MATERIALS, DESIGN AND MANUFACTURING FACILITY (CWB)

Design for Additive Manufacturing Metal & Multi-Jet Fusion (MJF)

20 Dec 2021

MATERIALS, DESIGN AND MANUFACTURING FACILITY (CWB)

Contents

1. Why DfAM
2. How DfAM

1. Why DfAM

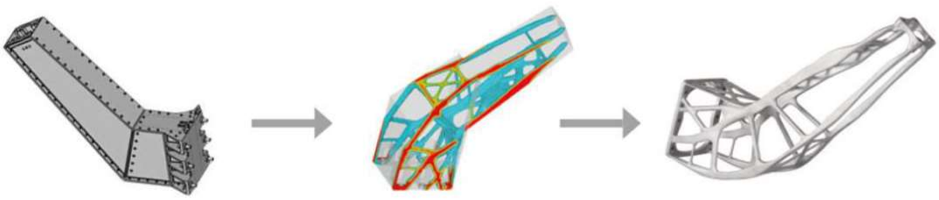
- Practice of designing a part / product that exploits the freedoms of additive manufacturing
  - Minimise production time, cost and risk of in-build failure
  - Maximising functionality and quality

- MDMF(CWB) 3d printing technologies for metal and nylon (PA12) materials
  - Metal: 3DSystems Direct Metal Printing (DMP) Flex 100
  - Nylon: HP Jet Fusion 540

- To realize the part / product that metal AM and nylon AM can help to:
  - Create internal as well as external complexity
  - Allow complex shapes and geometry to be produced with absence of any tooling
  - Have vary wall sections to achieve optimum strength

1. Why DfAM



Original design → Optimized topology → Redesigned antenna bracket

Design Consolidation

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2. How DfAM

- 4 key principles for DfAM
  - Design for correct additive manufacturing processes
    - With support structure: DMLS, FDM, SLA
    - Without support structure: MJF
  - Design for minimal material usage
    - **Generative design** (i.e. topology optimisation)
    - Lattice structure design
  - Design for improved functionality
    - Part customisation, internal fluid channels, added surface texturing, etc.
  - Design for part consolidation
    - Consolidate assemblies into a smaller number of parts
    - Reduce number of fixings, risk on delivery, assembly time and cost

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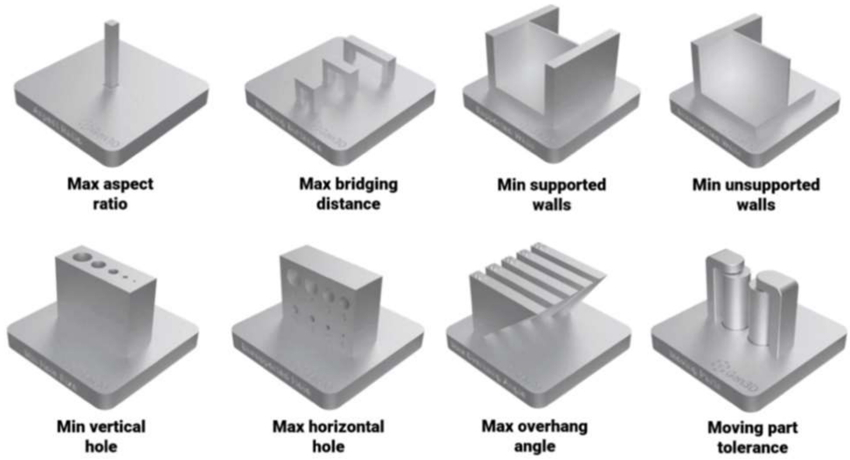
Design for correct AM processes

2. How DfAM

- Each of the different processes has different characteristics
  - Scale, cost, with / without support structure, geometric limitations

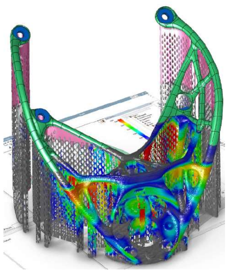


www.gen3d.co.uk

Design for correct AM processes – Our Metal 3D Printer

2. How DfAM

- Build volume: 100 x 100 x 80 mm
- ± 0.2% with ± 0.05 mm minimum
- Wall thicknesses down to 0.15 mm
- Needs to have support



LaserForm 316L (B)

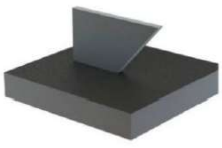
LaserForm 17-4PH (B)

DMP Flex 100

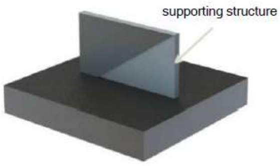
Design for correct AM processes – Metal 3D Printer

2. How DfAM

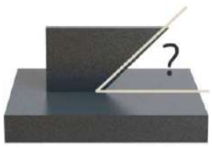
- Design basics – angled surfaces



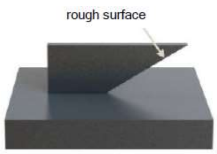
The powder in the build chamber does not provide any support to the part as it builds, so any angled surfaces will ideally be self-supporting.



