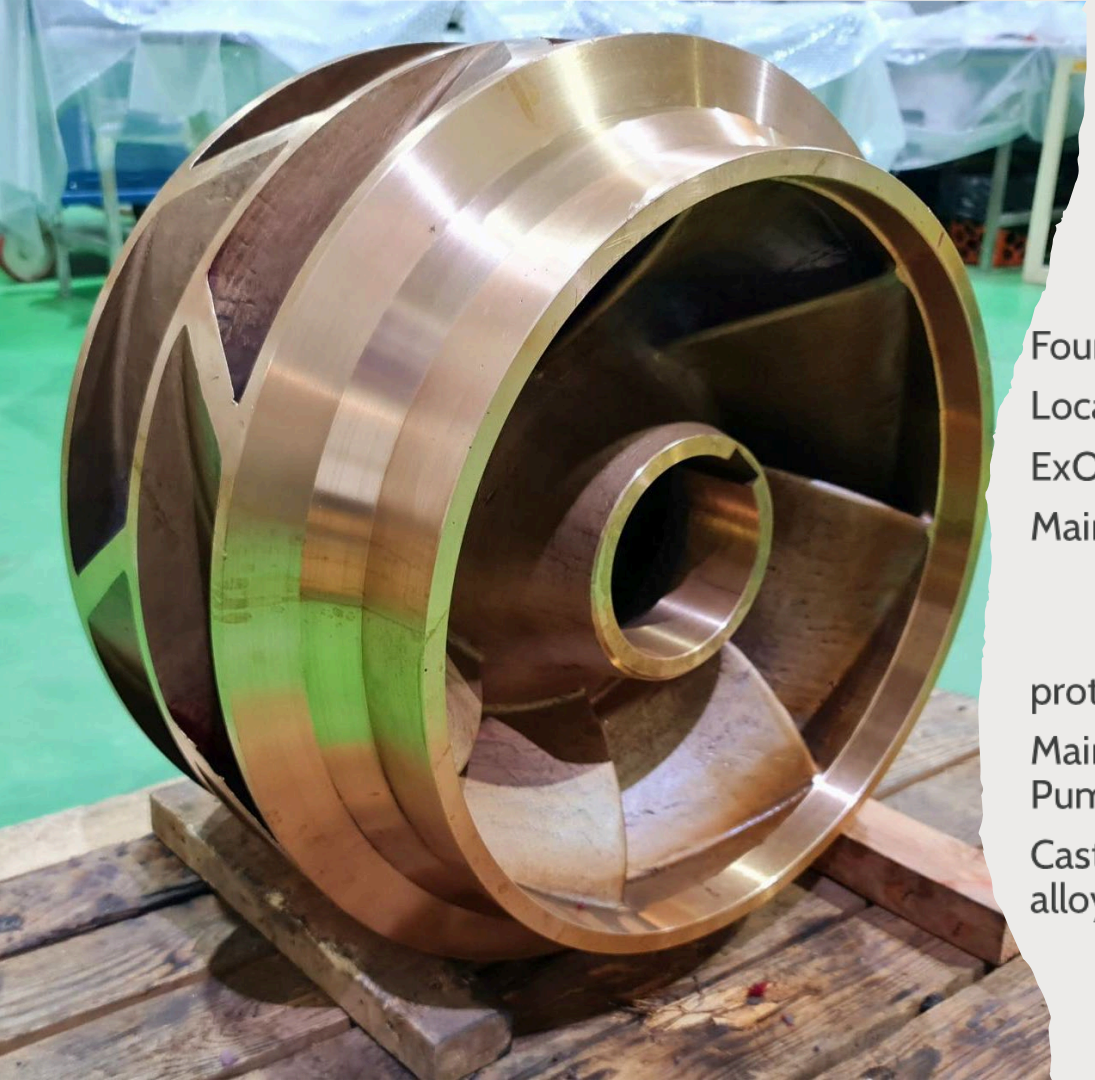
SPEED 3D MOLD: APPLICATION STORIES



Speed 3D Mold

Found: Year 2011

Location: Thailand

ExOne machine : 1 unit S-Max number #006

Main business :

