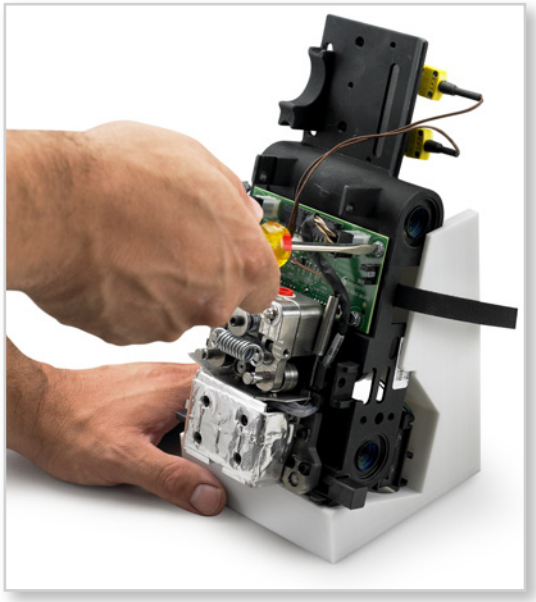
3D Printing Jigs, Fixtures and Other Manufacturing Tools

How to realize an extreme reduction in time and cost by making your custom manufacturing tools via additive manufacturing.

By Joe Hiemenz, Stratasys, Inc.

The fundamental objectives of manufacturing — improve quality, decrease cycle time and reduce costs — are the primary reasons that jigs and fixtures are so abundant. It doesn't matter if the operation is fully automated or entirely manual; jigs and fixtures are deployed throughout manufacturing operations with the goal of reducing costs while accelerating production processes.



When expanded beyond jigs and fixtures to include all manufacturing tools that serve as operational aids, they are even more widespread. They range from organizational bins and tool holders for 5S (a workplace organizational methodology) to templates, guides and gauges. They include sophisticated robotic end-effectors (grippers) and rudimentary trays, bins and sorters for conveyance and transportation. No matter the name, description or application, manufacturing tools increase profit and efficiency while maintaining quality.

Even though manufacturing tools are widespread, many manufacturing facilities don't use these tools to their fullest. Making them takes time, labor, and money. To stretch limited resources, there is an option: additive manufacturing. It is simple and automated; it is fast and inexpensive. This allows you to deploy more jigs and fixtures while gaining the ability to optimize their performance.

LOWERING THE BARRIER

By simply substituting additive manufacturing for your current methods of making jigs and fixtures, you can reduce their cost and accelerate delivery. In these terms alone, additive manufacturing systems are easily justified with short payback periods. But this ignores the larger impact on the bottom line. Additive manufacturing lowers the threshold for justifying a new tool, which allows you to address unmet needs throughout the production process.

If you were to look around the manufacturing floor, assembly area, and quality control lab, how many new opportunities would you find for a jig or fixture? What would the value be? Could it:

- reduce scrap and rework?
- decrease direct labor time?
- improve process throughput?
- improve process control and repeatability?

And with respect to the bottom line, how much more profit would the company gain?

More importantly, why aren't jigs or fixtures currently being used in these operations if they have value? Most likely, they were not justifiable. Although there is a benefit in having the jig or fixture, the return on investment isn't large enough to warrant the effort. You may have found that your time and money were better spent elsewhere.

Since there is never enough time in the day or money in the budget to do everything you would like to do, the decision to build a manufacturing tool puts priority on:

- Processes that aren't possible without a jig or fixture
- Most obvious and urgent needs
- Largest threats and most likely problems
- Quickest to implement and produce results
- Easiest to implement

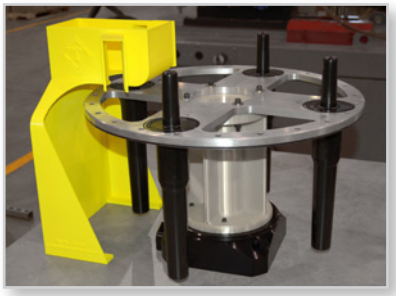
Deciding when and where to use a jig or fixture is no different from any of the other daily decisions we make. Action is taken when value outweighs investment or when the path has little resistance.

Additive manufacturing lowers the justification threshold by increasing your return on investment and decreasing the obstacles between a great idea and a solution. It does this by simplifying the process, lowering the cost, and decreasing lead time.

