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Fakulta strojní

KATEDRA
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A AUTOMATIZACE

3D digitization and Rapid Prototyping SLS/DLMS/SLM technology

Jiří Šafka

13.11.2020

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- **Principle of the technologies SLS, DMLS, SLM, EBM**
- **SLM 280HL**
- **Sample preparation of data for 3D printing**
- **Examples of practical examples**
- **Practical tests in the 3D print laboratory**

3D printing

Abbreviations

SLS – Selective Laser Sintering

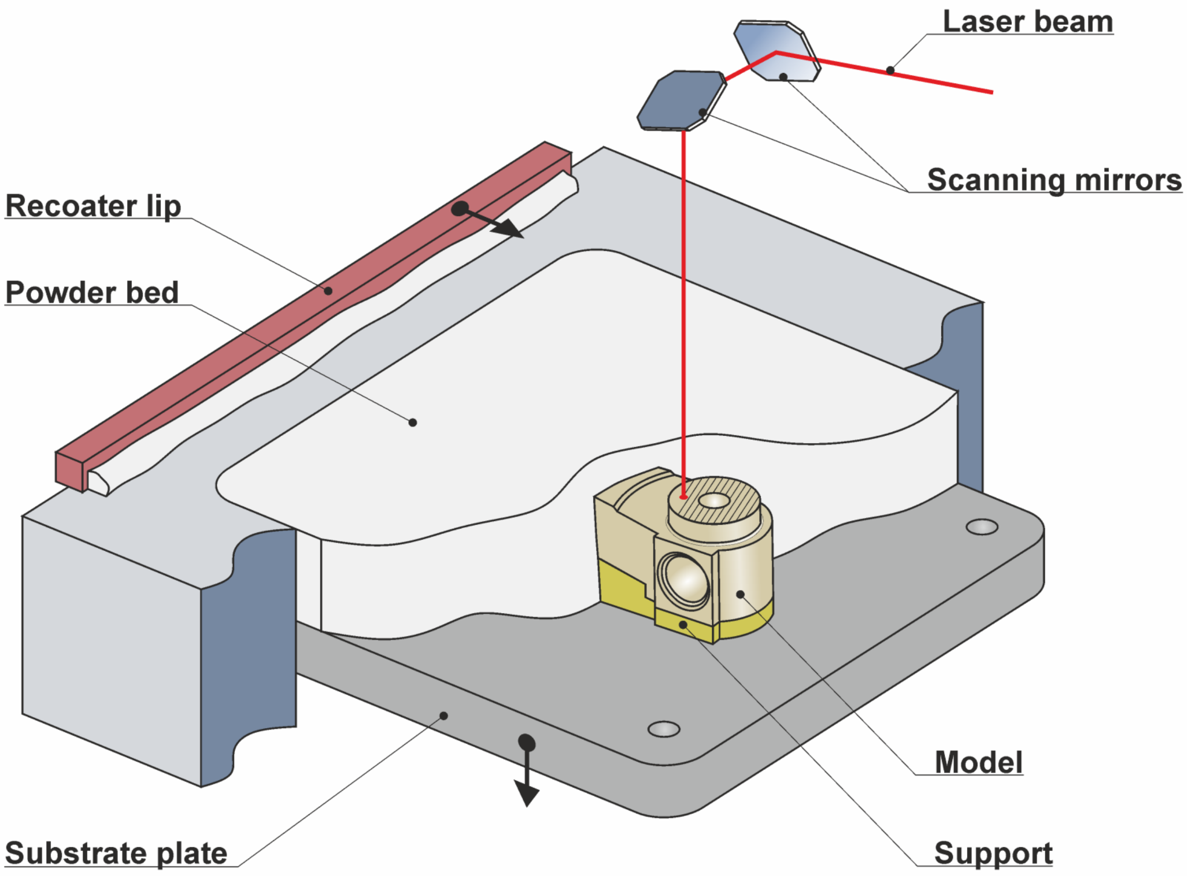
DMLS - Direct Metal Laser Sintering

EBM - Electron Beam Melting

