Markforged

5 Ways to Increase Bandwidth on Your CNC Mill with a Desktop 3D Printer

The Modern Machine Shop

The CNC mill is the foundation of most modern machine shops, and it’s usually the tool subject to competing demands for machine time. This means making tough choices when small volume parts are needed. One-off jobs like fixtures and workholding often take the mill out of production for revenue generating parts. Acquiring an additional mill for this support work is usually not financially realistic. Previously there hasn’t been a good solution to this problem — either jobs would be rejected for lack of bandwidth or deadlines would be missed and customers upset.

But What if There Was a Better Option?

In the last few years, a solution has emerged — in the form of desktop 3D printing. New materials are available for today's 3D printers that are stronger and more capable. Increasingly shops are now using an affordable desktop 3D printer to take on support jobs to free up their mill. With fast overall turn-around time and enough strength, stiffness, and accuracy for many smaller jobs, the desktop 3D printer is quickly becoming a cost-effective companion to the traditional CNC mill.

The Challenge of Competing Jobs

Scheduling jobs in a machine shop is a hard problem. The best use of expensive equipment to optimize return on investment (ROI) is to keep that equipment busy doing productive work. Thus, the ideal job on a CNC mill is a higher volume production order with little or no re-fixturing. But in real life, production interruptions are constant and often unavoidable. Many CNC mill jobs require custom fixturing pieces for efficient completion — and your mill is usually the tool used to do this one-off but necessary work, as well. These jobs are just as critical as production, but are cost work, not profit work. Moreover, these ancillary jobs are often more complicated than the final parts they are used to produce taking more time to program and machine the part.

In short, ROI and productivity — always tied to revenue and performance — are far better if production machines are producing. So if a shop can offload the one-off cost work from a CNC mill — that's a win.

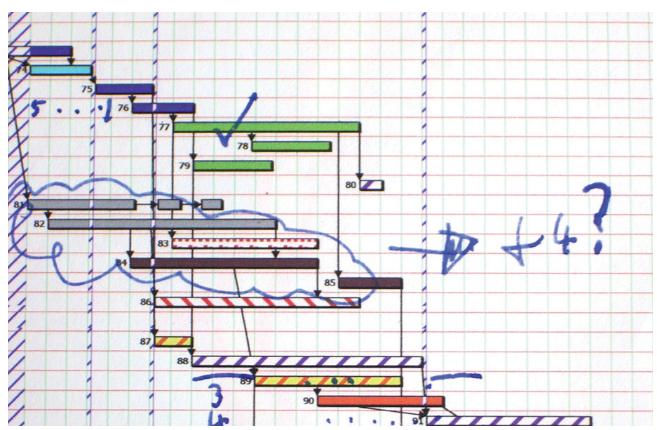


Figure 1: Good jobs, bad jobs....jobs, jobs, jobs.

The Many Roles of 3D Printing in the Machine Shop

Aluminum is often the material of choice for prototyping and fixturing due to its low cost, high availability, and ease of machining. Despite the fact that aluminum is often many times stronger than a prototype requires, machining a plastic instead — often acetal resin or similar — is often considered more difficult and not worth the time. Certainly, there is enough complexity in choosing a plastic that it's considered more direct and efficient to go straight to aluminum.

The key realization that brings 3D printing into the machine shop ROI mix is that desktop 3D printers are designed to make creating plastic parts hassle-free. A part is printed based on a CAD file — no setting up toolpaths in a CAM program — and is automatically completed on a smaller, cheaper machine, with minimal operator interaction. Common 3D printable plastics are sufficiently strong for a variety of prototypes, fixtures, and one-off parts, and a 3D printer makes working with plastic easy. More advanced plastics are strong, tough, and stiff — and especially well suited for checking shape and fit, or making fixtures for shimming, clamping, or orientation.

Why Now?

Various 3D printing processes have been available for over twenty years, yet the technology hasn't made great inroads into plants and shops. So what has changed?

Accessibility and quality are the key — even in 2016, the accessible workshop or workgroup 3D printer is a new product category. An increasing number of 3D printer companies have also chosen to support shop-scale customers with offerings boasting ease of use, reliability and readily available technical support formerly reserved for industrial 3D printers. This is not a feature of the hobbyist or consumer 3D printer market. While hobbyist

3D printers appeared a few years ago, these are finicky gadgets, not for the faint of heart — more time can be lost in attending to the printer than saved by using it!

