Tritone

Industrial Additive Manufacturing

NO LOOSE POWDER:

7 ADVANTAGES OF A PASTE BASED APPROACH TO METAL AM 2.0

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INTRODUCTION

Metal AM 2.0 promises a new era of affordable, high volume Additive Manufacturing (AM) of metal components. “Metal Binder Jet” technology is widely promoted by several industrial powerhouses as THE technology that will usher in a new era of growth in the coming years.
However, this core technology has been around for 30+ years and faces some significant challenges that make it a bad fit for many applications and factories.

THIS WHITE PAPER WILL INTRODUCE A COMPLETELY DIFFERENT APPROACH TO METAL AM 2.0 USING A PASTE BASED FEEDSTOCK INSTEAD OF LOOSE, DRY POWDER.

What’s the big deal? Does the paste make that big a difference? This white paper will help you understand exactly how a paste based feedstock addresses several key challenges facing binder jet adoption. We will share an overview of the MoldJet technology and some test results demonstrating the potential impact of this technology.
But first, some background.

WHY METAL AM?

Metal AM is an important technical advancement that offers several advantages over traditional manufacturing methods for producing metal parts. These advantages include:

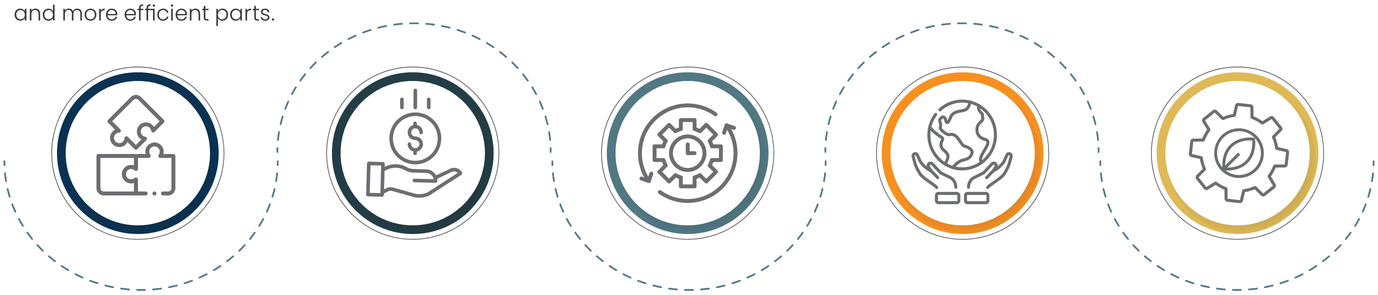
1. DESIGN FLEXIBILITY
With Metal AM, it is possible to create complex geometries and internal structures that are not possible using traditional manufacturing techniques. This can result in lighter, stronger, and more efficient parts.

2. COST EFFICIENCY
Metal AM can be more cost-effective for small production runs or for producing parts with complex geometries that would be difficult or expensive to machine or tool up for casting.

3. TIME EFFICIENCY
Metal AM can reduce lead times for producing parts, as the technology allows for rapid prototyping and fast production of parts.

4. MATERIAL EFFICIENCY
Metal AM can reduce lead times for producing parts, as the technology allows for rapid prototyping and fast production of parts.

5. SUSTAINABILITY
Metal AM reduces waste and environmental impact by using less raw material, producing less scrap, and reducing energy consumption compared to traditional manufacturing processes.



METAL AM 1.0 - LPBF

Over the past few decades metal AM applications and markets have grown dramatically, mostly driven by the Laser Powder Bed Fusion (LPBF) process. With this technique a high-powered laser is used to weld metal powder particles together, layer-by-layer, to build up a three-dimensional (3D) metal part. This “direct” metal fabrication process is widely used in industries such as aerospace, medical, and energy where the production of complex, high-value parts is required.

While this process has been proven with many commercial successes, the technology is just too slow and expensive for most industrial applications. LPBF is also limited to materials that are weldable.

METAL AM 2.0 – THE RISE OF SINTER BASED SOLUTIONS

Sinter-based approaches widen the appeal of Metal AM by dramatically improving process economics. In recent years this sector, driven primarily by the metal Binder Jet process has received significant investment and market attention. Several large industrial players have committed substantial resources to develop and industrialize the process.

These efforts are all in the pursuit of lower production costs and faster time to market. This is achieved by using the forming process to manufacture “Green Parts”. Green parts are metal powder that is “glued” together with special binders into the desired shape. Hundreds or even thousands of green parts can then be sintered simultaneously in a furnace to generate solid metal parts. Cost advantages of 10X and more when compared to laser-based processes are common.

