SLM SOLUTIONS

The Aluminium Industry meets the future with integrated 3D printing

ALUMINIUM Conference 2022

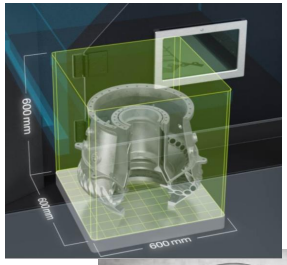
Alexander Braune – Application Eng. Manager

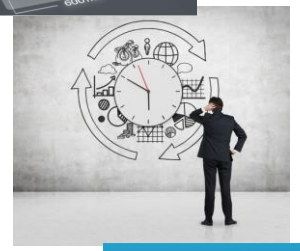
27.09.2022

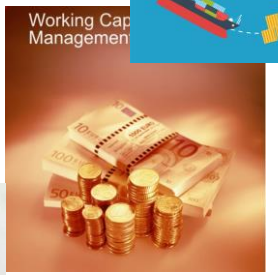
Customer Value of AM

Additive Manufacturing

- **Large Build Volume:** Produce highly complex components with sizes up to 600x600x600 mm with highest productivity based on 12x1000W laser power
- **Reduced Cycle Time:** Produce prototypes, end-use parts or spare parts within days instead of weeks/months, eliminating the need for tooling in many cases
- **Global Supply Chain:** Reduce global supply chain challenges by producing your parts locally. Only produce your parts when and where you need them
- **Working Capital:** Reduce your inventory and associated working capital with just-in-time production
- **Sustainability:** Reduce carbon emissions, energy costs and waste







Potential of Additive Manufacturing at Porsche

Industrialization Goals of Metal AM

In Automotive

Profitability

Cost per Part

Part Quality

Acc. IATF 16949

Safety

Industrial Standard

Part Design

Added Value

Repeatability & Sustainability“

SLM Solutions is acting as a solution provider and enables OEMs as well as Tier1 suppliers to realize their metal AM business cases for series production

Technology Pioneers to Market Leaders

- **Co-inventor of Selective Laser Melting Technology in 1996**
- **First to the market with multi-laser systems for industry leading build rates**
  - Dual laser SLM®280 in 2011
  - Quad laser SLM®500 in 2013
  - 12 laser machine: NXG XII 600 in 2020
- **Patented innovations increase productivity and quality**
  - Bi-directional recoating process
    - Minimize laser off-time
  - Multi laser overlap stitching
    - Seamless builds with multiple lasers
  - Sintered wall gas flow
    - Minimized variation of material properties
- **Focus on system safety**
  - Closed-loop powder handling

Specializing in Metal

SLM Solutions co-invented Selective Laser Melting and the expert advancement of that technology is all we focus on

SLM Solutions Headquarter

Lübeck | Germany

- **24,000 m2 headquarters and production facility in Lübeck, Germany**
- Co-inventor of Selective Laser Melting Technology in 1996
- Technology Pioneers:
  - 12 laser machine: NXG XII 600 in 2020
- Application Engineering
- Consulting and Applications Support
- Customer Support & Training
- Installation, Maintenance & Service