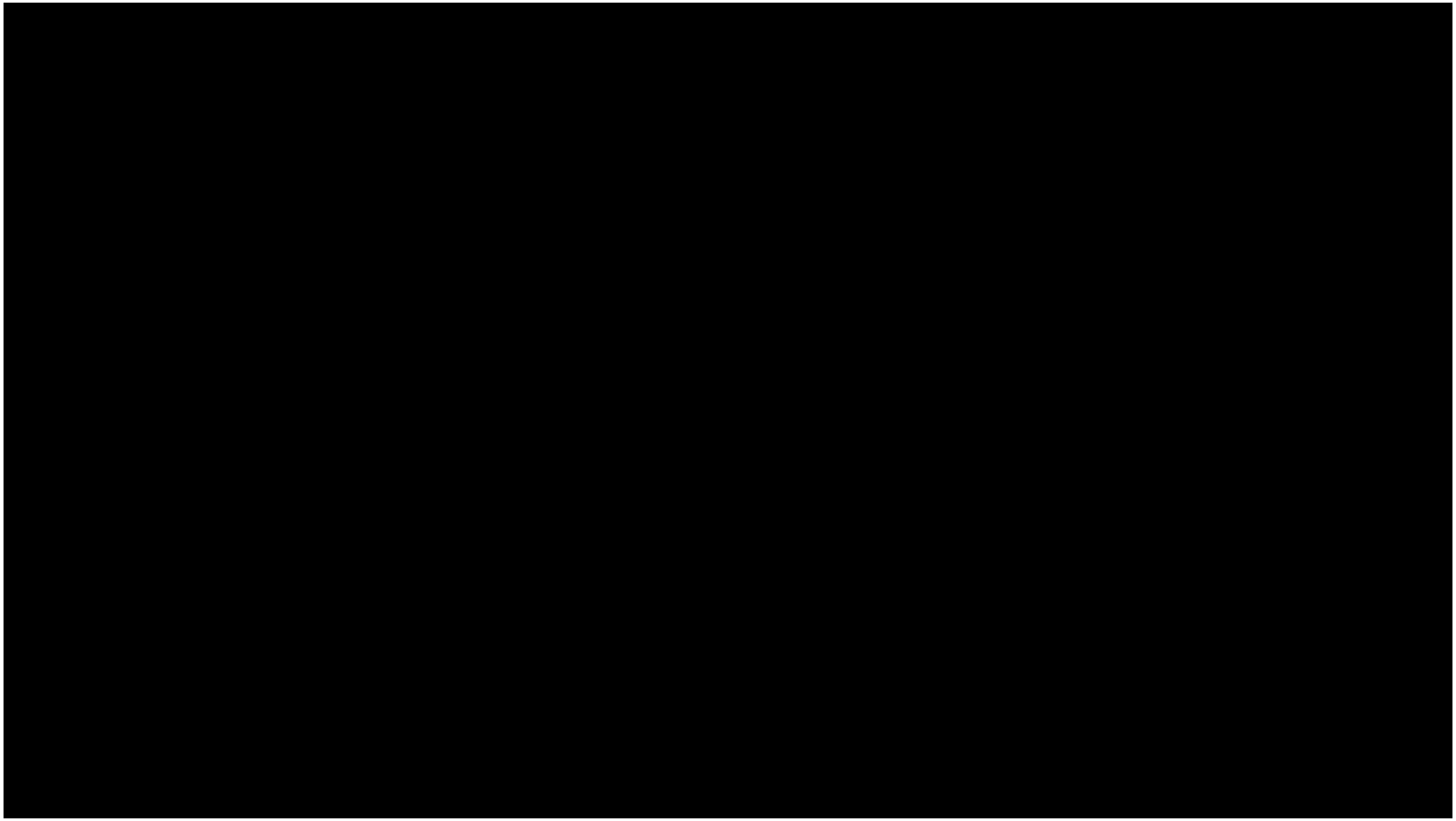
SLM – Selective Laser Melting

SLS

Principle of SLS/SLM/DMLS technologies



SLS – Selective Laser Sintering



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SLS – Selective Laser Sintering

SLS – Selective Laser Sintering

Selective sintering of powder

Suitable for plastics, ceramics, or other synthetic materials (carbon or etc)

There is only „sinitering process"

SLS – Selective Laser Sintering

- Patented in 1980
- Developed at University of Texas with money from DARPA (Defense Advanced Research Projects Agency)
- Suitable on different applications (automotive, aviation, medicine, architecture)

