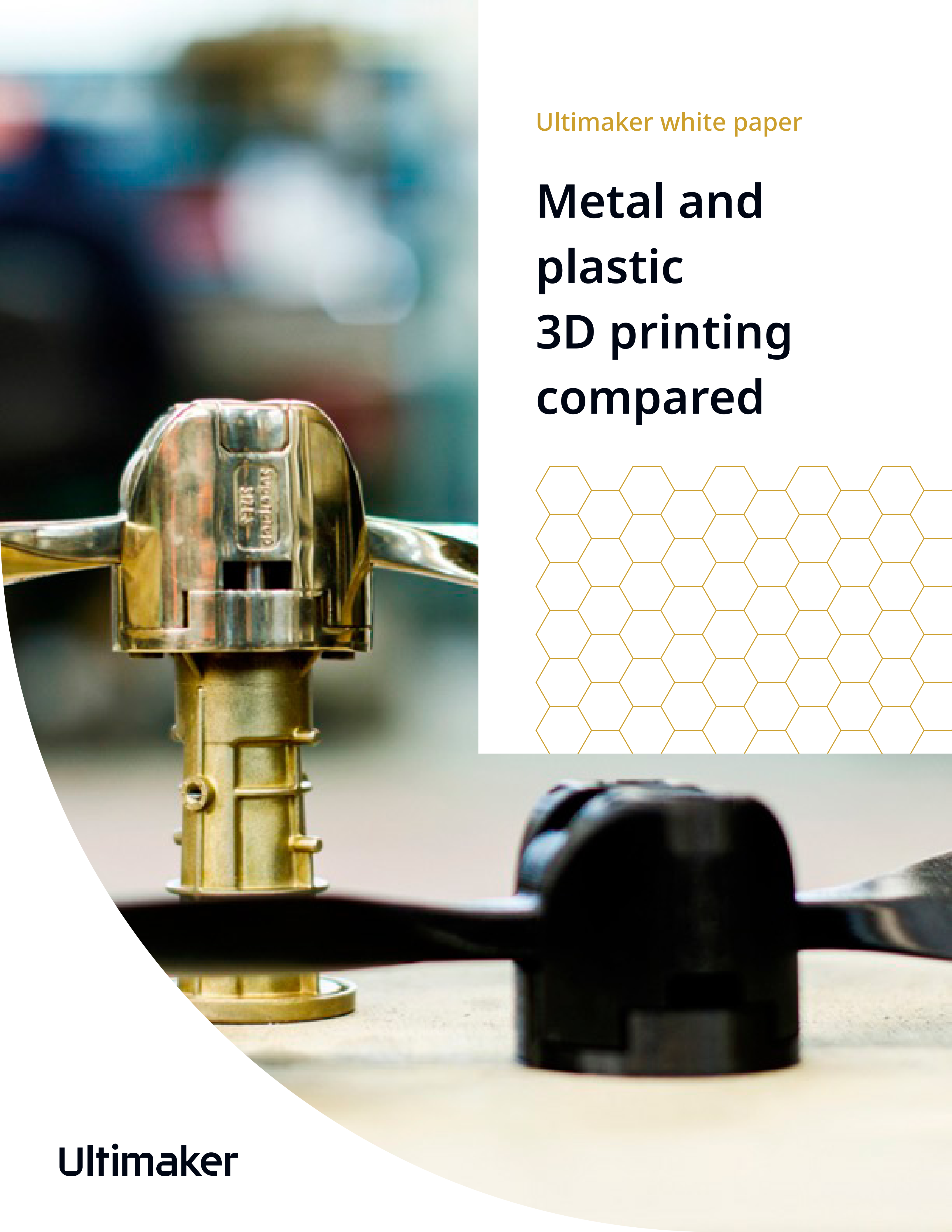

Ultimaker white paper

Metal and plastic 3D printing compared

Ultimaker

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Contents

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Introduction

When comparing metal and plastic 3D printing, metal is sometimes considered to be stronger, more durable, and of higher quality than plastic. But this isn’t always true. In many cases, a plastic 3D printed part can perform as well or better than a metal counterpart – and at a lower cost.

And while many choose to create metal parts by default, this can be overkill for some applications. It’s therefore critical to carefully assess the mechanical properties that a part requires, and select the material that best matches these, while remaining cost-effective.