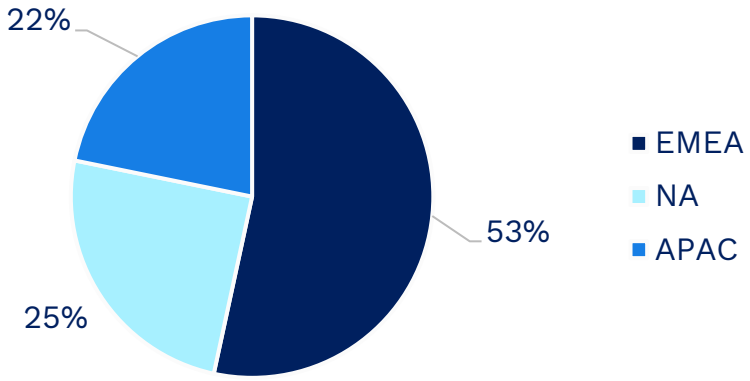
Application Center

Production hall

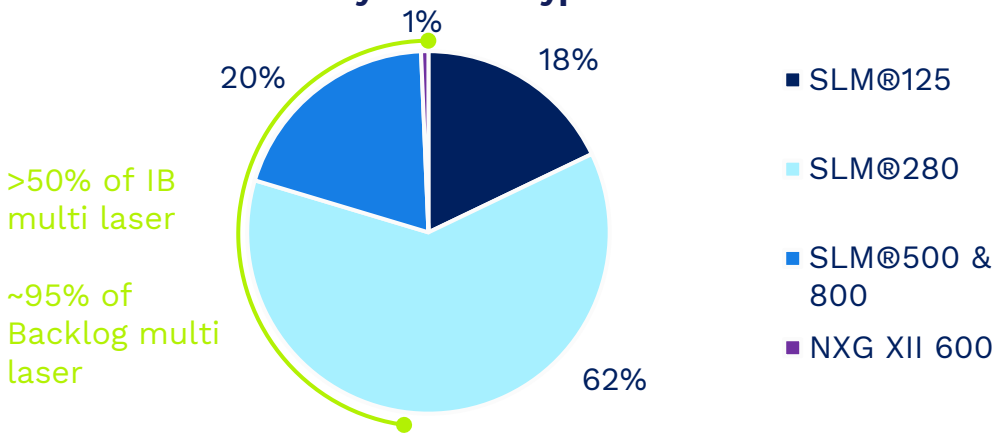
>750 machines installed globally

Serving a broad range of blue chip customers

Installed base by region



Installed base by machine type



Source: SLM
Note: Installed machine base as of Feb 2022

Serving more than 150 blue chip customers

including **Fortune 500** companies, **Dax30** companies, some of the **largest OEMs** as well as leaders in **space exploration**, **aviation**, **electro mobility**, **motor racing**, **science**, and many more...

Rolls-Royce · EMERSON · BLUE ORIGIN · Honeywell · AIRBUS · BOEING · Baker Hughes · SAFRAN · BMW · MAHLE · NASA · MAN Energy Solutions · BOSCH · Collins Aerospace

Industry Expertise

Automotive

- **First metal AM components in serial production** of luxury cars will accelerate adoption and push development in mass production
- **AM technology enable OEM`s to realize flexible production lines** to adapt to customized car programs and shorter time-frame model updates
- **New alloys,** such as high-temperature resistant aluminum alloys, open new applications
- **Based on AM design, newest E-Drive Technology** with lattice structures to reduce the weight, functional integration of cooling channels, higher stiffness and reduced assembly time by the integration of parts as well as improvements in part quality is realized
- **Tire mold industry** is using the design freedom of metal AM technology to improve the functionality of the tire.

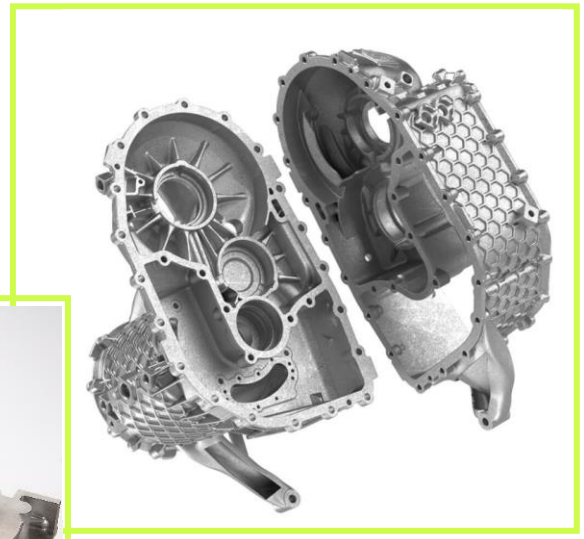
BMW

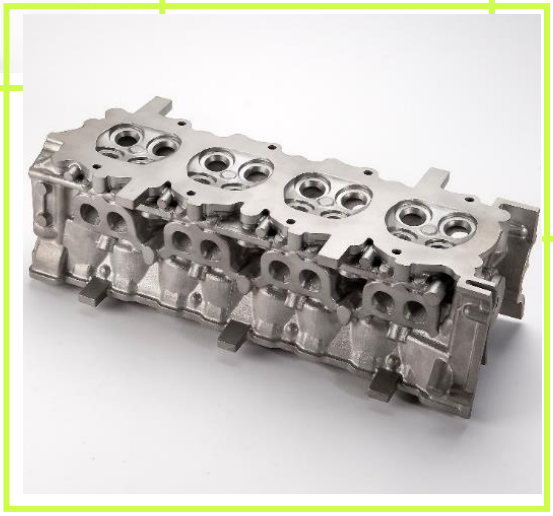
“Additive Manufacturing Campus”

