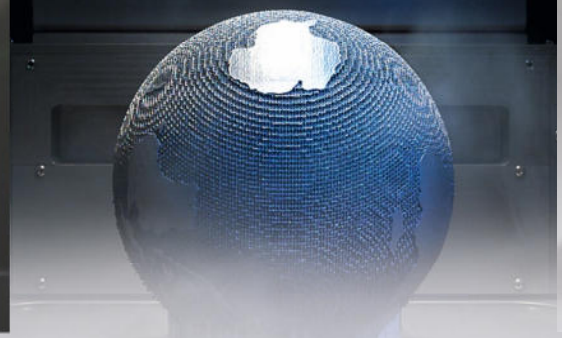
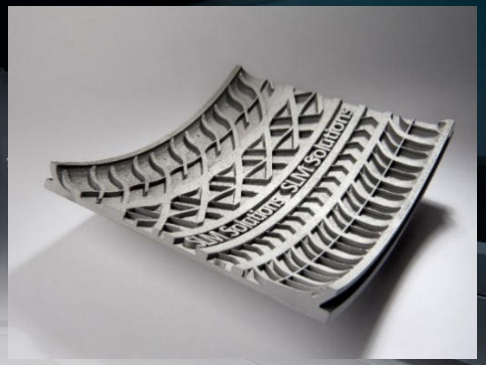
METAL 3D PRINTING TECHNOLOGY FOR TIRE MOULD SERIES PRODUCTION

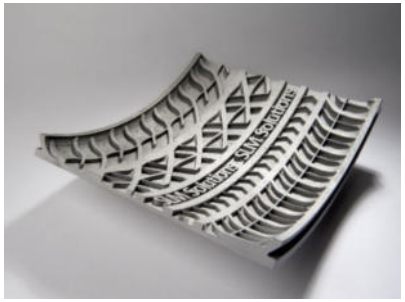




Dipl.-Ing. Ralf Frohwerk
Global Head of Business Development

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.

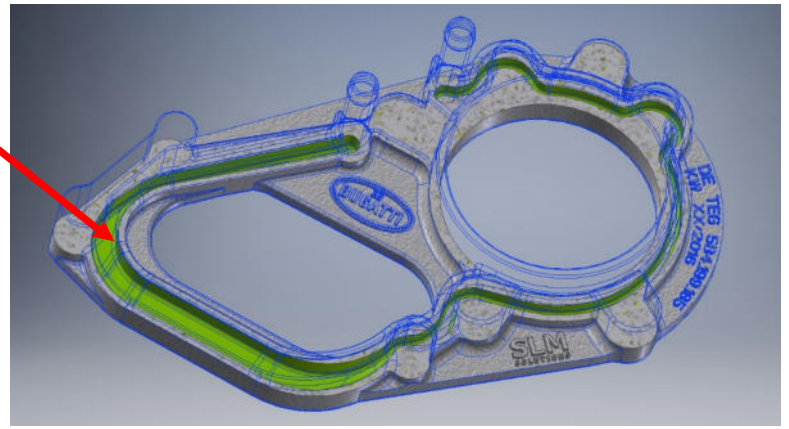
Project in cooperation of:

LZN Fraunhofer IAPT BIONIC PRODUCTION BUGATTI

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 ⇔ Rolf Lenk Werkzeug- und Maschinenbau GmbH
- **SOP - Start of Production (of the SLM part): May 2016**
- **Material: AlSi10Mg**
- **Build on: SLM 280 Twin**



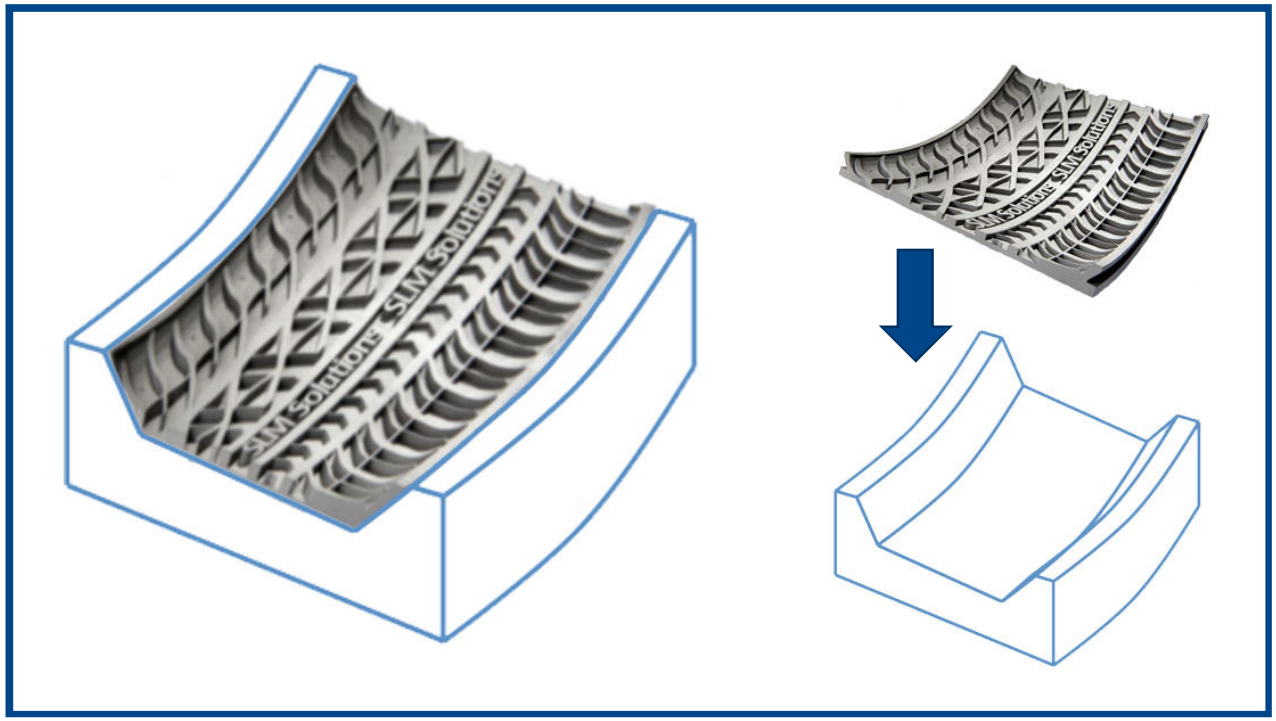
The world's most powerful road car with 1500 Ps !

