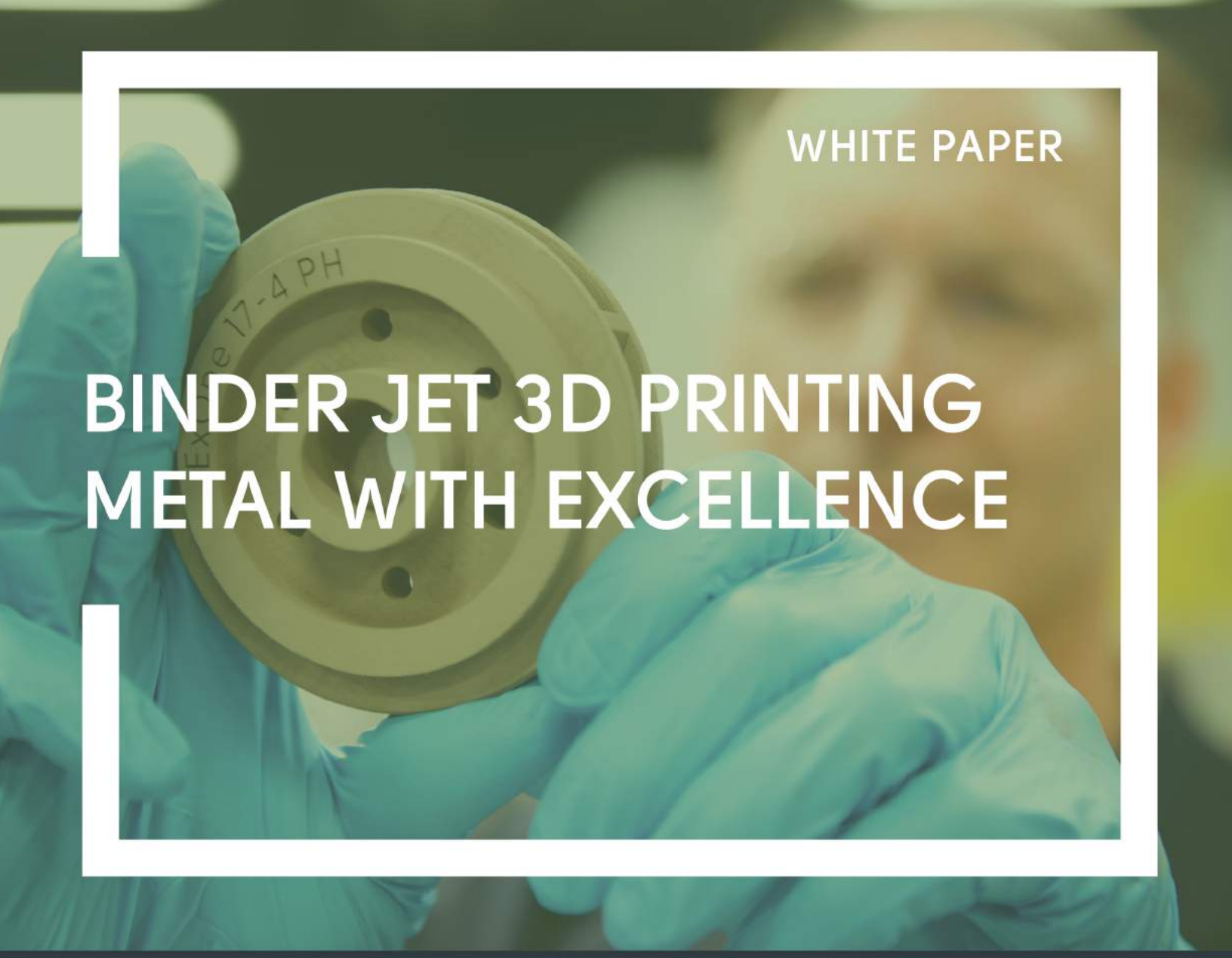


WHITE PAPER

BINDER JET 3D PRINTING METAL WITH EXCELLENCE

THE EXONE TRIPLE ACT

Improve the accuracy, density, and repeatability of your metal 3D print using exclusive binder jetting recoating technology.

ExOne™

Collaborate. Innovate. Accelerate.

