White paper

Producing manufacturing aids with HP Multi Jet Fusion 3D Printing

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In the era of mass production and lean manufacturing, companies are looking for ways to help boost productivity and reduce unit costs while maintaining quality and repeatability. The focus is on continuously improving production techniques, accelerating the various phases within the Product Lifecycle whilst keeping costs at minimum. Manufacturing aids such as jigs, fixtures, quality control aids, dies and punches and dummy parts play a critical role here.

To achieve the desired quality and quantity of production, the concept of accuracy and repeatability go hand in hand. Manufacturing aids are personalized tools used in the manufacturing process in order to achieve these requirements [1]. Jigs are devices that fix the part and guide the tool while fixtures only support the parts that are going to be mechanized or inspected.

Depending on the manufacturing process, manufacturing aids are a must. In general, manufacturing aids offer the following advantages:

- **Quality:** Defects are rapidly detected with gauges or pass/fail systems.
- **Repeatability:** Manufacturing aids facilitate uniform production with correct part placement. There is no need for selective assembly as any part can fit properly and can be interchangeable.
- **Skill reduction:** Tool-guiding elements ensure a tool's correct position in relation to the part, therefore there is no need for a skilful operator to correctly align the part.
- **Productivity:** Jigs and fixtures usually eliminate manufacturing steps such as individual marking and frequent checking due to incorrect part positioning and they reduce the amount of time needed to assemble different parts.
- **Cost reduction:** This increase in productivity plus the increase in satisfactory parts will result in a substantial cost reduction.

Often, this cost reduction is difficult to compute, as cost is closely related to quality improvement and defect prevention. The true cost isn't so much the cost of the manufacturing aid but rather the expense of a defective part or product, as this not only reduces quality but creates a time delay, generates additional costs, and negatively impacts operating profits [2].

In order to check for and prevent the most important defects, some metrics have been defined, such as "Critical to Quality."

Critical to Quality

Advanced manufacturing processes calculate this cost using the "Critical to Quality" (CTQ) standard, which is a measure of a product or a process whose performance standards or specification limits must be met in order to satisfy the customer [3].

Using manufacturing aids such as jigs and fixtures will help reduce CTQ risks, while some CTQ elements can be checked using quality measurement aids or metrology aids.

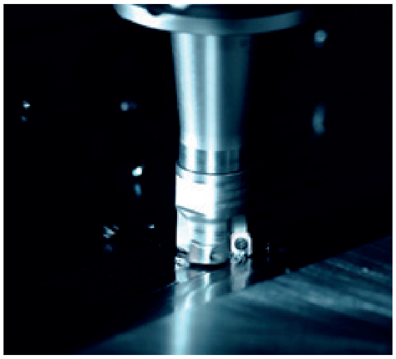
Manufacturing aid production today

Manufacturing aids are currently usually produced with the following materials:

- **Steel:** Different types are used depending on cost and the mechanical properties required. Mid-steel (steel that contains less than 0.3% carbon) is used in most applications because of its low price but at the expense of reducing mechanical properties [4].
- **Aluminium:** Another typical material used in CNC machining due to its softness.
- **Plastics:** Used to prevent damage to workpieces. Due to the non-conductive properties of plastics, they are used in electronic component production lines. One of the most common CNC-machined plastics is POM (Polyoxymethylene).

Currently, CNC is the most commonly used technology to produce manufacturing aids.

CNC is a subtractive manufacturing technology that, starting from a solid block of material, uses various cutting tools to remove material until the desired geometry is achieved.



CNC technology

It is well-suited for low-volume part manufacturing in a variety of materials, including metals and plastics. Accuracy is one of its main advantages—machined parts can be produced with tolerances of up to up to +/-0.025mm, which cannot be achieved with injection molding, for example.

However, some geometries—for example, internal corners with small radii, cavities with complex geometries and undercuts or thin walls—can be difficult or sometimes impossible to manufacture with CNC.

