MAMTeC

Bringing Additive Manufacturing down to earth!
From new idea to commercial product

3D Metaal Print Cluster
Additive Manufacturing Workshop

Session I 17-10-2017 **Marc de Smit**

3D Metaal Print Cluster

- Content of today

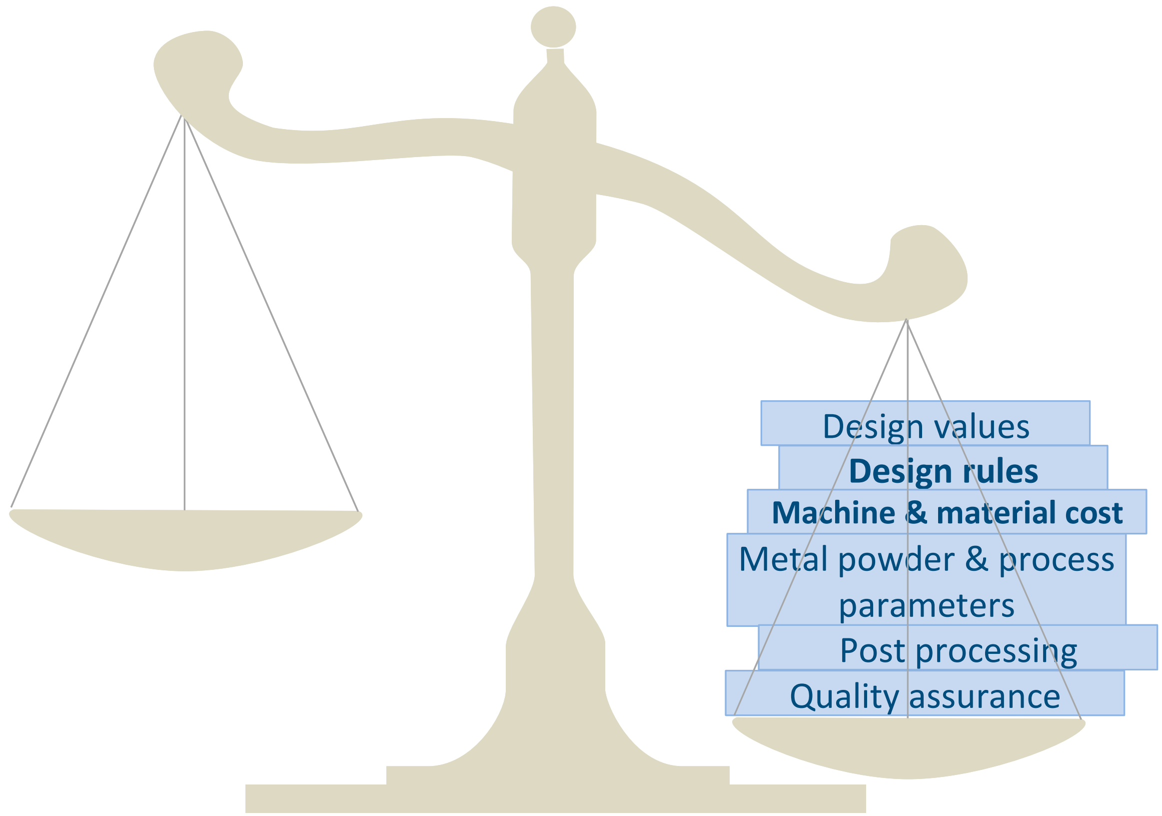
13:30	13:45	Ontvangst & introductie
13:45	14:45	Design rules
14:45	15:00	Costs of AM parts
15:00	15:15	Identification of Metal AM opportunities
15:15	16:05	Challenge: Identify Metal AM opportunities
16:05	16:35	Pauze
16:35	17:30	Discussie & afsluiting

Basic design rules for metal-AM

- Exercise!

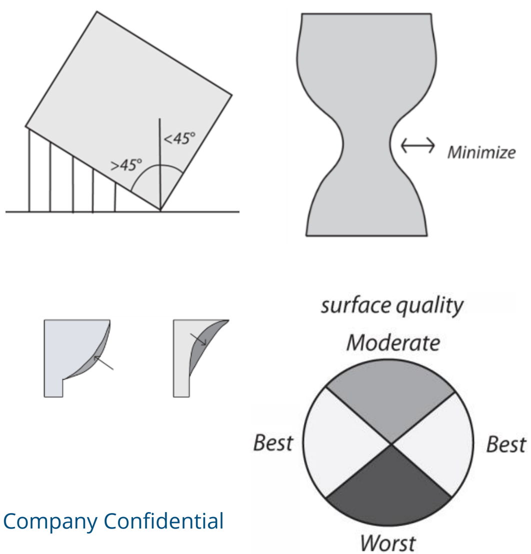
Metal Additive Manufacturing

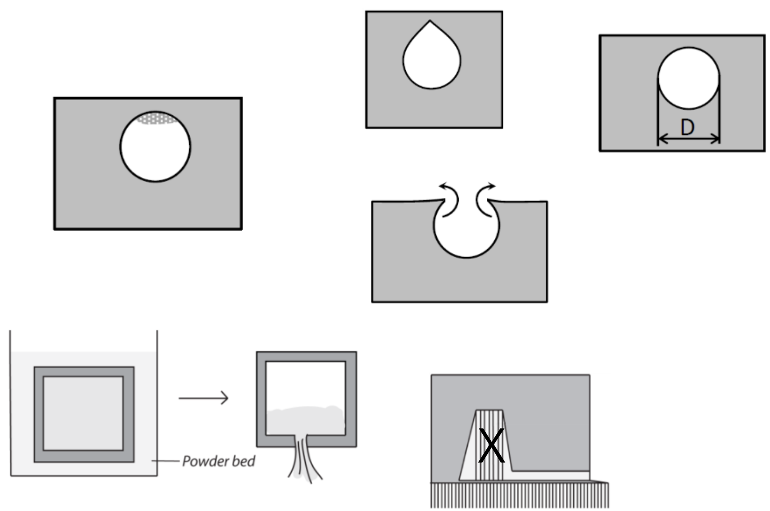
- Metal-AM Challenges



Basic design rules for metal-AM

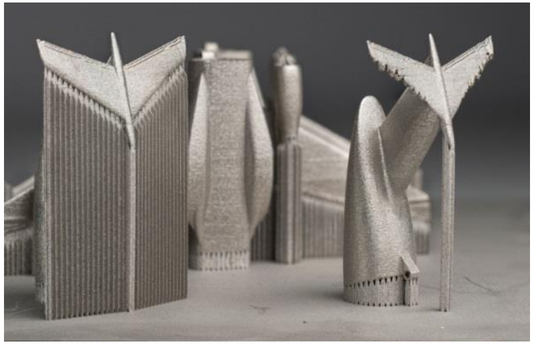
- Basic design guidelines are available
- Still many failures do occur
- Need for guidance to enable maximum use of advantages while the risk of failure is minimized

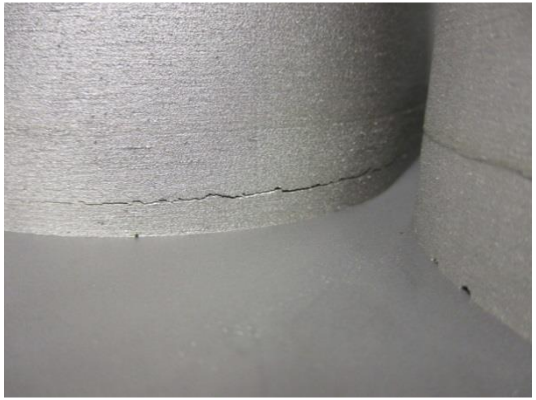




Criteria for design

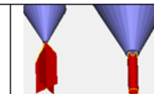
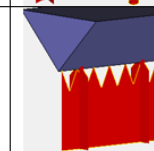
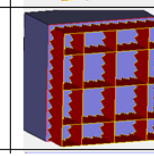
- Minimum support structures
- Sufficient support structures
- Minimum residual stresses = high geometrical accuracy
- Sufficient heat dissipation
- Implementation of excess material for post machining
- Powder removal must be possible
- Support removal must be possible
- Surface quality