Perhaps most importantly, 3D printing materials are better than ever. Tougher ABS, nylons, composites and photopolymers have appeared at an accessible level, and it seems nearly every week that some company is releasing a new 3D printable material with specialized properties.

Today, if you can use CAD, you can use a 3D printer to get valuable work done. If you can't — well, CAD has gotten a lot easier and more accessible too!

3D Printing Workflow

The first step in designing a part for 3D printing is the same as designing it for CNC milling — a 3D modeling program is used to construct a solid body. In many cases, a solid model that was designed for a machining process can be re-used for 3D printing, although an experienced 3D printer user can often make minor changes that make 3D printing more efficient. After design is complete, the model is most commonly exported from the 3D CAD program in the industry standard ".STL" file format.

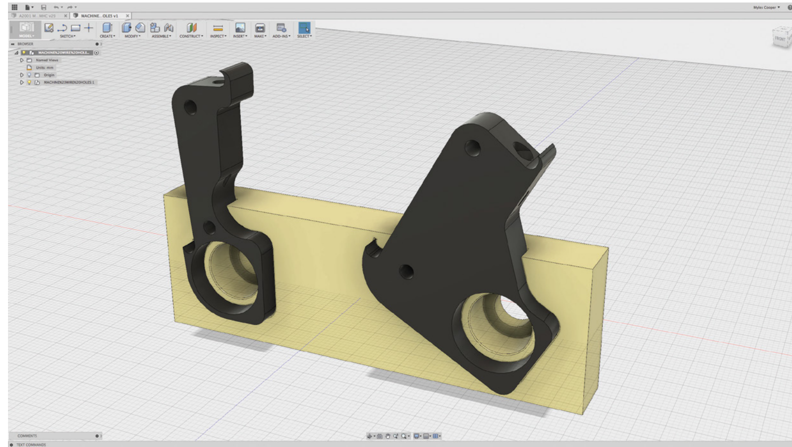
There is no CAM required in 3D printing — instead, the equivalent of the toolpath generation is performed automatically by a program called a 'slicer'. Nearly all professional 3D printers package this processing into easy-to-use slicer software. The slicer 'slices' the part into many discrete layers, and then automatically generates toolpaths and machine code, which is used directly by the 3D printer.

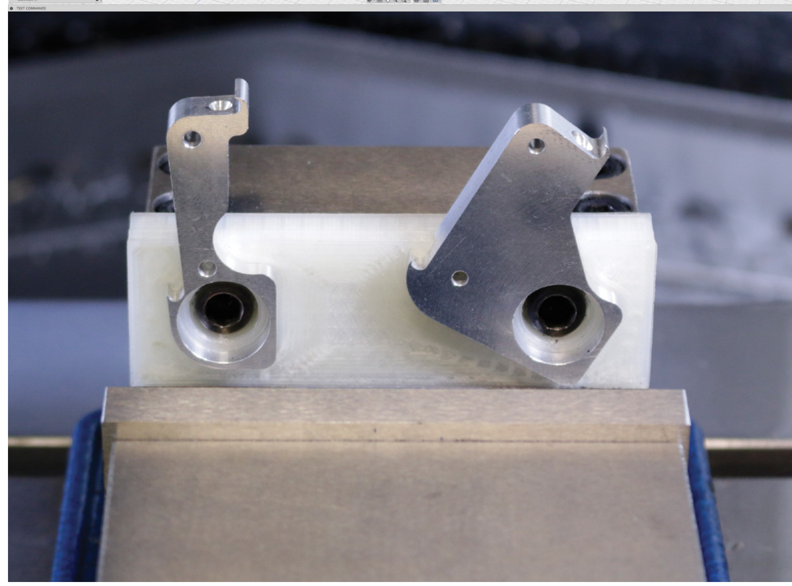
With some machines, the machine code is transported to the printer via a thumb drive, or a USB cable. Other machines are connected to your computer via Wi-fi or Ethernet over your office or shop network. Still others are internet-enabled to let you print from home or on the road.

While there are many different types of 3D printing processes, accessible professional 3D printers today utilize one of two fundamental types: thermoplastic extrusion or selective photopolymer curing.