Other technologies typically used to produce manufacturing aids, include injection moulding and extrusion.

Manufacturing aid requirements

Typical requirements for manufacturing aids include:

Simple construction: The design of manufacturing aids should be as simple as possible, as complex designs are more expensive and require more maintenance.

Accuracy: Critical to improving repeatability and reducing process time. Defining and producing manufacturing aids with a precise clearance will allow you to detect faulty parts that can easily be replaced.

Durability: Manufacturing aids are typically used in rugged environments and have to withstand usage. They should also be sufficiently stiff in order to handle the machining pressure. Rigidity is related to the material's Young modulus and its design.

Lightweight: Manufacturing aids should be as light as possible—to enable workers to manage them more easily—while maintaining the required mechanical properties. Also, lightweight robotic arm end effectors offer improved precision and lower power consumption.

Economically viable: Jigs or fixtures should be produced only once economic viability has been analysed and proven.

How 3D printing can optimize manufacturing aid production

Many companies are already becoming aware of the potential of 3D printing to optimize and streamline the various phases in the Product Life Cycle—and ultimately increase their competitive advantage.

HP Multi Jet Fusion technology is a relatively new 3D printing technology that powers HP's Jet Fusion 3D Printers, which can offer disruptive cost[1], speed[2] and quality[3] benefits compared to other 3D printing technologies.

3D printing can offer the following advantages versus traditional production methods in the development of manufacturing aids:

Productivity and time : Time is critical when a manufacturing aid or prototype is needed. Machining complex metal geometries takes significant planning and highly skilled CAM designers and machine operators. Usually, several iterations are required in order to achieve the perfect design for an application. Outsourced manufacturing aids using traditional production methods can take days or weeks to arrive.

3D printing can reduce lead times, so that more designs can be tested and final designs can be achieved in less time. It can also increase flexibility during the manufacturing process, for example, enabling faster production line tooling changeovers.

Cost: Skilled labor required to set-up and maintain complex and expensive CNC equipment can impact overall costs. This can be reduced with 3D printing, as once the design of a 3D part is completed, the file is sent electronically to the printer, and the part can be produced with relatively little human intervention.

Performance and personalization: 3D printing can produce geometrically complex parts that traditional methods are not always able to produce. In addition, parts designed for 3D printing can improve performance and lower costs—for example multiple parts consolidated into one. Hollow parts enhance 3D printing cost savings, as CNC requires more machining time and tools to remove material—in addition, parts must be split into small blocks of different sizes and joined manually afterwards. 3D printing is intrinsic in enabling incremental value, as it facilitates mass personalization. However, unlike traditional production methods, with 3D printing, personalization does not imply incremental cost.

Weight: As mentioned, the production of complex parts is now possible, enabling lighter parts with enhanced performance and ease of use for workers, thanks to lattice structures or topology optimization. Moreover, 3D printing materials are usually lighter than aluminium or steel.

Assembly consolidation: 3D printing can reduce lead times, because complex multicomponent assemblies can be consolidated into single parts. This also helps reduces the risk of errors and other issues during the assembly process, as well as helping to reduce labor costs.

Sustainability: 3D printing can contribute to a more sustainable supply chain thanks to reduction of waste, transportation and inventories through on-demand, localized/distributed printing and improved designs that reduce materials usage.

Taking manufacturing aids production to the next level

HP Multi Jet Fusion 3D printing technology offers additional benefits, including:

Productivity and time: With HP Multi Jet Fusion, besides not needing CAM, lead times can be significantly reduced as several design iterations can be done in parallel - multiple parts with different designs can be printed in a single production batch in a matter of hours. Moreover, HP Multi Jet Fusion can produce functional, quality[3] parts up to 10 times faster[2] than other 3D printing technologies. Manufacturing aid lead times can be reduced from weeks and days to hours.

