ADDITIVE MANUFACTURING SOLUTIONS PROVIDER
0800 689 1011
info@creat3d.co.uk
CREAT3D Ltd | 520 Eskdale Road | Winnersh Triangle | Wokingham | Berkshire | RG41 5TU
creat3d.solutions or order online at creat3d.shop

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GUIDE
Top 5 Tips when Designing for Additive Manufacturing (DfAM)

Designing for Additive Manufacturing (DfAM) is a deeply involved and evolving subject matter, with considerations to the type of 3D printing technology used, also the material, purpose of the part, geometry and part properties.

However, we all need to start somewhere on the journey towards designing parts that are optimised for 3D printing.

Getting into the DfAM mindset will enable your teams to get the most out of your Additive Manufacturing (AM) equipment. In the same way as you consider design and construction of a part for any other manufacturing method, you need to do the same for 3D printing.

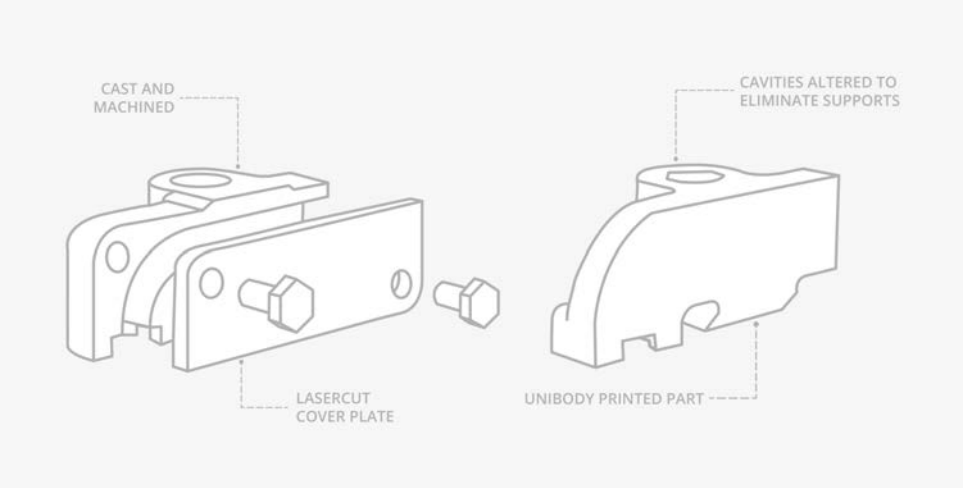
Our Applications Engineering team put their heads together to generate a top 5 list, highlighting some of the key factors worth considering when you are designing parts to be 3D printed, using FFF / FDM 3D printers.

Why bother about designing for Additive?

No matter what method of manufacturing is used, your part should be designed accordingly. For example, when CNC machining a part, 90º angles, sharp edges and less complex geometries are often preferred because this is easier and quicker to achieve.

Whilst you can in theory take the same CAD data and 3D print it, the way to achieve the true benefits of AM is to re-design for the additive manufacturing process. Doing this will remove traditional constraints and release a whole host of benefits;

- Ability to create parts with more complex geometries, curves and intricate details
- Better functioning and fitting parts
- Ability to print a single part, rather than assemblies
- Light-weighting the part
- Reducing material usage and cost per part
- Reducing production time



Top Five Tips for DfAM

1. Design for minimal supports

Consider the need for support material from the start of the design process. The goal is to optimise the part so minimal or even no support material is required.

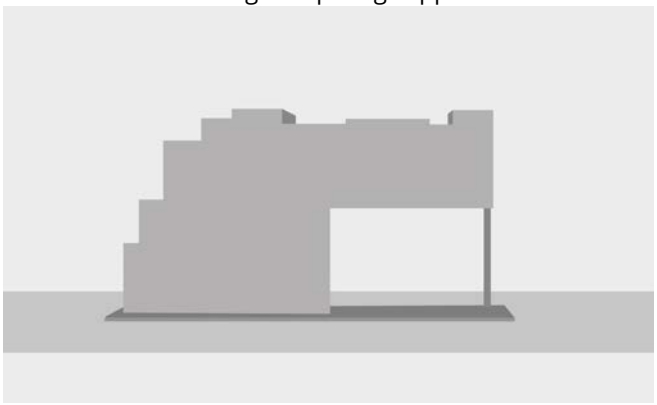
Reducing this need for supports will reduce material consumption and print times, whilst increasing the overall finish and quality of the final printed parts, as it eliminates potential degradation to surface quality (where supports adhere). It also reduces post processing time for support removal.