UNDERSTANDING THE CHALLENGE

At first glance, metal 3D printing using binder jetting sounds so easy. You lay down a thin layer of metal powder, inkjet a binder onto the particles where you want them to stick together, and then repeat, layer by layer, until your desired object takes form. Once you have a cured "green part," you sinter it in a furnace, so all of the particles fuse isotropically into the final object.

If only developing a breakthrough technology were that easy.

To print the highest-quality metal parts using binder jetting, your 3D printer must print the finest powders possible. While ExOne's printers have processed even finer powders, they typically process MIM powders with a median particle size of 9 microns. Using ultra-fine powders such as these helps to ensure the particles can sinter together to form a dense, uniform microstructure that delivers reliable functionality and performance.

Unfortunately, these fine powders are the most challenging materials to process. For starters, it's difficult to uniformly deposit them onto a flat surface. Similar to baking powder, these fine particles are prone to caking and clumping. When you release them onto a surface, they can form dust clouds. Once you do get them into place, a drop of liquid binder can cause them to ripple or displace. What's more, the bigger the surface area you're trying to cover, the more challenging it is to create a uniform printing envionment.

So, to successfully 3D print a metal part using binder jetting technology, you must understand and tightly control your powder recoating process. The final test of your 3D printer's quality will ultimately be revealed after sintering, where any flaws in the binding of the powders are ultimately exposed.

THE EXONE TRIPLE ACT

A Solution 20+ Years in the Making

Enter Triple Advanced Compaction Technology (ACT) from ExOne – the company that commercialized the first metal binder jetting with the RTS-300 in 1998 and recently launched its ninth metal 3D printer, the X1 25PRO. Each new metal 3D printer developed by ExOne over the years has featured improvements based on feedback from real customers using its binder jet 3D printers for R&D and real applications.

The new patent-pending Triple ACT system solves three of the most challenging aspects of creating a thin, uniform layer of metal powder for a print job: dispensing, spreading and compacting fine powders.

Because each function is truly unique in its objective, ExOne set about designing a three-tiered solution.

A TRIPLE CHALLENGE

- Dispensing
- Spreading
- Compacting

From fine powder to precise green part.

ACT One:
Dispensing — A Unique Ultrasonic Hopper

To solve the problem of caking, clumping and powder clouds, ExOne metal 3D printers have used several different dispensing methods over the years. Initially, the machines used a side-by-side box system that dispensed powder vertically and then spread the powder across the print bed area.

In an effort to invent the method that delivered the best results, the ExOne engineering team studied powder-handling techniques used by other industries processing fine powders. They found systems that used shaking and pulsing systems, sometimes in specific rhythms, to manage and move challenging fine powders. But there were limitations: most powder-dosing systems are used to place powder in one tight location, not across a wide build area, so ExOne's team used their research to invent a unique solution.