SLS – Selective Laser Sintering

EOS

EOS P 396

340mm x 340mm x 600mm

CO_2 laser – 70W

Layer thickness 100µm

SLS – Selective Laser Sintering

3D systems

ProX SLS 500

381 x 330 x 460 mm

CO_2 laser – 100W

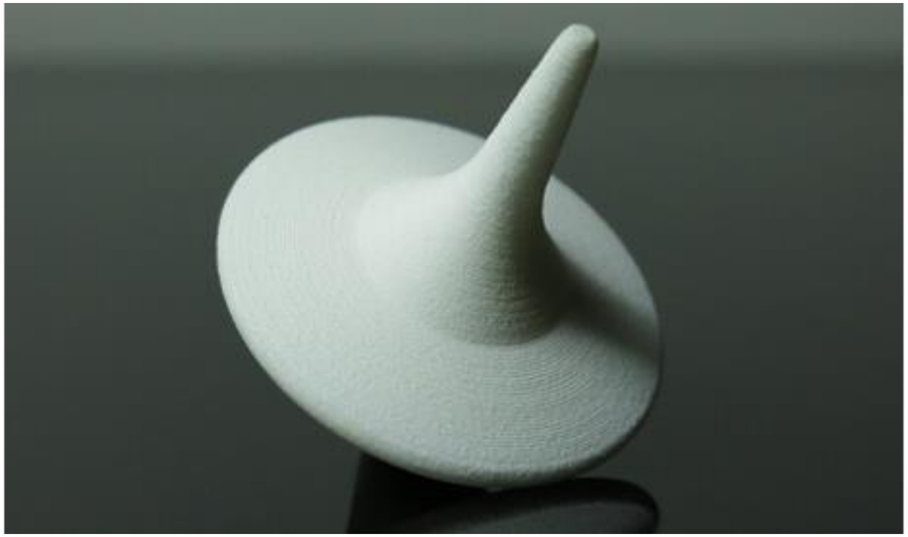
Layer thickness - 150µm

SLS – Selective Laser Sintering

Materials

PA 2200 – base polymer

PA2200

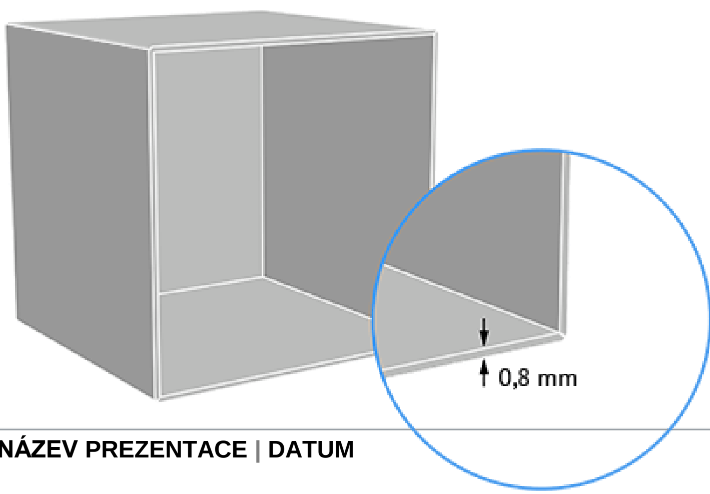


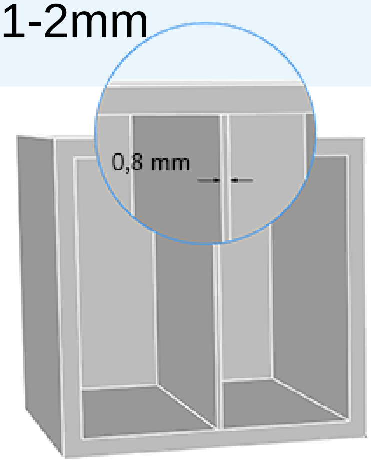
Standard layer thickness	100 - 150µm
High Definition layer thickness	60µm
Accuracy	± 0.3% (with a limit of ± 0.3 mm)

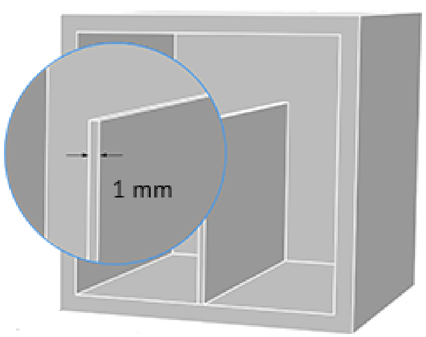
PA2200

Minimum Thickness and Geometry

Minimum wall thickness (flexible)	0.8mm
Minimum wall thickness(rigid)	2mm
Minimum wall thickness stemmed elements	0.8mm with support 1mm without support
Minimum wall thickness particular design aspects	1-2mm