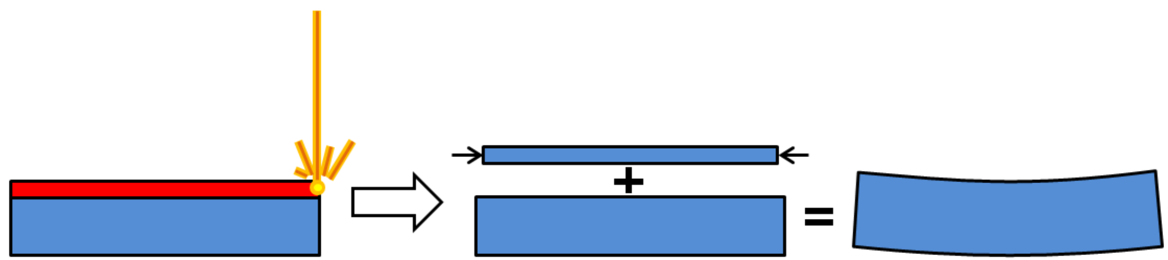
Standard supports

- Optimise design to reduce supports
- Supports must be assessable for removal
- Option is to make supports part of structure
- Lowest lines and lowest points must be sufficiently supported
- Take loads during support removal into account

Type	Description	
Point	small surfaces where block support becomes too small and unstable	
Line	Down facing edges and narrow down facing areas	
Block	Down facing surfaces	

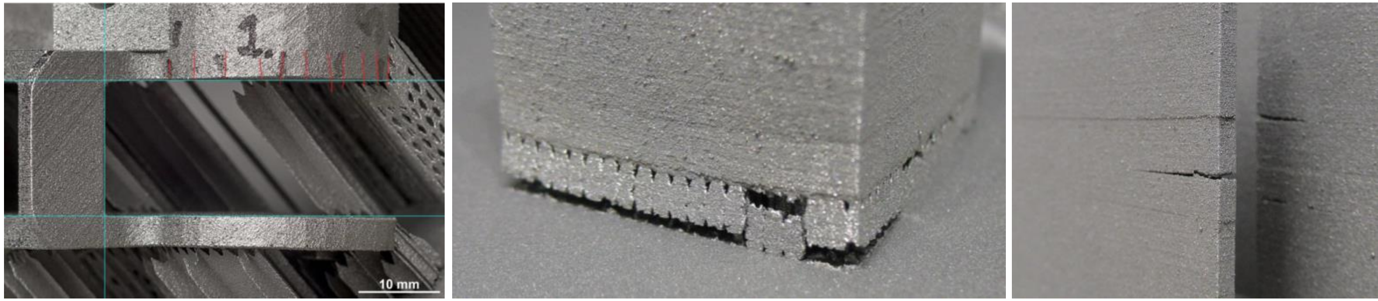
Residual stresses

- Thermal gradients result in residual stresses
- Influenced by:
  - Material parameters
  - Process parameters
  - Design
  - Product orientation



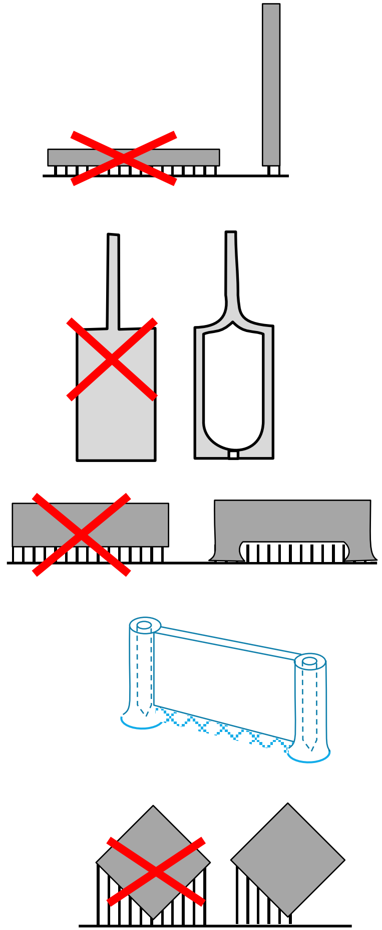
Residual stresses

- Deformations => inaccuracy
- Failure of supports =>
  - Displacement of part = inaccuracy and line in product
  - Disturbance of powder bed affecting other parts
  - Collision with wiper blade
  - Job failure



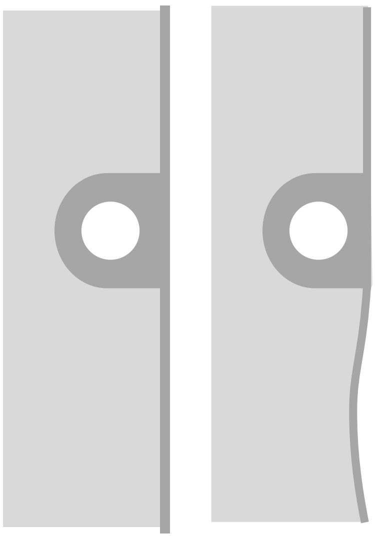
Residual stresses

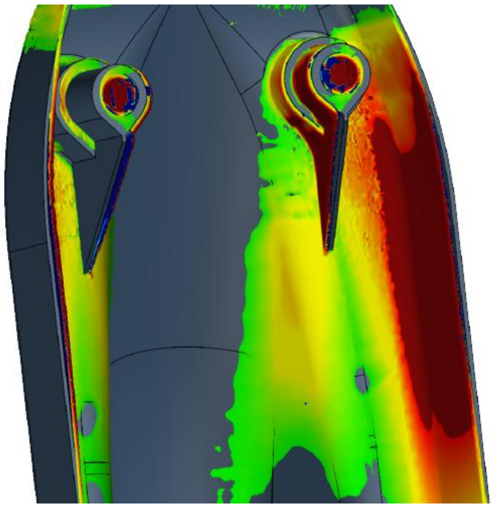
- Minimise surface area of layers
- Prevent sharp vertical edges
- Prevent large thickness variations
- In case of high stresses: Increase support strength
- If possible, allow some deformation



Residual stresses

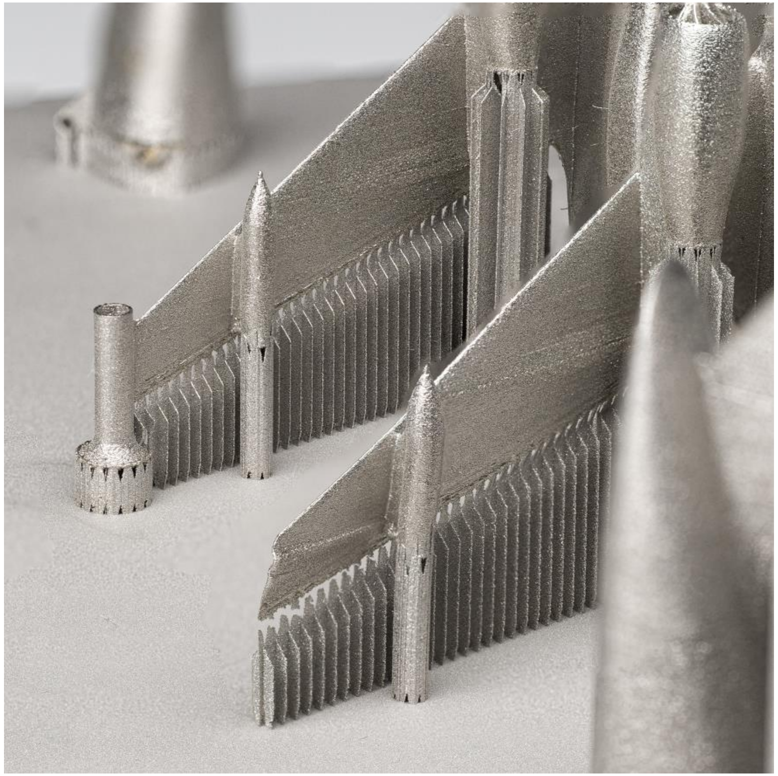
- Deformations of thin wall due to thick walled features
- Compensate design for measured (or expected) deformation





