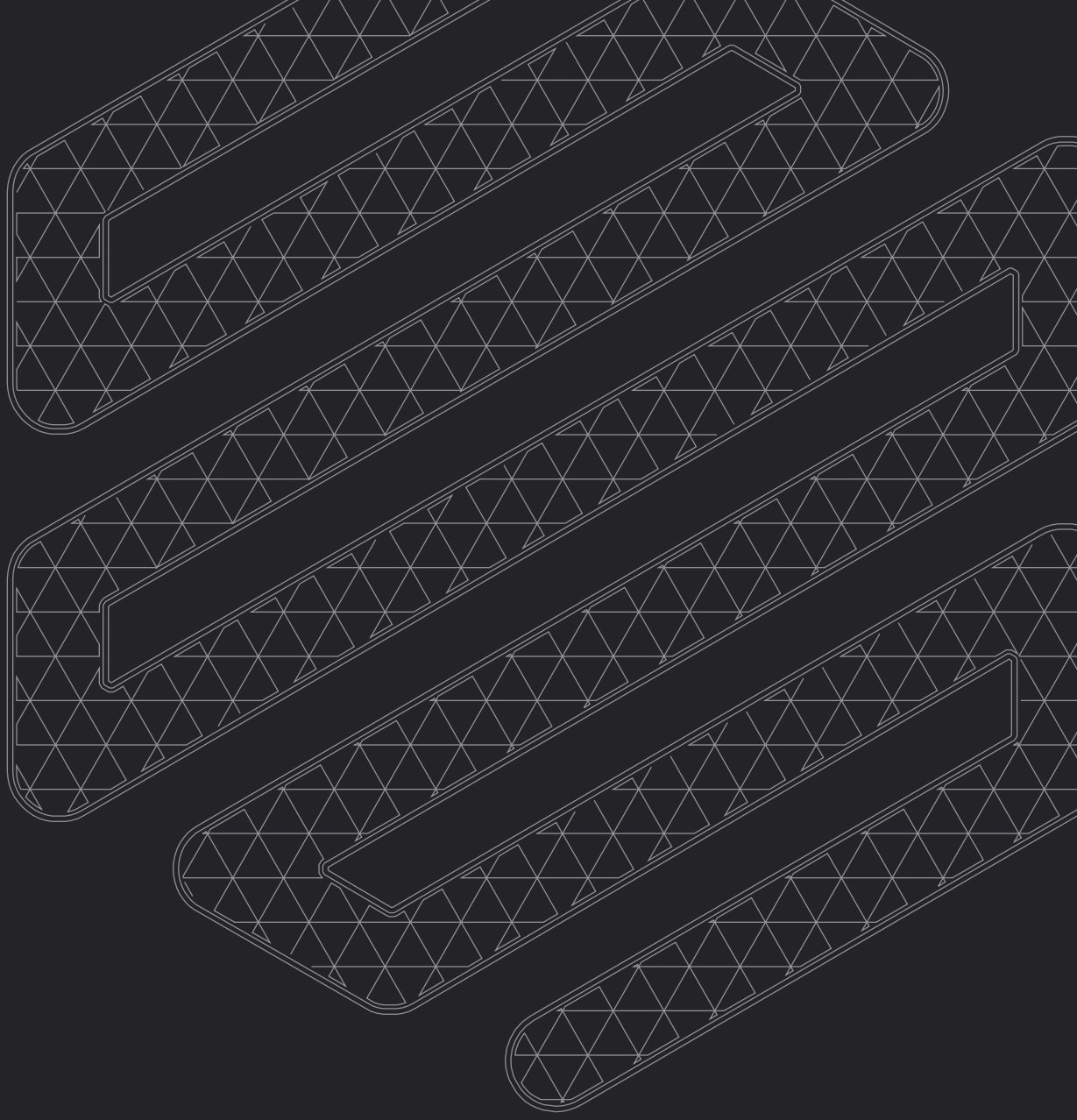


Markforged

Five Applications of Metal 3D Printing

Introduction

Metal 3D printing introduced a different, new way to fabricate parts. After hundreds of years of metal fabrication limited to cutting and forming operations, the idea of methodically building up raw material into a desired shape was completely foreign to the manufacturing industry. What sorts of parts could a 3D printer produce? Would it make traditional metalworking obsolete? These questions were initially left unanswered due to early printers being extremely expensive and difficult to operate, but more and more applications for metal additive manufacturing have emerged as the process has become more affordable and broadly adopted.