Sand mold and cores printing

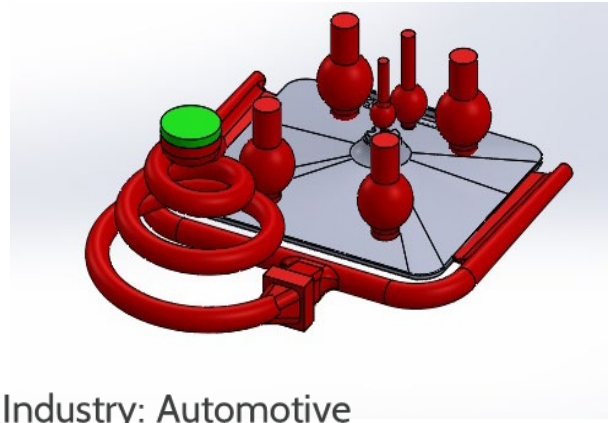
Casting parts for replacement, OEM, and prototypes

Main Industry: Marine, Oils & Gas, Automotive, Pumps, and maintenance services

Casting material: Bronze, cast iron, and aluminum alloy

Binder Jetting
Metalcasting for Replacement Parts

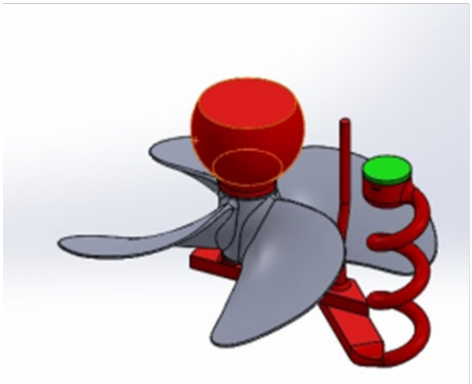
- Speed 3D Mold is a high-quality casting replacement part manufacturer in Thailand. The S-Max furan binder jetting system was installed in 2011 to serve complex casting parts to customers in maintenance services.
- S-Max with many years operation always be very reliable and precise for complex molds and cores.
- Sand mold from furan binder jetting is very powerful system that solve problems in timely replacement of parts and save customer's cost more than 30%.
- Enable castings with geometric features such as helical sprue, vertical walls, overhangs, undercuts and honeycomb.
- Speed 3D Mold offers a wide range of services from 3D CAD engineering/product design to the real part. Since 3D sand mold is near-limitless freedom in design geometry, it can apply to produce prototype, low volume, and complex parts.
- Customers admire the quality of casting parts from printed molds.



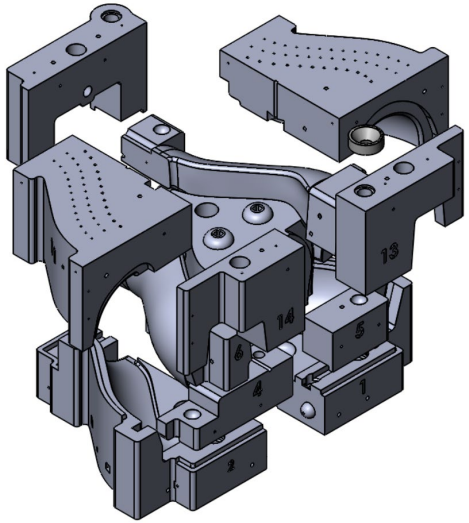
Binder Jetting Freedom of Rigging Design

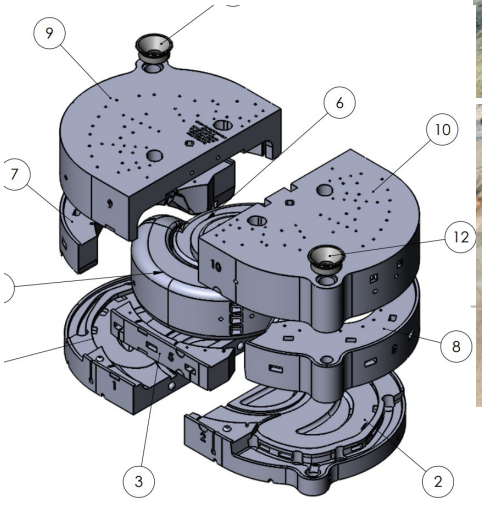
Industry: Automotive
Delivery time: 1 week from CAD to Cast
Alloy casting: Aluminum alloy A356
Challenge: Prototype

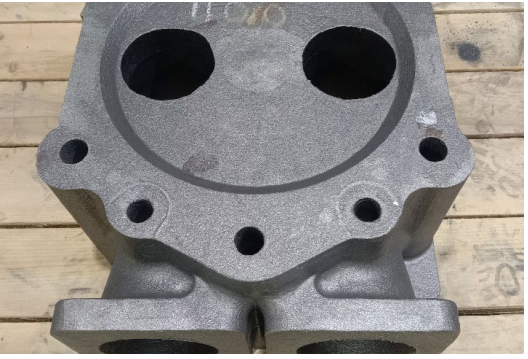
Industry: Marine
Delivery time: 1 week from CAD to Cast
Alloy casting: ASTM C95800
Challenge: New design



Binder Jetting Benefits
No pattern & short production time







STAY TUNED
Article will be published soon

SPEED 3D MOLD CO.,LTD.