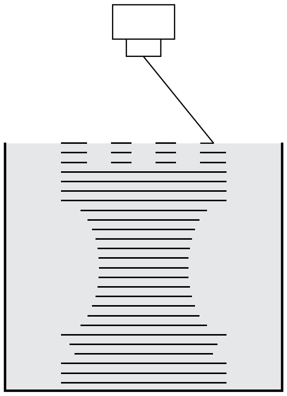
In this white paper, Ultimaker compares three common metal and plastic 3D printing technologies:
- Direct metal laser sintering (DMLS) metal 3D printing
- Bound metal deposition (BMD) metal 3D printing
- Fused filament fabrication (FFF) plastic 3D printing

Metal 3D printing technologies

There are various metal 3D printing technologies available, with multiple vendor-specific names and acronyms. To simplify matters, this white paper looks at two popular approaches: direct metal laser sintering (DMLS), and bound metal deposition (BMD).

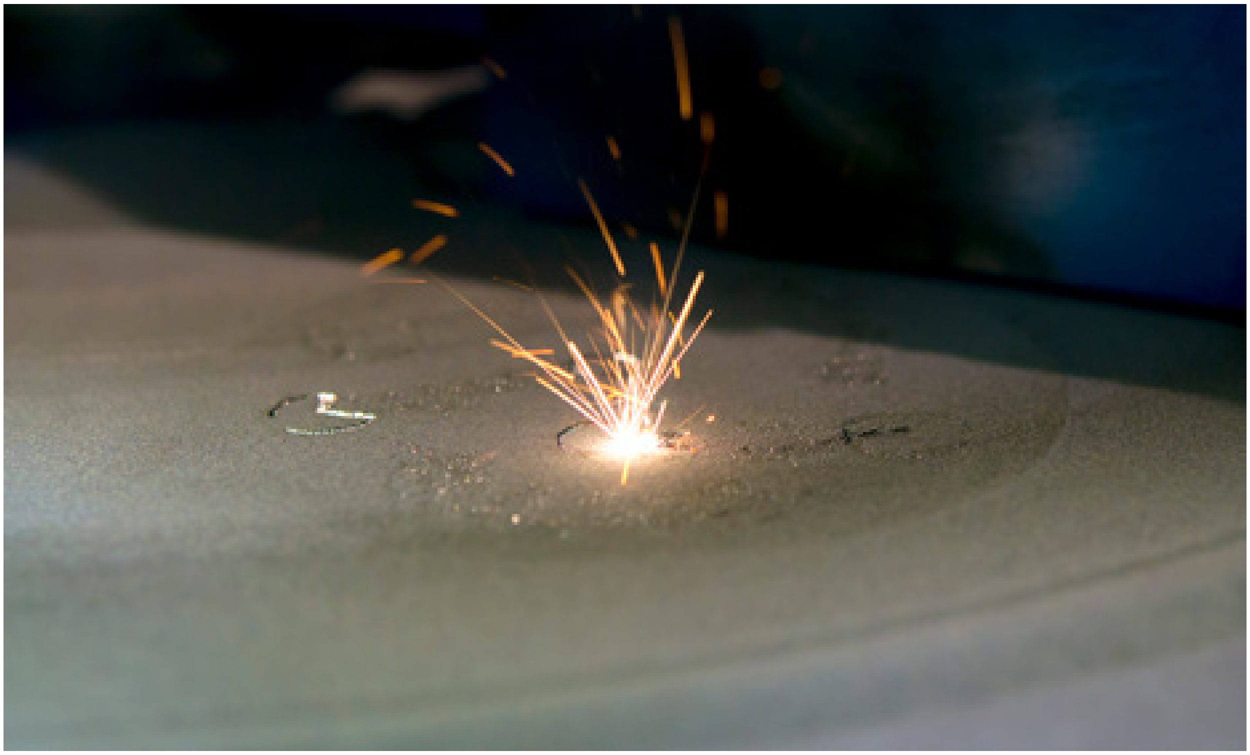
1. Direct metal laser sintering (DMLS)

Sometimes called selective laser melting (SLM), this technology uses a laser to melt a shape into a bed of powdered metal. The bed is then lowered, and the shape covered with a fresh layer of powder. Metal parts are thus produced layer by layer. To avoid warping, all printed parts must be attached to the build plate via support structures.