Thermoplastic extrusion printers, often called 'FFF' (Fused Filament Fabrication) printers, are essentially high precision, robotic glue guns that melt and extrude both common and engineering thermoplastics like ABS and Nylon. The tiny extrusion nozzles are moved about by an X-Y-Z gantry system to form the shape of the part. Photopolymer curing printers, called SLA ("Stereolithography") use lasers or light projectors to illuminate pools of light-curing epoxy to form the shape of the part. Both techniques work in layers, building up many thin layers (often about 1/10 mm, or 4 thou per layer) until a three dimensional geometry is produced.

Dimensional accuracy and resolution are related to the printer technology and the manufacturer implementation, but most professional 3D printers are capable of a shop role.





1 Workholding — Soft Jaws

Some fixtures, including soft jaws, include curved or complex surfaces and require surface milling operations with a ball nose end mill to achieve the desired geometry. Since 3D printing is an additive manufacturing process, and further, requires no toolpath programming in a CAM package, curved surfaces are no more difficult to produce than planar features — all geometry is automatically handled by software. A 3D printer excels at producing these types of fixtures, since the relative complexity of the part geometry generally does not significantly affect the print time for the fixture or any other part.

Rob Bradshaw of Superstition Machine Works uses his 3D printer to make soft jaws that hold complex shapes for drilling at difficult angles. According to Rob, "I print things to save hours of time machining...I'm drawing the soft jaws in the computer anyway."

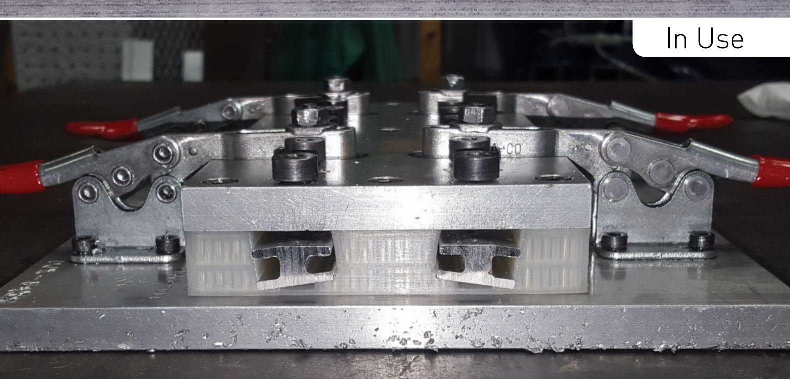
"Not only does it look good but it also worked perfectly. All 32 parts were cycled with no issue, with the last one fitting as well as the first."

2 Fixturing — Flats and Plates

Other fixtures are mostly flat, but include different operations that are time-consuming and may be difficult or tedious to machine — especially flat fixtures that need to be re-oriented multiple times to produce off-axis geometries. Plate-like shapes are particularly suited to 3D printing's layered or additive manufacturing technique, as plates are among the fastest shapes that can be printed, are well-matched with 3D printing techniques, and are predictably strong in-plane.


Before


After


In Use

Joe Walters, design engineer at Arow Global Corp., uses his team's 3D printer to create prototype extrusion profiles for rubber and aluminum extrusions — as well as replace steel drill jig components that are being used on Arow's manufacturing line.

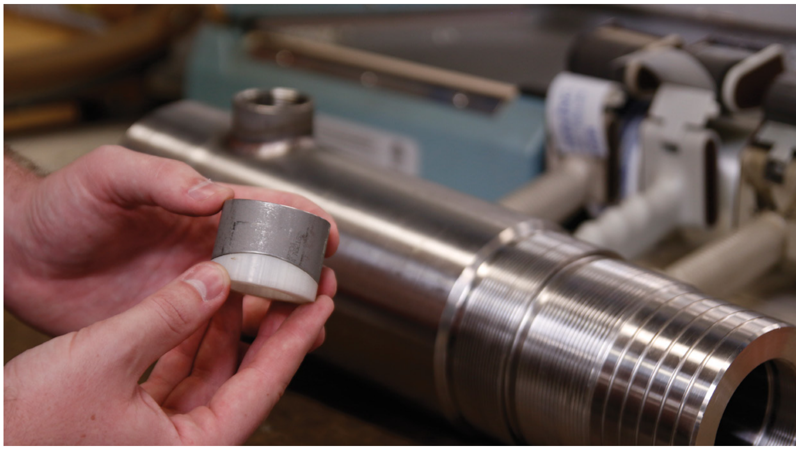
"We're able to take a part that would have costed $400, with two and a half week lead time of machining from one of our local vendors, we printed it over the weekend and the manufacturing floor likes it just as much, if not a little better, because it takes some of the weight out of that jig..."