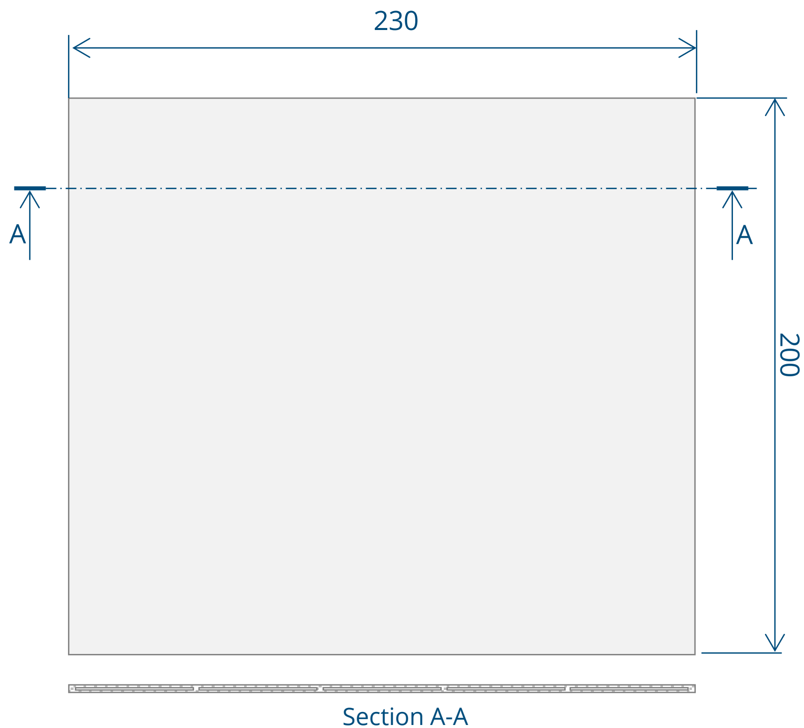
Residual stresses

- Exercise



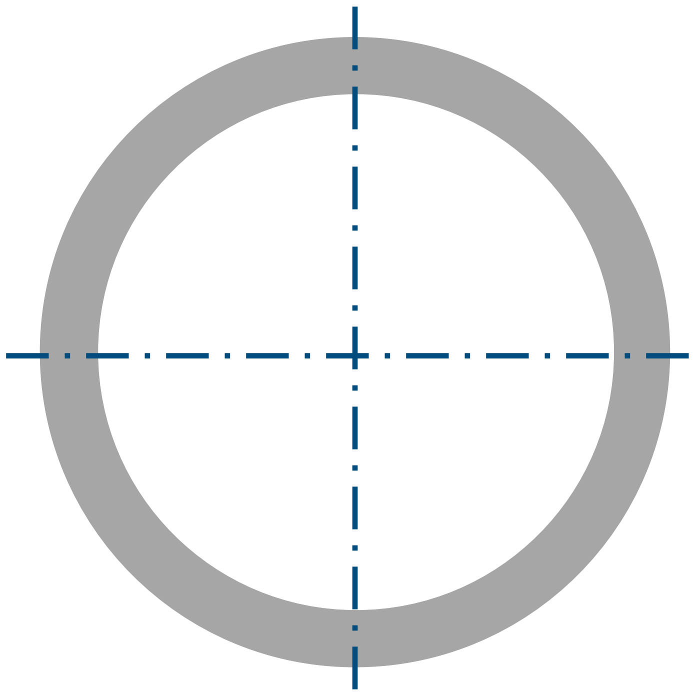
Residual stresses

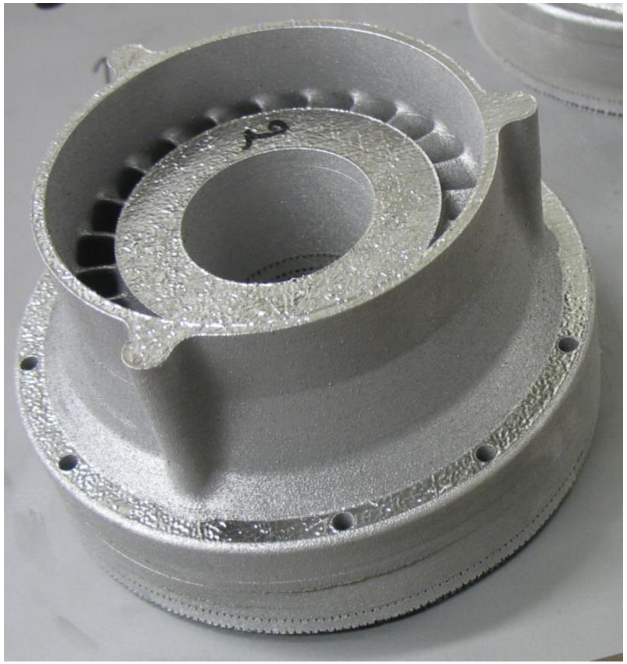
- Exercise 2



Residual stresses

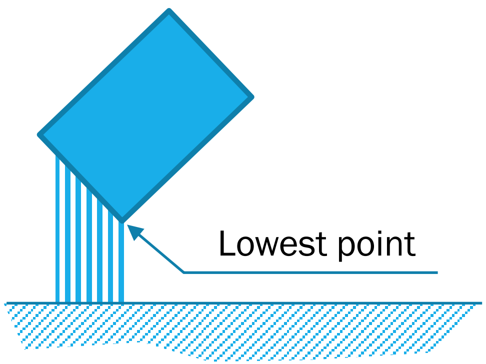
- Cylindrical shape

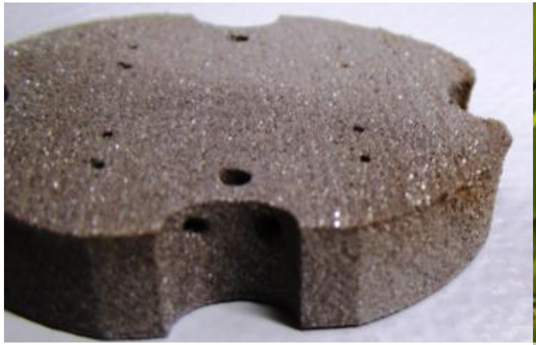




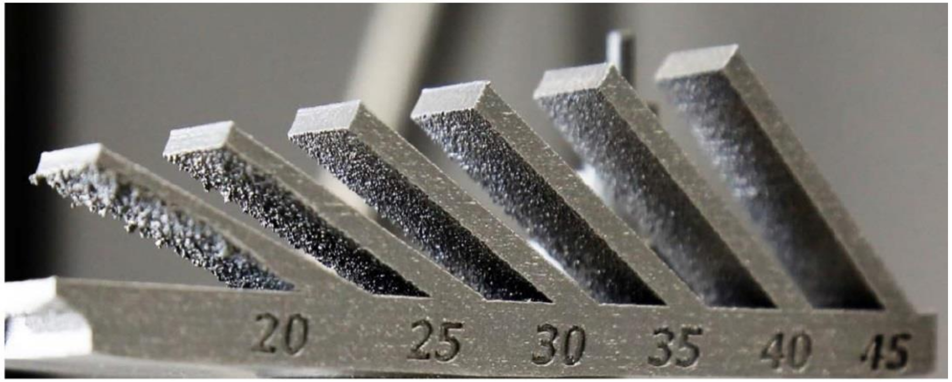
Sufficient heat dissipation

- Prevent overheating
- Apply sufficient supports under lowest points and lines





Down skins & Surface quality

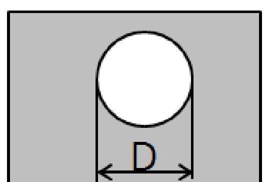


Source: Additive Metal Manufacturing Inc.