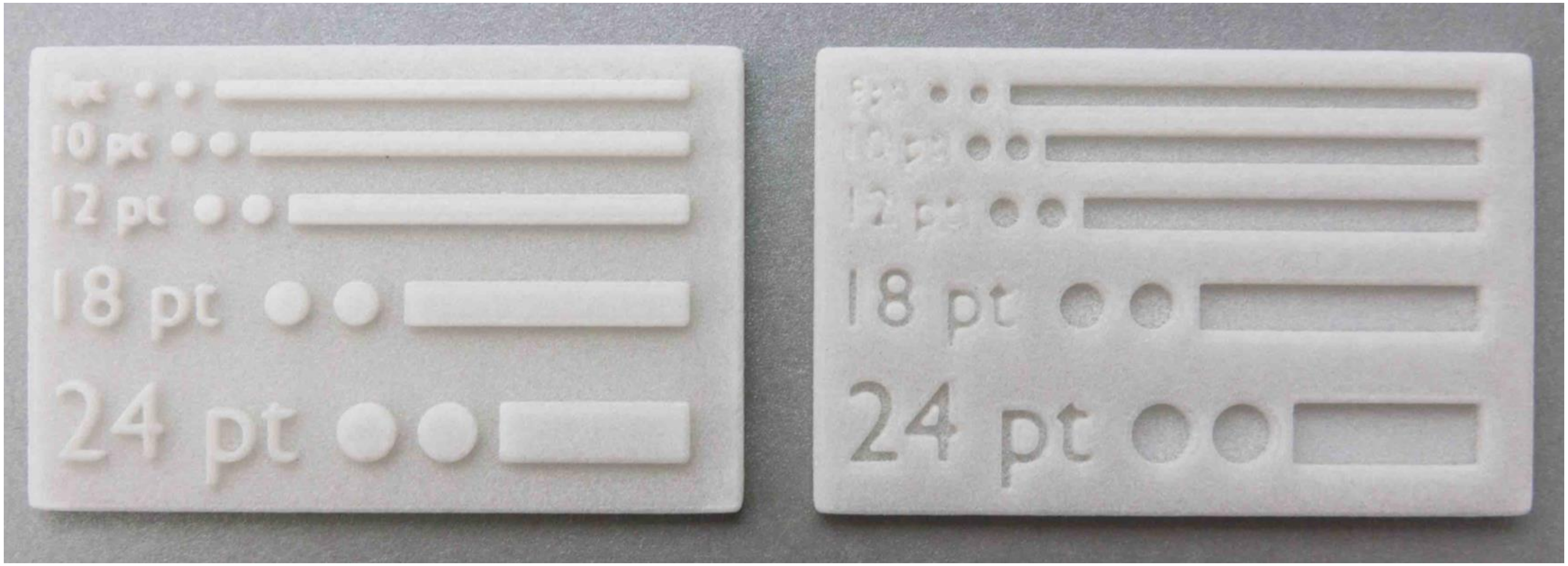
PA2200

Mechanical Properties	Conditions	Unit	Value
Density of laser-sintered part	EOS-Method	g/cm3	min. 0.90 / max. 0.95
Tensile Modulus	DIN EN ISO 527	N/mm2	1700 ± 150
Tensile strength	DIN EN ISO 527	N/mm2	45 ± 3
Elongation at break	DIN EN ISO 527	%	20 ± 5
Melting point	DIN 53736	°C	min. 172 / max. 180