After DMLS 3D printing, the part requires heat treatment to relieve residual stress. It is then removed from the build plate, using a wire electrical discharge machine (EDM).

Finishing requirements often include a combination of CNC milling, media blasting, belt sanding, and manual tooling.



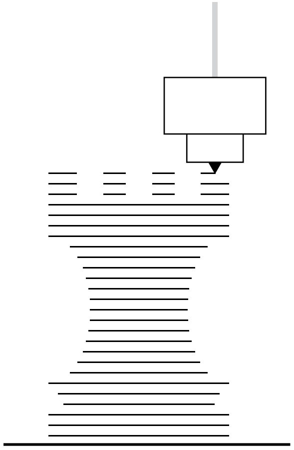
DMLS 3D printers use a powerful laser to build layers of melted metal powder

2. Bound metal deposition (BMD)

Also known as metal material extrusion, this technology is similar to FFF printing.

Instead of using powder, BMD uses metal bound in rods of sacrificial wax or polymer. The mix behaves like a thermoplastic material, which can be melted and extruded through a nozzle. This creates a metal-polymer object – also known as a ‘green part’.

After 3D printing, the unfinished part requires post-processing. It is washed, or ‘debound’, to remove the binder, then sintered in a furnace. This process fuses the material, leaving a finished metal part.



BMD printers extrude metal-polymer rods in layers to form a ‘green part’, which must be debound and sintered

Initial investment cost comparison

This table compares the cost of owning DMLS and BMD 3D printers, with an Ultimaker S5.

Note: All prices accurate at the time of publication and subject to change.*

	DMLS	**BMD**	**FFF** (Ultimaker S5)
3D printer cost	$550,000 (€493,000)	$49,900 (€50,000)	$5,995 (€5,500)
Other required and optional equipment	• Heat treatment furnace $17,000 (€15,200) • Wire EDM $50,000 (€45,000) • 5-axis CNC machine $120,000 (€108,000) • Optional media blast cabinet $10,000 (€9,000)	• Debinder $9,000 (€10,000) • Furnace $59,900 (€60,000)	• Optional reinforced print core $295 (€295) • Optional manual post-processing tools $100 (€89)
Contracted service program cost	• Installation and training included in purchase price • $20,000 (€18,000) maintenance per year	• $5,000 (€5,000) installation and training	• Not required
Most affordable material cost per unit	• From $110 (€100) per kg (75 kg required to fill powder bin)	• From $425 (€376) per cartridge	• From $49 (€33) per 750g spool
Other equipment and consumables	• Build plates, from $200 (€178) • $500 (€448) for rakes and filters • House argon or nitrogen	• Consumable start kit $7,000 (€7,000) – includes media, gas, debinder fluid, furnace effluent filters, build plates	• None required
Software cost	• $20,000 (€18,000) per license • $30,000 (€27,000) for additional material settings (optional) • $80,000 (€72,000) product lifecycle management software (optional) • $20,000 (€18,000) enterprise resource planning software (optional)	• $550 (€500) per year	• Free (Ultimaker Cura)
Total investment cost (excluding materials and optional extras)	**$777,700 (€697,826)**	**$131,350 (€132,500)**	**$5,995 (€5,500)**

** While most price conversions are calculated using currency exchange rates, some are based on regional MRP.*

Should you consider CNC machining?

Why is computer numerical control (CNC) machining relevant to this discussion? Because if you can afford to own an in-house metal 3D printer, you can afford a CNC-milling machine.

CNC machining remains a cost-effective way to produce metal prototypes, but requires designing for subtractive manufacturing. This has two main limitations: tool shape and tool access.

To reduce the time and cost of CNC machining, wall thickness, cavity depth, internal corner radius, and hole diameter must be considered. Internal geometries are limited to T-slot or dovetail shapes at specific angles. Small cavities and holes are limited to a 2.5 mm (0.1 inch) diameter.

If your part fits within these parameters, CNC machining can be cheaper and faster than metal 3D printing. CNC-machined parts also retain the blank metal's isotropic properties and can be made with higher accuracy: up to ±0.025 mm, compared to the ±0.100 mm of DMLS.

But to compete with the design freedom that metal 3D printing provides, a 5-axis CNC machine is required. Prices start at around $120,000 (€100,000).