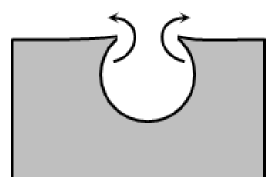
Horizontal Holes

- Max 6 mm without supports
- Min 0.5 mm, apply down skin parameters
- Tight tolerances=> machining is preferred

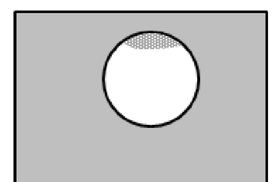
Source: Additive Metal Manufacturing Inc.



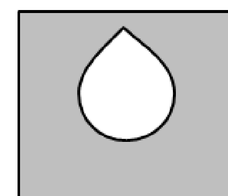
Min 0.5 mm
Max 6 mm



Deformation due to residual stress



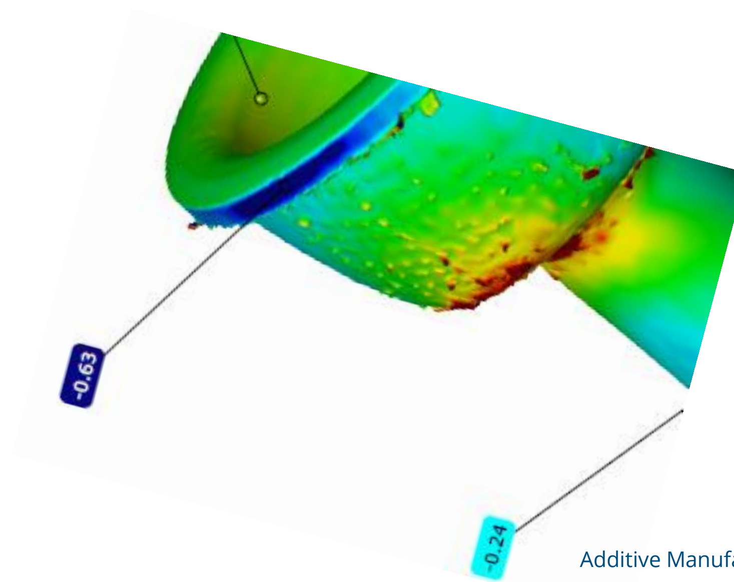
Sagging of upper part of hole



Adjusted hole design

Excess material for post machining

- How much material must be added for post machining?
- Depends on size and geometry.
- Generally add 0.6 mm to surfaces
- Add 0.8 mm on down skin surfaces



Removal of supports must be possible

Building envelope

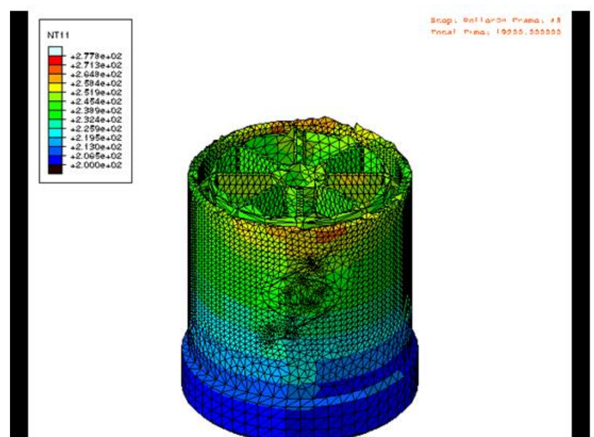
- Maximum part dimensions limited by size of building envelope
- Development= larger machines
- Multiple lasers work parallel
- Limitations in size:
  - Extreme long machine time
  - High loads
  - Distortions & cracks
  - Bending build plates

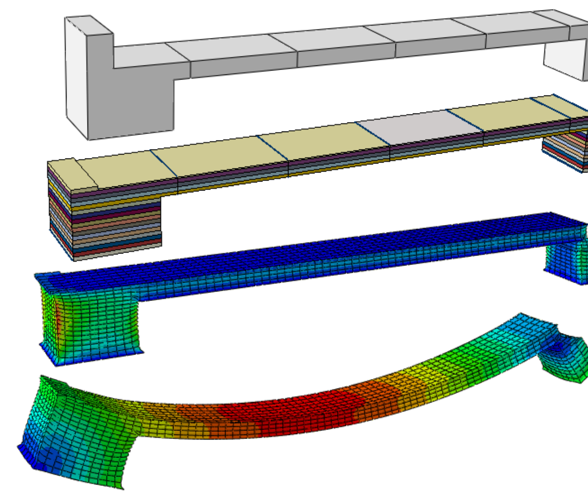
Machine	Maximum build size [mm]
Additive Industries MetalFab1	420 x 420 x 400
ARCAM A2	200 x 200 x 350 or Ø 300 x 200
ARCAM Q20	Ø 350 x 380
EOS PRECIOUS M080	Ø80 x 100
EOSINT M280	250 x 250 x 325
EOS M290	250 x 250 x 325
EOS M400	400 x400 x 400
Concept Laser MLAB ®	50;70;90 x 50;70;90 x 80
ConceptLaser M2 Cusing	250 x 250 x 280
Concept Laser X line 1000R	630 x 400 x 500
Phenix PXL	250 x 250 x 300
Realizer SLM 250	250 x 250 x 300
Renishaw AM250	250 x 250 x 300
SLM 250 HL	248 x 248 x 250 (350)
SLM 280 HL	280 x 280 x 350
SLM 500 HL	500 x 280 x 325
Matsuura LUMEX Avance-25	250 x 250 x 185
3D-Systems ProX 100	100 x 100 x 80
3D-System ProX200	140 x 140 x 10
3D-Systems ProX300	250 x 250 x 300
3D-Systems ProX400	300 x 300 x 300

Metal-AM Design tools

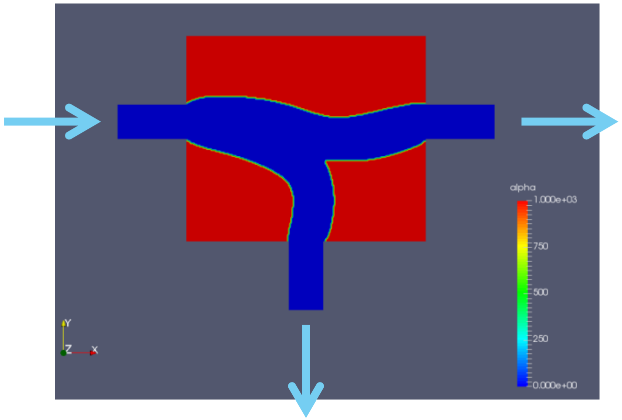
Software tools are being developed

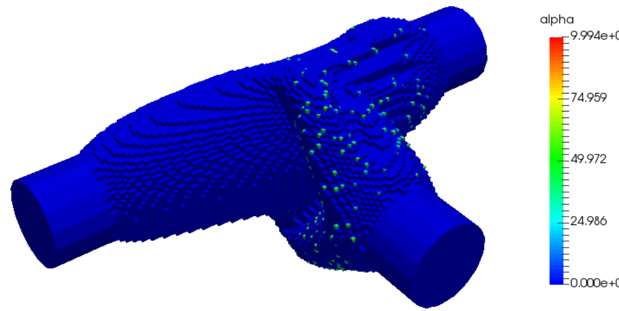
- Predict residual stresses: reduce risk
- Topology optimisation: enable design optimisation

