DfAM
Design For Additive Manufacturing

Louis Cao (Cao Vũ Nhân)
Chairman | Kawami System LLC
An authorized partner of Renishaw

Prepared by:
Paul Gallagher
Managing director
Renishaw Far East

© Renishaw 2016
So I’ve got complete design freedom, right?

Not quite!

Like any manufacturing process, AM technologies have their capabilities and their limitations.

Design for AM (DfAM) considerations for laser melted metal parts include:

• feature size
• surface finish
• overhanging features
• minimizing supports
• avoiding component distortion
Feature size

In machining, minimum feature size is governed by cutting tool size.

In AM, the minimum size of solid feature is limited by the laser spot diameter:

- Spot heats powder and creates a weld pool
- Molten metal cools to form a dense solid
- Spot size and laser power determines minimum feature size
Minimum producible feature size

Sintering of neighbouring powder means minimum feature size is larger than laser spot size, dependent on:

- Thermal conductivity of powder
- Energy imparted

With a 70 µm spot:

- Lattice struts down to 140 µm
- Wall thicknesses down to 150 – 200 µm
Surface finish

- At edge of the weld pool, grains soften but do not liquefy
- Some grains are captured by molten metal, others detach, creating textured surface
- Re-melting reduces surface roughness
- Layers often remain visible in finished part
- Surface finish driven by powder size, laser modulation and layer thickness
- 10 to 20 µm typical
Overhangs

Avoid large overhangs

- **Green** builds OK
- **Yellow** poor surface finish
- **Red** distorts

Avoid overhang angles greater than 45 degrees to vertical

- Shallow overhangs may deform or have poor surface finish
- Vertical edges are OK

< 45°

> 45°
Lateral holes

- Holes in the side of parts create overhangs
- Small holes (< 10 mm) do not distort
- Large holes will need supports, or to be modified to reduce overhangs
Minimising supports – feature shape

Overhangs can be built using supports
Supports are waste material and have to be removed after the build is complete
Changing the shape of lateral holes can remove the need for supports

Teardrop and diamond holes do not need supports

Interior supports needed for large bore
Minimising supports – re-orientation

Re-orientation can be used to minimise supports

- May require addition layers and build time
Minimising supports – case study

AM beer bottle opener

- Original sleek design (left)
- First optimisation to reduce weight (right) resulted in several overhangs (orange circles), needing supports (grey)
Minimising supports – case study

AM beer bottle opener

- Second iteration (left) included modifications to the shape to minimise support.

- Third iteration (right) involved a re-orientation, leaving only self-supporting overhangs (grey circles), needing just one tiny support to connect the bottle opener to the build plate.
Residual stress

AM is a welding process, although spot size is small and energy density is high

- Stress can build up in thick cross-sections, or where cross sections vary in thickness
Part distortion

**Stress** (particularly thick sections)

- Avoid thick part sections
- Thin and consistent sections are best
- Use thicker build plates where stress is likely to be high

Separation from supports due to high stress

Standard and thick build plates
Part distortion

Warping (thin wall sections)

Fill solid structures with lattices to maintain stiffness and minimise mass
Summary

• Awareness of AM characteristics & limitations is critical to success
• DfAM rules encourage reduction in part weight, build time and cost
• Modern build preparation software simplifies and speeds up the DfAM process
Case study #1 – fully self-supporting design

Topological optimization doesn’t necessarily deliver an efficient build

• Functionally efficient design of bike seat-post

• High level of supports needed (yellow)
Case study #1 – fully self-supporting design

Before

- Arch builds unsupported
- 45° self supporting

After

- Radius < 3 mm
- Re-orientate
- Web angle
Case study #3 – designed supports for pipe section

Original design

Essential elements (left) and minimal mass design (right)
Case study #3 – designed supports for pipe section

Designed primary supports

- Orientated to avoid supports inside the tube
- Flange mass minimised
- Small flat face on flange for supports to attached to
- Self-supporting ‘wings’ due to orientation and profiled leading edge

Flange detail with primary supports designed to break off cleanly
Case study #3 – designed supports for pipe section

Efficient primary supports

• More time in CAD, but very little time spent of build preparation

• Reduced mass through efficient flanges (25% less part volume)

• Primary supports require less material than secondary supports, reducing build costs
Summary

• Heavy use of secondary supports is a sign of insufficient design for AM
• Primary supports are more considered and controlled
• With careful thought, it is sometimes possible to eliminate supports altogether
• Companies that view AM strategically are investing in good design for AM
QuantAM 2017

- Dynamic slice review
- Flexible material development
- Discrete event visualisation
- CAD kernel & 3D Interop
QuantAM – Open Access Platform

- Orientation
- Support
- Build Setup
- Toolpath review
- Material Development
CAD optimisation and simulation

**CATIA**
Generative Design (Topological optimisation)

**DELMIA**
Toolpath generation powered by QuantAM

**SIMULIA**
Part and build simulation
InfiniAM – Process Monitoring

Process monitoring

Data reporting

Mobile apps
Modus 2 (With Apex patch and error map)

- Inspection planning
- Freeform surfaces
- Error mapping
Controlled workflow

Design
Integration with specialist applications and partners

AM build preparation
Exploiting system capabilities

Production management
Remote process monitoring

Verification
Sophisticated measurement made simple
Thank you

Your product design

Renishaw expertise

Your AM process

Global support

your product
our expertise