The Binder Jet process is promising, however there are fundamental physics challenges that may not be solved. A brief overview of the Binder Jet process and key challenges is presented below.

When reviewing these challenges, it seems clear that an entirely new method to achieve the promise of sinter-based metal AM should be considered. That is the path chosen by the Tritone team as they invented the MoldJet process.

SINTERING

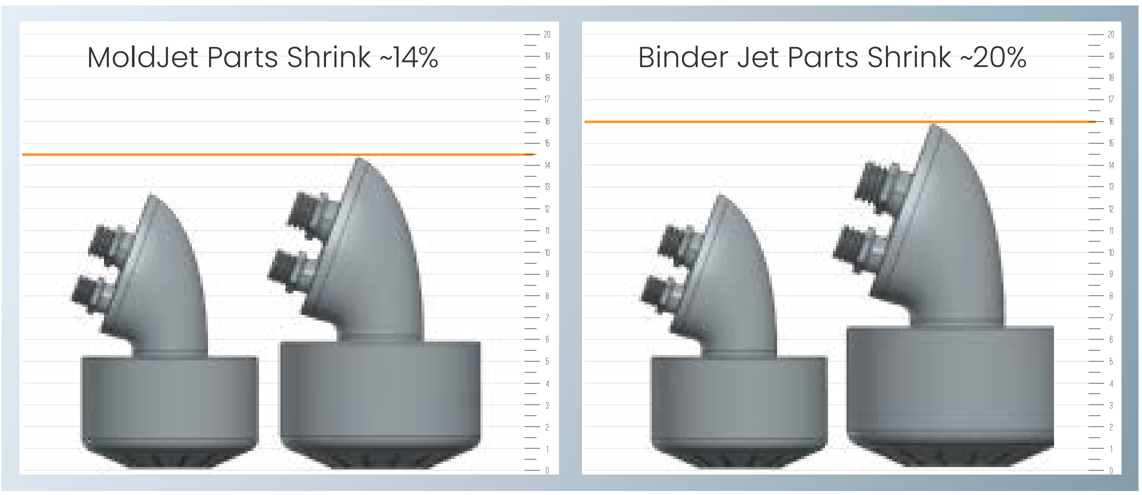
One commonality between Binder Jet and MoldJet is that both processes manufacture green parts which are then sintered to reach their final form as solid metal parts. A few comments are relevant to the balance of this paper:

1. Sintering of powder metal “green parts” is a mature industrial process that has been implemented at scale for decades by Metal Injection Molding (MIM) and other manufacturing technologies. Billions of dollars of sintered metal parts have been produced annually – long before additive manufacturing.

2. When green parts are sintered, they shrink as the powder particles fuse together.

3. The sintering / shrinking process has been proven to produce extremely consistent results – IF the parts entering the sintering furnace are consistent.

4. Green parts that are DENSER going into the sintering furnace shrink LESS and hold better tolerances. MoldJet parts shrink around 14% while Binder Jet parts shrink 20% or more. That is 30% less shrink.



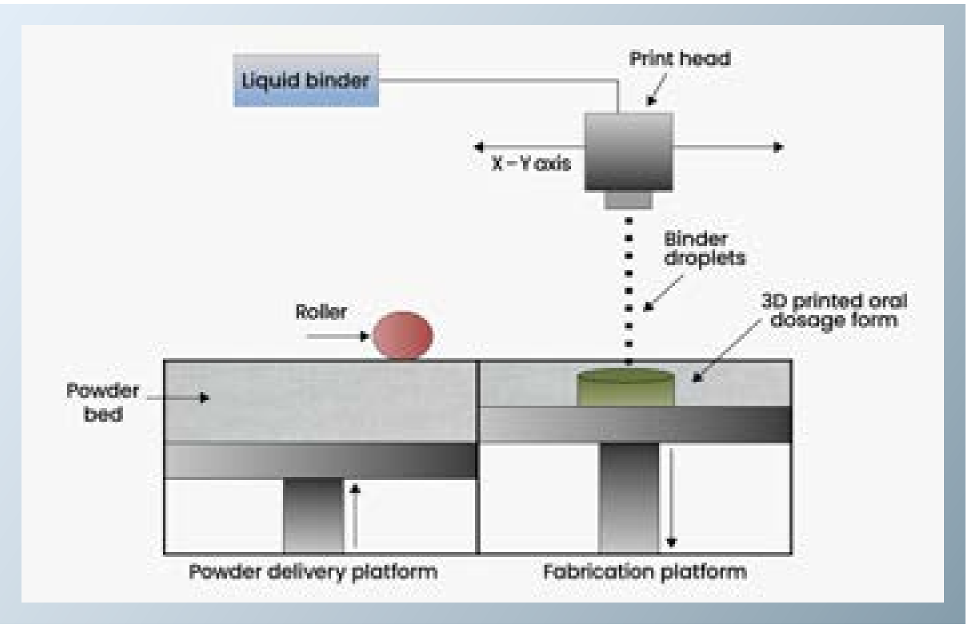
BECAUSE MOLDJET PARTS SHRINK MUCH LESS IN SINTERING, THERE IS LESS CHANCE FOR DISTORTION AND INACCURACY.