CNC machines can be cheaper than metal 3D printers, but limit geometric freedom

Technology comparison

Each 3D printing technology has its own strengths and weaknesses, so is suitable for different manufacturing applications. Here are the advantages and challenges found in each system:

Direct Metal Laser Sintering (DMLS)

Advantages	Challenges
• Geometric complexity carries no extra cost • Allows the creation of stiff and lightweight parts • Repeatable and consistent results • Highest metal density in metal 3D printing • More in-depth process simulation and reporting than other technologies	• Metal powder is volatile and requires an oxygen-free build chamber • Higher cost-per-part than traditional manufacturing • Post-processing can take up to 50% of the fabrication time. This includes heat treatment (annealing), cutting from build plate, unsintered powder removal, and surface treatment • Slow printing process • Some part geometry angles must be avoided to avoid collision with the recoating arm • Struggles to print fully enclosed hollow parts as powder must drain • Expensive to remake a failed print • Parts are welded to build plate due to residual stress • Changing materials requires decontamination with a wet separator vacuum • Recommended to use one machine per metal alloy family

Bound Metal Deposition (BMD)

Advantages	Challenges
• Geometric complexity carries no extra cost • No safety concerns with volatile metal powder • Faster than DMLS • Non-metal interface layers allow for easier post-processing • No residual stress on printed or sintered parts • Office-friendly	• Less strength and density than DMLS • Requires extra post-processing, such as washing, drying, sintering, and surface treatment • When sintered, parts shrink by roughly 20%, requiring software scaling • Green parts are fragile (similar density to a crayon) • Changing materials requires separate material feed trays, print heads, and nozzle brushes

Fused Filament Fabrication (FFF)

Advantages	Challenges
• Geometric complexity carries no extra cost • Minimal post-processing • Scalable due to affordable hardware • Plug-and-play operation • Requires no dangerous chemicals • Use of water-soluble supports for geometric design freedom • Open material systems that match injection molding portfolios • Office-friendly	• Most thermoplastic properties are more limited than metal • Manual post-processing required for some prints • Print orientation important due to inter-layer anisotropic mechanical properties • Software does not have the same print simulation features as DMLS systems