Cost: With HP Multi Jet Fusion, complex geometries do not increase production time or cost, as this technology allows a high throughput independent of part complexity, whilst maintaining optimal mechanical properties[3]. HP MJF can produce parts that have been redesigned (hollowed or topologically optimized) to reduce the quantity of material required to manufacture them, resulting in further cost savings.

In comparison to other 3D printing technologies, HP Multi Jet Fusion can produce quality functional parts[3] at the lowest cost[1], thanks to a system that enables high throughput and productivity to maximize printer usage, combined with HP 3D High Reusability materials that offer up to 80% surplus powder reusability[4].

Plus, the ease of use, ease of cleaning and predictability of HP MJF technology optimizes operator time and the operator skill-set required, which can ultimately help reduce labor costs.

Price per unit evolution for injection molding, CNC machining and HP Multi Jet Fusion

Fine and small features: HP Multi Jet Fusion technology can produce thin walls (up to 0.5mm) and print fine details[3].

Design freedom: With HP Multi Jet Fusion technology, a part's weight can be reduced or its design optimized while still maintaining the required robustness. Moreover, HP MJF can produce parts that have nearly the same mechanical properties[3] for the XY axes compared to the Z axis—therefore, in the design process there is no need to factor in mechanical behavior.

Chemical resistance and fluid-tightness: HP Multi Jet Fusion technology can produce fluid-tight parts that don't require post-processing. Also, parts printed with HP MJF technology and HP 3D High Reusability PA 12[4] achieve high chemical compatibility[5] with several fluids, including water, brake fluid and alcohols.

HP Multi Jet Fusion use case

HP Inc. Drill extraction shoe

HP Inc. is a consumer electronics company that produces 3D and 2D printers, PCs and peripherals. HP is pioneering the use of HP Multi Jet Fusion technology to streamline processes throughout its supply chain and has identified myriad opportunities where HP Multi Jet Fusion can replace traditional manufacturing methods. Just one example is a tool in HP's printhead manufacturing line—a drill extraction shoe.

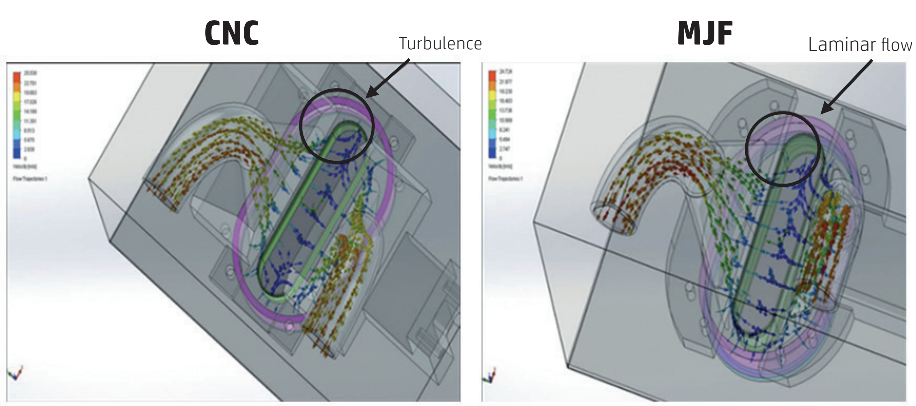
The nozzles of HP printheads are manufactured with a laser-cutting process. This process uses water to prevent overheating of the laser and the silicon plates. The drill extraction shoe is used during cutting to remove the silicon sludge and water that continuously appears, enabling a more efficient laser-drilling process.

Sufficient extraction pressure (~3 to 4.5 kPa) and a clean extraction shoe are needed for proper laser drilling. The tool must withstand a certain amount of heat caused by stray laser pulses during the drilling process.

As can be seen in the picture on the right, the original CNC machined tool on the left is made of 7 sub-parts, most of them mechanized from an aluminium block and two of them extruded from aluminium. The HP MJF redesigned part is on the right, and has been consolidated into a single part.