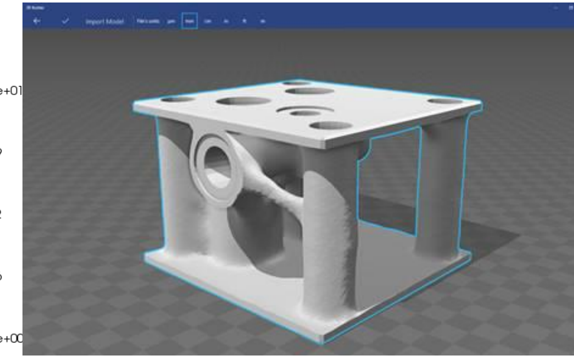


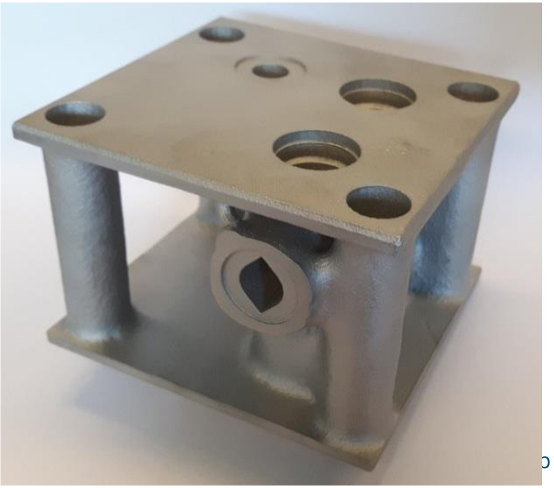


Topology Optimization: Optimal internal geometry



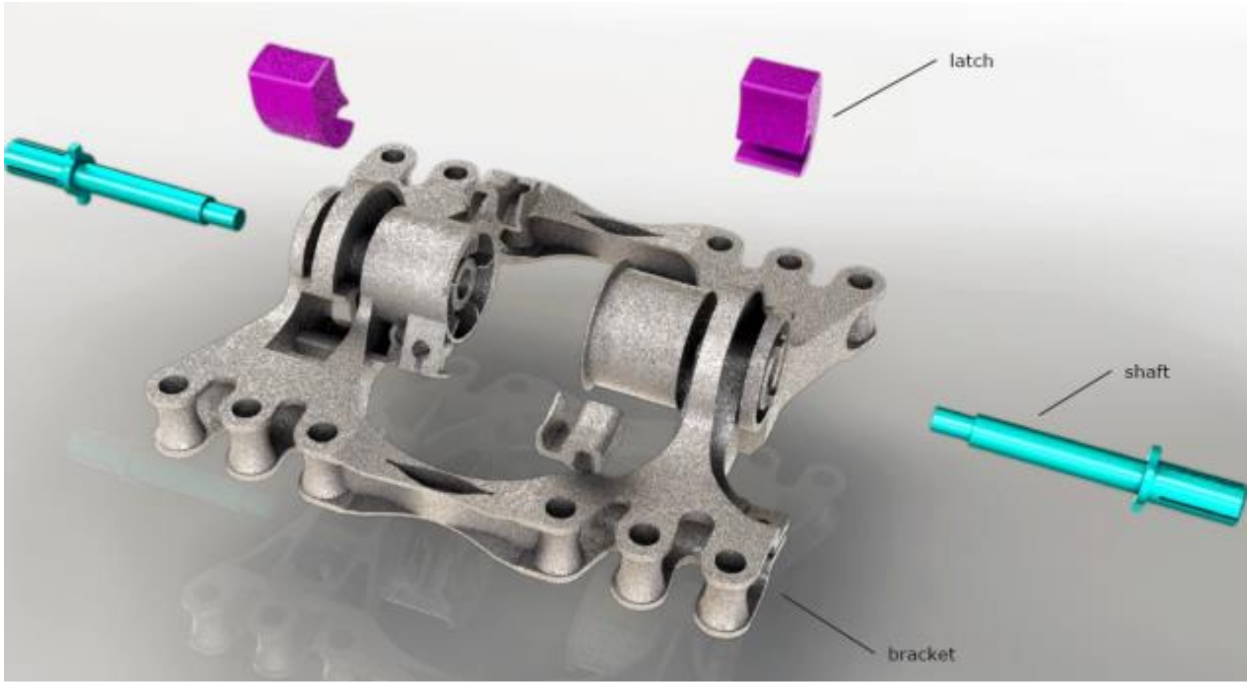




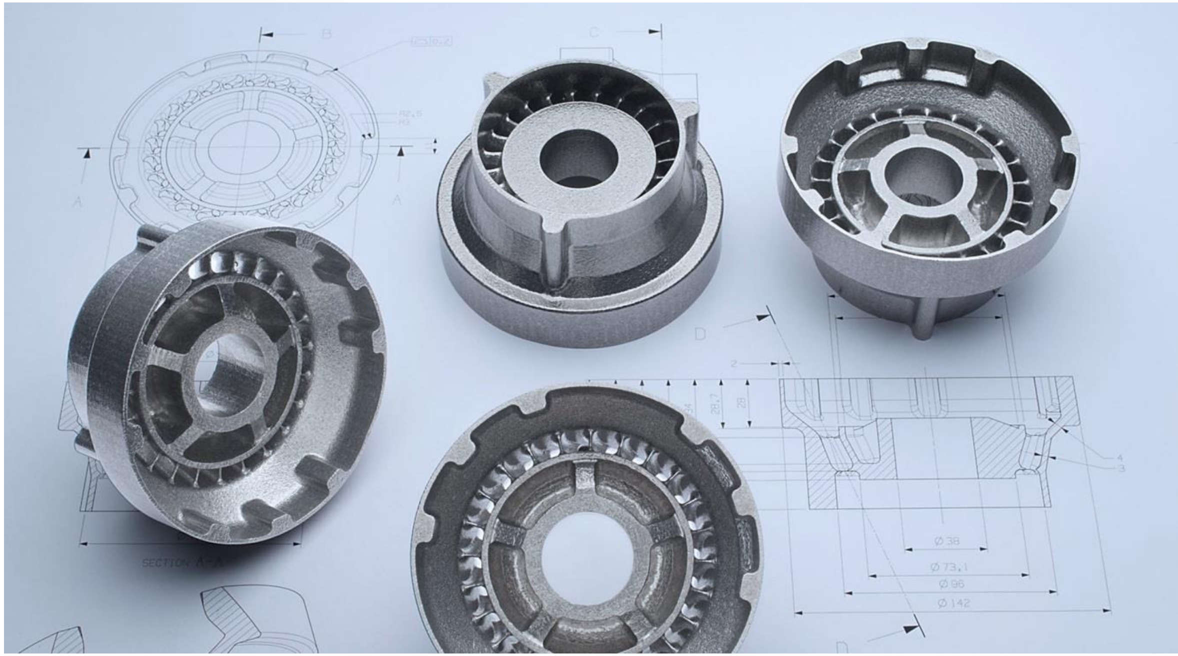


Practice design rules

- Example product

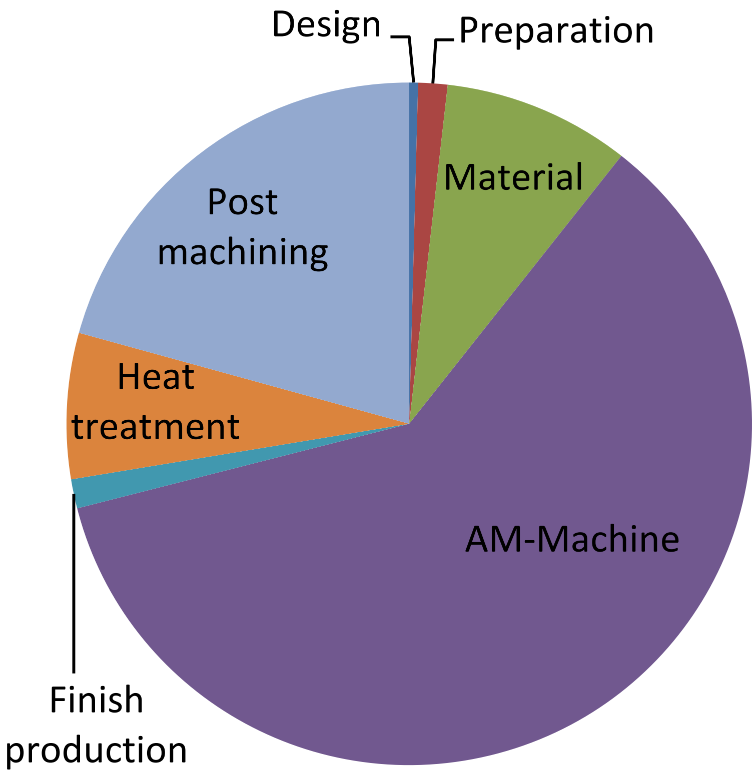


Questions about design rules



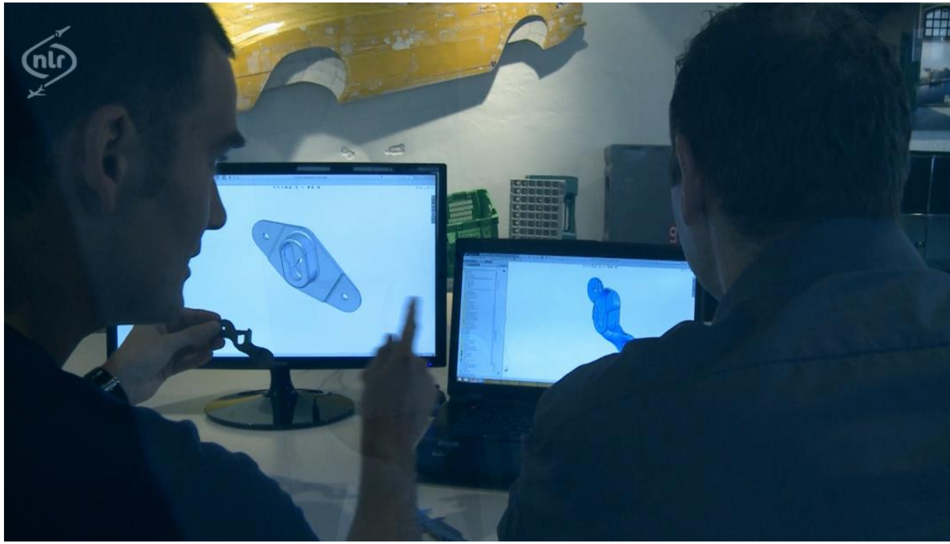
Cost of AM parts

- None recurring work preparation
- Machine operation
- Metal powder
- Metal-AM facility costs
- Finishing production and preparation for post processing
- Heat treatment
- Removal of supports, surface processing & post machining



Cost of AM parts

- Work preparation
  - Design for AM
  - Determine part orientation
  - Support design
  - Fill build plate with parts