Munich / Germany

Powertrain Application: Aluminium Alloy

- SLM applications are well known in the automotive industry, in achieving consistent function integration and significant performance optimization of components

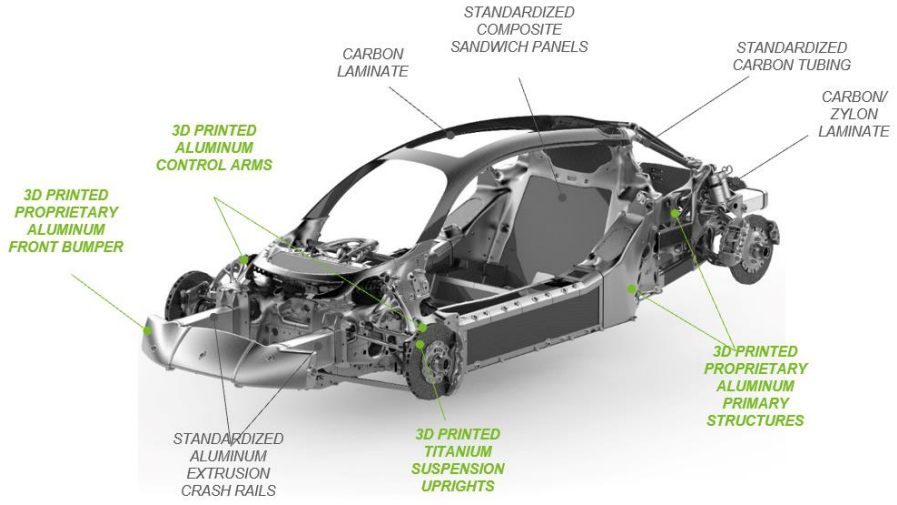


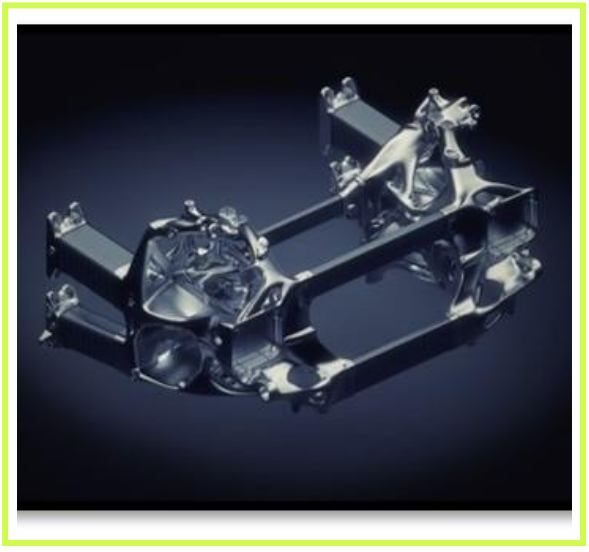


Body & Chassis Application

Divergent

- More durable; stronger and stiffer; 20-60% lighter for increased power to weight and efficiency