3 Gages and Quality Control

A 3D printer can do more than produce parts — it can enable simpler quality control (QC) as well. A well-developed CNC machining process can quickly churn out many copies of a part, but as the volume of the job grows, it can be challenging to spot part defects and react to broken tooling, which would minimize scrapped parts. This is where inline QC becomes valuable, and a good go/no-go gage can save time and money. Each project is different, but producing a gage may require a good deal of complicated machine fixturing or extensive multi-axis milling — both of which can tie up expensive CNC machinery for hours.

Many commercial desktop 3D printers today can easily produce parts with the tolerances that a good QC gage requires. Furthermore, since the 3D printer requires no complex fixture setups, creating the perfect gage is as simple as designing it CAD and sending it off to the printer — no operator monitoring required. Even better, this offloads what was previously a time-consuming job from a CNC machining center, allowing a production machine to do just that — produce.

Daniel Shepherd, Quality Manager at Turret Lathe Specialists, a high precision job shop, uses 3D printed nylon gages to ensure that stainless steel fittings have been machined with the correct radius. This allows Turret Lathe to be confident that the fittings will withstand critical pressure applications when welded to piping for use in the oil and gas industry.



"A lot of the template and fitting tools that we used to make out of aluminum, ...they match the quality of the old aluminum tools with no question. We haven't had any issues with tools breaking, at least not any sooner than they would have had they been made out of aluminum. And knowing that we're saving on time and money, that just sweetens the deal."

Non-Marring and Modular Fixtures

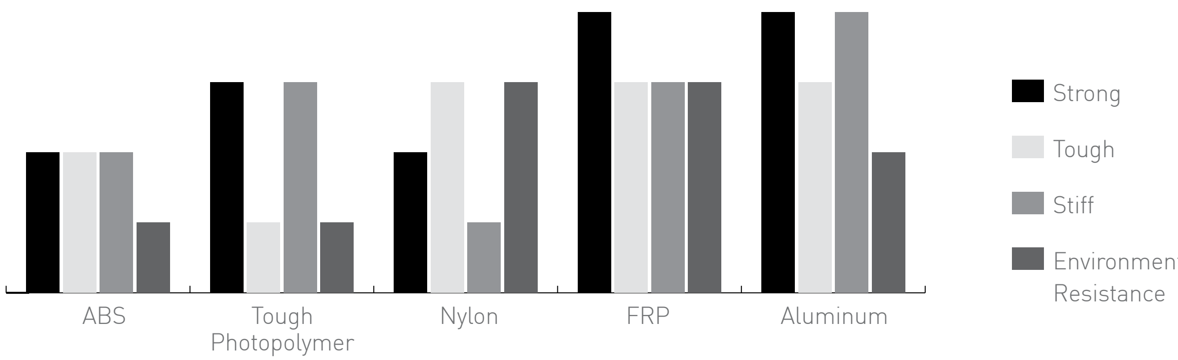
Preserving the surface finish on parts that have just come back from a finishing house is not easy, especially when a job dictates final machining operations or touch up work on parts which have already undergone powder coating or anodization. Aluminum is often an inappropriate material for custom fixturing at this point, as it is often harder than the surface finish material and can easily mar an otherwise flawless surface. Workholding fixtures at this stage are instead commonly machined from a relatively stiff, non-scratch plastic, such as acetal resin or UHMW-PE. But producing these fixtures requires time on in-house CNC equipment, once again displacing production jobs.

Keith Durand of Markforged, Inc. uses 3D printed modular fixtures to hold musical instrument parts for bending and machining operations in brass — the plastic surfaces of the 3D printed parts preserve the delicate surface finish of the instrument during production and assembly. He can also produce curves and complex guiding surfaces that would be extremely expensive and challenging to produce with a CNC mill, requiring either a machine with more than three axes and multiple re-setting and re-fixturing operations.