  - Generate build file



Cost of AM parts

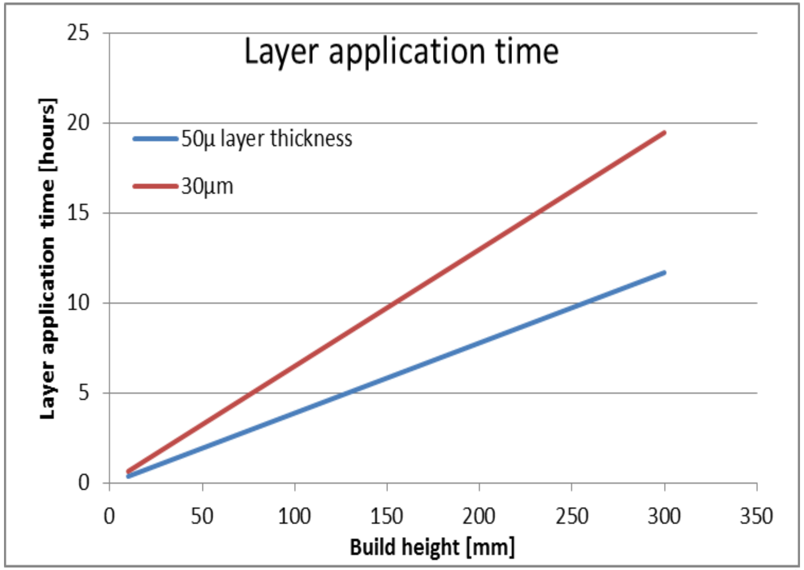
- Machine operation
  - Fill the powder buffer
  - Check the powder layer application system
  - Check inert gas supply
  - Check the inert gas filter
  - Place a flat substrate plate in the machine.
  - Activate pre-heating.
  - Clean the laser glass
  - Start the build job

Cost of AM parts

- Metal powder
  - Ti6Al4V ± 350 €/kg
  - Inc718 ± 70 €/kg
  - Inc625 ± 55 €/kg
  - SS316L ± 50 €/kg
  - Aluminium AlSi10Mg ± 100 €/kg
  - Aluminium Scalmalloy ± 300 €/kg

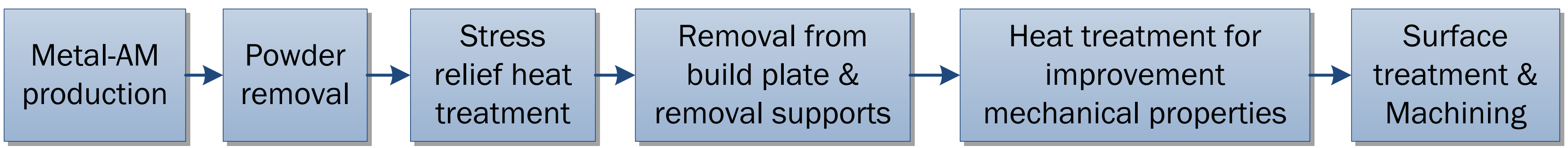
AM Machine costs

- Metal-AM facility costs
- ca. 100€/hr
- AM machine time = layer application time + laser time
- Laser time depends on volume & complexity
- Build rate 5 – 20 cm^3 cm/hr