Czinger 21C

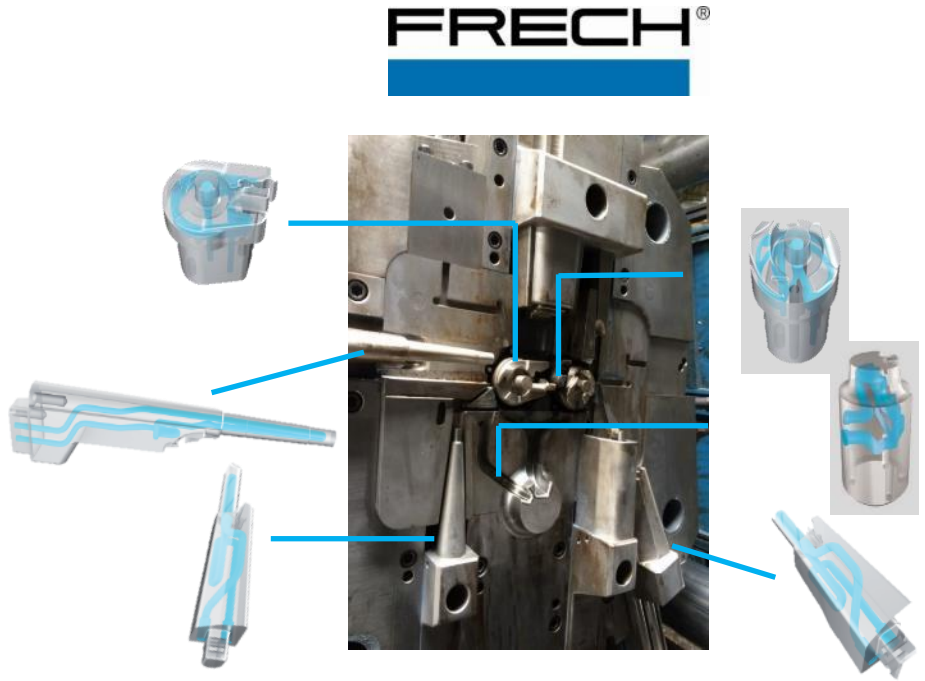
DIVERGENT

Iconic Design. Revolutionary Technology. Dominating Performance. Sustainable System.

Die Cast Tool with Conformal Cooling Inserts

Advantages:

1. Improved surface of the die cast part
2. Reduction of releasing agent
3. Longer tooling life time
4. Less material stress in the die cast part
5. Shorter cooling of period > shorter cycle time



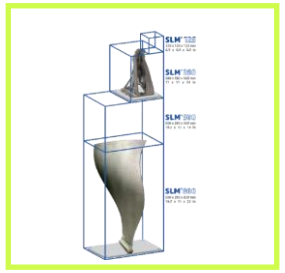
- **Cooling time from 12s to 5s (60%)**
- **Total cycle time reduction of 12%**

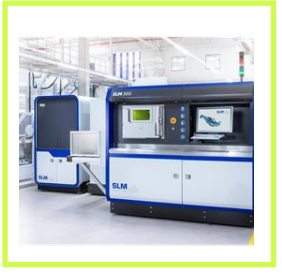
State of the Arts Metal Powders

ALUMINIUM ALLOYS	TOOL AND STAINLESS STELL	NICKEL ALLOYS	TITANIUM ALLOYS	COBALT ALLOYS	COPPER ALLOYS
AlSi10Mg	1.2709	IN625	Ti Gd.II	CoCr28Mo6	CuSn10 Bronze
AlSi7Mg	1.4404 (316L)	IN718	Ti6Al4V Grade 23	SLM® Medi-Dent	CuNi2SiCr
AlSi9Cu3	1.2344 (H13)	IN939	Ti6Al4V Grade 5	Other Materials on Request	CuCr1Zr
Other Materials on Request	1.4545 (15-5PH)	HX (2.4665)	TA15		Other Materials on Request
	1.4545 (15-5PH)	Other Materials on Request	Other Materials on Request		
	Invar 36®				
	Other Materials on Request				

QUALIFIED MATERIAL SOLUTIONS

Our experts continuously collaborate with customers to develop new alloys optimized for selective laser melting and qualified parameters perfectly paired with our powder

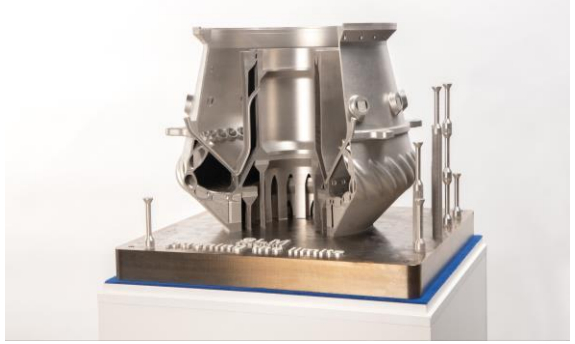




	SLM®125	SLM®280	SLM®500	SLM®800	NXG XII 600
Build Envelope	125 x 125 x 125 mm 4.9 x 4.9 x 4.9 in	280 x 280 x 365 mm 11 x 11 x 14 in	500 x 280 x 365 mm 19.7 x 11 x 4 in	500 x 280 x 850 mm 19.7 x 11 x 33 in	600 x 600 x 600 mm
Laser Configuration	Single (1x 400W)	Single (1x 400W / 700W) Twin (2x 400W / 700W) Dual (1x 700W & 1x 1000W)	Twin (2x 400W / 700W) Quad (4x 400W / 700W)	Quad (4x 400W / 700W)	12 x 1000W
Build Rate	up to 25cm^3/h	up to 88cm^3/h	up to 171cm^3/h	up to 171cm^3/h	**5x faster compared to a Quad Laser System**