"The most complicated bending fixture was for the F-branch — it had to be the right shape to bend things around, but had to have clearance so I could get the tube in there in the unbent configuration AND out once the part was bent… 3D printing more or less makes it complexity free. Machining this particular fixture would have cost a small fortune."

Selecting the Right Material

While not every 3D printer can print every material, below is a table noting which materials are generally considered suitable for effective shop use, and why. These materials can be 3D printed by machines costing between $3000 and $30,000, with more expensive printers typically offering a larger build volume and a greater range of printable materials. Most fixtures for use with 4" or 6" machining vises can be printed in a medium sized build volume. In this table, materials are not identified by manufacturer or maker — new materials are regularly introduced into product lines, and some printers can use a wide range of 3rd party materials.



ABS is the most commonly available plastic for workshop or workgroup printers, and is well known and familiar, being the most common consumer plastic. It is not usually considered robust enough to be an engineering plastic. The main drawback of ABS is that it produces a distinctive odor and potentially irritating fumes when melted and thus 3D printing with ABS requires adequate filtration for use in office environments.

Tough Photopolymer is a recent material for photopolymer printers. Formerly, photopolymer prints were too brittle for workshop use, but these new materials — which include additives to reduce strength but increase toughness — are more suitable for engineering and workshop use, and have similar mechanical properties to ABS.

Nylon is also readily available, although far fewer workgroup and workshop professional printer makers provide technical support for it. An engineering thermoplastic, it is among the most chemically resistant plastics, and is well known for toughness and self-lubrication properties. Nylons suitable for printing at room temperature are very tough, but not as strong as photopolymers.

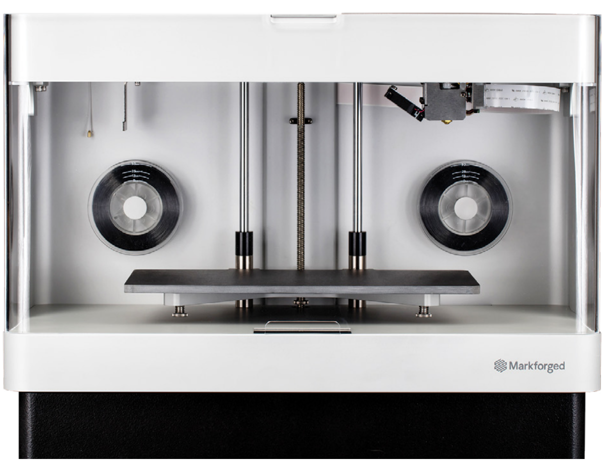
FRP, i.e., "Fiber Reinforced Plastic", is becoming more widely available. These materials, which include chopped fibers to increase *stiffness* or continuous fibers to increase *strength,* are very commonly used in injection molding, aerospace, and automotive manufacture.

We have not included the most common hobbyist material — PLA — a recyclable material favored for low cost and easy operation. This material is quite useful for prototyping, but does not hold up as well as the others in load-bearing, fixturing, or impact situations.

In addition, various 3rd party material and 3D printing machine manufacturers offer alloys of some of the above (for example, ABS-Polycarbonate), with blended characteristics that represent trade-offs between strength, toughness, stiffness, and chemical properties.

The 3D Printer for Every Machine Shop

No matter the size of a machine shop, the right 3D printer can help keep expensive tools free for jobs that matter most. Markforged makes the only engineering desktop 3D printer — the Mark Two — which marries the tough, non-marring properties of nylon with an internal reinforcement structure composed of continuous strand, high strength composite fibers like carbon fiber, Kevlar® and fiberglass to produce industrial strength parts, such as tooling and fixtures, without the machine and operator time costs associated with CNC production of workholding pieces. The Mark Two benefits from the near-metal strength achieved by composites, with the part complexity and set-and-forget ease-of-use of 3D printing. Designed to be a precision engineering tool, the Mark Two complements the existing CNC machinery in a machine shop by providing additional capabilities above those offered by traditional 3- and 4-axis mills, while delivering a robust and reliable platform for the production of plastic parts with minimal user input.



Want to see the Mark Two engineering 3D printer in action? Request a demo today at https://markforged.com/mark-two-demo/

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