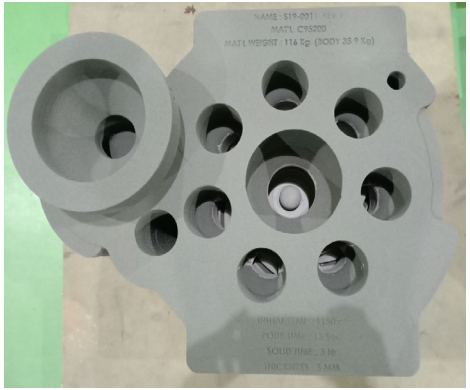
Application

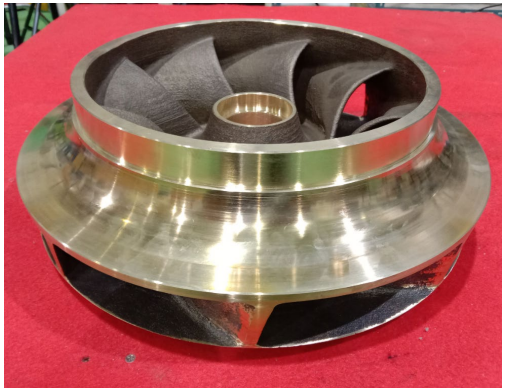
- Industry: Marine
- Solution 3D printer: S-Max Furan binder
- Delivery time: 2 weeks
- Alloy casting: Cast iron
- Challenge: Make the new part from obsoleted production

Global Casting Magazine 世界铸造

Application

- Industry: Pump
- Solution 3D printer: S-Max Furan binder
- Delivery time: 3 weeks from CAD to machine finishing
- Cost saving : 30-35%
- Alloy casting: ASTM C95800- Nickel Aluminum Bronze





Application

- Industry: Pump
- Solution 3D printer: S-Max Furan binder
- Delivery time: 3 weeks
- Cost saving: 30 %
- Alloy casting: Ductile Cast Iron

Obsoleted part

As cast part

New part

We are looking forward to meeting you in person on the ExOne Booth

Further information are coming soon

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SPEED MOLD CO.,LTD.

BINDER JETTING PROCESS INORGANIC

Binder Jetting Inorganic Process

Sample Layout with Box in Box

JobPrep → 3D Printing Process → Box-in-Box Conveyance → Microwave Curing → Automated Desanding Station → Quick Finishing → Final Part

Differences to Furan Process:

- Interchangeable BIB (Box-in-Box) Job Box with conveyance to post processes *(D- G, I & J)*
- Part curing in Microwave *(H)*
- Automated Desanding Station *(J- O)* requiring just 1 layer of parts in the jobbox
- Easier finishing significantly reduces labor cost

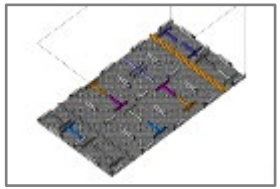
3D printing system	
A	S-Max / S-Max Pro
B	Transport container (fresh sand)
C	Transport container (recycled sand)
D	Transfer station
E	Job box
F	Shuttle
G	Conveyor
H	Microwave
I	Transfer belt
Desanding	
J	Transport module
K	Desanding module
L	Control cabinet
M	Screw Conveyor
N	Collection hopper with recycling bin
O	Industrial dust collector
P	Finishing table

