Understanding Bound Metal Deposition^{TM}

Strength of Studio System parts

Several factors impact the strength and stiffness of parts printed on the Studio System. These factors include:

① The Bound Metal Deposition™ fabrication process

② Material properties—such as the density, elastic modulus, and yield strength—of the chosen metal material.

③ Structural properties—including infill geometry, shell thickness, and the orientation of the part when printed.

Given the number of variable parameters for each printed part, the strength and stiffness of Studio System parts will vary. However, in practice, users of the Studio System can expect printed parts to be 30-60% less stiff than their machined counterparts, with a comparable increase in stresses and deformation.

This tech note

- Explains the technology behind the Studio System
- Discusses the impact of alloy-specific material properties, infill geometry, shell thickness, and printing orientation on overall part strength

❶ Bound Metal Deposition™

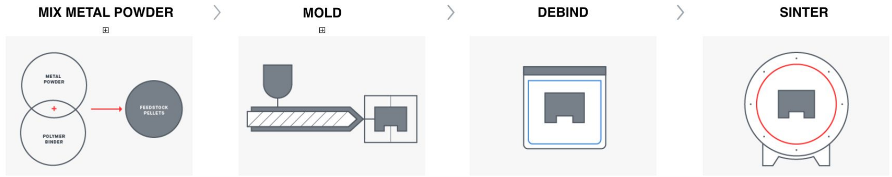
The Studio System™ uses a fabrication process called Bound Metal Deposition™ (BMD™). BMD leverages one of the safest, most-widely used 3D printing processes, Fused Filament Fabrication (FFF) and the well-understood materials and processes of metal injection molding (MIM). In MIM, powdered metal material held together with binder is injected into a mold. It is worth noting that at its introduction, MIM represented a significant advancement beyond previous powder metal sintering processes by enabling new capabilities in terms of geometric flexibility for more complex parts. The Studio System takes advantage of the innovations of MIM and combines them with FFF 3D printing to offer users the benefits of shape complexity, without the limitations of tooling, feature size, and draft angles.

Strength of Studio System parts

The material, or feedstock, used in MIM is a homogeneous pelletized mixture of fine metal powder and a multi-component binder. Once injected, the feedstock takes the shape of the mold's negative space. Then, the binder is removed in a solvent debind process before sintering where the metal particles consolidate to create a strong, dense metal part.

MIM

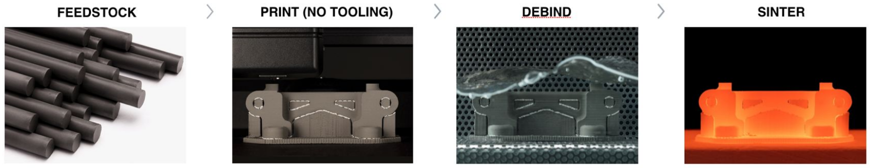
Metal injection molding workflow



With BMD, the Studio System follows a similar process and utilizes the well-studied materials of in MIM. The Studio System media is a mixture of metal powder and Desktop Metal's proprietary binder in rod form. The bound metal rods are heated and extruded onto the build plate, shaping a part layer-by-layer.

BMD

Bound Metal Deposition workflow



Given the proximity of the metal injection molding process and materials to the Studio System technology, the resulting metallurgy of Studio System parts is similar to metal injection molded parts.

2 Material properties

There are well-established testing specifications for characterizing metals printed with the Studio System (e.g., ASTM B883: *Standard Specification for Metal Injection Molded (MIM) Materials*). As an example, the table below illustrates the mechanical properties of Desktop Metal's 17-4 PH stainless steel.