BINDER JET PROCESS OVERVIEW

In the Metal Binder Jetting process, a layer of metal powder is spread over a build platform, and a liquid binder is jetted onto the powder in a pattern that represents the cross-section of the part being printed. The binder selectively glues the powder particles together, forming a layer. The build platform is then lowered, and the process is repeated for the next layer until the 3D part is complete.

After printing, the glued "green" parts are cured and then recovered from the powder bed for further processing. The green parts are then sintered in a furnace to fuse the metal particles together to form a solid metal part.

While this process has the desired benefits of productivity and economics, there remain several key challenges to overcome on the route to mass adoption. Some of these challenges include:



General schematic of the Binder Jet printing process.
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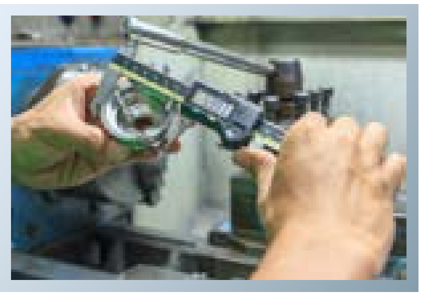
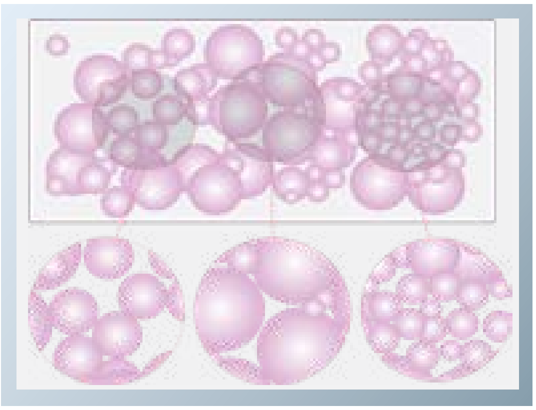
BINDER JET KEY CHALLENGES

MANAGING LOOSE POWDER
Metal Binder Jet 3D printing requires a significant amount of loose metal powder, which must be carefully handled, stored, and recycled. There are significant safety concerns with maintaining large amounts of ultra-fine metal powder in manufacturing facilities. Additionally, if powder is not properly managed, it can lead to contamination which affects final part quality. With hundreds or even thousands of pounds of powder across multiple pieces of equipment, changeover of materials can be a daunting task.



POOR REPEATABILITY DUE TO DENSITY GRADIENTS
A core assumption of the Binder Jet process is that micron-scale loose powder can be spread and packed with perfect consistency. A second assumption is that jetted binders will infiltrate the powder bed consistently.
In practice, spreading and infiltration are impacted by changes in humidity, surface chemistry, saturation rates and other factors. These process variations result in random density gradients in the printed green parts. Density gradients cause inconsistent tolerances after sintering.

LABOR INTENSE DEPOWDERING
After printing, parts must be carefully excavated from the mass of metal powder. This labor intense step works against the economics of the print process. Many part geometries with (especially internal passages) are simply too difficult to de-powder effectively. Additionally, green parts are fragile at this stage and can result in yield losses.



Loose particles in a dry powder bed have localized pack density inconsistencies.

As binder droplets impact the powder bed, inconsistent wetting can occur, leading to density gradients which lead to non-uniform shrinking in sintering.
This non-uniform shrinking results in poor dimensional tolerances.