NXG XII600 – 12 x 1000W

Engine Midframe – Inconel 718



Success Story: 4 Cylinder Head

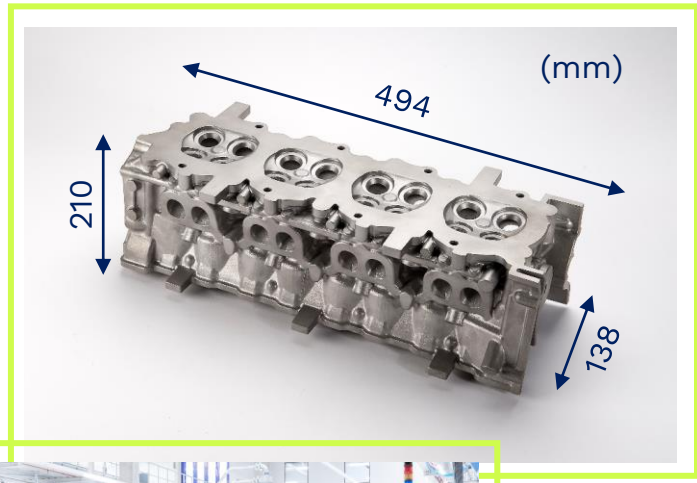
SLM® 500 Quad-700W – 90µm

Material Data Sheet

Al-Alloy AlSi10Mg[1]

90 µm / 700 W[9]				As-built	
Build-up rate[10]		[cm³/h]		86.0 cm³/h	
Component density[11]		[%]		≥ 99.0 %	
Tensile test[12]				M	SD
Tensile strength	R_m	[MPa]	H	398	5
			V	380	16
Offset yield strength	$R_{p0.2}$	[MPa]	H	230	3
			V	206	4
Elongation at break	A	[%]	H	7	1
			V	5	1
Reduction of area	Z	[%]	H	6	1
			V	4	2
Young's modulus	E	[GPa]	H	67	8
			V	65	4
Hardness test[13]				M	SD
Vickers hardness		HV5		112	2

Roughness measurement[14]			As-built		Corundum blasted		Glass-bead blasted	
			M	SD	M	SD	M	SD
Roughness average	Ra	[µm]	13	1	9	1	7	1
Mean roughness depth	Rz	[µm]	76	7	47	4	37	4