Tire vulcanization mould segment

Current tire mould design with one piece massive segments

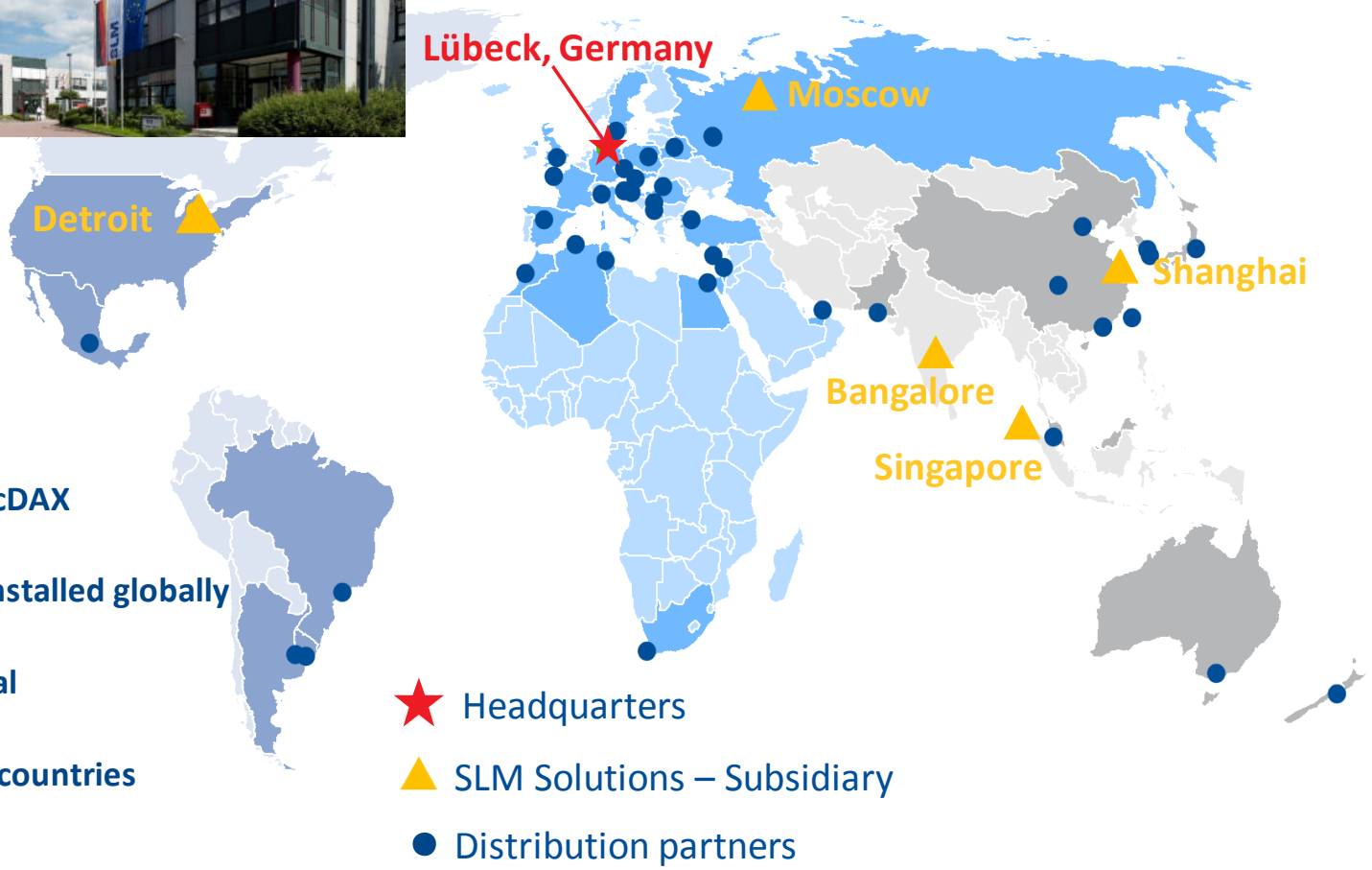
New generation of tire mould design with additive 3D printed tread insert & standardized segment body