If the angle is too acute, the surface will need a supporting structure built in as part of the model. This supporting structure will then need to be removed by machining or wire cutting, increasing energy use.

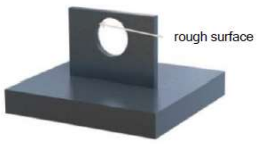


The minimum angles that will be self supporting are approximately:
- Stainless steels: 30 degrees
- Inconels: 45 degrees
- Titanium: 20-30 degrees
- Aluminium: 45 degrees
- Cobalt Chrome: 30 degrees

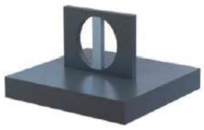


If the angle is near the point where it needs supports, the downward facing surface will become rough and may require considerable post-finishing.

Small holes can be accommodated easily. Holes of less than 6mm diameter are ideal.



Larger circular holes will result in a roughened surface at the top which may need post-machining.



Large holes will require support structures to be added in the centre to prevent the part collapsing or becoming distorted during the build process. These supports will need to be removed by wire cutting or machining.

If the hole has an angled or arched upper area it will probably not require any supports. This is one of the features of DMLS that can have a significant impact on the design process.

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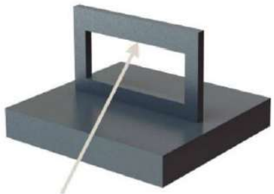
Design for correct AM processes – Metal 3D Printer

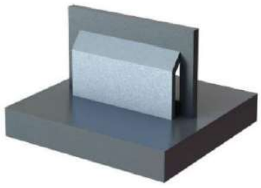
2. How DfAM

- Design basics – downward facing surfaces



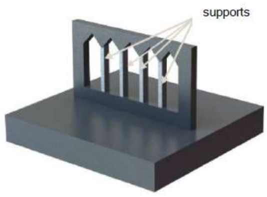
Any downward facing surface will require support. Support structures will need to be removed by wire cutting or machining, which will increase the energy and waste involved in the process.

The most simple support structure will fill the hole that creates the downward facing surface. This can be removed by wire cutting or machining.



An offset support structure can be used that will be easier to remove. In this case, the base of the support will be cut when the part is removed from the base by wire cutting, leaving one edge to be cut in order to remove the rest of the support.

An alternative to this approach will be to turn the part through 45 degrees to make all the surfaces angled and remove the need for supports. Orientation is a major issue in finding the most efficient build method - please see item 3 in Other Issues for more details on the limits and possible pitfalls of using angled edges like the ones shown above...



If the top surface of the hole can be made of a series of angles (which are self supporting) the supports can be minimised to the base of each angled surface.

If the hole is simply for weight reduction or cooling, for example, it can be modified as a series of semi-circular topped slots which will not require supports. However, the 'pillars' between the holes need to be self-supporting.

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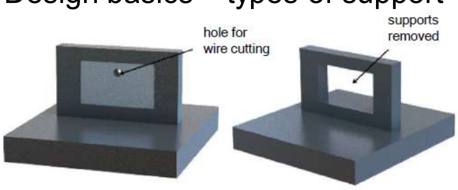
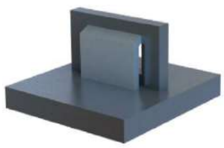
Design for correct AM processes – Metal 3D Printer

2. How DfAM

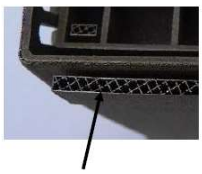
- Design basics – types of support



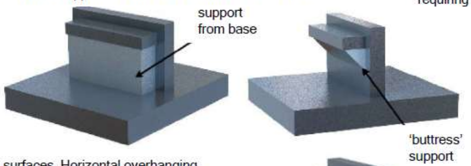
1. Simple fill in. The most simple form of support is to fill in the area that needs support, and then cut this out when the build is complete by wire cutting or machining. If the support area is to be removed with wire cutting, a small hole needs to be placed in the support area to allow the wire to be located.