THE MOLDJET PROCESS ELIMINATES DENSITY GRADIENTS BY MIXING BINDER AND POWDER INTO A HOMOGENEOUS PASTE BEFORE GREEN PARTS ARE FORMED

MOLDJET PROCESS OVERVIEW

The first step is creating the first layer of the component mold from a wax-like polymer using an **inkjet printing process.** In this process, the mold material is heated in a reservoir and jetted accurately onto the substrate by the print heads to form a mold layer.

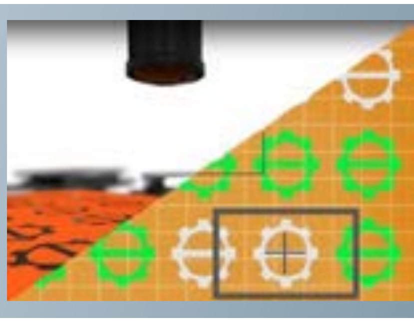
The entire layer of mold cavities is then filled with metal paste. The paste consists of metal powder, an aqueous carrier, and an organic binder system. A proprietary applicator design ensures a homogeneous transfer of paste into the mold cavities, eliminating density gradients. Hundreds of cavities can be filled in a single pass of the paste applicator.

After the mold cavities are filled on each layer, a series of drying and hardening steps remove the water based carrier. This step prepares the build substrate for the next layer of mold material to be applied.

After all layers are printed the complete build tray is removed from the machine for secondary processing. At this stage, the print is a solid block of mold with parts embedded inside. The tray can be handled without PPE.

A printed mold layer prior to filling with paste

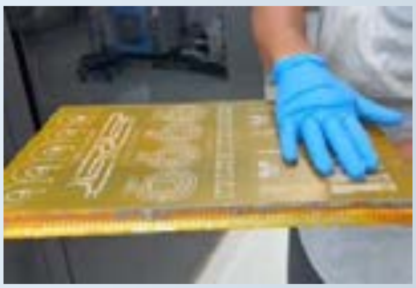
Paste being applied into mold cavities, b: the build layer after cavities are filled and dried.



Camera based inspection provides for real time defect detection and repair

DEMOLDING

The next process is removal of the mold material to reveal the green parts. This is a 2-step, hands free operation. First the bulk mold material is melted away in a low temp oven, then any remaining material is dissolved with solvents. A range of standard industrial equipment is available “off the shelf” for use in these steps depending on the scale of production required. There is no “de-powdering” step required as there is no loose powder to remove.



A completed build tray, ready for demolding operations

Mold is removed to reveal green parts ready for thermal debind and sintering

Tough green parts can be handled and post processed

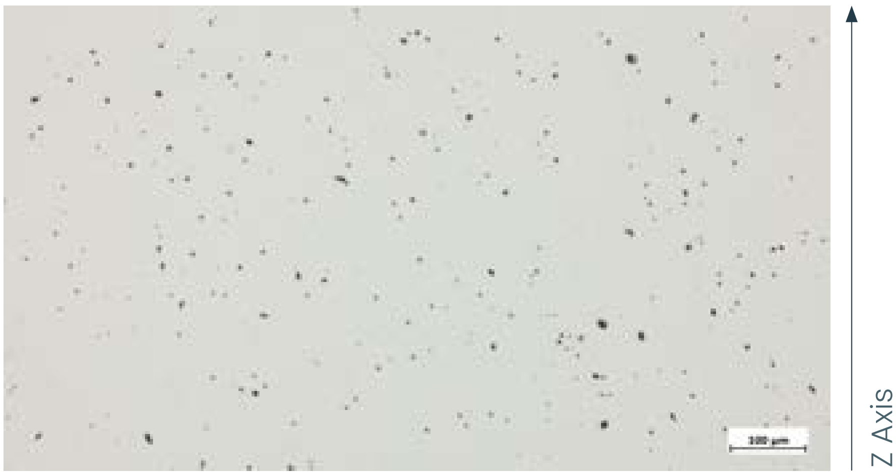
TEST DATA RESULTS

MATERIAL TEST DATA

In addition to the internal development work ongoing with MoldJet, an industrial driven project, testing is also ongoing at the Fraunhofer IFAM institution in Dresden Germany. Engineers at this facility have operated MoldJet equipment at their institution since 2021 and are currently developing new materials and applications for leading industrial and research clients.

The Fraunhofer team holds regular public forums to discuss the technology and are available to take on projects for customers worldwide.
The Institute shares the following data to set expectations across a range of materials they have worked with significant amount of handling (and even shipping) without damage. Sintered and Green parts can be polished individually or in bulk to improve surface finish if required, holes can be tapped etc.