-Twin Shell Design -



SLM Solutions Group AG
Company Update

Location and global sales, application and service footprint



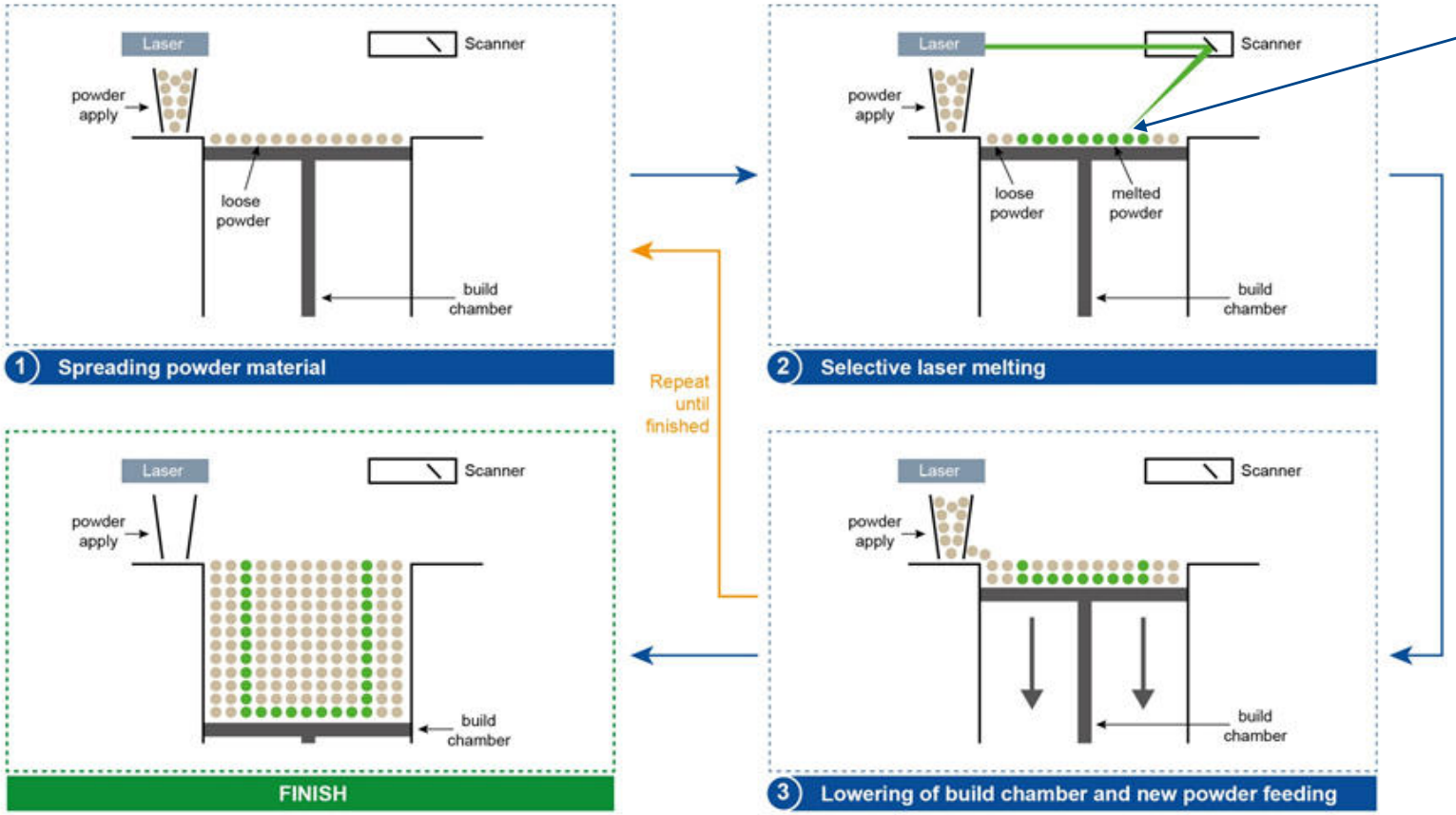
- March 2016 enters TecDAX
- > 370 SLM machines installed globally
- > 380 employees global
- Global presence in 43 countries

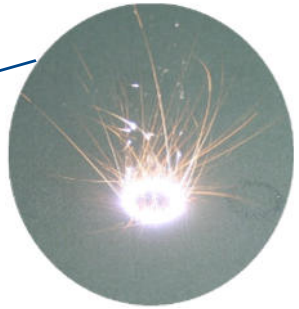
NEW ! SLM Solutions Group AG – Headquarter – Lübeck

Launch: May 2018

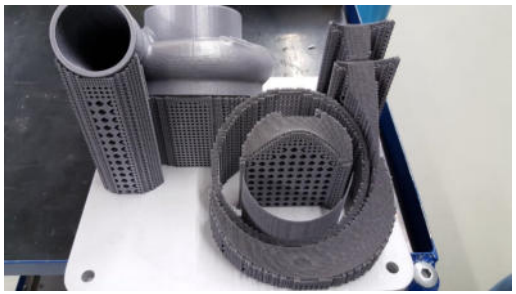
Selective Laser Melting Technology & Process