Binder Jetting Job Preparation

JobPrep

Digital Job box File Prep

Machine & Material Prep



MaterialiseMagics

Siemens NX

AutodeskNetfabb

XLayouter*

Other tools providing CLIoutput **

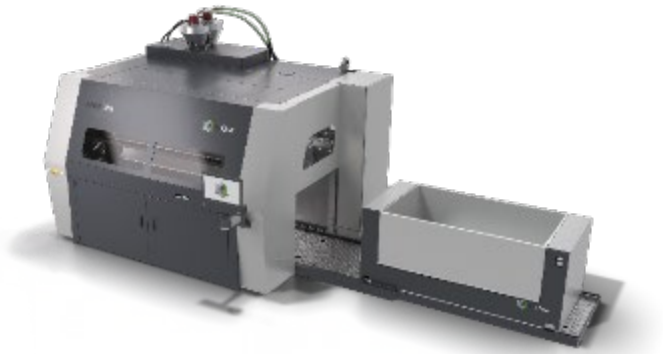
Build-Processor Interface

CLI Interface

XPrep

Netfabb integrated

Print Data



* Std.with Innovent+, M-Flex and X1 25Pro

** Might require interface customization and testing

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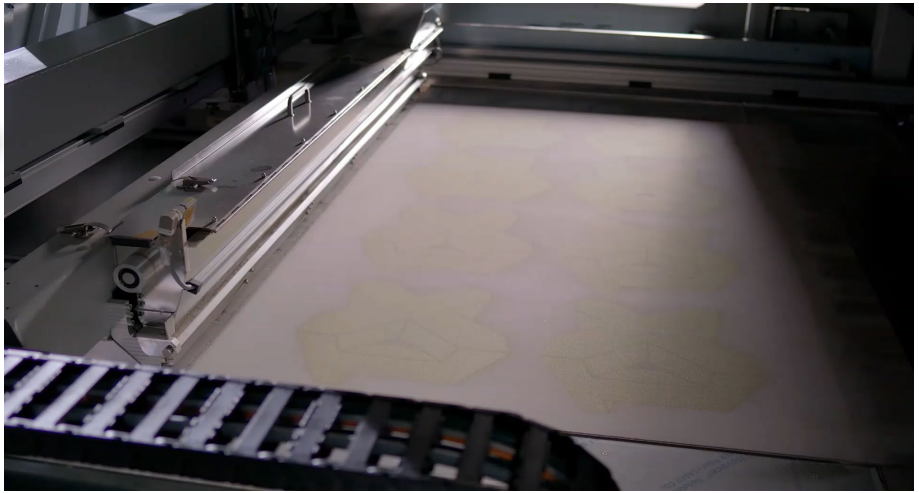
Binder Jetting Inorganic Process

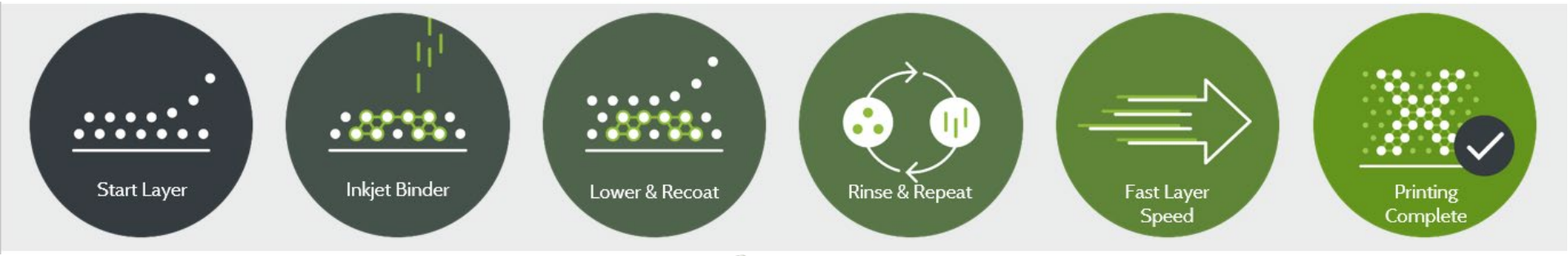
3D Printing Process

S-Max Pro Inorganic Benefits

- Low emissions during printing and casting
- Supporting Green Foundry with environmentally friendly consumable handling and storage
- Cost reduction with reduced recoater cleaning