Material

PA 3200 GF – polyamide with glass

PA 3200 GF

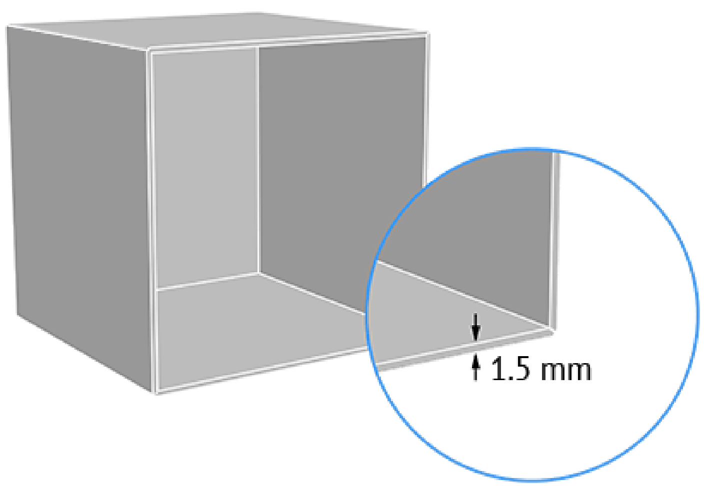


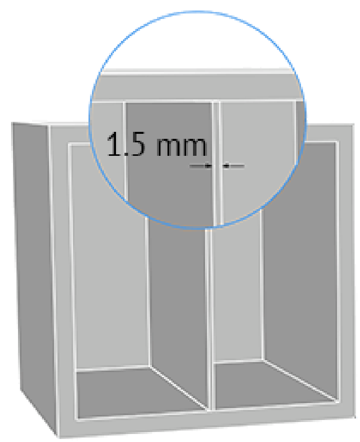
Standard layer thickness	100µm
Accuracy	± 0.3% (with a limit of ± 0.3 mm)

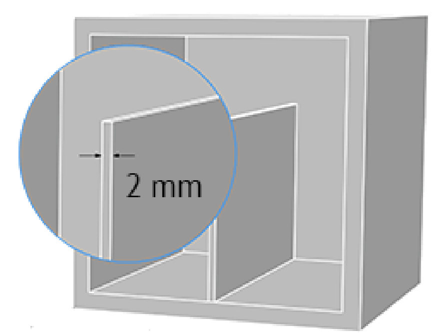
PA 3200 GF

Minimum Thickness and Geometry

Minimum wall thickness	1.5 mm
Minimum wall thickness for particular design aspects	2 mm