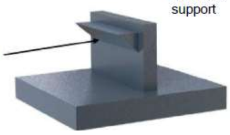


2. Offset supports. Offset supports require less machining. They rise vertically and then angle in to support specific surfaces. The base of the support is usually removed with the wire cut removal of the part, requiring only the supported surface to be machined.

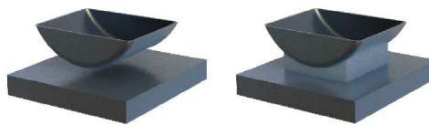


All support structures are formed from fine lattices, to minimise energy consumption and build time





3. Overhanging surfaces. Horizontal overhanging surfaces can be supported from the base, although this will require a considerable amount of material and energy. A better solution is to 'buttress' the surface from the main geometry at an angle. Better still, design the support into the geometry and remove the need for any additional work.



4. Supports for curved surfaces. Sometimes, it is necessary to support a downward facing curved surface to prevent the geometry failing or a very rough surface being formed. In this case, a support structure is formed under the part which is then removed by wire cutting or machining when the part is removed from the base.

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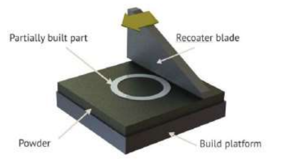
Design for correct AM processes – Metal 3D Printer

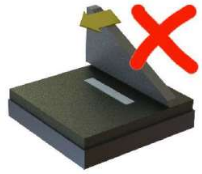
2. How DfAM

➤ Design basics – direction of build and cross sections

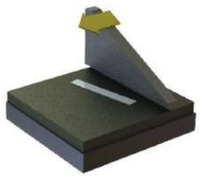


As the re-coater blade passes over the part, depositing another layer of powder, it can touch the layer below, sometimes with force. The orientation of the part is, therefore, important. The ideal geometry is a circular profile which provides a smooth lead in for the blade, and a stable cross section as it builds.

An open 'U' or similar shape is also ideal, as the lead in for the blade is again rounded, and the basic profile will be strong as it builds, resisting the force of the recoating blade.

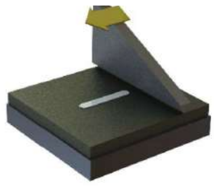


The 'worst case' geometry would be a thin section parallel to the re-coater blade. The blade will tend to 'bounce' off the parallel wall, and the section itself will not resist the force of the blade as it builds.



Any flat surfaces need to be at least 5 degrees from parallel with the blade to allow the blade to touch the part at a point, not a face.

In addition to touching the part at an angle, it helps if the geometry is inherently stiff, which will resist bending forces as the re-coater blade passes over the part.



Long, thinner parts with rounded ends will build well, as they also provide a smooth lead in for the blade and are inherently stiff. However, all these issues need to be considered in parallel with the other limits (build angles, etc) mentioned elsewhere in this section.

MATERIALS, DESIGN AND MANUFACTURING FACILITY (CWB)

Design for correct AM processes – Metal 3D Printer

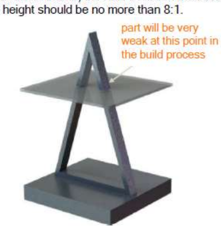
2. How DfAM

➤ Design basics – part strength during the build process

As the re-coater blade passes over the part, more force will be applied to the geometry as it gets taller. As a rule of thumb, the ratio between the section and the height should be no more than 8:1.

The exact proportions will always depend on the specific geometry, but if the section gets too high, there is a danger that the re-coater blade will bend the part, and possibly damage itself in the process, terminating the build sequence.

To prevent these problems, vertical sections need to be bridged at certain points. The best method of achieving this will be to use 'arches' to avoid the creation of downward facing flat surfaces.



Even a part that will be strong when it is finished may need some support during the build process. This triangular section will be very weak as the build gets close to the apex.

This kind of structure may need a simple support structure up the middle to provide some rigidity before the part is completed.

If the reason for the open structure is simply weight reduction, it may be easier to perforate it with holes (ideally less than 6mm in dia) that will reduce weight, but not require any supports.

