METAL 3D PRINTING TECHNOLOGY FOR TIRE MOULD SERIES PRODUCTION

Dipl.-Ing. Ralf Frohwerk
Global Head of Business Development
SLM applications are well known in the automotive market
3D metal printed brake caliper out of titanium
The Chiron is the most powerful, fastest and exclusive production super sports car

The largest functional component
3D printed out of titanium. Ti6Al4V (Grade23)

Tensile strength: 1250 N/mm²
Dimensions: 41 cm x 21 cm x 13.6 cm
2 kg lighter than its 4.9 kg machined aluminum counterpart.

Project in cooperation of:

Build on SLM500 Quad
Build time: 45h
No of Layers: 2213
SLM Part in Series Production for Bugatti Chiron!

- **Motor Bracket with integrated cooling channel**
- **Supplier:** [SLM Solutions](#) 
- **SOP - Start of Production (of the SLM part):** May 2016
- **Material:** AlSi10Mg
- **Build on:** SLM 280 Twin

The world's most powerful road car with 1500 Ps!
Tire vulcanization mould segment

Current tire mould design with one piece massive segments

New generation of tire mould design with additive 3D printed tread insert & standardized segment body

-Twin Shell Design-
SLM Solutions Group AG Company Update
Location and global sales, application and service footprint

- March 2016 enters TecDAX
- > 370 SLM machines installed globally
- > 380 employees global
- Global presence in 43 countries

Headquarters

SLM Solutions – Subsidiary

Distribution partners
NEW ! SLM Solutions Group AG – Headquarter – Lübeck

Launch: May 2018
Selective Laser Melting Technology & Process
Powder bed fusion: Selective Laser Melting (SLM) cyclic-process

1) Spreading powder material

2) Selective laser melting

3) Lowering of build chamber and new powder feeding

Finish part with support structure welded on the substrate plate
**Powder specifications for the SLM process**

- Spherical Particles
- $10 \, \mu m < \phi < 45 \, \mu m$
- $20 \, \mu m < \phi < 63 \, \mu m$ *(Alu & Titanium)*
- Good Flowability
- Dryness
- Pureness *(Chemistry)*

Finally, we can generally handle any weldable metal material in the SLM process!
SLM Solutions technology covers the most relevant metals...

<table>
<thead>
<tr>
<th>Material Properties</th>
<th>Alloys</th>
<th>Co-Alloys</th>
<th>Ni-Alloys</th>
<th>Ti-Alloys</th>
<th>Tool Steel and Stainless Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Light weight</td>
<td>High toughness</td>
<td>High corrosion resistance</td>
<td>High strength, low weight</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Good alloying properties</td>
<td>High strength</td>
<td>Excellent mech. strength</td>
<td>High corrosion resistance</td>
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<tr>
<td></td>
<td></td>
<td>Good processability</td>
<td>Good bio-compatibility</td>
<td>High creep rupture strength</td>
<td>Good bio-compatibility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(casting and pressing etc)</td>
<td>Good corrosion resistance</td>
<td>up to 700°C</td>
<td>Low thermal expansion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Good electrical conductivity</td>
<td>Outstanding weldability</td>
<td></td>
<td>Good machinability</td>
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<tr>
<td></td>
<td>AlSi12</td>
<td>CoCr28Mo6 (acc to ASTM F75)</td>
<td>Aerospace</td>
<td>Bio-material for implants</td>
<td></td>
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<tr>
<td></td>
<td>AlSi10Mg</td>
<td>SLM Medi-Dent</td>
<td>Medical implants</td>
<td>Aerospace</td>
<td></td>
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<tr>
<td></td>
<td>AlSi7Mg</td>
<td></td>
<td>High temperature</td>
<td>Gas turbines</td>
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<tr>
<td></td>
<td>AlSi9Cu3</td>
<td></td>
<td></td>
<td>Rocket motors</td>
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<tr>
<td></td>
<td>AlMg4.5Mn0.4</td>
<td></td>
<td></td>
<td>Nuclear reactors</td>
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<tr>
<td></td>
<td>Other materials on request</td>
<td></td>
<td></td>
<td>Pumps</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Turbo pump seals</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Tooling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IN 625</td>
<td>IN 718</td>
<td>HX (2.4665)</td>
<td>Pure Titanium</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ti6Al7Nb</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Ti6Al4V</td>
<td></td>
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<td>Grade X materials on request</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1.2709</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1.4404 (316L)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1.2344 (H 13)</td>
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<td></td>
<td></td>
<td></td>
<td>1.4540 (15-5PH)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1.4542 (17-4PH)</td>
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<td></td>
<td>Other materials on request</td>
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</tr>
</tbody>
</table>
Provider of integrated system solutions – product portfolio

Key products

- SLM 125
- SLM 280
- SLM 500
- SLM 800

Other
SLM Solutions – Key products

**SLM 125**
Build Chamber: 125 x 125 x 125mm
Laser – Single: 1 x 400 W

**SLM 280 – 2.0 NEW!**
Build Chamber: 280 x 280 x 365mm
Laser – Single: 1 x 400 W or 700 W
Laser – Twin: 2 x 400 W or 700 W

**SLM 500**
Build Chamber: 500 x 280 x 365mm
Laser – Twin: 2 x 400W or 700W
Laser – Quad: 4 x 400W or 700W
Build rate: up to 171 cm³/h

(a) Depending on material and build part geometry

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PRS – Part Removal Station
PSV – Powder Sieving & Feeding Station
**SLM 500<sup>HL</sup> - Quad Scan-Head (clone and independent)**

**Optical Design for multiple QUAD production**

Fibre laser 4 x 400W
SM „Gaus“ Profile
3D Scan-Optic without F-Theta

Overlap areas with the same high density and mechanical properties compared to single scanner/laser area?