In this white paper, we'll discuss the advantages that metal 3D printing possesses over conventional fabrication methods and show five application spaces where metal 3D printing wins out.

Metal 3D Printing has Three Distinct Benefits over Conventional Fabrication

While metal 3D printing is not replacing traditional manufacturing methods, it is changing how we think about fabricating metal parts. Building a part additively instead of subtractively brings distinct advantages: **3D printing offers more geometric freedom, requires no tooling, and fabricates parts using a completely automated workflow**. Each application of metal additive manufacturing can be traced back to at least one of these advantages, and understanding them will enable you to effectively identify potential applications of metal 3D printing in your own operation. By leveraging these applications, you can 3D print parts in metal faster and more affordably than you could fabricate them any other way.

Benefits of Using Metal 3D Printing

Geometric Freedom

In traditional manufacturing practices, complexity adds cost, lead time, and skilled labor. Making intricate geometries using subtractive processes is more expensive and time consuming than simple, blocky shapes that require little-to-no material removal, fewer machine setups, and less frequent tool changes. As a result, the scope of geometries that can be created using traditional processes is restricted; parts designed for machining are typically confined to cost-effective geometries. **With metal 3D printing, however, complexity is free**. An additive process creates overhangs and intricate geometries with no more effort than simple shapes. Parts that previously required complicated machine setup and excessive material removal can now be produced layer-by-layer with little effort.

No Tooling

Many forms of metal fabrication require tooling. Whether casting, bending, or extruding, making metal parts also involves producing hardware that cuts or forms the material into its final shape. In situations such as CNC operations where this type of tooling is not necessary, fixtures are often needed to hold the workpiece in place. **3D printed parts require no fixturing or tooling**. This allows fabricators to create parts with minimal overhead, **decreasing part cost for low-volume production**. In addition, the lack of tooling costs enables businesses to take new jobs where tooling would have previously proved cost prohibitive.

Automation

Most manufacturing processes require continual human oversight to ensure successful outcomes. For machined components, designs must be programmed in CAM before tool touches stock. CNC machines themselves require labor, calibration, tool changes, and fixturing — all only doable by a skilled operator. **Metal 3D printers automatically produce parts from design files**, so no CAM is necessary. Eiger, Markforged's 3D printing software, processes the file for printing with minimal human input. This helps you **get parts in hand faster and more affordably than traditional processes** that require skilled labor.

Five Applications of Metal Additive Manufacturing

The benefits of metal 3D printing inform which types of parts should be printed and which should be fabricated using other methods. Printing parts that leverage the advantages of the process allows you to get the most out of your machine. For example: complex prototypes are a great application because they require geometric complexity, and fast single-part turnaround times. On the other hand, mass production of regularly shaped components does not draw upon any of the three strengths and is better left to existing mass production methods.

With the main benefits of metal additive manufacturing in mind, here are five common application spaces to help set a direction when thinking about effective use cases. Next to each application space are the benefits you leverage when printing these parts.

Functional metal prototypes

End-of-arm tooling

Custom tools

Complex bracketry

Low-volume end-use parts

Next, we'll go into each application group, discussing specific benefits and showing examples of each application in action.

Functional Metal Prototypes

For processes such as investment and die casting, manufacturers often create preliminary tooling to produce prototypes. This lengthens lead time and adds cost; with each design change, more resources have to be invested in tooling fabrication. Another option is to prototype on a CNC, but machining casting prototypes with complex geometries can end up being just as expensive and time consuming as making prototype tooling.

Metal 3D printing offers a way to produce metal prototypes without tooling. This allows customers to have accurate metal parts in hand in a matter of days, helping evaluate designs more quickly while avoiding expensive tooling rework. Engineers can explore more designs in a shorter period of time while compressing their product development cycle.

MEDICAL IMPLANT REMOVAL TOOL

Replace Expensive CNC Operations

For orthopedic surgeons, it is important to practice with new tools before they are actually put into use. That is why Shukla, a manufacturer of orthopedic extraction devices, uses the Markforged Metal X system to 3D print functional prototypes. This "helicopter socket" is a specialized attachment used to remove previously implanted medical hardware. The part's complex geometry makes it expensive and difficult to machine. The ease at which the Metal X can make intricate metal parts allows the company to qualify functional prototypes and get tools into the hands of surgeons faster.