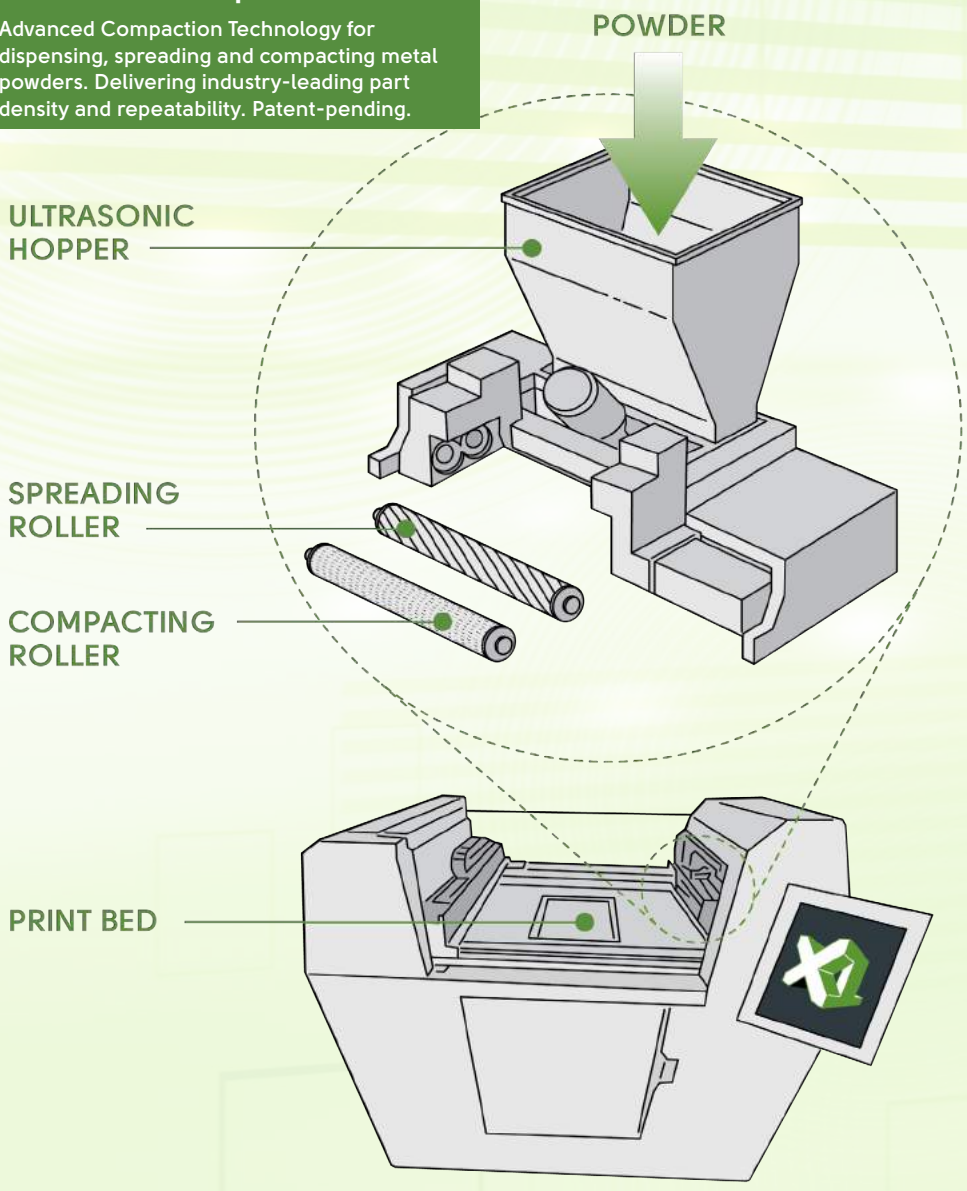
With trial and feedback over machine generations, ExOne developed and refined Step One of the Triple ACT system: a unique hopper design with a dispensing screen that ultrasonically vibrates to release a highly controlled dose of powder as it quickly moves across the span of a print bed.

The new, scalable approach releases a consistent and fine layer of powder particles across large build areas.

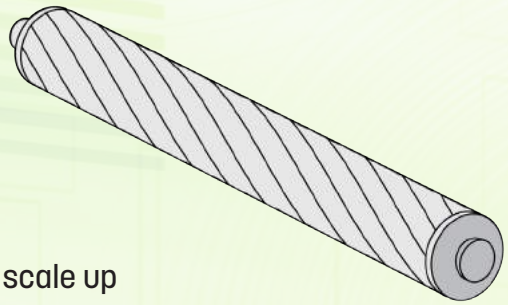
After powder is precisely dosed in locations across the bed, it must then be evenly spread and compacted – ACTs Two and Three – in order to deliver a quality print layer, and the highest ultimate part density.

The ExOne Triple ACT

Advanced Compaction Technology for dispensing, spreading and compacting metal powders. Delivering industry-leading part density and repeatability. Patent-pending.



ACT Two:
Spreading — A New Roller with a Knurl Design



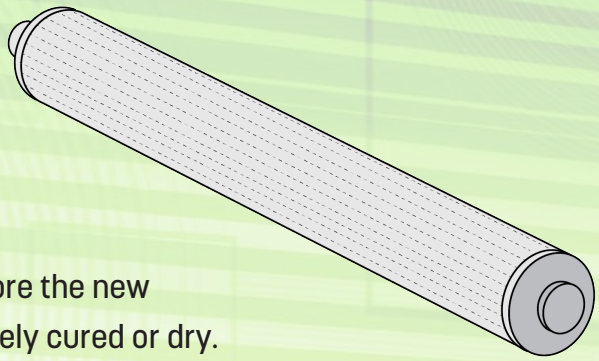
For most generations of ExOne metal 3D printers, a similar method of spreading and compacting the powder across the bed was used: a rolling pin.