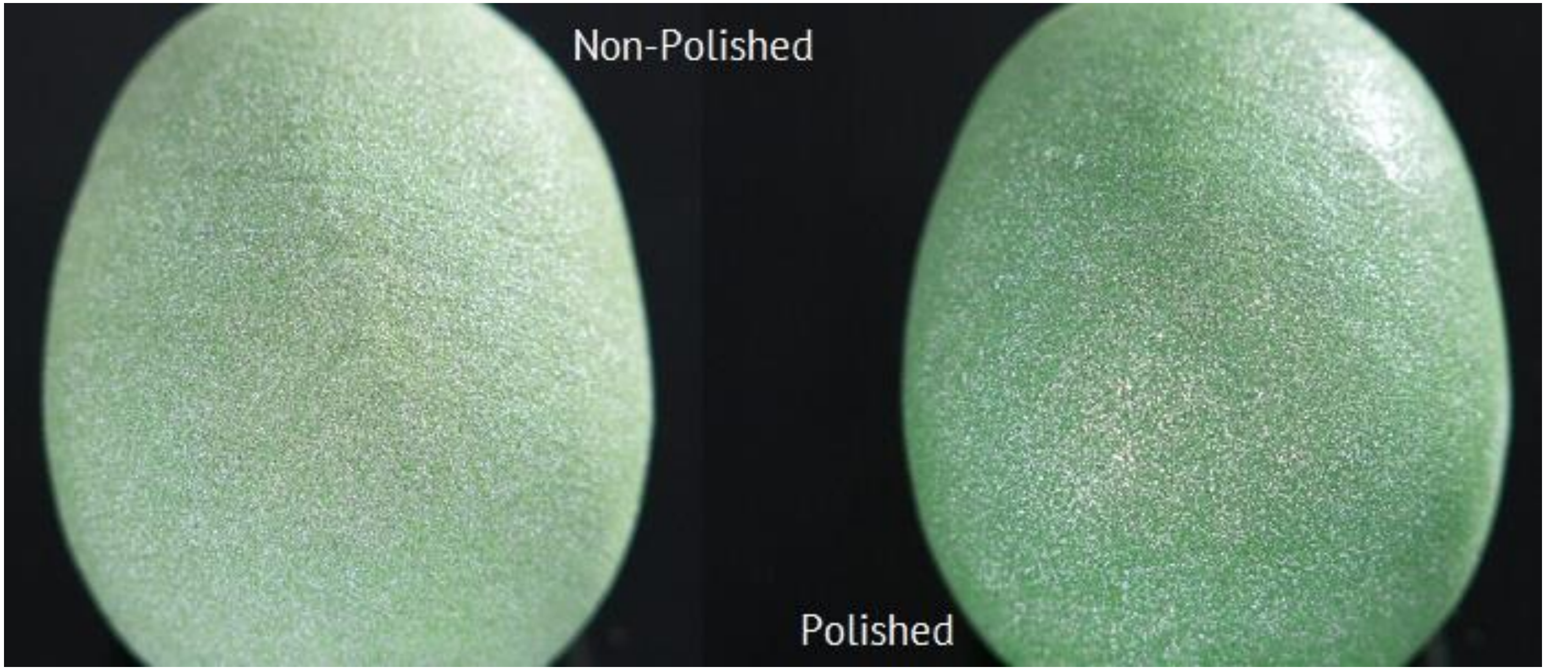
PA 3200 GF

Mechanical Properties	Conditions	Unit	Value
Density of laser-sintered part	EOS-Method	kg/m3	1220
Tensile Modulus	DIN EN ISO 527	MPa	3200
Tensile strength	DIN EN ISO 527	MPa	51
Strain at break	DIN EN ISO 527	%	9
Melting point	DIN 11357	°C	176

Material

Alumide – polyamid with Al material

Alumide

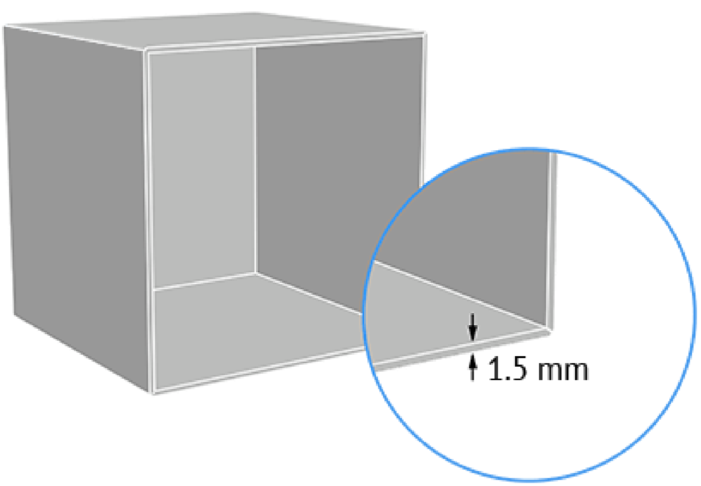


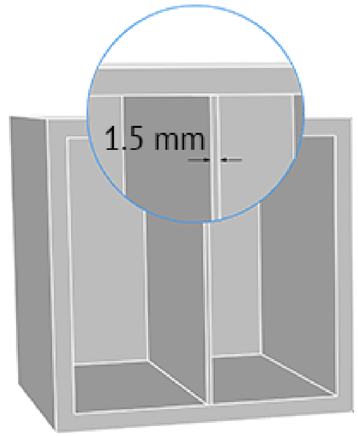
Standard layer thickness	150µm
Accuracy	± 0.3% (with a limit of ± 0.3 mm)

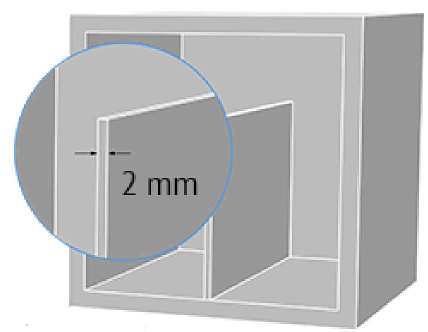
Alumide

Minimum Thickness and Geometry

Minimum wall thickness	1.5 mm
Minimum wall thickness for particular design aspects	2 mm