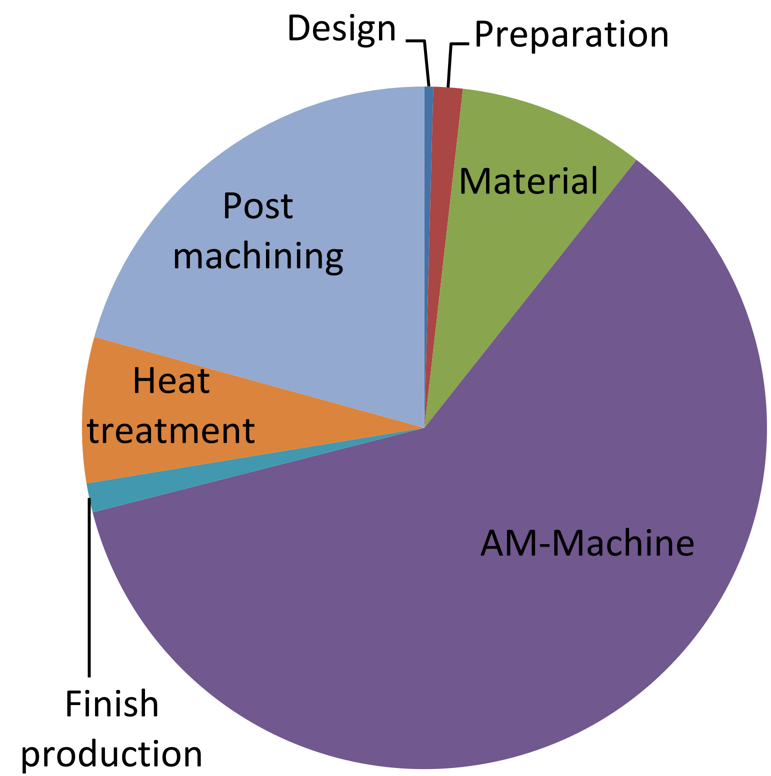
Cost of AM parts

- Finishing production and preparation for post processing
- Heat treatment
- Removal of supports, surface processing & post machining



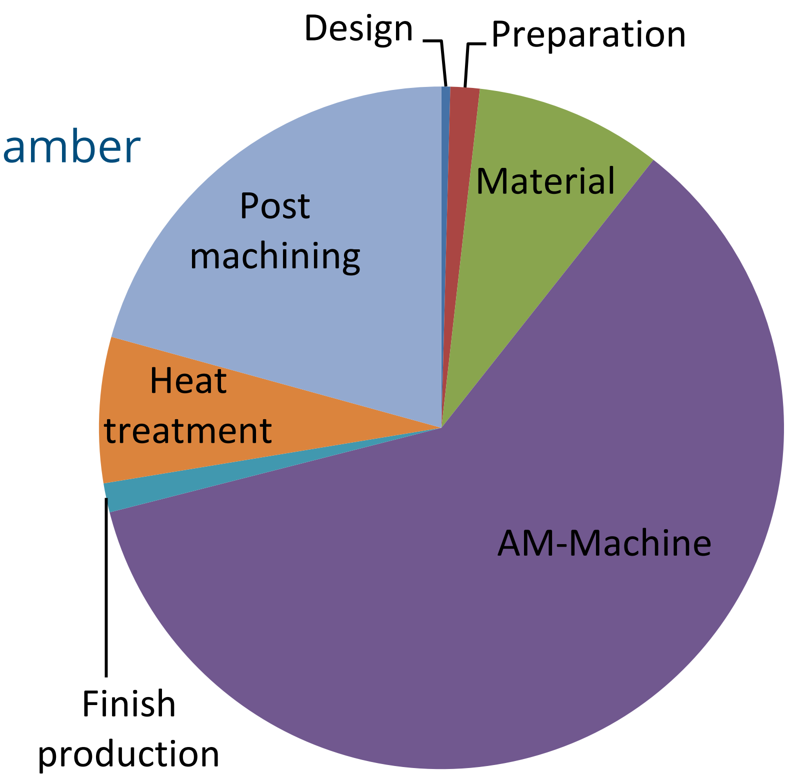
Cost of AM parts

- Cost distribution depends strongly on:
  - Part design
  - Material
  - Tolerances
  - Required quantity
  - …



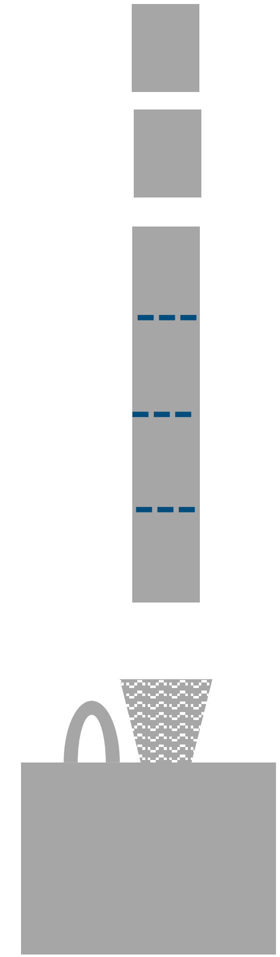
Cost of AM parts

- Cost reduction 2014 → 2020 due to:
  - Laboratory → Industrial
  - Reduction labour costs
  - Increase build rate: Single laser/small chamber → Multiple lasers/large chamber
  - Lower scrap rate



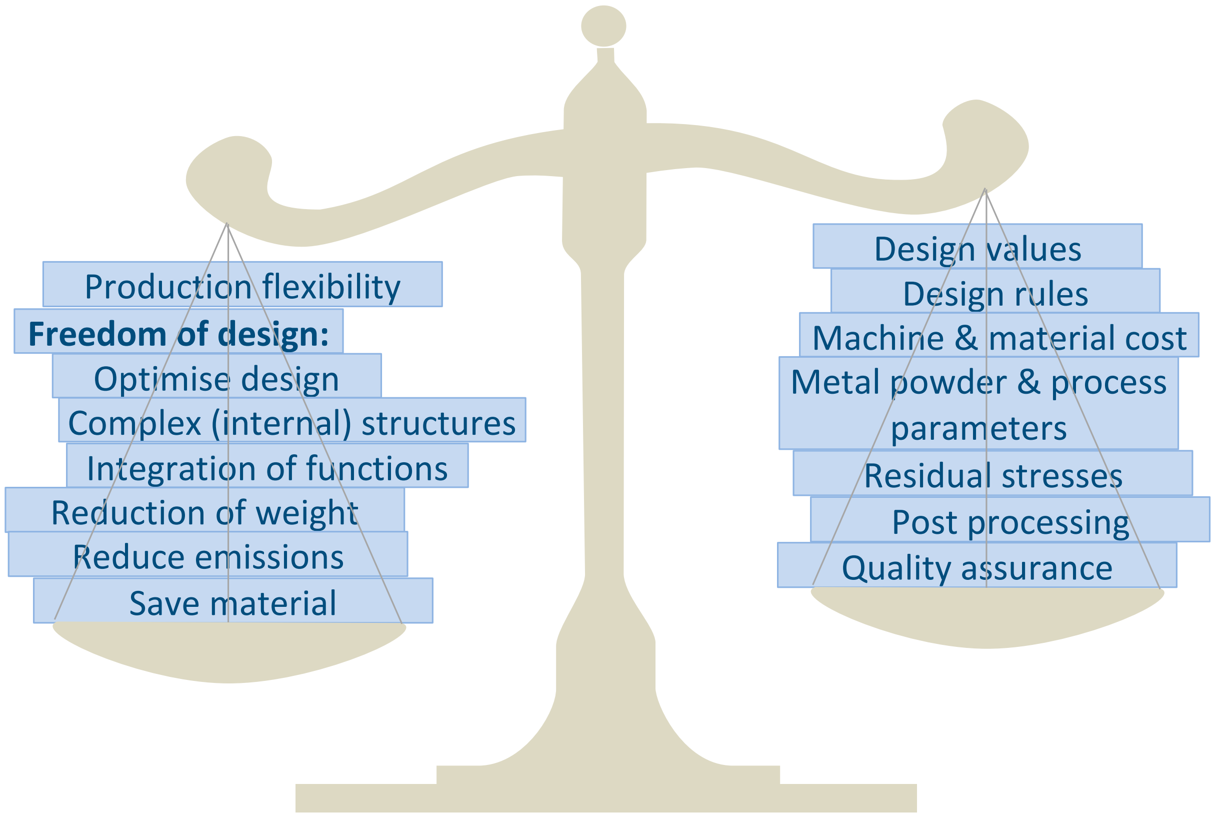
Cost of AM parts

- Reduce part costs:
  - Larger series (spread non recurring costs)
  - Reduce machine time & material costs
    - Minimise weight & height
    - Maximise layer thickness
  - Efficient filling of machine
  - Minimise & optimise post machining
  - Stack multiple products
  - Combine subtractive with additive



Identification of Metal AM opportunities

Identification of Metal AM opportunities



Identification of Metal AM opportunities

Added value through:

- Lower weight
- Better performance
- Reduced lead time
- Longer life
- Less parts
- ...