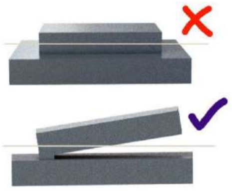
MATERIALS, DESIGN AND MANUFACTURING FACILITY (CWB)

Design for correct AM processes – Metal 3D Printer

2. How DfAM

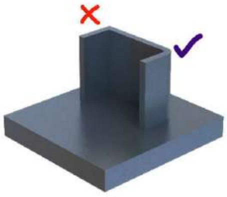
- Design basics – other issues

1. Avoid sharp edges. Very sharp edges cannot be built in DMLS, and it is better to design parts with minimum radii of approximately 0.5mm.

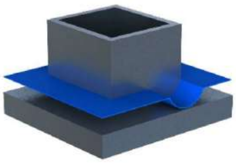


2. Avoid thick sections. The heat build up when creating very large horizontal sections can affect the build geometry, particularly when using titanium. A better approach is to angle the part to minimise the horizontal section at any one time.

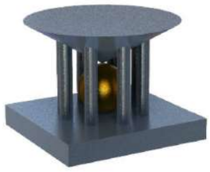
3. Avoid angles facing into the re-coater blade Angled parts that lean into the path of the re-coater blade may cause the blade to collide with the part and terminate the build.



4. Avoid sharp edges. Sharp corners can act as 'stress raisers' in DMLS in the same way as they can in most processes. Always try to use radii on corners instead of sharp edges.



5. Use the wire cut removal path. The path used to wire cut the part from the base can be used as an integral part of the component design, rather than simply as a straight cut.



6. Build multiple parts. The nature of the DMLS process allows for multiple parts to be built 'in situ'. This can save considerable time and assembly cost for appropriate geometry.

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Design for correct AM processes – Metal 3D Printer

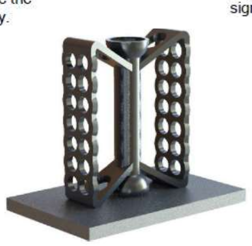
2. How DfAM

- Design basics – case study – bicycle pedal

A conventional 'rat trap' bicycle pedal (left) has a large number of surfaces. If it is built in the horizontal plane, the large number of downward facing surfaces will require a significant amount of support (right). A large number of these can be offset, which will reduce the removal time, but building the part would require a considerable amount of energy.

If the geometry is modified to reduce the number of downward facing surfaces (mainly by putting in a number of 45 degree angled surfaces) the amount of supports needed is reduced significantly (right).

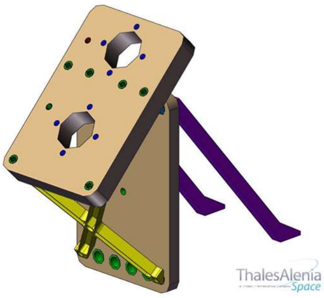
However, by changing the orientation of the part to vertical, the number of supports needed is dramatically reduced.



This vertical orientation, combined with design changes to the pedal, would allow designs to be produced that require no supports at all.

Design for correct AM processes – Metal 3D Printer

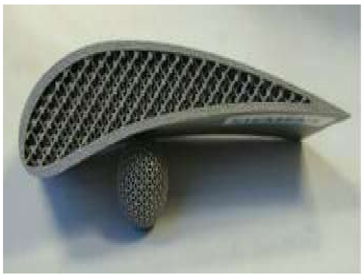
- Additive redesign of Satellite antenna bracket
  - Parts weight loss 22%;
  - Cost saving 30%;
  - Shorten the production cycle in 2 months



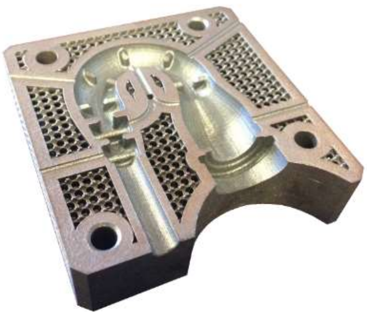
Original Design

Additive Redesign

Design for correct AM processes – Metal 3D Printer



Lattice engine blade



Lattice Radiator

Engine with bionic lattice structure

MATERIALS, DESIGN AND MANUFACTURING FACILITY (CWB)

Design for correct AM processes – Our Nylon 3D Printer

2. How DfAM

- Build volume: 332 x 190 x 248 mm
- ± 0.3% with ± 0.2 mm minimum
- Wall thicknesses down to 0.6 mm
- Self-supporting nature
  - Freedom to print complex and intricate geometries
  - Enables to print assemblies in single, continuous pieces

Jet Fusion 540

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