1. Short Introduction Materialise
2. Design for Manufacturing / M3DP
3. General Design Process
4. Topology Optimization
5. Example
Materialise at a glance

- Growing our 3D printing expertise
- Speaking your language
- Passionate about innovation

- +1900 employees
- Offices in 18 countries
- +245 patents granted
- +180 patents pending
- +175 3D Printers
Fields of experience i.e. automotive
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Design for Manufacturing (DFM)

Concept / Idea

Manufacturing Process

- Manuf. time
- Manuf. restrictions
- Manuf. costs
- etc.

Design for manufacturing drivers

Final Product
Checklist for M3DP

- **Maximum dimensions:**
  - 250 x 250 x 250 mm (TiAl6V4)
  - 500 x 280 x 365 mm (AlSi10Mg)
  - 250 x 250 x 280 mm (316L / Inconel 718)

- High part complexity
- High price to weight ratio
- Long lead time for conventional manufacturing
- Single-item-production and small series < 500 pc. (possibly high tool costs for conventional manufacturing)
- Possible benefits for a product due to design freedom
- High demands on accuracy and surface quality only at specific interfaces
- Required material is AlSi10Mg, TiAl6V4, 316L or Inconel 718
Agenda

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General Design Process for Metal 3D Printing

1 General design process for Metal 3D Printing
   1.1 Definition of boundary conditions and requirements
   1.2 Definition of buildup strategies
   1.3 Preliminary design
   1.4 Final design

2 Manufacturing

Iterations possible
General Design Process for Metal 3D Printing

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Iterations possible
Case 1: Definition of Requirements

Requirements for surfaces A and B:
- High surface quality
- High dimensional accuracy
List of Requirements

- Avoid thinking about conventional manufacturing
  - Fewer boundaries present
  - Complexity for free!

- Define the requirements for interfaces as precisely as possible

- Try to define requirements that are achievable with M3DP directly
  - Reduction of:
    - Post machining efforts
    - The need for support structure
    - Costs and time

- Define the needed CAD file formats
General Design Process for Metal 3D Printing

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Iterations possible
Buildup Strategies – Basic Design Considerations

- Avoid material accumulations and large layers to be exposed
- Avoid notches and abrupt changes in wall thickness
- Minimize horizontal segments
- Prefer round or elliptical designs of material transitions
- Minimal wall thickness of 1 mm
- Consider an overhang angle $\geq 45^\circ$
Case 1: Orientation and Interfaces

Material: AlSi10Mg
Buildup direction: Z
Interfaces: Section A-A and B-B
Orientation assures:
- Highest possible quality of interfaces
- Low support volume
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Iterations possible
Cost Drivers for Metal 3D Printing

- Melted volume (EUR / ccm)
- Alloy (€: Ti > 316L > Al)
- Post machining
- Complexity for free! ➔ Freedom in design!
Self Supporting Structures

- Adequate part design can reduce the amount of necessary supports
- Tradeoff between additional part volume and post processing efforts
Case 1: Preliminary Design

Integration of angled geometry for self supporting

Deff ≥ Dcritical
Internal supporting would be necessary

Deff < Dcritical
Case 1: Reduction of Support Structures

Building platform

Variable radius to reduce stresses

$D_{\text{eff}} < D_{\text{critical}} = 8 \text{ mm}$
General Design Process for Metal 3D Printing

1. General design process for Metal 3D Printing
   1.1. Definition of boundary conditions and requirements
   1.2. Definition of buildup strategies
   1.3. Preliminary design
   1.4. Final design

2. Manufacturing

Iterations possible
Case 1: Final Design

- Radii at pipe to flange connection
- Final design of interfaces
Case 1: Final Design – Manufacturing File

Consider necessary offsets for post machining:

- Wire EDM
- Drilling of bores
- …
- Offset on all interfaces if specific surface accuracy is required.

1 mm optional offset

Offset on bores or close holes completely

Building platform
General Design Process for M3DP Case 1

1. General design process for Metal 3D Printing
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   1.4 Final design

2. Manufacturing

- Material, interfaces, surface quality
- Least support structure, complied with interfaces
- Design of cross section (no support necessary)
- Radii integration, interface design
- Addition of offsets for post processing
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Topology Optimization – General Aspects

- High lightweight potential
- Part design according to loading paths
- Reduction of manufacturing volume and time → Reduction of cost!
- Reduction of support structures
Topology Optimization – SIMP Approach

1. Initialize (Starting guess)
2. FEM Analysis
3. Sensitivity Analysis
4. Optimisation
5. Update design variable
6. Converged?
   - Yes: Plot results/post-processing
   - No: Reiterate

According to: Bendsoe
Topology Optimization – Conventional Bracket

Conventional Bracket Design

Material: AlSi10Mg
Mass: 470g
Preparation for topology optimization

Definition of design (grey) and non design space (blue)
- Accessibility of tools for bolting considered
- Mass: 1320 g

Constraints
- Supports in bottom bores
- Loads (F= 15 kN) in both upper bores (35° to perpendicular)
Topology Optimization – Optimization Result

Optimization parameters
- Maximize stiffness
- Mass target: 10% of previous mass

Optimization result
- Structure following load paths for this load case
Topology Optimization – M3DP Redesign

Main Design: Polynurbs or clay modeling based CAD tool

Smoothing + Interfaces: 3-matic STL
Topology Optimization – M3DP Redesign

Bracket properties

- Material: AlSi10Mg
- Mass: 160 g (mass reduction of 66%)
Bracket analysis

- Von Mises Stress < 170 MPa
  (Rp0.2 = 350 MPa)
- Displacement < 0.14 mm

More potentials in mass saving through further material reduction

- Generally higher von Mises Stress acceptable
- Especially in dark blue areas
Topology Optimization – Manufacturing Result
Topology Optimization and M3DP: Opportunities for Lightweight Design

Conventional Bracket → Design Space → Optimization Result

FE Analysis

155 MPa

165 MPa

Manufacturing

M3DP – Redesign

→ Conventional Design:
  - Material: AlSi10Mg
  - Mass: 470 g

→ M3DP Design:
  - Material: AlSi10Mg
  - Mass: 160 g

⇒ Weight Reduction: 66 %
Conclusion

- Not only highly complex parts are suitable for AM
- If production lot is in the right range, standard applications can be interesting if we do a re-design of the part.
- We want to offer serial production capacity to our clients.
- Main focus is „cost reduction“ for the client.
Thank you for your attention!