The ideal designs are generally self-supporting and designed with the print orientation in mind:

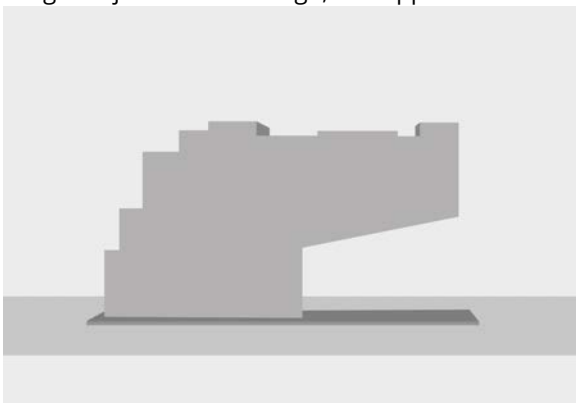
- Overhangs tilted above 45º from the horizontal generally do not require supports
- Keep bridges between horizontal pillars to be no greater than 6mm
- If applying fillets to the base of objects, lead into the fillet with a chamfer to maintain the initial angle above the 45º threshold
- Add angles to the top of holes making them teardrop shaped in vertical faces

It is also worth considering, splitting complex prints with critical features on multiple planes into sections, to reduce supports, decrease print time, and ensure print success.

90º angle requiring supports



Slight adjustment to design, no supports needed

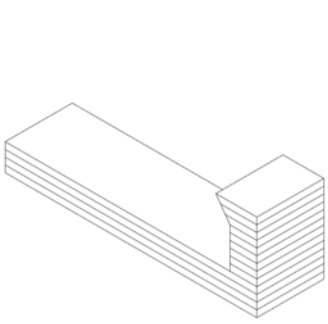


2. Consider the loadings

When designing the part in CAD, consider how to orientate the part to take account for any loading requirements it may have after printing.

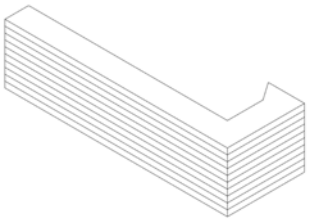
Most printed parts are anisotropic in nature. That means that the material strength is not uniform in all directions, and the difference according to build orientation can be between 1/2 to 2/3 as strong between the XY and Z axis. If you want stronger parts, orientate them in a manner that will allow any mechanical forces to be dispersed longitudinally along the length of the part to maximise strength.

Orientation 1 with load



Print orientation | Load

Orientation 2 with load



Print orientation | Load

It can occasionally be more effective to split a part for printing. Each split can then be printed to prioritise the strength of each segment. It's worth considering splitting for the following cases:

- Parts with customised elements can be designed with a core base geometry and interchangeable modules
- Elements of parts that undergo increased wear or strain can be isolated into components that can be changed out regularly (also see Tip 4)
- Designs requiring specific strength profiles across multiple axes can be printed in sub-components in different orientations and joined post-print

3. Widen geometric transitions

Add chamfers and fillets to the part design to spread any potential loading required on the Z axis across several layers. This will reduce reliance on a single layer point of failure and spread the load across different features of your part.

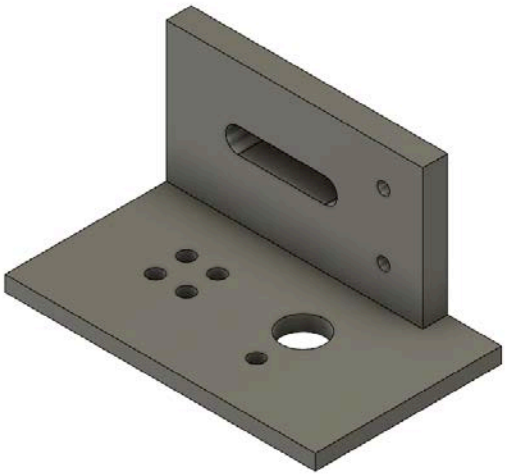


Fig. 1 – two sheet metal components welded together. This can be 'copied' to AM but there is a concentrated point of failure at the joint.

