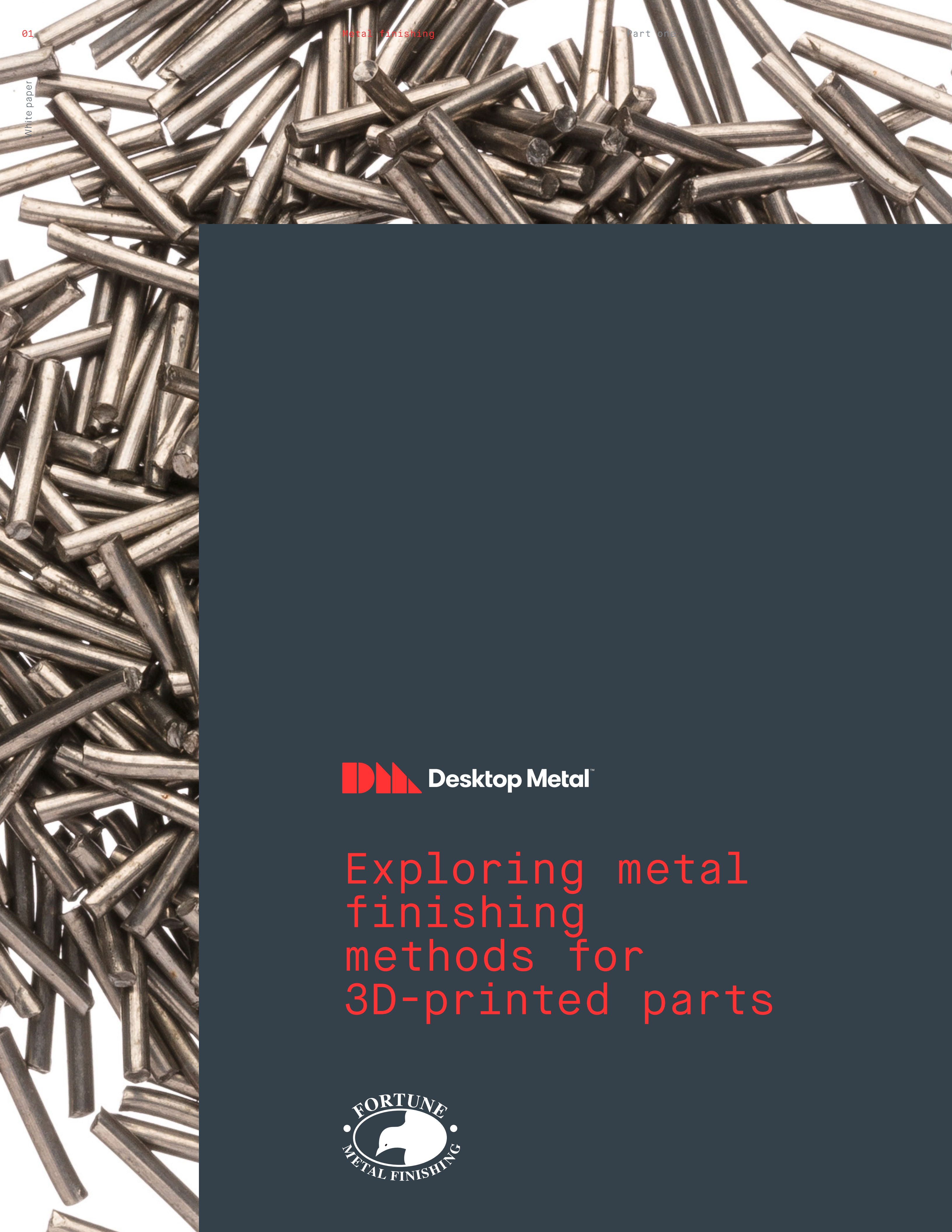


Desktop Metal

Exploring metal finishing methods for 3D-printed parts

Fortune Metal Finishing

Overview

Almost all metal parts whether forged, stamped, cast, machined or 3D-printed, require some secondary finishing or post-processing before the part reaches a final state.

The technique by a which a part is finished during post-processing is an important consideration. The best method depends on the application requirements and can have a significant impact on total cost-per-part. Often, 3D-printed parts have complex geometries, requiring manufacturers to consider finishing techniques and their impact on the printed parts.

Desktop Metal partnered with Fortune Metal Finishing (FMF)—a leading supplier of metal finishing equipment and supplies—to test various finishing methods on metal parts printed with the Studio System™ to observe resulting surface finish and other characteristics.

This study focuses on three techniques for metal finishing: centrifugal disc, centrifugal barrel, and media blasting.

Method tested

Centrifugal disc
Centrifugal barrel
Media blasting

Key observations

Impact of de-burring on edges
Appearance of layer lines
Uniform finish on the part surface

Background

The automation of mass finishing methods began in the 1950s as manufacturers looked to reduce the cost of hand finishing for high-volume production. Mass finishing is a process of smoothing the surface of metal parts through a mostly hands-off approach. There are many mass finishing and media blasting techniques that utilize different equipment and media. Fundamentally, the process utilizes either a tumbling, vibratory, or abrading action to modify the surface of the part.