Video





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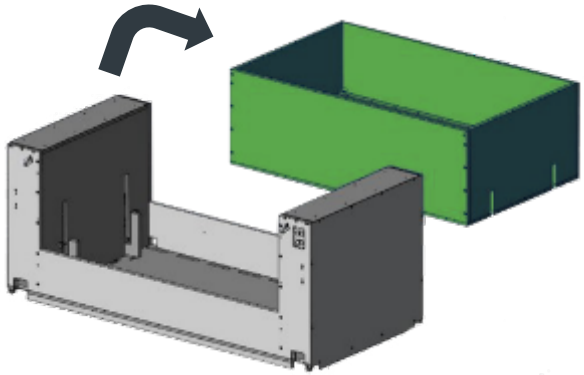
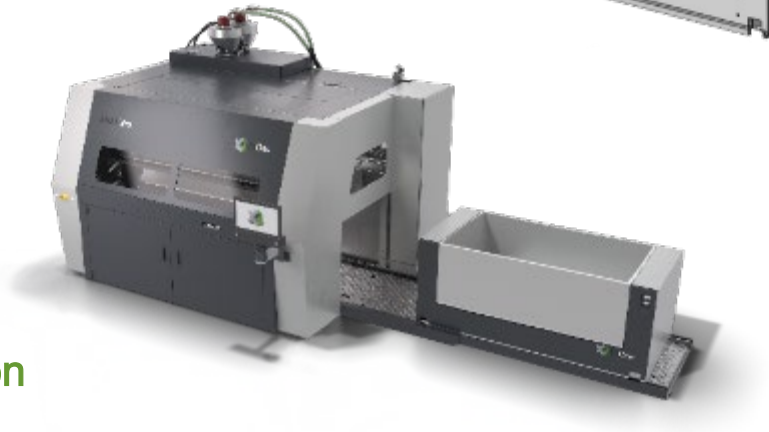
S-Max Pro | Box-in-Box

Box-in-Box Conveyance

- **Interchangeable job for improved performance**
  - Quick box exchange for continued printing
  - Box-in-box format (mm): 1,800L x 1,000W x 400H
  - Integrated base plate perforation for fast auto desanding
- **Supporting all ExOne binder systems**
  - IOB, HHP, CHP, Furan
- **Special benefit for IOB and HHP**
  - Off-line microwave curing





Multi-Binder Capable
Higher Machine Utilization

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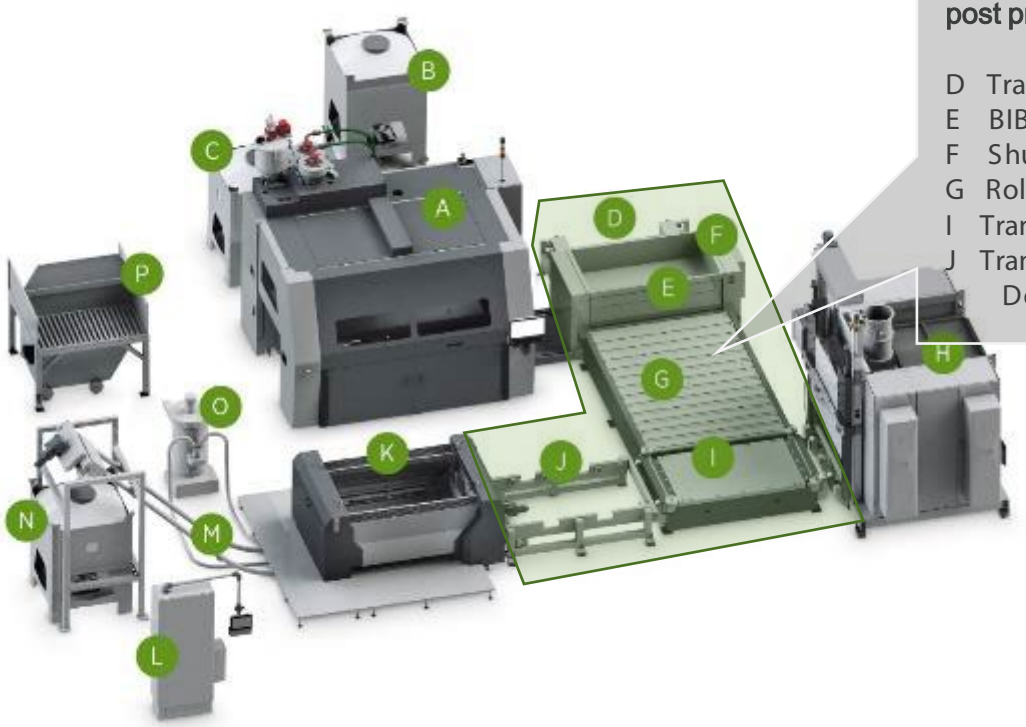
Binder Jetting Inorganic Process

Box-in-Box Conveyance

3D printing system	
A	S-Max / S-Max Pro
B	Transport container (fresh sand)
C	Transport container (recycled sand)
D	Transfer station
E	Job box
F	Shuttle
G	Conveyor
H	Microwave
I	Transfer belt
Desanding	
J	Transport module
K	Desanding module
L	Control cabinet
M	Screw Conveyor
N	Collection hopper with recycling bin
O	Industrial dust collector
P	Finishing table