Strength of Studio System parts

Mechanical properties for Desktop Metal 17-4 PH stainless steel.

	standard	**Studio System™** as-sintered	ASTM B883 as-sintered (min)	Wrought[3] for reference
Yield strength (MPa)	ASTM E8M	**660**	650	980
Ultimate tensile strength (MPa)	ASTM E8M	**1042**	795	1060
Elongation at break	ASTM E8M	**8.5%**	4%	8%
Young's modulus (GPa)	ASTM E8M	**195**	190 (typ)	200
Hardness (HRC)	ASTM E18	**37**	-	35
Density (relative)	ASTM B311	**98%**	-	100%

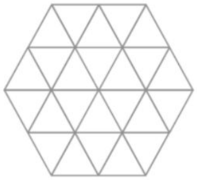
3 Structural properties

The role of infill

As an extrusion-based process, BMD enables the fabrication of parts with closed-cell infill—a fully-enclosed, internal lattice structure is printed within the part. With the exception of very small geometries, all Studio System parts are printed with closed-cell infill. Printing with infill reduces fabrication time and material usage, both of which contribute to a reduction in part cost. Infill also reduces the weight of a part while maintaining the design-intent of the part surfaces. *[For more information on infill and density of Studio System parts, see Tech Note* "Density of Studio System parts"*].*

Infill geometries vary widely (e.g., hexagonal, square, triangular), but the common feature of all such structures is an array of hollow cells formed between relatively thin vertical walls. In combination with the outside shell, infill-based structures feature excellent rigidity at minimal weight.

The shape of the infill geometry has a significant impact on both the effective modulus and the degree of anisotropy of structural properties. The Studio Printer prints with triangular infill, which offers several benefits over hexagonal or square infill geometries. Triangular infill results in a constant elastic modulus in the X-Y plane, ranging from 18-28% of the solid material's elastic modulus, depending on print parameters.

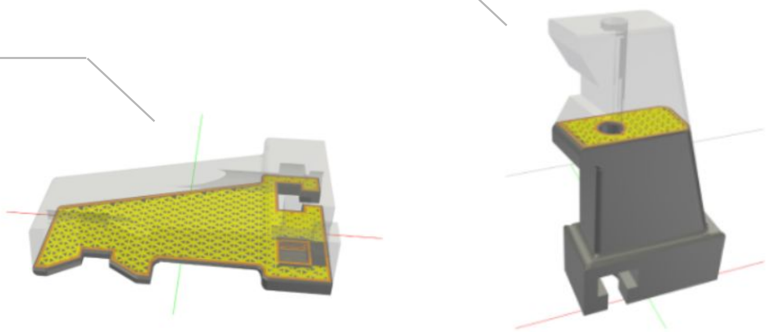


Infill geometry	Rigidity in XY	Rigidity in Z
Triangular cells	Isotropic: elastic modulus in X-Y plane, ranging from 18-28% of the solid material's elastic modulus, depending on infill parameters.	Anisotropic: elastic modulus is proportional to the relative density of the infill cells. For infill 50% dense, the effective modulus is half that of the solid material.

Strength of Studio System parts

The role of printing orientation

Given that the in-plane Young's modulus is 18-28% of the solid Young's modulus, and the out-of-plane modulus is 48-73% of the solid Young's modulus, the exact stiffness of a part varies to some extent depending on the printing orientation. For example, when loaded under the same conditions, the gripper arm printed in two orientations shown below will have different stiffnesses.



Gripper jaw printed in the z-direction

Gripper jaw printed in the xy-direction

The role of part shell

Parts printed with the Studio System feature a 1.2 - 2.4mm thick shell (depending on print parameters), which adds to the part's rigidity. The shell tends to concentrate the load-bearing material on the part's outer edges, where it contributes most to the moment of inertia. (When orienting a part for printing, rigidity in a particular direction is only one of several factors to consider - other factors include part stability, material usage, and surface quality. [*For more information on optimal part orientation, please see the design guidelines].*

4 Conclusion

Given the number of variable parameters for each printed part, the strength and stiffness of Studio System parts will vary. However, in practice, users of the Studio System can expect printed parts to be 30-60% less stiff than their machined counterparts, with a comparable increase in stresses and deformation.