Material: AlSi10Mg

Part weight, without support: 13,9 Kg

Layer thickness: 90 µm – **Part build time: 27 h**

Build rate: 194 cm³/ h

AM Components in Series Luxury Chassis

BMW - Group

- **Innovation:**

  Topologically and production process optimized

- **Serial Production:**

  Produced on a qualified SLM®500 machine around the clock

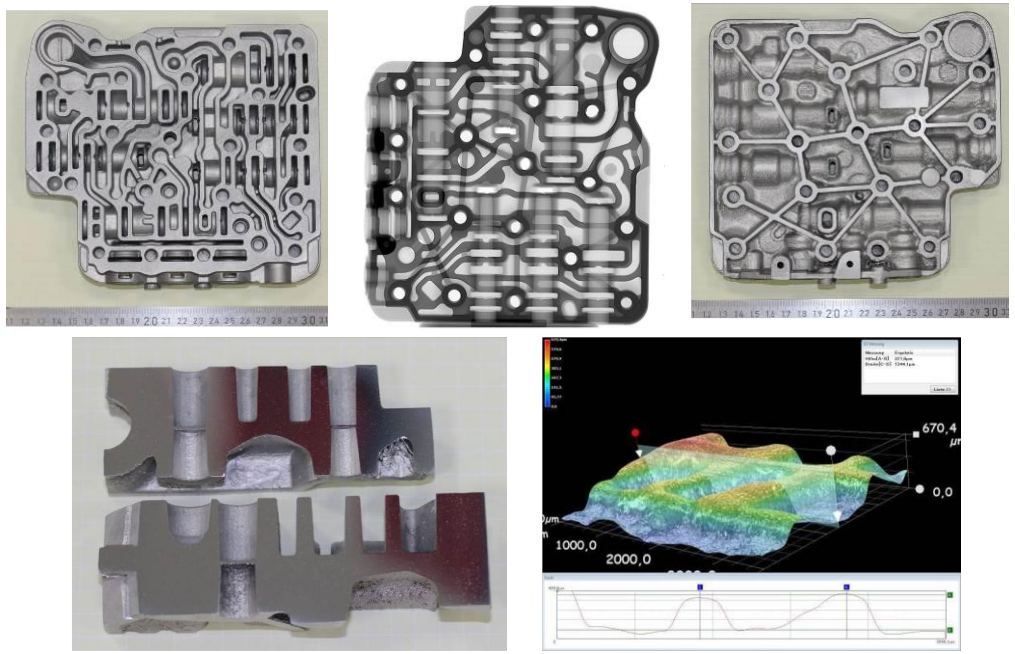
At the **Plant in Landshut, BMW** has brought the AM process into the body & chassis and welded the parts into an intelligent mixed construction

Hydraulic control unit

CVT transmission

Comparison: Die cast vs. SLM®process

- Material: AlSi9Cu3
- Weight: 930g
- Build Time: 5,5 h/pc
- Surface Roughness ✓
- Surface Flatness < 0,4 ✓
- Tolerances < +/- 0,2 ✓
- X-Ray Analysis ✓
- Density ✓
- Hardness ✓
- Tensile Strength ✓



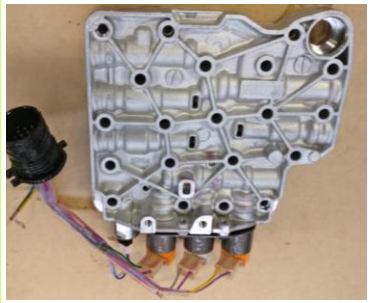
SLM®technology provide equal or better material properties as die cast

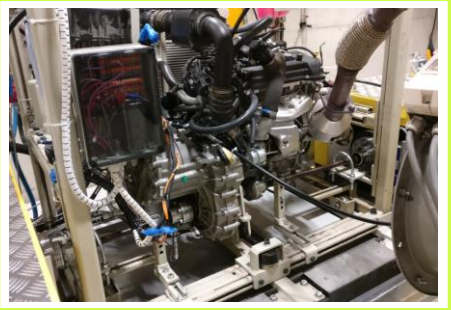
Hydraulic control unit

CVT transmission

Durability test

- Completed with a machined and preassembled hydraulic control unit and tested in a CVT transmission
- This test represents the lifetime of the transmission in the car, 60.000km on a test bench
- Test cycle: 10 - 120°C, 6 wks. 24h/day
- After the test, the part was dimensionally and functionally OK ✓