InterchangeableBox-in-Box with conveyenceto support post processing

D Transfer Station
E BIB Job Box
F Shuttle
G Roller Conveyor
I Transfer Belt
J Transport Module of Auto Desanding Station

Binder Jetting Inorganic Process

Microwave Curing

Microwave Curing:

1. To evaporate the water component of the binder
   → aiming for approx. 120 °C
2. The whole job box, including support sand, is processed
3. Most beneficial for the process is to fill similar size parts in one job.
4. The use of silica sand is most common
5. Curing of a semi-filled job box
   in approx. 30 - 40 min

Advantage versus oven process

- Significantly faster cycle time
- Complete part curing from inside out

Binder Jetting Inorganic Process

Auto-desanding Station

Desanding	
J	Transport module
K	Desanding module
L	Control cabinet
M	Screw conveyor
N	Collection hopper w. recycling bin
O	Industrial dust collector

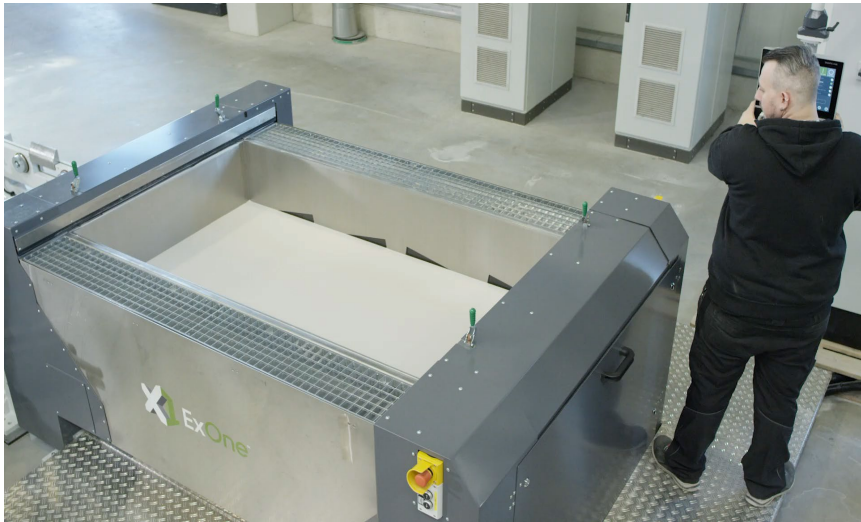
Automated Desanding Station offers:

- Perforated bottom plates that open holes for the sand to flow through
- Automated sand removal for unpacking of cores and molds

Added value:

1. OEE increase
   - ✓ Fully automated process, also for instant recycling sand recovery
   - ✓ Desanding labor cost reduced ~95%, from ~90 minutes to ~3 minutes
   - ✓ Increased yield due to better mold and core quality with less risk of core damage compared to manual extraction
2. Ergonomic and health improvement
   - ✓ Significant physical relief for the operator thanks to ergonomic part removal
   - ✓ Reduction of fine dust pollution
3. Optional future expansion with full automation through robot-assisted core removal and finishing

Video



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Binder Jetting Inorganic Process

Quick Finishing

Benefits

- Easy finishing compared to furan process
- Requiring only
  - compressed air up to 0 .8 bar
  - very soft brush
- After finishing the inorganic parts offer an excellent surface quality and edge sharpness

BINDER	INORGANIC
Air pressure (flat surfaces)	0.2 – 0.8 bar
Air pressure(holes)	0.1 – 0.2 bar
Distance	min. 20 cm

Binder Jetting Inorganic Process

Final Part

Typical Part Specifications

- Typical bending strength250 to 400 N/cm²
- Bending strengths are adjusted by print head resolution settings
- Hot bending strength suitable for aluminum alloys
- Dimensional accuracy: +/0.5 mm
  dependent on size and geometry of the component
  (up to 0.1% of component size)

Resolution [mm]	AD901-addition [%]	Bending strength [N/cm²]		Hot bending strength [s]
		X-direction	Y-direction	X-direction
0.10	0.00	330	280	39
	1.00	270	220	55
0.11	0.00	270	220	40
	1.00	240	200	60
0.12	0.00	240	200	37
	1.00	220	180	64
0.13	0.00	210	175	30
	1.00	190	170	62