Powder bed fusion: Selective Laser Melting (SLM) cyclic-process



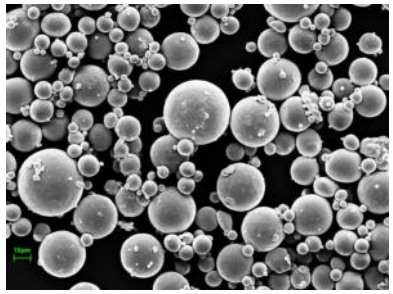
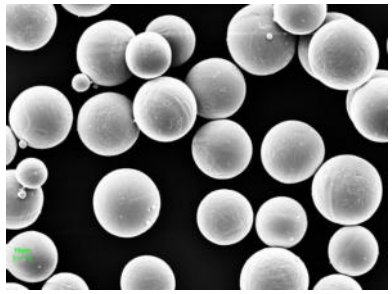
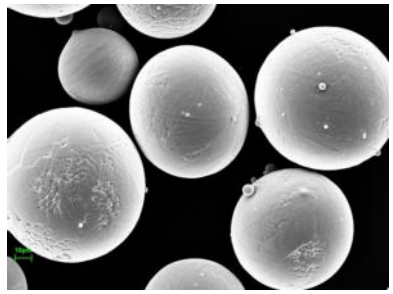


Finish part with support structure welded on the substrate plate



Powder specifications for the SLM process

- Spherical Particles
- 10 µm < ø < 45 µm
- 20 µm < ø < 63 µm (Alu & Titanium)
- Good Flowability
- Dryness
- Pureness (Chemistry)

Finally,we can generally handle any weld able metal material in the SLM process!

SLM Solutions technology covers the most relevant metals…

	Al-Alloys	Co-Alloys	Ni-Alloys	Ti-Alloys	Tool Steel and Stainless Steel
Material Properties	■ Light weight ■ Good alloying properties ■ Good processability (casting and pressing etc) ■ Good electrical conductivity	■ High toughness ■ High strength ■ Good bio-compatibility ■ Good corrosion resistance	■ High corrosion resistance ■ Excellent mech.strength ■ High creep rupture strength up to 700°C ■ Outstanding weldability	■ High strength, low weight ■ High corrosion resistance ■ Good bio-compatibility ■ Low thermal expansion ■ Good machinability	■ High hardness and toughness ■ High corrosion resistance ■ Good machinability
Applications	■ Aerospace ■ Automotive ■ General industrial applications	■ Dental ■ Medical implants ■ High temperature	■ Aerospace ■ Gas turbines ■ Rocket motors ■ Nuclear reactors ■ Pumps ■ Turbo pump seals ■ Tooling	■ Bio-material for implants ■ Aerospace ■ F1 motor sport ■ Maritime applications	■ Plastic injection and pressure diecasting moulds ■ Medical implants ■ Cutlery and kitchenware ■ Maritime ■ Spindles and screws
Alloys	■ **AlSi12** ■ **AlSi10Mg** ■ **AlSi7Mg** ■ **AlSi9Cu3** ■ **AlMg4.5Mn0.4** Other materials on request	■ **CoCr28Mo6 (acc to ASTM F75)** ■ **SLM Medi-Dent**	■ **IN 625** ■ **IN 718** ■ **HX (2.4665)**	■ **Pure Titanium** ■ **Ti6Al7Nb** ■ **Ti6Al4V** ■ Grade X materials on request	■ **1.2709** ■ **1.4404 (316L)** ■ **1.2344 (H 13)** ■ **1.4540 (15-5PH)** ■ **1.4542 (17-4PH)** Other materials on request

SLM Machine Products

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

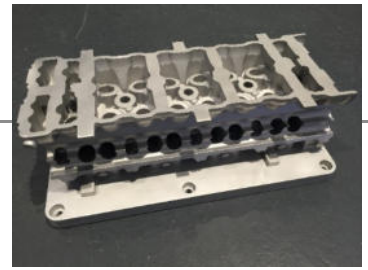
Laser – Quad: 4 x 400W or 700W **Build rate: up to 171 cm3/h(a)**

(a) Depending on material and build part geometry

PSV – Powder Sieving & Feeding Station

PRS – Part Removal Station

SLM 500^{HL} - Quad Scan-Head (clone and independent)