Identification of Metal AM opportunities

"This process has enabled us to reduce the weight of a 4-cylinder engine by 120 kg or 25%,"

The number of components in the DTI 5 engine has been reduced by 25%, making a total of 200 fewer parts.

industry news

Renault Trucks: Metal Additive Manufacturing could reduce engine weight by 25%

A team of Renault Trucks engineers and designers is looking to metal Additive Manufacturing to boost the performance of its engines. The Renault Trucks Lyon Powertrain Engineering department has focused on using the technology as a future engine manufacturing process, resulting in a prototype DTI 5 4-cylinder Euro-6 step C engine being designed exclusively using Additive Manufacturing.

Renault has reported that rocker arms and camshaft bearing caps were manufactured by metal AM and successfully bench-tested for 600 hours inside a Euro-6 engine.

"The aim of this project is to demonstrate the positive impact of metal Additive Manufacturing on the size and weight of an engine. This process has enabled us to reduce the weight of a 4-cylinder engine by 120 kg or 25%," stated Damien Lemasson, project manager at Renault Trucks. "The tests we have carried out prove the durability of engine components made using 3D printing. It's not just cosmetic."

Metal Additive Manufacturing is opening up new opportunities for engine manufacturers. The process allows engineers to optimise the size of parts, reducing the number of assembly operations and therefore the number of components in an engine. In the short-term, this manufacturing procedure can be used for highly specific applications or small runs.

"Additive Manufacturing releases us from constraints and unlocks the creativity of engineers," added Lemasson. "This procedure is a source of disruptive technology for the engines of tomorrow, which will be lighter and more functional, thereby offering optimal performance."

The number of components in the DTI 5 engine has been reduced by 25%, making a total of 200 fewer parts. Following on from these successful initial tests, engineers at Renault Trucks will be continuing their work on this manufacturing process to further increase the performance and functionality of truck components.

www.corporate.renault-trucks.com

The re-designed metal AM version of the rocker arm is shown during a bench test inside a Euro 6 engine

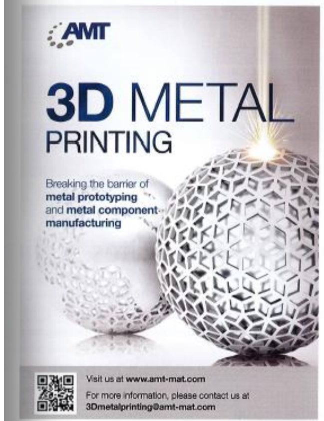
The original rocker arm in a Renault Trucks Euro 6 DTI 5 engine

turbine blades are made out of a powder of high performing polycrystalline nickel superalloy, allowing them to endure high pressure, hot temperatures and the rotational forces of the turbine's high speed operation. At full load each of these turbine blades is travelling at over 1600 km/h, carrying 11 tons, is surrounded by gas at [illegible] and cooled by air at over 400°C. The advanced blade design tested in Lincoln provides improved cooling features that can increase overall efficiency of the Siemens gas turbines.

[illegible] uses AM technology for rapid prototyping, but has already introduced serial production solutions for components in the gas turbines' compressor and combustion system. The first AM component for a Siemens heavy-duty gas turbine has been in commercial operation since July 2016.

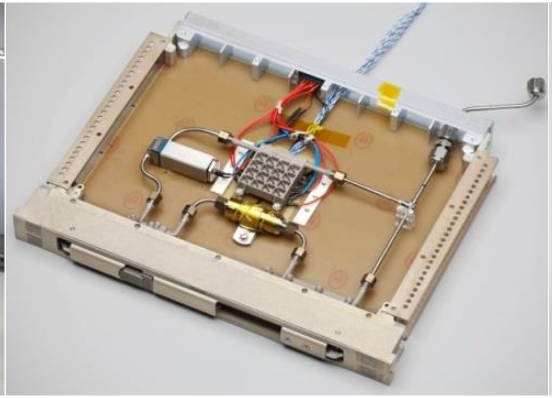
www.siemens.com/press/3D-printing

The advanced blade design provides improved cooling features



Additive manufacturing for Thermal control

- Additive manufacturing of heat exchangers and other components
- When very stable temperatures and/or low mass are crucial
- Active thermal control (pump) or passive thermal control (heat pipes)


Additive manufacturing for aerodynamic flow visualization

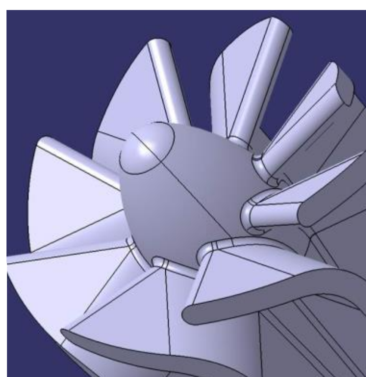
- Additive manufacturing of bubble generators
- Application in wind tunnels for flow visualization
- Small components with very complex internal structures

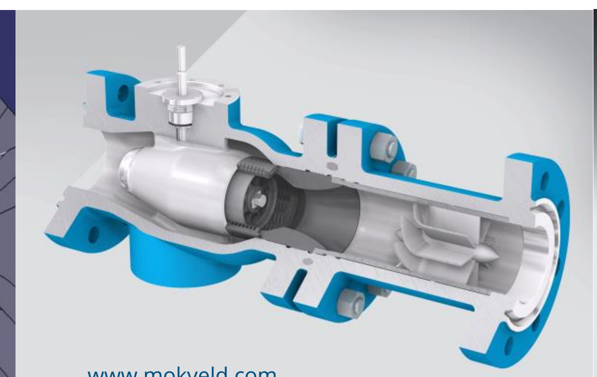
AM of optimised structural components

- Automotive application: Suspension upright
- Originally a cast part
- Topology optimised

Mokveld vortex breaker

- Component in separation and produced water treatment system
- Customised design for specific application
- Optimised design for minimum pressure loss and turbulence





I AM

You Too?

TWO MOST POWERFUL WORDS,
FOR WHAT YOU PUT AFTER THEM SHAPES YOUR REALITY.

Identification of Metal AM opportunities

Voor de volgende sessie

- Demonstrators voor Sessie II
- Bij voorkeur 3D files inbrengen met tekening waarop materiaal en toleranties aangegeven zijn.
- Naast ontwerpgegevens is de te verwachten productieomvang van belang.
- De voorbeelden dienen uiterlijk drie weken voor de tweede sessie door het NLR ontvangen te zijn.

Now @ MAMTeC

- Bringing Additive Manufacturing down to earth!

- From new idea to commercial product