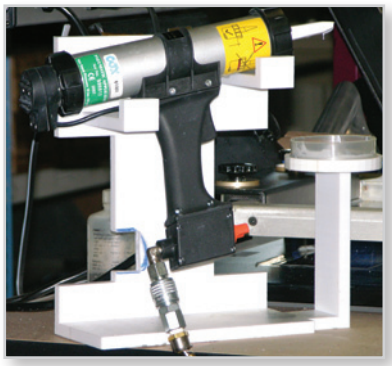
When using Fused Deposition Modeling (FDM) as the additive manufacturing approach to make jigs and fixtures, the process has just three steps: prepare the CAD file, build the tool, and post process it. Unlike conventional fabrication methods, FDM requires little experience and minimal direct labor.

In many cases, jigs and fixtures are manufactured with only 15 minutes of hands-on labor. More importantly, they are manufactured with little training on how the process works and no need for prior experience. Combined, this makes FDM an ideal "self-serve" option for jigs and fixtures. According to Natalie Williams, Quality Manager at Thogus Products, an injection molder that specializes in low-volume manufacturing and highly engineered materials, "It is so much easier for me to model a fixture and print it myself than it is to design it and work through an outside machine shop."

For Thogus, additive manufacturing is easy and fast. "For one 12-cavity CMM fixture the lead time, if outsourced, was 7 to 10 days. I built it overnight," she says. Manufacturers using FDM 3D Printers to create custom manufacturing tools often experience lead time reduction from 40 to 90 percent. Additive manufacturing also can increase return on investment substantially by reducing the cost of a jig or fixture. Typically, companies realize savings of 70% to 90% when compared to outsourced fixtures that are machined or fabricated. For Thogus' 12-cavity fixture, the savings were 87%. "The machine shop wanted $1,500 for the fixture. I made it for less than $200 in materials," says Williams.



According to Thogus' quality control manager, it is simpler, faster and less expensive to make their own FDM fixtures than to outsource them to a machine shop.



When machined fixtures were quoted at $12,000 and seven days, Thermal Dynamics opted to make them with FDM to save $10,000 and several days.

Top NASCAR team, Joe Gibbs Racing, uses FDM to make fixtures, some of which have been in service for more than two years and have cut lead time and expense by an average of 70%.

Making the tool fabrication process faster and more affordable, additive manufacturing will increase the number of jigs, fixtures, and other manufacturing tools, which will improve the bottom line. Additive manufacturing can also optimize manufacturing tool performance. Before additive manufacturing, designs that were sufficient to do the job were acceptable for jigs and fixtures. Due to the expense and effort to redesign and re-manufacture them, revisions were reserved only for those that did not work as specified. Although "good enough" may have added a few seconds to an operation or increased the scrap rate by a small percentage, the savings might not have warranted further investment in the tool.

Additive manufacturing changes that thinking. For a few dollars, it can deliver the next generation manufacturing tool in time to have it in service the next day. For a tool that has marginal performance, all that is needed is a little time and initiative to redesign it. Doing so may only drive out a few seconds from an assembly operation, for example, but that time adds up. If the fixture makes 500 items per day per worker, a two-second savings reduces direct labor by 70 hours per person per year. For the same part, a one percent reduction in scrap would save 1,250 parts per year.

The bottom line: additive manufacturing lowers the threshold so that manufactures can put more jigs and fixtures, with optimized designs, into service. This drops more money to your company's bottom line.

IMPLEMENTING AN ADDITIVE MANUFACTURING APPROACH

Before creating your first 3D CAD model and loading a Fortus system, take materials and dimensional tolerance into account. While additive manufacturing is ideal for many manufacturing tools, it isn't right for

all of them. The main consideration for materials is whether plastic will suffice. Traditionally, jigs and fixtures have been fabricated in metal. For some, metal may be a requirement. For others, metal may have been just a practical option because it is conducive to milling, turning, bending and fabricating. In this case, additive manufacturing may be an option. With a range of materials to select from, the FDM additive manufacturing process can offer chemical resistance (petroleum, solvents), thermal resistance (up to 390° F/ 200° C) and resilient mechanical properties.

Plastic manufacturing tools may also deliver some unexpected advantages. For example, Thogus uses FDM-made robotic attachments that absorb impact. In the event that the robot arm crashes into an obstacle, the FDM part is likely to isolate the arm from damages, which prevents expensive repairs and downtime. In another example, BMW uses plastic, hand-held tools because they are lighter and easier to handle, reducing worker fatigue.

When deciding whether to try additive manufacturing on some initial tool-making projects, for dimensional accuracy, pick tools requiring tolerances larger than 0.005 inch (0.127 mm). Tighter tolerances are possible,

By using additive manufacturing to recreate a gripper with internal vacuum channels, Digital Mechanics eliminated five external hoses that hampered operations.

This ergonomic and lighter BMW hand tool reduced worker fatigue.