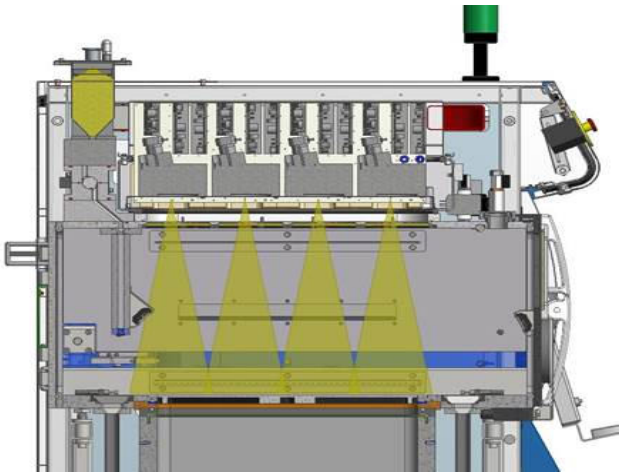


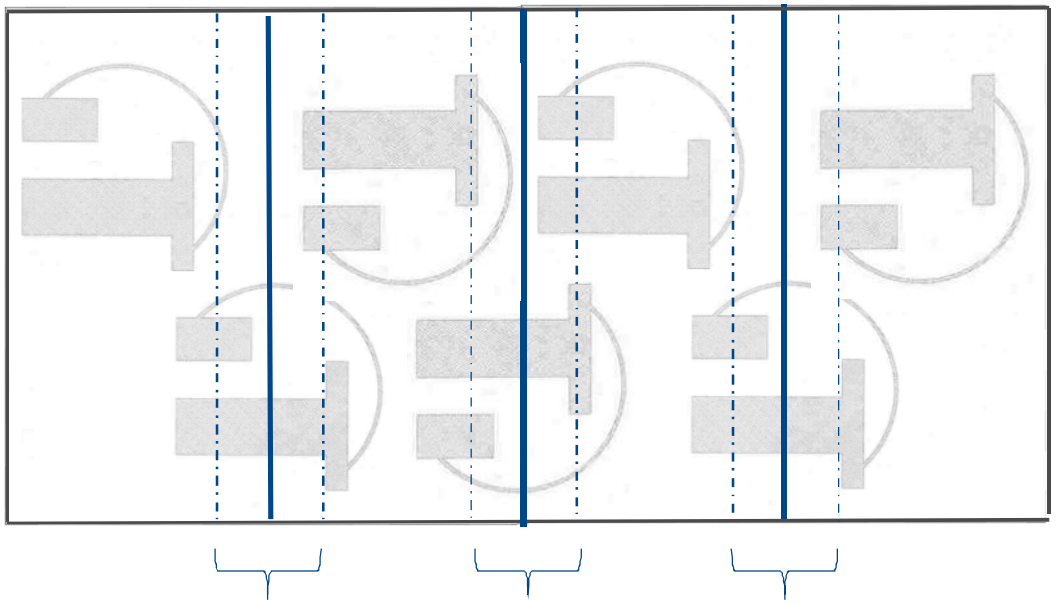
Optical Design for multiple QUAD production

Fibre laser 4 x 400W

SM „Gaus“ Profile

3D Scan-Optic without F-Theta

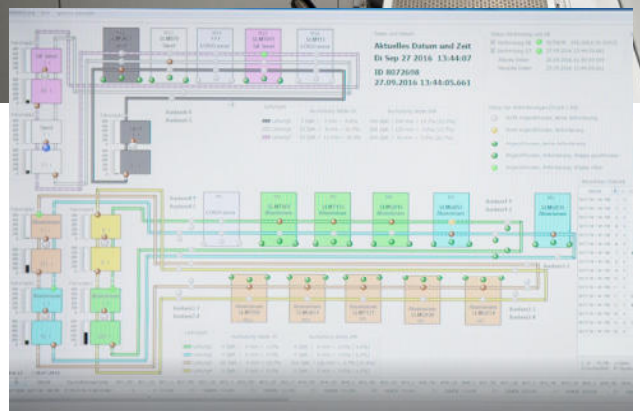




Overlap areas with the same high density and mechanical properties compared to single scanner/laser area?

YES!

FIT AG – Germany – 14 x SLM 500 for series mass production



FIT
ADDITIVE MANUFACTURING GROUP

SLM 280 V2.0 - Next Generation of AM Production!

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

Higher part quality due to improved gas flow system !

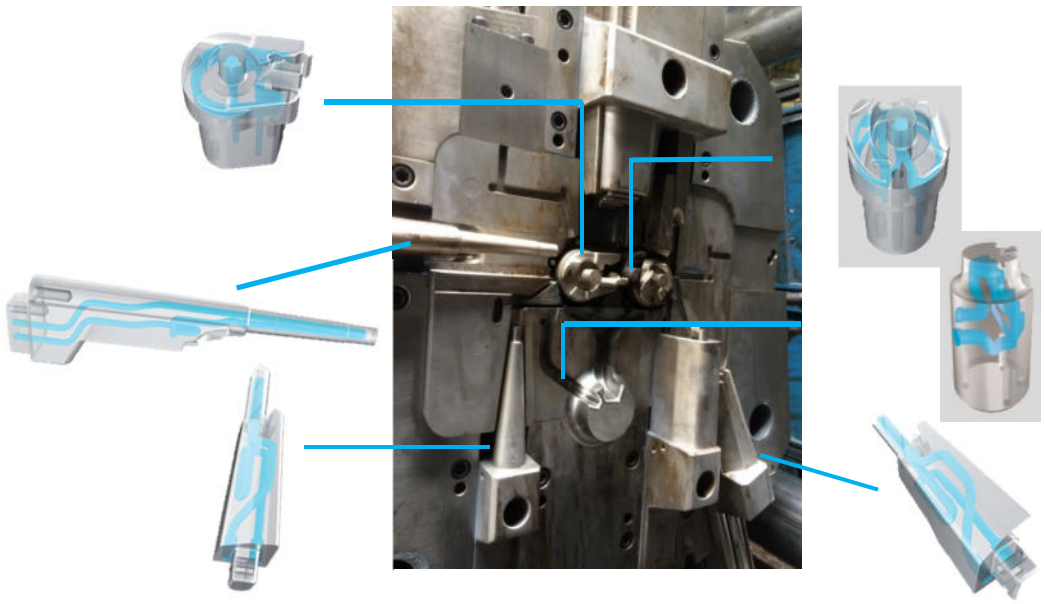
- Build envelope of 280 x 280 x 365 mm

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 cm^3/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