*Results based on FS001

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Binder Jetting Inorganic Process

Final Part
Storage

Correct storage & transport:

- The cured printed product is hygroscopic, so should be used quickly for best results or kept in a dry storageenvironment
- The strength drops faster with increased humidity than with a rise in temperature
- As a result, it is advisable never to store the cores at a relative humidity higher than 40%
  The temperature should not exceed 30°C
- Evenly balanced support is crucial for storage to prevent bending of filigree cores. Foam support can be fitted if required
- For transport, desiccant bags can be used to minimize moisture content inside the airtight transport box

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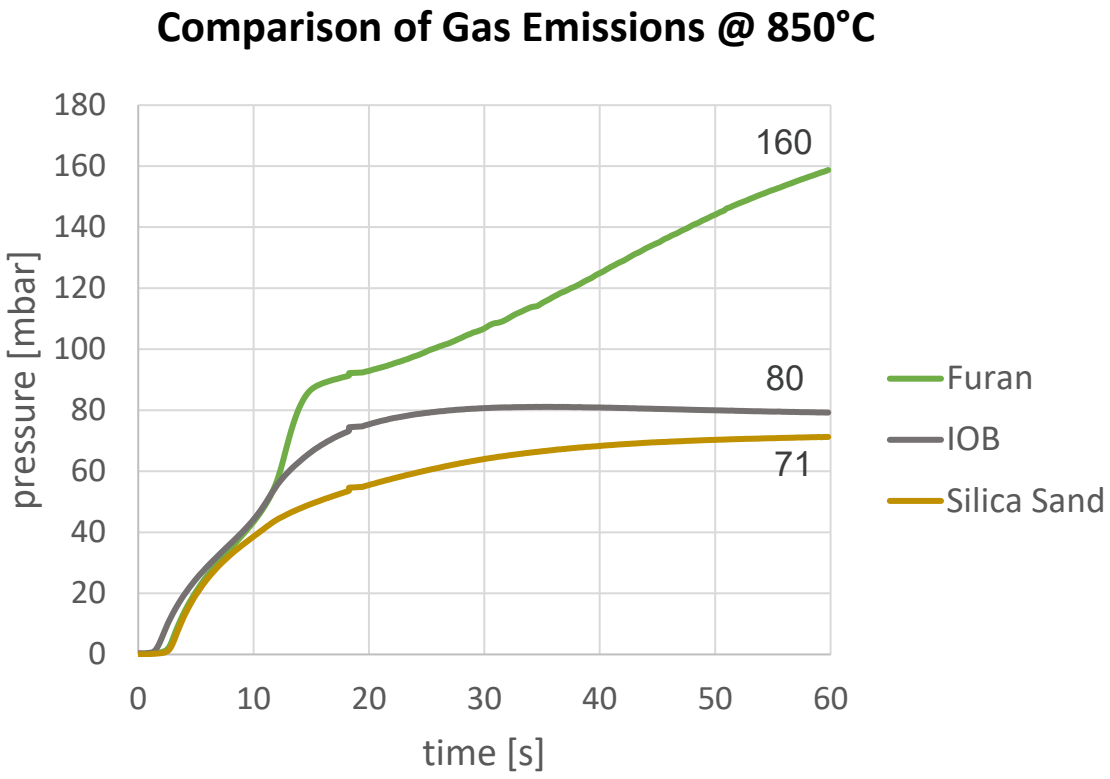
Benefits of Inorganic 3D Printing

1. **Low emission**
   for printing and casting is improving yield

2. **Supporting Green Foundry**
   with environmentally friendly consumable handling and storage

3. **Significant cost reduction**
   - Auto desanding
   - Minimal finishing required
   - Reduced recoater cleaning effort
   - Potential for fully automated robotic line for unpacking, finishing, inspection and storage.

Benefits of Inorganic 3D Printing



- **Low emission**
  for printing & casting

LOI (Loss Of Ignition):

Furan LOI: 1.2-3.1%
dependent on binder content

IOB LOI: < 0.5%
dependent on binder content

Silica Sand LOI: 0.2-0.3%
Base LOI due to organic portion of sand and moisture

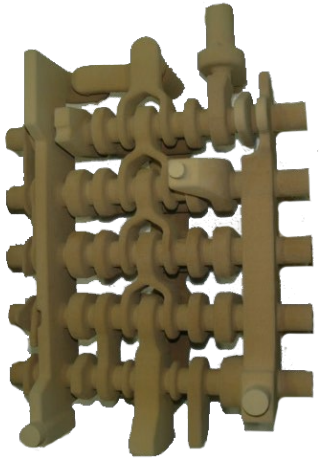
CASE STUDIES OUTLOOK

Binder Jetting Metalcasting Innovation Focused on Quality

Greenfield foundry designed around ExOne sand binder jetting process.