CAST FITTING

Eliminate Need for Prototype Tooling

Before going into mass production, it is important to verify the form and function of cast metal parts. The flanges and internal geometries on this coupling are very challenging to machine, so this design would normally go through a weeks-long prototype tooling process before getting a part in hand. With the Metal X, however, engineers can skip tooling altogether and additively manufacture the component in just a few days.

End-of-Arm Tooling

End effectors are the parts of a robot that physically interact with its surroundings. These conformal, often custom-made components are typically CNC machined, introducing the costs associated with machining intricate parts. For companies that operate facilities which carry out multiple automated tasks, each new end effector introduces additional expenses.

Metal 3D printers can produce conformal end-of-arm tooling easier and cheaper than traditional methods. 3D printing software automatically generates toolpaths, allowing engineers to skip the CAM process. Additionally, the part complexity of conformal grippers introduces no additional cost, so they can be optimally designed to grip parts securely and precisely. End-of-arm tooling can be produced with an internal lattice structure, resulting in a lighter tooling payload and faster robot operation. Compressing lead times for end effectors leads to increased agility, allowing for frictionless adoption of automation into manufacturing workflows. Universal arms can be utilized for a wider range of projects when custom grippers can be fabricated on demand.

SHEET METAL GRIPPERS

Outfit Custom Manufacturing Cells

Lean Machine, a Canadian metal fabricator in Saskatchewan, uses a Markforged Metal X to increase the utility of their automated sheet bending cell. Used mostly for low-volume sheet bending jobs, the cell utilizes an industrial robot arm to move sheet metal blanks through a bending progression. The grippers pictured to the left were designed to grab the blanks without interfering with the bending tools during production. Printing the end-of-arm tooling allowed Lean Machine engineers to get the bending cell up and running faster while preserving CNC bandwidth for revenue-generating parts.

PIPE COUPLING JAWS

Get Production Lines Up Faster

These grippers are used to move threaded pipe couplings through a cell that presses in a plastic seal. The abrasive steel threads on the inner diameter necessitate conformal, wear-resistant end effectors, which can be inexpensively produced with a metal 3D printer. A full set of these end effectors can be produced in a couple days with minimal skilled labor, helping get the manufacturing line up faster and more affordably.

Custom Tools

While most tools are mass produced, many situations call for specialized instruments that are manufactured in low volumes. These custom tools are made to be used on uncommon geometries and are traditionally expensive to produce; investing in tooling for only a few parts is cost inefficient, while machining intricate geometries depletes shop resources.

Metal 3D printing allows manufacturers to bypass steep overhead costs and create these custom tools at a low cost per part. Free complexity allows the engineer to design tools customized for a specific function, whether it involves interfacing with complex surfaces or accessing hard-to-reach spaces.

CUSTOM WRENCH

Easy-to-Swap Insert Tooling

This custom tool utilizes Markforged's composite 3D printing technology in tandem with metal 3D printing. The continuous carbon fiber-reinforced handle is paired with a unique metal 3D printed insert to make a durable wrench. Printing only the interfacing surface in metal makes for a lightweight, durable tool that can be produced affordably and swapped out with a different tool if necessary.