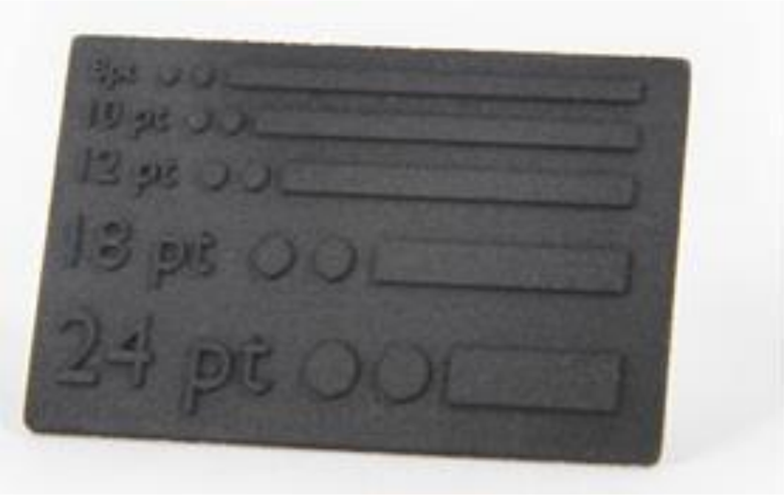
Alumide

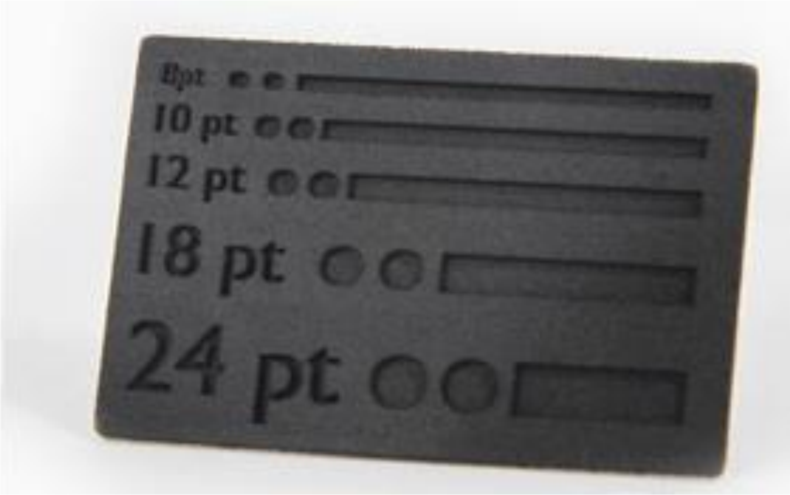
Mechanical Properties	Conditions	Unit	Value
Density of laser-sintered part	EOS-Method	g/cm3	1.35 ± 0.05
Tensile Modulus	DIN EN ISO 527	N/mm2	3600 ± 150
Tensile strength	DIN EN ISO 527	N/mm2	45 ± 3
Elongation at break	DIN EN ISO 527	%	3 ± 0.5
Melting point	DIN 53736	°C	min. 172 / max. 180

Material

Flexible – TPU-65A

Flexible



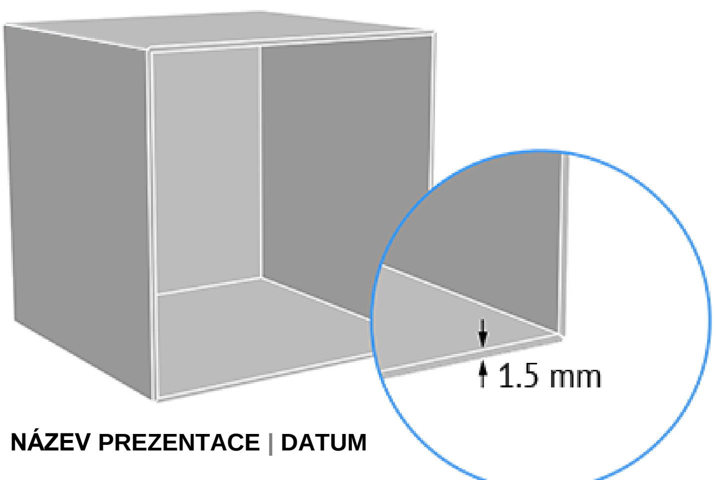


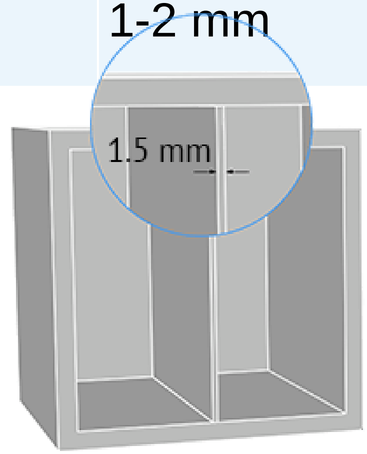
Standard layer thickness	100μm
Accuracy	± 0.3% (with a limit of ± 0.3 mm)