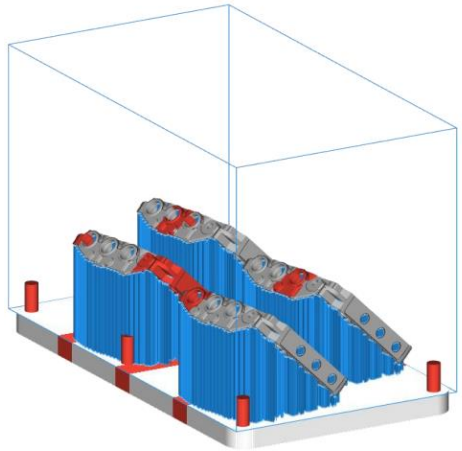


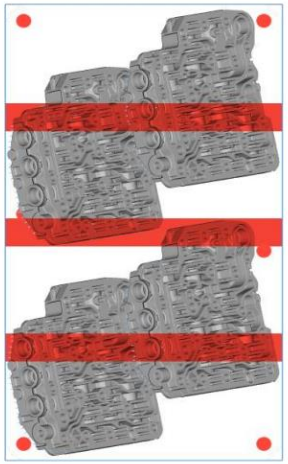


AM printed hydraulic control unit passed lifetime durability test

Hydraulic control unit

AlSi10Mg printed on SLM®500 Quad





Conventional Production
for Prototype in Sand Cast
Tool cost: app: 20 t€

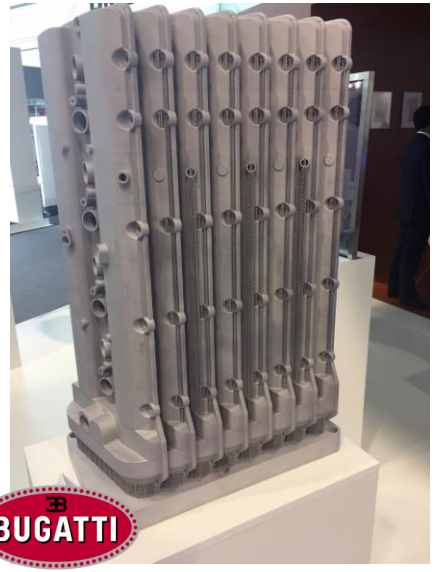
Covered app. 70 AM parts

Layer Thickness/Laser Power	30µm/400W	60µm/400W	60µm/700W	90µm/700W
Build Time - total (4pc)	49 h	29 h	22	22h
Build Time for 1 part	12,3 h	7,3 h	6,5 h	5,5 h
Production cost for 1 part	525,- €	347,- €	322,- €	288,- €