HP Multi Jet Fusion helped enable:

- The water-tightness required for manufacturing aids that contain pressurized fluids, without needing to post-process or coat the parts
- The design to be optimized to reduce turbulence in the part using finite element analysis. The shape of the end of the pipe has been modified to optimize the flow during the section transition



Old design

Proposed design

- Cost reduction of 95% versus the original part[6]
- Weight reduction of 90% versus the original part[7] thanks to topology optimization and material reduction
- Lead-time reduction from 3-5 days with CNC machining to just 24 hours with HP MJF
- Assembly reduction by consolidating seven sub-parts into one single part

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1. Based on internal testing and public data, HP Jet Fusion 3D 4210 Printing Solution average printing cost-per-part is 65% lower versus the average cost of comparable fused deposition modeling (FDM) and selective laser sintering (SLS) printer solutions from $100,000 USD to $300,000 USD on market as of April, 2016 and is 50% lower versus the average cost of comparable SLS printer solutions for $300,000 USD to $450,000 USD. Cost analysis based on: standard solution configuration price, supplies price, and maintenance costs recommended by manufacturer. Cost criteria: printing 1.4 full build chambers of parts per day/5 days per week over 1 year of 30 cm³ parts at 10% packing density on fast print mode using HP 3D High Reusability PA 12 material, and the powder reusability ratio recommended by manufacturer.
2. Based on internal testing and simulation, HP Jet Fusion 3D average printing time is up to 10 times faster than average printing time of comparable fused deposition modeling (FDM) and selective laser sintering (SLS) printer solutions from $100,000 USD to $300,000 USD on market as of April, 2016. Testing variables for the HP Jet Fusion 4210/4200 Printing Solutions: Part quantity: 1 full build chamber of parts from HP Jet Fusion 3D at 20% of packing density versus same number of parts on above-mentioned competitive devices; Part size: 30 cm³; Layer thickness: 0.08 mm/0.003 inches.
3. Based on HP's unique multi-agent printing process. Excellent dimensional accuracy and fine detail within allowable margin of error. Based on dimensional accuracy of ±0.2 mm/0.008 inches on XY for hollow parts below 100 mm/3.94 inches and ±0.2% for hollow parts over 100 mm/3.94 inches, using HP 3D High Reusability PA 12 material, measured after sandblasting. See hp.com/go/3Dmaterials for more information on materials specifications. Based on the following mechanical properties: Tensile strength at 48 MPa (XYZ), Modulus at 1700-1800 MPa (XYZ). ASTM standard tests with HP 3D High Reusability PA 12 material. See hp.com/go/3Dmaterials for more information on materials specifications.
4. HP Jet Fusion 3D printing solutions using HP 3D High Reusability PA 12 provide 80% post-production surplus powder reusability, producing functional parts batch after batch. For testing, material is aged in real printing conditions and powder is tracked by generations (worst case for recyclability). Parts are then made from each generation and tested for mechanical properties and accuracy. Industry-leading surplus powder reusability based on using HP 3D High Reusability PA 12 at recommended packing densities and compared to selective laser sintering (SLS) technology, offers excellent reusability without sacrificing mechanical performance. Tested according to ASTM D638, ASTM D256, ASTM D790, and ASTM D648 and using a 3D scanner for dimensional accuracy. Testing monitored using statistical process controls. Liters refers to the materials container size and not the actual materials volume. Materials are measured in kilograms.
5. Tested with diluted alkalies, concentrated alkalies, chlorine salts, alcohol, ester, ethers, ketones, aliphatic hydrocarbons, unleaded petrol, motor oil, aromatic hydrocarbons, toluene, and DOT 3 brake fluid.
6. Cost reduction data according to HP: Cost per part: CNC machined $450. HP MJF $18.
7. Weight reduction data according to HP: CNC machined part weight 575 g. HP MJF part weight 52 g.

References

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[3] "CTQ tree," 3 June 2017. [Online]. Available: https://en.wikipedia.org/wiki/CTQ_tree. [Accessed 31 Januray 2018].

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