Using FDM, BMW prints jigs and fixtures that would not be possible with conventional machining and fabrication. 3D printing allows them to be easier to use and more functional.

but as a rule, stick with this value when keeping the process simple.

DESIGN

Your current inventory of jigs and fixtures were designed with consideration for the capabilities and limitations of the fabrication methods used to create them. By adhering to design for manufacturability (DFM) rules, you made them practical, kept cost to a minimum, and made lead times reasonable. These rules don't apply to additive manufacturing. They have no bearing on time, cost, quality, performance, or practicality. In some cases, adhering to old DFM rules may actually have the opposite effect. So, throw out the old rules and start with a clean slate and a fresh design.

The additive nature of the process gives you unmatched freedom of design. What may have been impractical is now realistic and reasonable. Jigs and fixtures can have complex, feature-laden, and freeform configurations without adding time and cost. In fact, added complexity may even reduce cost and time. For example, pockets, holes and channels reduce material consumption, build time and total process time.

To leverage additive manufacturing, let the function and performance of the jig or fixture dictate the design. Follow the lead of companies like Digital Mechanics AB and BMW. Digital Mechanics capitalized on the freedom of design for a vacuum-assisted robotic gripper. Conventionally made, the gripper had

external hoses hanging off it. With additive manufacturing, each finger of the gripper was given an internal vacuum channel that eliminated the hoses.

For BMW, freedom of design allows assembly line workers to have a tool that reaches under, behind, and inside the rear of the bumper. Manufacturing engineers focused solely on the function, which resulted in an organically shaped bumper-reach tool.

Design freedoms can also improve the ergonomics of manufacturing tools. The weight, balance and position of the tool have direct effects on technician comfort, process cycle time and ease of access and storage. To achieve optimal ergonomics, simply design it into your tools. For example, BMW redesigned a badge alignment fixture to improve balance and reduce weight. This reduced worker strain and improved the cycle time for badge attachment.

One very simple way to leverage the freedom of design is to consolidate assemblies into single parts. Often, jigs and fixtures are composed of many pieces. This is unnecessary with additive manufacturing. If reproducing an existing tool, start with a redesign that consolidates as many components as possible into one piece. If designing a new item, create it as one piece. Only split off parts when it is advantageous to the operation of the jig or fixture.

Integrating parts into a single component has many advantages:

- Eliminate tolerance challenges
    - Holding tight tolerances is costly. If two mating parts are combined into one, then all costs and concerns about controlling the tolerances of the mating parts are eliminated.
- Eliminate assembly time
    - Assemblies, obviously, must be assembled. This takes time, especially for one-off items like jigs and fixtures, where perfect fits are not guaranteed.
- Minimize documentation and overhead
    - The sum of the parts is less than the whole when it comes to time and cost. Consolidating parts reduces costs for actions such as design, documentation, quoting, ordering, and inventory management.

MANAGEMENT

No longer consider your jigs, fixtures, and other manufacturing tools as assets. Instead, think of them as expenses, and disposable. As assets, jigs and fixtures are stored (inventoried) between uses. They remain in inventory until the product line is retired or they are worn beyond repair. With the time, cost, and effort of making manufacturing tools through conventional methods, they are too valuable to be discarded as a disposable, expensable item.

This approach carries many indirect costs, however. There is cost for the shelf space (warehousing expense); cost to manage and track the inventory; and cost to locate a jig or fixture when needed. For sporadically used tools, these costs can be quite significant.

The opposite can be true with additive manufacturing. Often, it takes more to inventory the jigs and fixtures than it does to re-make them. So, companies adopt a management approach called digital warehousing where only the digital file is carried in inventory. It may seem unthinkable to scrap a perfectly good manufacturing tool, but for those with infrequent use, this approach reduces cost and labor.

Make a fixture when it's needed. When its job is done, send it off with the scrap material for recycling. Then digitally warehouse its design between uses. This print-on-demand approach

is also handy when a replacement is needed for a broken manufacturing tool or duplicates are needed for increased production to meet an unexpected surge in sales.

CONCLUSION

Additive manufacturing can lead to big changes that maximize profits by driving out every wasted second and penny from the manufacturing process. For those who aren't ready to toss out long-established design guidelines, simply replace the usual fabrication processes with additive manufacturing. Either way, the savings on the manufacturing floor and in jig and fixture production will be substantial.

If you have a 3D CAD drawing and access to an additive manufacturing machine, you are ready to start making manufacturing tools with as little as 15 minutes of hands-on labor. Combine the simplicity with typical time and cost reductions of 40% to 90%, and you will understand why additive manufacturing spurs companies to make more jigs, fixtures and other manufacturing tools than ever before.

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