CNC machining

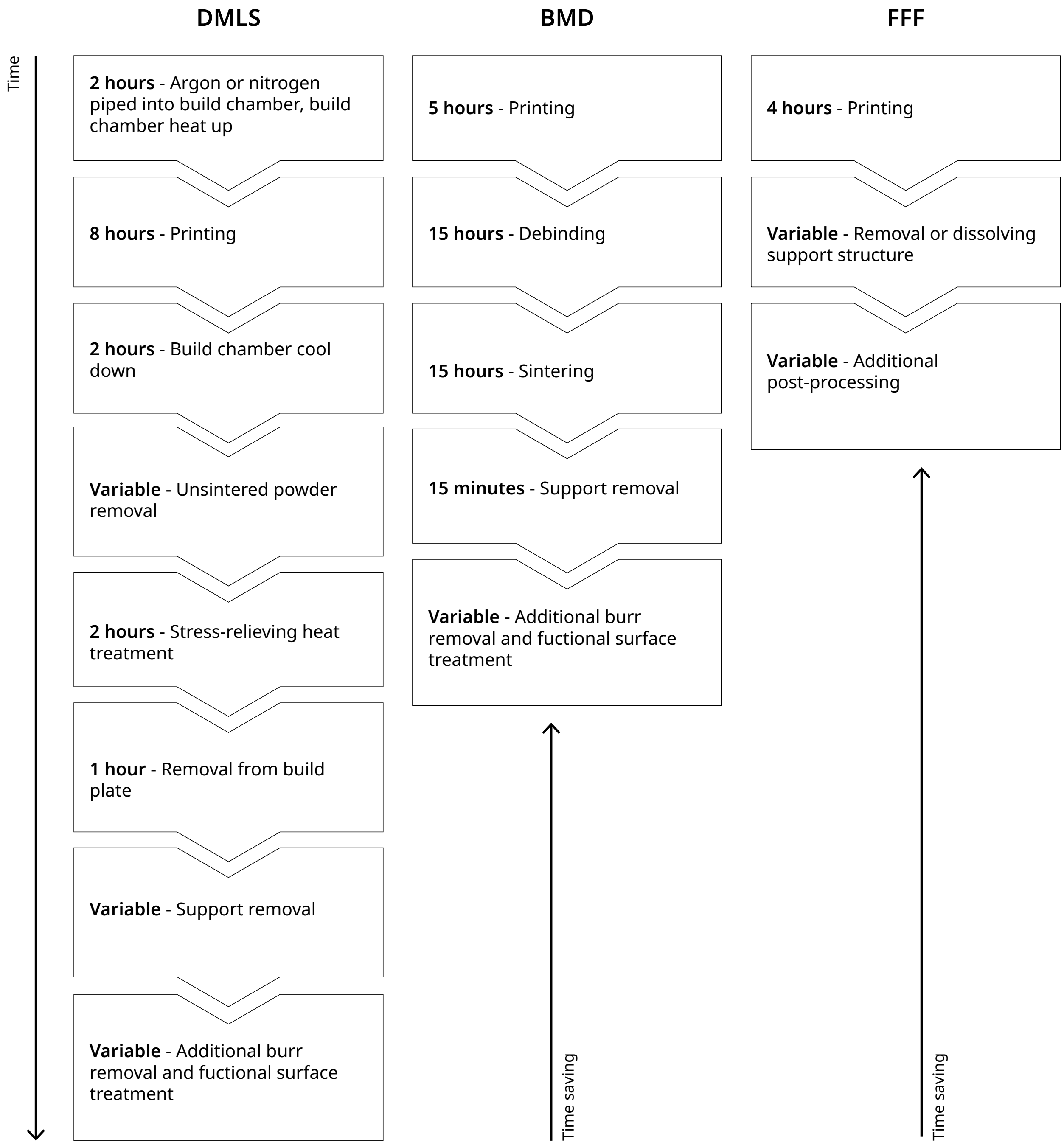
Advantages	Challenges
• Larger milling area than additive build volumes • Tight tolerances (up to ±0.025 mm or • ±0.001 inch) • Parts have fully isotropic physical properties • Most materials can be machined • Fast process when part geometry is optimized for subtractive manufacturing	• Geometric complexity takes longer and costs more • Results in wasted material • Some internal geometries are impossible • Parts cannot be light-weighted with reduced infill • Noisy and messy compared to 3D printing • Geometric features are limited to specific tool geometries

Below is a comparison of each manufacturing system's key features:

	DMLS / SLM	BMD	FFF	CNC
Usable build volume	250 x 250 x 325 mm (9.85 x 9.85 x 12.8 in)	254 x 170 x 170 mm (10 x 6.7 x 6.7 in)	330 x 240 x 300 mm (13 x 9.5 x 11.8 in)	2,000 x 800 x 100 mm (78 x 32 x 40 in)
Typical build speed	~ 2.0 mm^3/s (depending on powder recoating speed)	Up to 4.4 mm^3/s	Up to 24 mm^3/s	Too many variables to compare (material machinability, tool velocity, cut continuity, tool and block vectoring)
Materials	Various, including grades of stainless steel, aluminum, titanium Ti64, Inconel, bronze, copper, precious metals	Stainless steel 17-4 PH (other stainless steel grades, titanium, and Inconel are in development as MIM alloy ports)	Various engineering grade polymer filaments, including glass and carbon fiber reinforced, and metal-filled	Nearly all engineering materials, machined from a blank block
Material system type	Closed material system	Closed material system	Open material system (2.85 mm thermoplastic filament)	Not applicable
Additional facilities / equipment	Floor space, ventilation, inert house gas supply (nitrogen or argon), oxygen sensor, HAZMAT for unused powder disposal, wet vacuum, dry powder (class D) fire extinguishers, personal protective clothing (including respirator), flammable storage cabinet	Floor space, optional external / house gas connection for sinter furnace	Optional ventilation	Floor space, storage for blank material, coolant supply, flammable oily waste disposal, safety gauntlets, chip scoop, refractometer for measuring coolant solution
Training	Five days for three operators, learning one material	One training day	Recommended: 30 minutes to three hours	Two days for two operators
Applications	High-end functional prototyping, low-volume end-use parts, customized products, spare parts	Functional prototyping, low-volume end-use parts, customized products, spare parts	Rapid prototyping, functional prototypes, low-volume production, spare parts, metal casting mold cores	Functional prototyping, low to mid-volume end-use parts, customized products, spare parts with simple geometries

Workflow comparison

Please note that the times shown below are estimates that assume the same part size and part geometry across the three technologies. They represent the various production processes required by each system, accounting for the difficulty of post-processing metal compared to plastic.