- Kimura Foundry America began operations in Shelbyville, IN in 2018 with two S-Max® and one S-Print® sand binder jetting systems
  - International growth after success in Japan with six ExOne systems that drove 500% revenue increase in the first five years
  - Developed a patented ceramic sand with a low thermal expansion to prevent veining and other defects. Material recycling system enables 99% sand reuse
  - Core and mold production in-house helps guarantee quality and fast delivery with all aspects of production, from engineering to printing to QM, under one roof
- Able to deliver rapid prototype castings 8x faster than with traditional methods
- Third S-Max added in 2022, the 10th globally for Kimura Group

Dr. Yoya Fakuda
President, Kimura Foundry America



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Binder Jetting | Swiss Iron Foundry

Global adoption of the S-Max® Pro and accessories growing

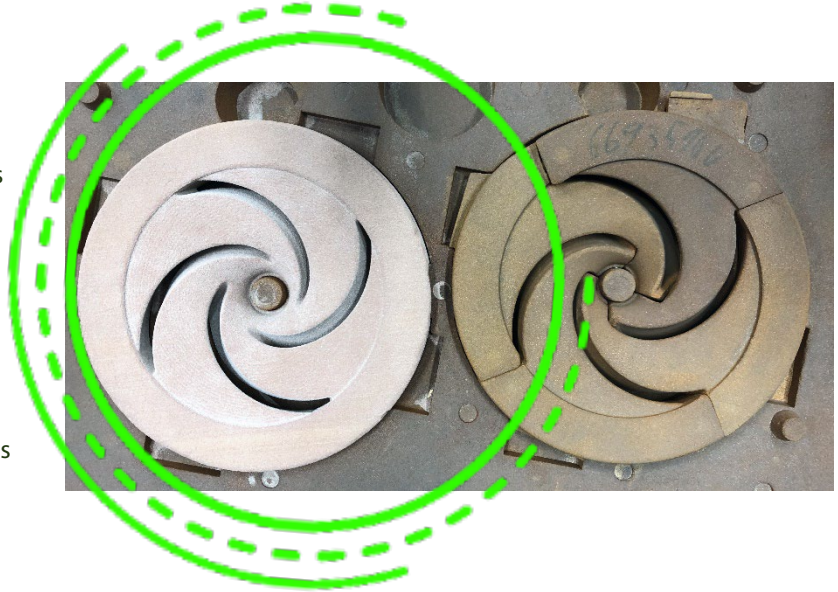
- Eisengiesserei Mezger AG, an iron foundry based in Switzerland, purchased an S-Max Pro with the desanding system, Fluidmatic material supply system, and other accessories, including the Scout app for monitoring their machine remotely
  - The new desanding system for furan helps depowder parts faster, reducing labor costs and increasing efficiency
  - Allows the customer to take full advantage of the recyclability of the sand, feeding it directly into a recycling container for reuse
  - Sustainable production recovering 95% of material and reliably using an 80 % mix of recycled sand in new printing jobs
- Installed in June 20 20 , Mezger reports high satisfaction with the system, which they are now running 24/ 7. They can now deliver cast parts to customers in as fast as three days

Binder Jetting | Reduced Assembly Increases Yield

Monolithic coreoptimizes production while driving down costs

INDUSTRY Water Treatment and Pumps
APPLICATION Impeller cores
LOCATION Sweden
CHALLENGE Goal to speed up production while optimizing product and process. Traditional core shooting took seven days to manufacture impeller cores in four parts glued together with core gum.

SOLUTION
3D PRINTER ExOne S-Max®
MATERIAL Printed silica sand with CHP binder for iron casting
COST Overall production costs decreased ~30 %
BENEFITS One-piece design only possible with binder jetting eliminated the process step of gluing core parts together while also increasing yield since gas pockets caused by core gum no longer caused defects. Production is also faster as post-processing is reduced since the printed impeller has no drafts and up to 480 cores can be printed in one 24-hour process.



"The quality of the impeller cores has improved significantly through the 3D printing process. At the same time, the production costs have decreased by around 30%"

TorbjörnAndersson, 3D Technician at Xylem

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