Productivity Comparision: SLM®500 Quad 400W-30 µm vs. SLM®500 Quad 700W-90 µm

Build time reduction: - 55 %
Part cost reduction: - 45 %

SLM®800 Application`s



Cam Cover W16

AlSi10Mg

60 µm layer thickness

4d 7h 42min build time

8 piece fully loaded plate

SLM®800

Vertical build part orientation for long **components up to 850 mm**

- Reduced internal stresses
- Higher surface quality
- Higher flatness

DIVERGENT

Suspension Arm

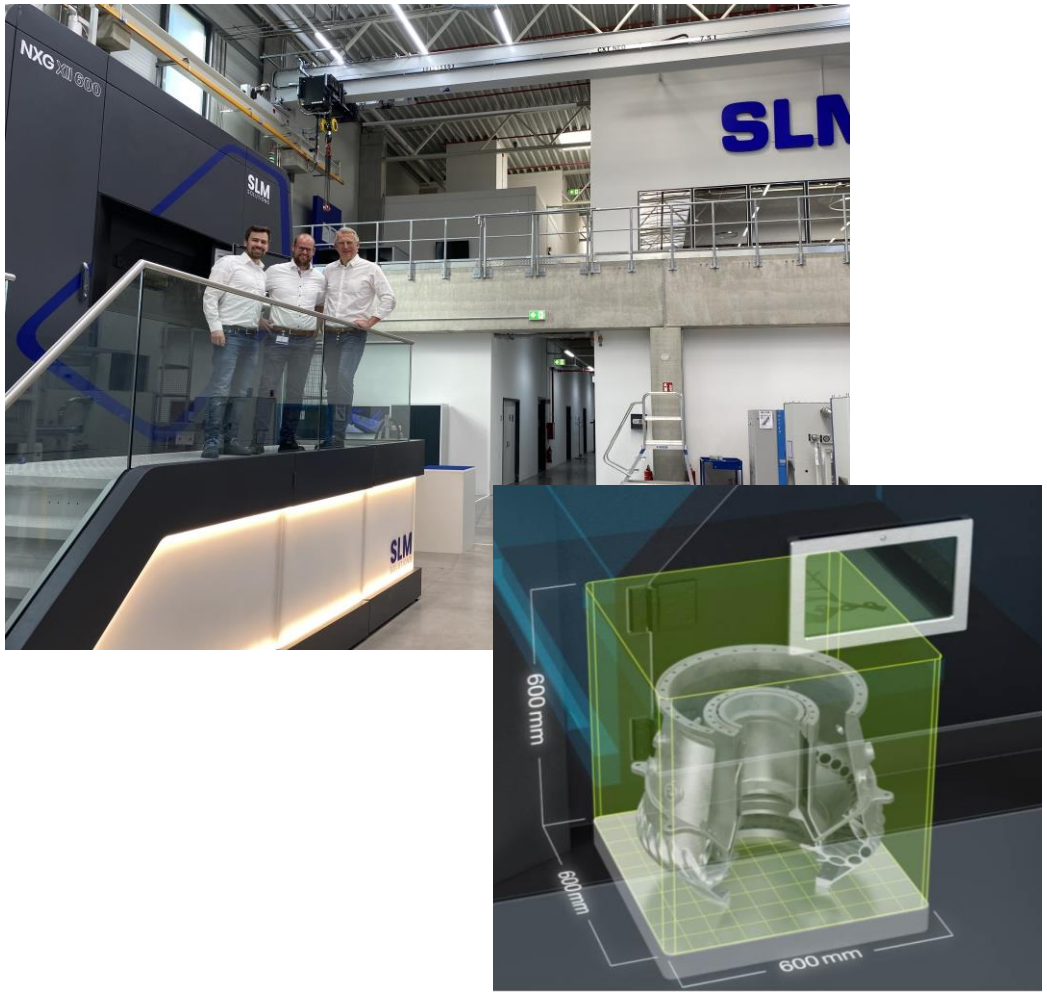
TiAI6V4

60 µm layer thickness

5d 3h 35min build time

38 piece fully loaded plate

Industry Demand for NXG XII 600



DIVERGENT

Collins Aerospace

SINTAVIA

MORF3D
AEROSPACE

MAN Energy Solutions

MAN

Leading Space Company

Public References:
https://www.slm-solutions.com/investor-relations/announcements/corporate-news/

NXG XII 600®Application

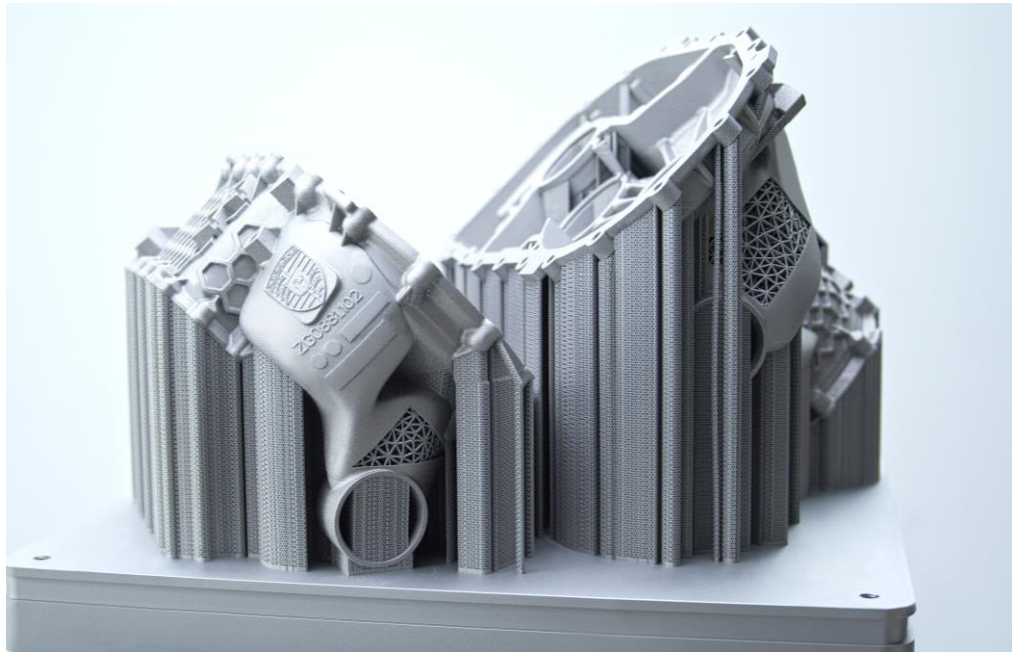
Porsche: E-Drive Housing

Part Specifications

- Material: AlSi10Mg
- X,Y dimensions: 590 x 560 mm
- Height: 366,3 mm
- Total Volume: 5,66 liters
  - Parts: 3,51 liters
  - Supports: 2,15 liters

Build parameters

- Laser Power: 900 W
- Layer thickness: 90 µm
- **Build time: 21,2 h**
- Build-up rate: 267 cm³/h



Weight reduction app. 10%

E - Housing with integrated cooling channels

Stiffness between electric motor and gearbox increased by 100 % due to the lattice structures

Thank you

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