The media, compound, and equipment used determines the amount of material removed and the resulting smoothness and/or shine of the final part. It is important to understand the key tolerances of the part to identify the appropriate finishing method and media, ensuring it is not too aggressive and delivers the desired surface finish. Precision tolerances, tight-fit parts, ultra-low friction parts, and cosmetic appearance will require more careful consideration when selecting a finishing method.

Fundamental rules of mass finishing

1. **Mass finishing works equally on all sides and edges of the part,** but it affects flat surfaces, curved surfaces, and edges differently.

2. **There is a difference between surface smoothness and shine.** The average roughness (RA) measures the smoothness of a part and can be measured with a profilometer.

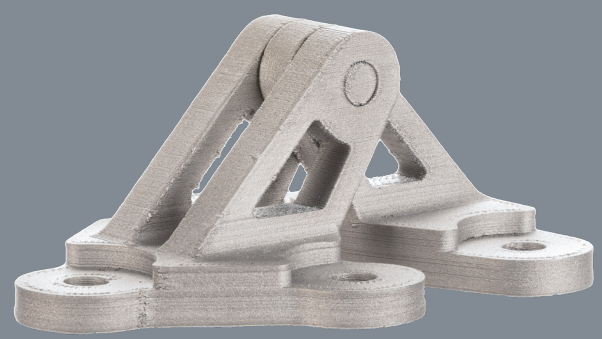
3. **Typical batch size differs based on the type and size of the equipment.** Estimated cost-per-part should be calculated before selecting a finishing method.

4. **The desired surface finish may impact the design specifications,** so it is important to consider the finishing method prior to fabrication. In order to maintain required tolerances, parts may need to be “over-built” or “masked” in some areas to allow for removal of material during post-processing.

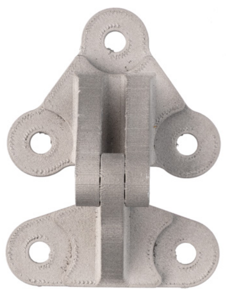
5. **There is no one-size-fits-all solution for metal finishing.** For some applications, visible printing lines are acceptable and minimal post processing is needed. Different finishing techniques are better suited for applications that require a smooth and/or bright finish (<60 RA) versus those where a rougher surface finish is acceptable.

Challenges of finishing metal printed parts

Metal 3D-printed parts have relatively rough surfaces, and the complex geometries and internal channels inherent to the layered build process create challenges when finishing these parts. Layering can also lead to inconsistencies where significant variations of RA can occur on the same part. Often, the build side that lays flat on the platform is often smoother than the top and sides of the part.



Evaluation



Sample part: “The hinge”

The part tested in this case study is a hinge, printed in 17-4 PH stainless steel with the Studio System™ from Desktop Metal. In a process called Bound Metal Deposition™, the printer heats and extrudes bound metal rods—metal powder held together by wax and polymer binder—to shape the part layer by layer, similar to FDM. The part was then debound and sintered, causing the metal particles to fuse together and the part to densify.

FMF tested three finishing methods—centrifugal disc, centrifugal barrel, and media blasting—to observe their impact on metal 3D-printed metal fabricated with the Studio System. Within each method, several variations of processing time and media type were tested.

The methods tested are considered to be aggressive, meaning they apply frequent and abrasive contact between the media and the part surface. This enables a large number of parts to be finished in a short period of time. In this experiment, no additional post-processing steps were applied to the printed parts.

Key objectives

To identify methods that would allow de-burring of the part's edges without compromising edge definition

To reduce visibility of layer lines

To achieve a uniform finish on the part surface

1

Centrifugal disc

Centrifugal disc machines incorporate a large drum with stationary sides and a rotating disc at the bottom. The rotation of the disc forces parts and media upward, providing a highly efficient de-burring and finishing process. It uses a variety of abrasive and polishing media mixed with a specialized liquid compound to agitate and tumble-finish the parts. Centrifugal disc machines are classified as high-energy mass finishing equipment. FMF tried two techniques using the centrifugal disc machine, varying processing time and media used.

Wet cut with Duramedia 3DCM® (20 min)

Duramedia 3DCM® is a premium ceramic formula designed for the hard alloys common in additive manufacturing. Its high density increases cutting capability. Typical ceramic media is 90-100 pounds per cubic foot where as Duramedia 3DCM® is 125-130 pounds per cubic foot. It offers the highest metal cutting rate of any ceramic or plastic media manufactured and is long-lasting due to minimal wear. Duramedia 3DCM is manufactured by Washington Mills Ceramics in Sun Prairie, Wisconsin USA.

Wet polish (10 min)

Wet cut with Duramedia 3DCM® (60 min)

Wet cut with plastic media (60 min)

Relatively soft abrasive for quick stripping soft metals, ideal for alloys commonly used in automotive and aerospace

Wet polish (10 min)

Summary: The longer polishing period improved surface finish uniformity, but the edges of the part started to lose definition. Preference between the variations will depend on application requirements and whether priority should be given to the surface quality or design integrity.