**YES!**
FIT AG – Germany – 14 x SLM 500 for series mass production
SLM 280 V2.0 - Next Generation of AM Production!

The fully new designed SLM 280 V2.0 with more than 90 improvements!

- Build envelope of 280 x 280 x 365 mm
  App. 25% larger build envelope than other mid-size machines

- 2 x 400W or 700W Quad laser technology – simultaneously

- Higher productivity
  - 20% more productivity due to tougher possible parameter
  - 30% more productivity due to 700Watt Laser option

- Overlapping areas with homogenous metal structure

- Patented bidirectional recoating system

- Build Speed up to 88 cm³/h (Quad – Aluminium Alloy)

- Open software architecture

- PSV – Powder Sieving & Feeding Station - 90 l powder tank
  The continuous metal powder feeding is done under inert gas atmosphere
Case Study
Tire Mould Segments
Die cast tool with conformal cooling inserts

Advantages of conformal cooling inserts
- Improved surface of the die cast part
- Reduction of releasing agent
- Longer tooling life time
- Less material stress in the die cast part
- Shorter cooling of period > shorter cycle time

In this case:
Cooling time from 12 s to 5 s (60%) > total cycle time reduction = 12 %
New generation of tire mould design with additive 3D printed tread insert & standardized segment body
-Twin Shell Design-

- Production of the tread insert only, which is app. 20% of the total segment
- Standardized segment body
- The rear side of the tread insert can be convex or flat or customized design
- Improved tire functionality by means of optimized 3-dim. blades/lamellas

- Material: Aluminium - AlSi10Mg
- Material: Tool steel - 1.2709
- Material: Stainless steel - 1.4404 (316 L)
- Material: Stainless steel - 1.4542 (17-4PH)
### Tire Vulcanization Mould Segments

**10 Tire mould „half segments“ on SLM 500 Quad – 400W**

<table>
<thead>
<tr>
<th>SLM 500 Quad - 400 W</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material:</strong></td>
<td>Tool Steel 1.2709</td>
</tr>
<tr>
<td>Layer Thickness</td>
<td>50 µm</td>
</tr>
<tr>
<td>Build time SLM 280 TWIN</td>
<td>54h 15min (10 x half segments)</td>
</tr>
<tr>
<td><strong>Material:</strong></td>
<td>Aluminium Alloy AlSi10Mg</td>
</tr>
<tr>
<td>Layer Thickness</td>
<td>50 µm</td>
</tr>
<tr>
<td>Build time SLM 280 TWIN</td>
<td>23h 15min (10 x half segments)</td>
</tr>
</tbody>
</table>

**1x total PCR mould**

with 8 x segments, which means 16 x „half segments“ can produce in

**1.2709 = less than 4 days**

**AlSi 10 Mg = less than 2 days**
Sipes production on SLM 280 V2.0 Single vs. Twin in 30 & 50 µm

2 x designs (416 pc and 439 pc) in total 855 sipes

### SLM 280 - 400 W

<table>
<thead>
<tr>
<th>Material:</th>
<th>Tool Steel 1.2709</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part volume</td>
<td>155.672 mm³</td>
</tr>
<tr>
<td>Build height (z-axis)</td>
<td>25 mm</td>
</tr>
<tr>
<td>Build time SLM 280 Single /30µm</td>
<td>32h 49min</td>
</tr>
<tr>
<td>Build time SLM 280 Single /50µm</td>
<td>22h 2min</td>
</tr>
<tr>
<td>Build time SLM 280 Twin /30µm</td>
<td>17h 31min</td>
</tr>
<tr>
<td>Build time SLM 280 Twin /50µm</td>
<td>12h 45min</td>
</tr>
</tbody>
</table>

- 62 %
Tire mould segment (Retreading)

3 D printed - SLM segment

Casting segment
3D printed tire mould segment as „Ventless Twin Shell®“

Micro-slots evacuate air but block rubber

- Well-known air evacuation functionality from the puzzle mould
- Micro-slots in solid tread shell made by Avonisys Laser-Micro-Milling
- Mould cost saving potential of up to 50%

1) Laser post-process
2) Micro-slots in tread
3) Cured rubber print

Micro-slots < 0.05mm

SLM Solutions Group AG presentation – Global Retreading Conference at the TTC on 29th May 2018 – Ralf Frohwerk
The way of success!

- **Twin Shell tire mould design:** with volume minimized tread segment
- **Functional integration:** optimized 3-dimensional geometries slits
- **Optimized tread segment split:** in multi pieces with efficient orientation on build platform
- **Productivity:** Multi-laser technology, up to 4 x 700W with a beam focus 80 µm
- **Safety:** Closed-loop powder management under inert gas
- **Accuracy & low surface roughness:** Open system architecture - efficient optimization of your build scan strategy
Thank you for your attention!
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