Build on SLM 280 Twin

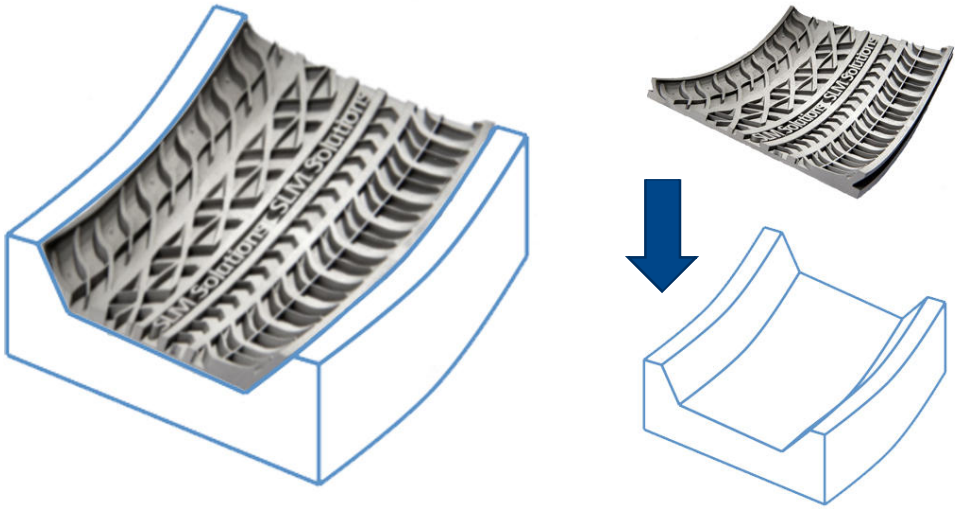
In this case:

Cooling time from 12 s to 5 s (60%) > total cycle time reduction = 12 %

Tire mould – „Twin Shell Design“ out of SLM process

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

-Twin Shell Design -

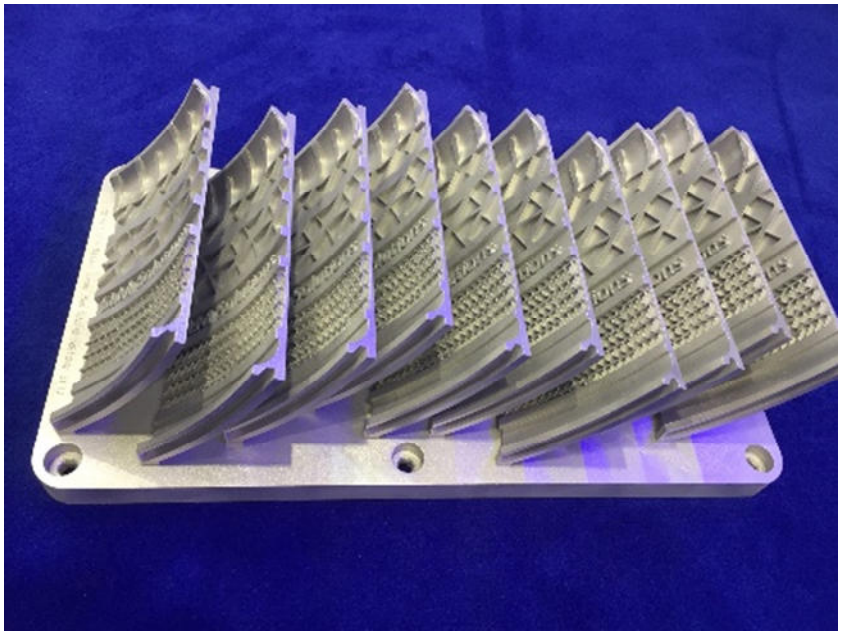


- **Production of the tread insert only,** which is app. 20 % of the total segment
- **Standardized segment body**
- **The rear side** of the tread insert can be convex or flat or customized design
- **Improved tire functionality** by means optimized 3 -dim. blades/ lamellas

- **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-produced on SLM 500 Quad

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

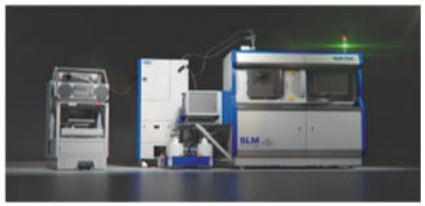


SLM 500 Quad - 400 W	
Material:	**Tool Steel 1.2709**
Layer Thickness	50 µm
Build time SLM 280 TWIN	**54h 15min** (10 x half segments)
Material:	**Aluminium Alloy AlSi10Mg**
Layer Thickness	50 µm
Build time SLM 280 TWIN	**23h 15min** (10 x half segments)