2

Centrifugal barrel

Centrifugal barrel finishing—also categorized as high energy—is the fastest method of mass finishing. The parts are rotated around a horizontal main shaft in octagonal barrels containing media, water, and liquid compound. The circular drive plate connected to the shaft rotates in one direction while the connected barrels rotate in the opposite direction, creating a centrifugal force that increases gravitational pull by 15 to 20 times. Both abrasive and polishing media can be used in a wet process in centrifugal barrels, as well as dry granular polishing media. Barrels can be segmented to run multiple parts at once while avoiding part-to-part contact. FMF tried three techniques using the centrifugal barrel machine, varying processing time and media used.

Wet cut with Duramedia 3DCM® (90 min)

Wet cut with Duramedia 3DCM® (40 min)

Wet polish (10 min)

Wet cut with plastic, ceramic, and cob (4 hr + 2 hr)

Plastic—Relatively soft abrasive for quick stripping soft metals, ideal for alloys commonly used in automotive and aerospace

Ceramics—Best for heavy cutting and hard metals

Cob—Organic, soft blasting grit, safe for delicate parts and soft substrates

Wet polish (30 min)

Summary: The intent of the first test variation was for the wet cut media to double as a polishing step, but did not render the anticipated results. The second technique was much better in achieving both surface smoothness and a uniform finish. The results of the centrifugal barrel test suggest that longer run-times and different media may render even better results for finishing 3D-printed parts.

3 Media blasting

Media blasting is the process of using compressed air to push a loose, abrasive media through a nozzle directed at the surface of the part within a blasting cabinet. Depending on the desired surface quality and reflectivity, several types of media are available in a variety of shapes and sizes. Round particles provide higher reflectivity, whereas angular particles provide more of a matte finish and better anchor patterns for adhesive bonding. There are also different types of equipment for various styles of media blasting, including suction, wet-blast, and direct-pressure—which is the most aggressive by a factor of 3-4 times. It is important to note that standard media blasting is not a mass finishing option. Only one part can be blasted at a time unless robotic automation is used. Desktop Metal tested three variations of media blasting using different types of media: aluminum oxide, stainless shot, and glass bead.

Aluminum oxide

Most widely used abrasive in blast finishing for fast etching and profiling

Stainless shot

Stainless steel, round spheres designed for polishing and shot-peening

Glass bead

Round, soda-lime glass used to achieve a bright, satin finish with minimal stress on the part

Summary: The glass bead was found to brighten the surface of the part. This approach retained more of the layering and any imperfections of the part, but gave the overall surface a shiny appearance. The metal shot produced results faster than the glass bead and was tested twice, using two different grits: 400 and 180. This gave the surface a bright finish, but also reduced edge sharpness (more so by using the 400-grit media). The third media, aluminum oxide, gave the part an overall matte finish and did not fill the edges.

Media blasting is used mainly when parts have been post-processed by other methods—machining, grinding, or sanding—and gives the surface an overall consistent finish.

Summary

As additive manufacturing continues to evolve, FMF is working to better understand optimal processing techniques and variations for individual applications.

With the exception of media blasting, mass finishing methods all tend to work on edges faster than on flatter surfaces. Edges tend to round over in many cases long before the "flats" of a 3D-printed part are sufficiently finished. As a result, the part may not have an entirely uniform appearance and may not adhere to required tolerances. The best results occur when the as-printed part finish has a low RA and is as consistent as possible.

Complex internal passageways present challenges when it comes to finishing. Abrasive flow machining may be a good option to parts with fine, intricate channels.

Parts fabricated with the Studio System™ for prototyping applications may not require the flawless finish that the mass finishing industry often benchmark against.

Ultimately, the method chosen for finishing metal 3D-printed parts depends on the application requirements. Does the part need to serve as a prototype, or does it require a uniform finish for presentation purposes? Is it a functional part where both tolerances and aesthetics are important? The type of equipment, media used, cycle time, and number of steps depend on the starting finish and the required finish. If the goal is to achieve a uniform finish, blasting might be the better choice. It is also a relatively easy and inexpensive process.

About Desktop Metal™

Desktop Metal Inc, based in Burlington, Massachusetts, is accelerating the transformation of manufacturing with end-to-end metal 3D printing solutions. Founded in 2015 by leaders in advanced manufacturing, metallurgy, and robotics, the company is addressing the unmet challenges of speed, cost, and quality to make metal 3D printing an essential tool for engineers and manufacturers around the world. In 2017, the company was selected as one of the world's 30 most promising Technology Pioneers by World Economic Forum, and was recently named to MIT Technology Review's list of 50 Smartest Companies.

About Fortune Metal Finishing

Fortune Metal Finishing is a surface preparation company that specializes in developing processes and selecting equipment for finishing high value parts. Desktop Metal is working with Fortune Metal as an R&D partner and to develop finishing solutions for parts printed with their 3D printing systems. Fortune Metal is privately owned and operated. Please contact Ursula Liff at uliff@fortunemetal.com with any questions regarding Fortune Metal's continued research and development in 3D part finishing.