DMLS

- **2 hours** - Argon or nitrogen piped into build chamber, build chamber heat up
- **8 hours** - Printing
- **2 hours** - Build chamber cool down
- **Variable** - Unsintered powder removal
- **2 hours** - Stress-relieving heat treatment
- **1 hour** - Removal from build plate
- **Variable** - Support removal
- **Variable** - Additional burr removal and fuctional surface treatment

BMD

- **5 hours** - Printing
- **15 hours** - Debinding
- **15 hours** - Sintering
- **15 minutes** - Support removal
- **Variable** - Additional burr removal and fuctional surface treatment

FFF

- **4 hours** - Printing
- **Variable** - Removal or dissolving support structure
- **Variable** - Additional post-processing

Application opportunities where plastic can replace metal

Given the cost of creating metal parts, there are opportunities for 3D printed plastic parts to replace metal ones. This is particularly true with advances in material science and affordability. We see this in applications where plastic parts offer a cheaper, lighter, and more ergonomic alternative to metal.

Below are four key material properties where thermoplastic filament could outperform metal. For each of these properties, we suggest an advanced polymer filament from a leading materials company. Each material has a preconfigured print profile downloadable from Ultimaker Cura, which takes the guesswork out of 3D printing these filaments using Ultimaker machines.

Heat resistance and flame retardancy

While commonly 3D printed metals like stainless steel and aluminum can withstand temperatures up to 400 °C, they also conduct heat, making them unsuitable for many applications. The following polymer filaments perform well for heat-resistant applications:

DSM Arnitel ID 2060 HT is the first high-temperature copolyester thermoplastic on the market. It has excellent heat resistance: up to 175 °C for 1,000 hours and 190 °C for 500 hours. Applications include air-fuel management systems, engine shields, covers, gaskets, and automotive seals. Due to this high performance, it can also provide a viable aluminum or rubber replacement for light-weighting applications under the hood.

Clariant PA6/66 GF 20 FR filament is a semi-crystalline thermoplastic, reinforced with glass fiber. It achieves UL 94 V-0 flammability standards and outstanding wear resistance. Combined with the flame retardant Exolit®, it will extinguish a flame in less than ten seconds, rather than remain ignited. It also has reduced thermo-oxidative degradation, meaning its polymer bonds are slower to lose their mechanical properties when exposed to heat. These properties make it suitable for functional end-use parts and prototypes.

Chemical and corrosion resistance

Stainless steel 17-4 PH is known for its corrosion resistance. But depending on the specific chemicals your part will be exposed to, some thermoplastic filaments have excellent chemical resistance built in.

Arkema FluorX is made from Kynar® PVDF (polyvinylidene fluoride). It is chemical resistant to automotive fluids (oil, gas, and lubricants), fully halogenated hydrocarbons, alcohols, acids, and bases. It is also heat resistant, retaining its form up to a continuous 150 °C.

DuPont Zytel® 3D12G30FL BK309 is a specialty nylon that is able to resist most solvents, cleaning agents, automotive fluids, and fuels at room temperature. Reinforced with 30% glass fiber, it exhibits similar mechanical and chemical properties to well-known injection molding grades.

Wear resistance

When a low-friction coefficient is important, polymers often outperform metal. Metal-to-metal contact requires lubrication to reduce friction and wear. For applications that necessitate dry or low-lubrication conditions, self-lubricating polymers can increase the service life of components and reduce maintenance frequency. Such applications include plain bearings, toothed wheels, gears, piston rings, and seals.

Igus Iglidur I180-PF is a self-lubricating filament that's up to 50 times more wear resistant than other polymers. This means it is suited to applications that demand low friction and high abrasion resistance, such as lubrication-free bearings, moving assemblies, and complex wear parts, jigs, and fixtures.