1x total PCR mould
with 8 x segments, which means 16 x „half segments“ can produce in

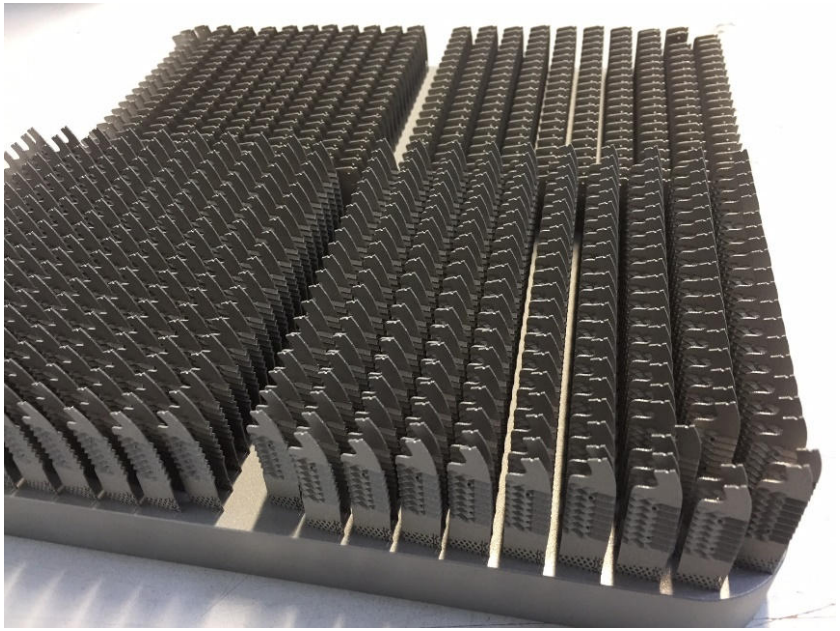
1.2709 = less than 4 days

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

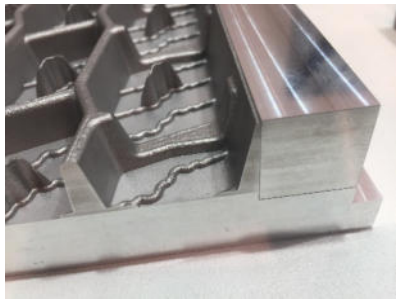


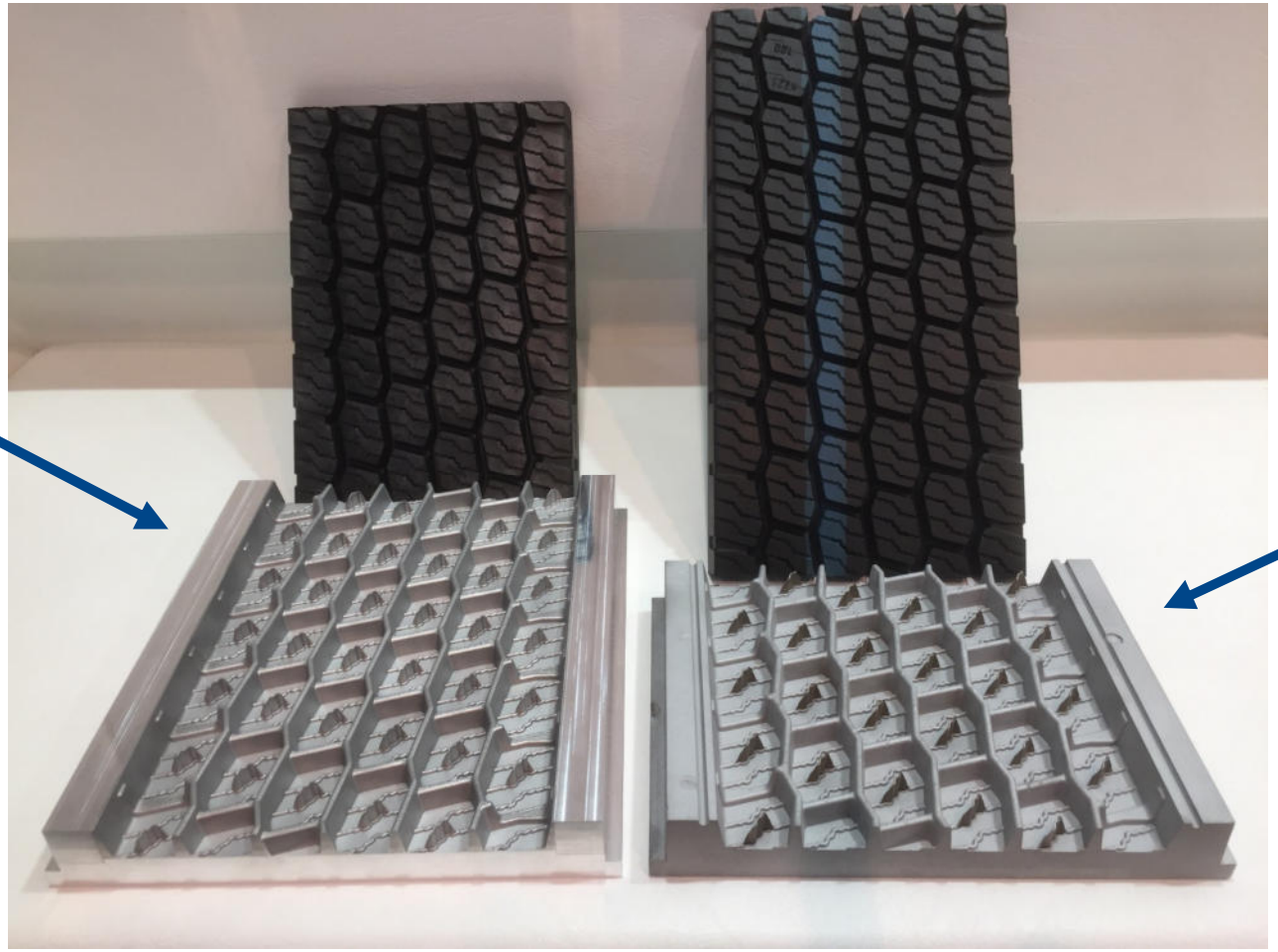
SLM 280 - 400 W	
Material:	**Tool Steel 1.2709**
Part volume	**155.672 mm³**
Build height (z-axis)	**25 mm**
Build time SLM 280 Single /30µm	32h 49min
Build time SLM 280 Single /50µm	22h 2min
Build time SLM 280 Twin /30µm	17h 31min
Build time SLM 280 Twin /50µm	12h 45min