The following image shows a cross-section typical MoldJet metal density of 99.3-99.7%. Note the very small level of porosity scattered randomly and evenly throughout the part. There is no evidence of the printed layer lines and no density gradients.



*No printing layers visible in the microstructure

Fraunhofer IFAM Branch Lab Dresden

PART REPEATABILITY DATA

Parts produced by MoldJet have been tested extensively to confirm both accuracy and repeatability. These measurements were taken from hundreds of samples of the same part geometry produced by*:

- Metal Injection Molding (MIM)
- Metal Binder Jet (2 different platforms)
- MoldJet (2 separate batches of parts)

The resulting measurement data indicates superior accuracy and repeatability of the MoldJet samples. In this test, MoldJet parts showed less than half the variability of Binder Jet parts and was almost equal to MIM.

* Note: The data below is provided by a MIM industry leader and is authorized for publication.

PART LENGTH: 45 mm

	TEST RESULTS (in mm)					
	MIM process	Binder Jet (A)	Binder Jet (B)	MoldJet (A)	MoldJet (B)	MoldJet (Average)
Average part measurement	44.95	44.28	45,92	44.96	45.0	44.99
Standard Deviation	0.033	0.119	0.104	0.043	0.058	0.051
*CoV Coefficient of Variance	0.07%	0.27%	0.23%	0.09%	0.13%	0.11%

*CoV measures the dispersion of data points around the mean and is an excellent indicator of process repeatability (the ratio of the standard deviation to the mean).

A PASTE BASED SOLUTION: MOLDJET

The MoldJet process was developed to provide a manufacturing process for industrial standard end-use parts. Specifically:

SOLVED:
- MANAGING LOOSE POWDER
- POOR REPEATABILITY DUE TO DENSITY GRADIENTS
- LABOR INTENSE DEPOWDERING

1 **MANAGING LOOSE POWDER – SOLVED:**
THE MOLDJET PROCESS HAS NO LOOSE POWDER
MoldJet's paste-based feedstock eliminates the need to deal with loose powder in manufacturing plants. It is a cleaner, safer process where all the material is used directly to make parts. There is no need to have entire build boxes full of powder to make a handful of parts. The paste feedstock also enables a very straightforward material changeover process.

2 **POOR REPEATABILITY DUE TO DENSITY GRADIENTS – SOLVED:**
MOLDJET ENSURES UNIFORM DENSITY DISTRIBUTION
With MoldJet's paste feedstock system, powder and binders are mixed continuously prior to deposition. This process ensures homogenous, dense, consistent green parts in all regions of the build box, run after run. (Please refer to Charts A & B on Page 10 for more details).

3 **LABOR INTENSE DEPOWDERING – SOLVED:**
MOLDJET POST PROCESSING IS A HANDS-FREE OPERATION
MoldJet demolding processing is a hands-free sequence that prepares the parts for sintering. Because parts are produced in a dissolvable mold material, there is no loose powder to remove from the parts. The mold material is simply removed in a hands-free process. MoldJet green parts are also quite tough and durable which allows for handling, automation, and even finishing operations in the green state.

Loose powder is mixed with binder and carrier to form a paste feedstock, thus, producing a dense and strong green part.

THE 7 KEY ADVANTAGES OF MOLDJET: A PASTE BASED FEEDSTOCK

1. A healthier, safer, cleaner factory work environment for employees and machines.
2. Better dimensional repeatability on parts after sintering.
3. Better utilization of the system and sintering.
4. Post processing after manufacturing is a hands-free and industrial operation.
5. Easy changeover of materials & there is no loose powder contaminating the machinery.
6. Materials are protected from oxidation by the inert environment of the paste, such as Titanium, Copper and more.
7. Initial investment to get started with MoldJet is much lower than Binder Jet leading to a faster technology adoption and ROI. Less equipment is needed, and sintering can be outsourced.

ABOUT TRITONE TECHNOLOGIES

Tritone Technologies transforms metal Additive Manufacturing to address the demanding standards and needs of industrial production. The company's innovative technology enables industrial throughput of accurate parts with a range of metal and ceramic materials, suitable for the Automotive, Aerospace, Medical and Consumer Electronics industries. Founded in 2017, Tritone is led by an experienced team of experts with a track record in driving technology and business growth. Backed by private equity firm Fortissimo, Tritone is a global company and is based in Israel with presence in North America and Germany.

Tritone Technologies: www.tritoneAM.com | Info@tritoneAM.com

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