Old and new: For many applications, 3D printed plastics can provide a more affordable alternative to metal

Strength and stiffness

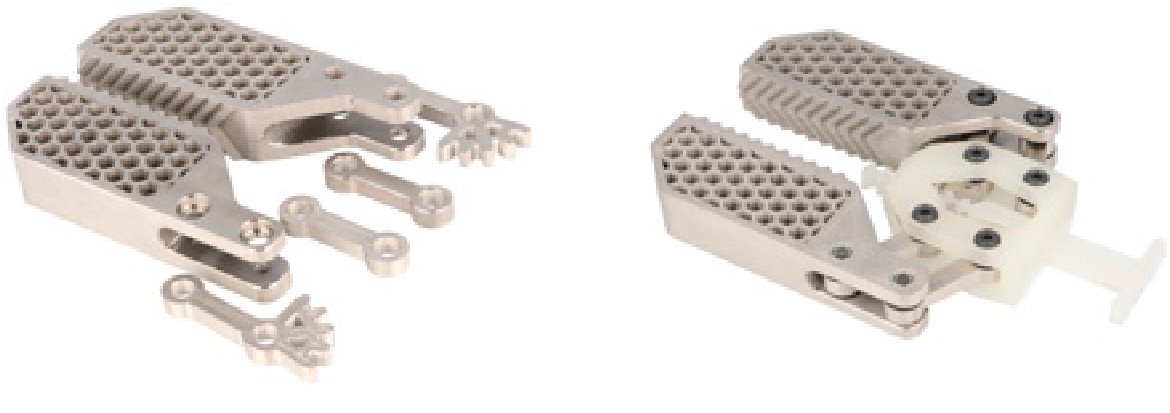
If tensile strength is a critical property for load-bearing parts, your default material choice may be stainless or tool steel. However, polymers reinforced with either glass or carbon fiber enable plastic 3D printed parts to offer a low-cost and light-weight alternative, with good strength and stiffness.

XSTRAND™ GF30-PA6 from Owens Corning is an FFF-compatible filament strengthened by 30% glass fiber. It is an excellent all-rounder, providing high tensile and flexural strength at yield, a wide operational temperature (-20 °C to 120 °C), and good chemical and UV resistance.

DSM Novamid® ID1030 CF10 is a 10% carbon fiber reinforced polyamide. It can be used to 3D print durable parts with good mechanical properties, close to what is usually only achievable by injection molding. It is suitable for applications including under-the-hood brackets, structural jigs and fixtures, and high-performance structural parts.

3D print metal with FFF

Ultrafuse 316LX from BASF is a metal-polymer filament that offers an easy and low investment entry into metal 3D printing. Compatible with 3D printers with an open material system, the filament is a metal-polymer composite comprising austenitic stainless-steel type 316L powder. Tailored to existing, MIM industry standard catalytic debinding and sintering, it produces high-quality final metal parts. Possible applications include tooling, jigs and fixtures, functional components, and small-batch parts.



This gripper demonstrates a light-weighted application unlocked by BASF Ultrafuse 316LX, using FFF technology

Metal vs. plastic 3D printing

Despite its high price, metal 3D printing offers significant advantages. But these advantages only make financial sense for a handful of applications in industries that prioritize product innovation, and that need to meet certified quality standards. For DMLS, these applications include light-weighting, assembly part reduction, and topological optimization for the aerospace and automotive industries.

BMD is a more accessible, but less developed, technology. Despite its lower purchase price, the cost-per-part is high, due to the need for debinding and sintering. While BMD's promised material portfolio will increase the technology's viability, this has yet to be fully realized, and will still form an expensive closed material system.

Put your budget to the best possible use

It would be an error to assume that previously outsourced metal parts should automatically be 3D printed in metal. Instead, polymer 3D printers with an open material system can offer a cost-effective in-house solution that supports rapid iteration and validation.

The Ultimaker S5 – in combination with the Ultimaker Material Alliance Program – allows you to print with materials from more than 80 global brands like BASF, DSM, and DuPont. This unique collaboration enables FFF 3D printing technology to provide a turn-key workflow with increasingly sophisticated material portfolios.

Explore more 3D printing knowledge

Learn more from industry leaders and experts or request a quote, on the Ultimaker website

Request a quote

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About Ultimaker

Since 2011, Ultimaker has built an open and easy-to-use solution of 3D printers, software and materials that enable professional designers and engineers to innovate every day. Today, Ultimaker is the market leader in desktop 3D printing. From offices in the Netherlands, New York, Boston, and Singapore – plus production facilities in Europa and the US – its global team of over 400 employees work together to accelerate the world's transition to digital distribution and local manufacturing.

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