TAMPER-PROOF SOCKET HEAD

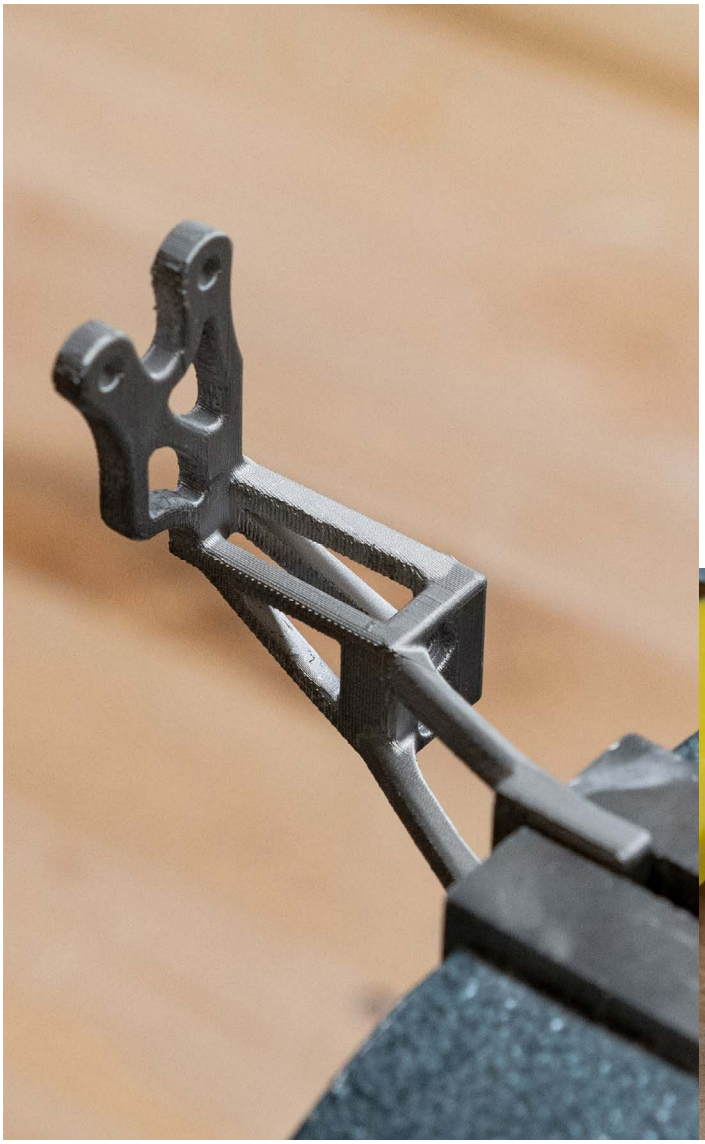
Fabricate Completely Custom Tools

Tamper-proof hardware is used in applications from fasteners on military vehicles to wheel locks on sports cars. Tools for this hardware are manufactured in low volumes and contain custom, specialized geometries. As a result, they can be cost prohibitive to produce using traditional methods. Metal 3D printing allows engineers to create these parts in small batches for a fraction of the price.

Complex Bracketry

While many brackets and fixtures are easily made through traditional methods, some shapes prove difficult or impossible to machine effectively. For example, thin, complex lattices used to optimize weight and performance require multiple machine setups, small tools, and excessive material removal.

Metal 3D printing is an ideal manufacturing method for these types of brackets and fixtures that require high strength and stiffness. Complex geometries pose no challenge to the 3D printing process, so lightweight brackets with intricate contours are often inexpensively produced using metal additive manufacturing. There is lower machining overhead and lower risk of failure.



CUSTOM SENSOR MOUNT

Build Unique Geometries

This bracket for a robotic system is designed to precisely position a sensor. Lightweighting of the mount necessitates thin, complex geometries that are infeasible to machine. Metal additive manufacturing is the only affordable option that produces brackets both light and stiff enough for the job.

Low-Volume End-Use Parts

Most major advancements in manufacturing have been centered on improving the techniques of mass production and driving the cost of high-volume fabrication down. Unfortunately, because of the steep price of tooling, these methods have a high cost per part at low volumes, which is why one-off and legacy parts tend to be so expensive. Metal additive manufacturing can remedy this issue because printers make parts without the need for tooling, eliminating the need to spread tooling overhead across a large batch of parts.

AUTOMOTIVE LEGACY PART

Replace Low-Volume Cast Parts

Legacy parts are components that are no longer in production. Oftentimes the original tooling and engineering drawings for the part no longer exist, leaving engineers with the arduous and expensive task of reverse engineering tooling to produce a handful of final parts. This vintage carburetor cover was 3D scanned and then printed without the headache of tooling overhead, allowing for affordable production of a single part that was otherwise cost-prohibitive to manufacture.

The Metal X

The Metal X system is a safe and affordable metal additive manufacturing solution that is up to 90% less expensive than alternative metal additive manufacturing technologies, and 95% faster and cheaper than traditional fabrication techniques like machining or casting. By binding metal powder in printable plastic matrix filament, Markforged has eliminated the safety risks associated with traditional metal 3D printing while enabling new features like closed-cell infill for reduced part weight and cost. The Metal X comes equipped with powerful, cloud-based software that manages printers, active jobs, materials, and error detection to make it the simplest way to manufacture metal parts.

Visit **markforged.com/metal-x** to learn more about how the Metal X can support your business.

You can also call 1(844)721-7211 or visit design-point.com for inquiries.