- 62 %

Tire mould segment (Retreading)

3 D printed - SLM segment

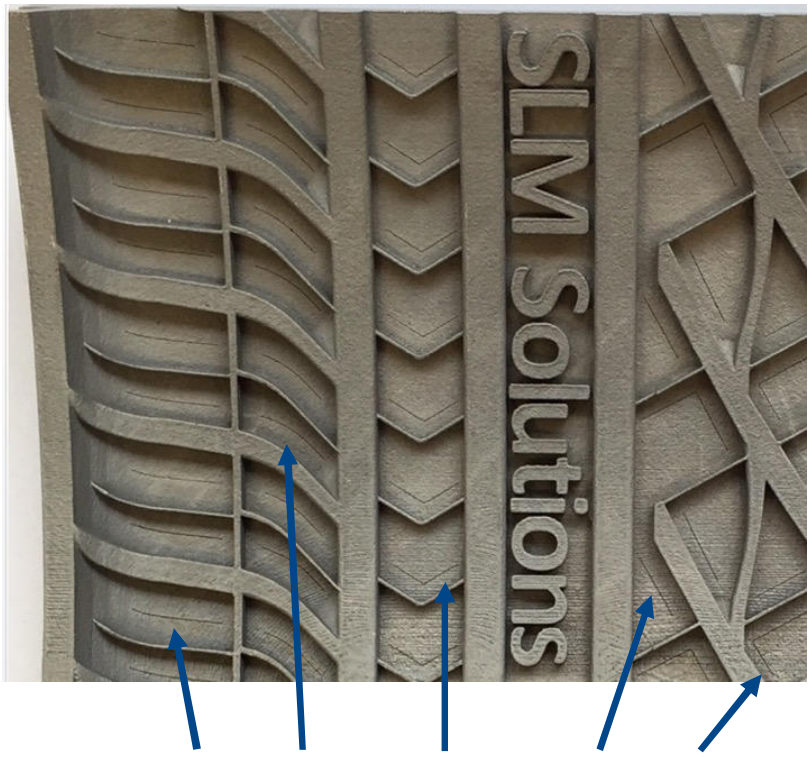




Casting segment

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

Micro-slots evacuate air but block rubber



Micro-slots < 0.05mm

1) Laser post-process

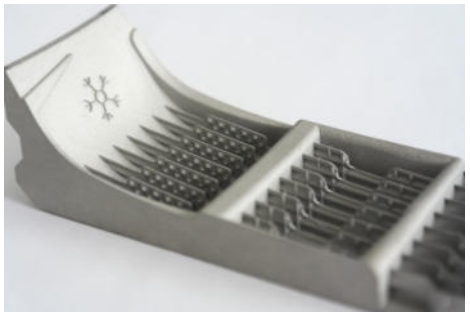
2) Micro-slots in tread

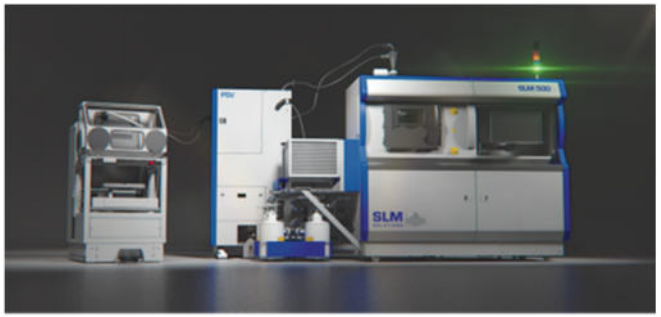
3) Cured rubber print

- 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%

The way of success!

- **Twin Shell tire mould design:** with volume minimized tread segment
- **Functional integration:** optimized 3 -dimensional geometries slits
- **Optimzed 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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