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How Binder Jet 3D Printing for Metals Compares to Selective Laser Melting and Electron Beam Melting

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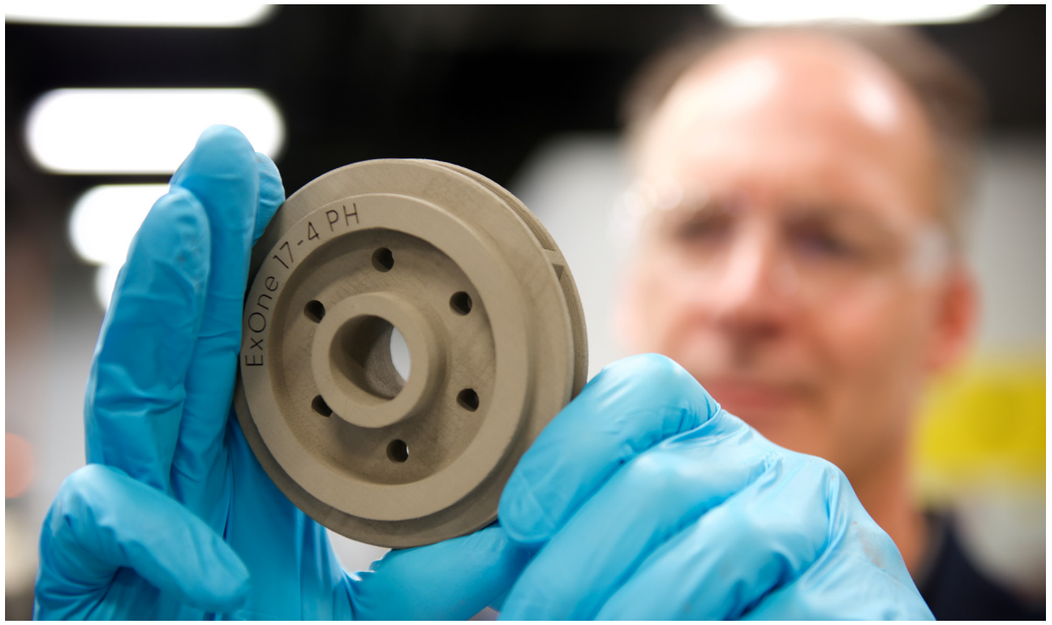


Endless powder: A thin layer of metallic powder material is applied to the construction platform and by a laser or electron beam melted. This process includes selective laser melting and electron beam melting.

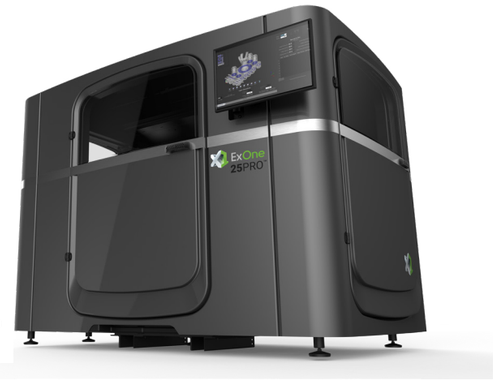
As a process, binder jetting is getting renewed attention for its ability to 3D print at volume-production speeds, especially when it comes to delivering precise, dense parts. Much of this attention is driven by a raft of announcements about new entrants to the metal binder jet 3D market.

But how does it compare to other additive manufacturing (AM) processes for metal? The most common AM processes for metal include material extrusion (ME), binder jetting (BJ), powder bed fusion (PBF), and directed energy deposition (DED).

This article will compare BJ to the other most commonly deployed metal AM processes in the market, both of which are PBF processes: selective laser and electron beam melting (SLM and EBM).

In the PBF techniques, thermal energy – applied by a laser in SLM and an electron beam in EBM – is used to fuse metal powder particles in a bed. In binder jetting, a liquid binding agent is selectively deposited through an inkjet head to powder particles in a bed. Each process builds the part one thin layer at a time. However, there are important distinctions:

Thermal Considerations. When printing each layer with SLM and EBM, the part undergoes rapid heating and cooling. In addition to leading to anisotropic material properties, this thermal stress imparted on the printed objects must be relieved before the part is used. BJ is the only process where the shaping of the part is executed at a consistent, low temperature. It is only after this so-called "green part" is sintered that it becomes a final part with isotropic mechanical properties.



ExOne's 9th Metal 3D Printer, the X1 25PRO

File Preparation and Support. SLM requires both thermal and structural supports to be designed to support the 3D build. With EBM, meanwhile, the powder surrounding the part is partially sintered during the build process, enabling it to act as a mechanical support. However, EBM still requires the design of thermal supports. BJ requires no supports because it is supported by unbound powder during the low-temperature build. However, similar to parts produced using metal injection molding (MIM), BJ parts often require ceramic supports in the sintering furnace.

Speed Considerations. There are several ways to look at speed: time to build a layer, time to print a complete part, and total start-to-finish time from loading powder into a printer to having a usable part. In many cases, 3D printing is the fastest and easiest part of the process. Setup and post-print steps have their own burden in time and complexity.

In printing time alone, one must also consider the number and volume of parts being built. For example, while BJ is regarded as the fastest printing strategy, EBM may, at times, outperform BJ for the printing of a single unit when one considers other necessary BJ process steps such as curing and sintering. However, SLM is often the slowest when considering total end-to-end process time.

The more units that are added, the more advantageous BJ becomes. That's simply because SLM and EBM must draw out each part's layer individually with a single point, whereas the number of passes an inkjet must make to process parts in a single bed is the same, whether it contains one or many units. While many SLM systems now contain multiple lasers, the build speed is still significantly slower than BJ and it is unknown whether the additional lasers cause additional thermal stress in the part. Thus, the added 3D printing time to produce four units in SLM and EBM is typically several times the time it takes for one unit. In BJ, it depends on how many units can fit in the printer's build area, and if the four units all fit in one bed, the added time may simply be 5-10% of the time it takes to build one.

Necessary Processing Steps. SLM, EBM and BJ all have unique processing steps and tasks that are required before, during and after the 3D printing is complete. All of these steps vary in terms of time required, complexity and operator skill requirements.

For BJ, depowdering a bed to remove green parts, curing and sintering are all core to the process. Resetting the machine takes about an hour. Both SLM and EBM, meanwhile, require skilled machine preparation including cleaning and component changes, which takes significant time, usually about 2-3 hours. After printing, SLM requires the part to be de-stressed for several hours at 400-800°C to relieve thermal issues caused by the rapid heating and cooling during the build. Removing supports is required for both PBF methods, with SLM requiring machining.

Final Part Microstructure. When examining the microstructure of the final part, research conducted by ExOne and presented at the 28th Annual International Solid Freeform Fabrication Symposium shows that both EBM and SLM produce columnar grain structures with relatively large grains, while the BJ process generates a fine equiaxed grain structure. Size and shape of the final grain size is an essential factor in determining the final mechanical properties of the component. The uniform microstructure that BJ produces results in isotropic mechanical properties and good fatigue life.