This simple approach worked with limited success in the smallest build areas. But as ExOne's metal 3D printers began to scale up in size, it wasn't as effective in consistently spreading the particles across the entire bed area evenly. While the rolling pin did help to evenly spread the powder to an extent, it was actually more effective at compacting the powder close to its original drop location.

So, ExOne's team decided to separate the spreading and compacting functions, using two new roller pin designs for each function. The new spreading roller is truly unique, with a specific knurl design to increase the friction or engagement with the surface of the powder. This special face helps to evenly pick up and spread powders in a consistent way, over a certain height setting, to ensure the powder is spread in such a way to be consistent and even.

ACT Three:
Compacting — A Critical Final Step for Dense Parts

The final step of the Triple Act is compacting the now evenly spread powder. The goal is to press the particles tightly together so when the inkjet head doses binder onto them, it can form the most dense bond possible.



However, the compaction pressure must also not be too great, or else it could damage layers that have already been printed below the new recoating layer and are not yet fully cured. While each 3D print layer is heated after binder is applied, and before the new coating of powder is laid down, the layer is not completely cured or dry.

Imagine adding a new layer of sand to a damp sand castle at the beach, and then using a rolling pin on top of it to even it out. You have to use just enough force to compact the particles, but not so much that you crush the work you've already done below the new layer.

In binder jetting, these already-printed layers are sensitive to disruption in the X, Y and Z directions, and so compaction force and the precise Z-layer at which pressure is applied must be tightly controlled.

What's more, ExOne's Triple ACT compacting roller also features a special surface finish designed to not further spread or move the powders during this final step.

Independent Research: Roller Systems Can Improve Part Quality

Research performed by the University of Waterloo in Ontario with an ExOne M-Flex metal 3D printer, and published in the peer-reviewed journal, Additive Manufacturing, confirmed that a roller system is vital to the quality of metal 3D printed parts using binder jet technology. While the M-Flex featured a roller system that predated the Triple ACT, it confirmed the importance of such systems on final part quality:

On Higher Green Part Density
"Based on the density values, it is seen that powder compaction through roller rotation plays an important role in increasing green density," adding that the roller system "leads to higher green densities when the roller is actuated."

On Delivering Less Accuracy Distortion in X and Y
"The powder particles are pushed closer together with each spread. The compaction of the powder layers is also beneficial in minimizing the seeping of the liquid binder outside the intended part area. This seeping out effect can be detrimental as it can lead to layer shifting. In fact, layer shifting is consistently observed in many of the samples printed with the deactivated roller rotation."

Reference: Issa Rishmawi, Mehrnaz Salarian, Mihaela Vlasea. (2018). Tailoring green and sintered density of pure iron parts using binder jetting additive manufacturing. Additive Manufacturing, Volume 24, 508-520. ISSN 2214-8604. Retrieved from https://doi.org/10.1016/j.addma.2018.10.015

AN ADVANCED RECOATING SOLUTION

Smart dispensing, spreading and compacting

Taken together, ExOne's system for precision dispensing, spreading and compacting fine powder delivers industry-leading part density and the repeatability **required for production 3D printing, especially in larger build areas**.

ExOne's Triple ACT system achieves densities of 97% or greater, depending on the material and how much density a customer desires, which can now be precisely dialed in with ExOne's Triple ACT system and other process controls.

What's more, part density variability across the build area is now 0.3% – an improvement of 90% over ExOne metal printing systems before deployment of the Triple ACT system.

Previously, part quality on the farthest edges of the build area showed less density than those in the centermost areas of the print bed.

Depending on the type of powder being printed – ExOne metal 3D printers also print ceramics and other material types – layer thickness can now go down to 10 microns.

ExOne metal 3D printers now enabled with the exclusive Tiple ACT system are production ready.

LET'S SOLVE THE TOUGHEST PROBLEMS. AND CHANGE THE WORLD.

ExOne™

Collaborate. Innovate. Accelerate.

Meet the X1 25PRO metal 3D printer — featuring the exclusive Triple ACT system for delivering industry-leading part density and repeatability.