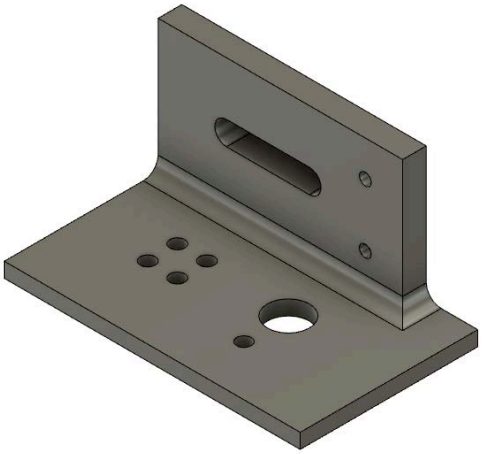


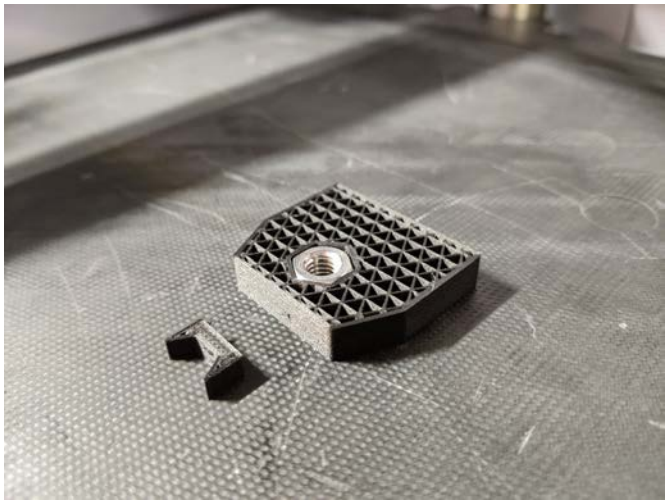
Fig 2 – by adding a fillet, the load and stress applied to the joint are spread. This simple change for AM allows easy manufacturing of fillets.

Adding chamfers and fillets in subtractive manufacturing techniques increases required toolpaths and involves additional tools which is why we have tended to not add them during the design stage or removed them when moving into manufacturing design. With Additive it is easier to print stronger curves to strengthen features with no effect on print times, while increasing the overall strength of the final part.

4. Design to augment the use of machined hardware

Consider which aspects of the parts should be 3D printed, and consider integrating other pre-manufactured components into your print

- Threads and inserts: Instead of printing or tapping threads into plastic, embed "off the shelf" machined hardware during the print process, or add metal heat-set inserts post print
- Wear surfaces: Dowel pins can be used to provide a hardened metal wear surface for areas of printed parts that interact with abrasive surfaces, prolonging the life of the part
- Alignment: Use pressed-in dowel pins or shoulder bolts to precisely align multiple components
- Concentricity: Bushings or sleeve bearings provide cylindrical precision and smooth concentric clearance fits
- Hybrid: Consider using multiple forms of AM technology for combined parts. For example, adjust the CAD to be 2 parts, converting what was a single metal gripper, into metal pads (in Tool Steel for abrasion resistance) with a nylon base (for light-weighting).



Embedding a M6 stainless steel nut during print process

Creating a hybrid metal and nylon part using two forms of AM with this end-of-arm gripper

5. Design walls and features that match the nozzle diameter

Design in multiples of nozzle diameters to maintain accuracy, strength, and efficient print times.

Where part dimensions are designed as multiples of these factors, it enables efficient slicing of the part, minimising any compromises or undesired changes due to the software making "best fit" outcomes. Setting these parameters at the early design stage can save print time, potential gaps between inner and outer walls, and give a general increase in part strength.

- Ideally, for FFF, wall thicknesses are in multiples of the nozzle diameter. For example, using a Markforged (CFF) composite printer, the nozzle is 0.4 mm. Therefore, it is good practice to design feature thicknesses to multiples of 0.4 mm within CAD.
  Nozzle size impacts on lots of areas including pitch and markings. When printing lettering ideally engrave rather than emboss the text in your design.

Summary Tips

Design with the manufacturing process in mind, so in this case, design for Additive to get the best outcome.

1. Design for minimal or no supports
2. Consider orientation in the design to factor in print load requirements
3. Widen geometric transitions with chamfers and fillets
4. Design to augment; use of machined hardware, embedding components during or post print, or take a hybrid approach using multiple AM techniques
5. For FDM, design walls and features to be in multiples of the nozzle diameter

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