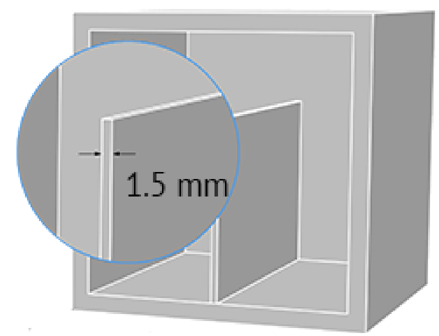
Flexible

Minimum Thickness and Geometry

Minimum wall thickness (flexible)	1.5 mm
Minimum wall thickness (rigid)	3 mm
Minimum wall thickness stemmed elements	1.5 mm with support 1.5 mm without support
Minimum wall thickness particular design aspects	1-2 mm







Material

CarbonMide – Polyamide with carbon material

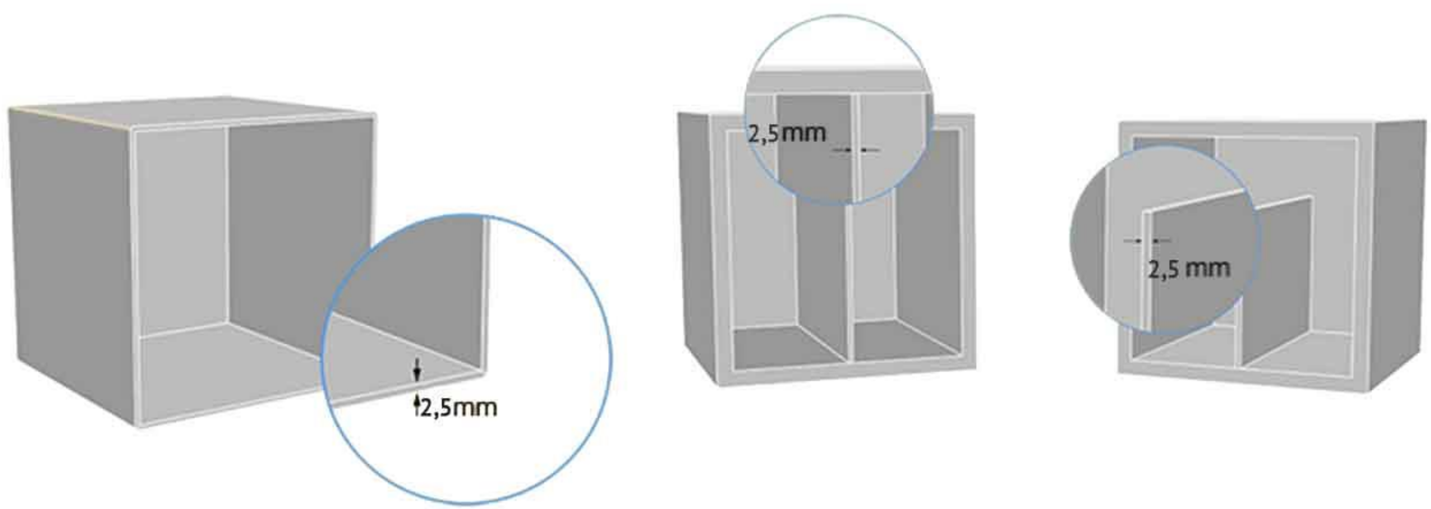
CarbonMide

Standard layer thickness	150µm
Accuracy	± 0.5% (with a limit of ± 0.5 mm)

CarbonMide

Minimum Thickness and Geometry

Minimum wall thickness (flexible)	2.5 mm
Minimum wall thickness (rigid)	2.5 mm
Minimum wall thickness stemmed elements	0.8 mm with support 1 mm without support
Minimum wall thickness particular design aspects	1-2 mm



CarbonMide

Mechanical Properties	Conditions	Unit	Value
Density of laser-sintered part	EOS-Method	Kg/cm3	1040
Tensile Modulus X Direction	ISO 527-1/-2	Mpa	6100
Tensile Modulus Y Direction	ISO 527-1/-2	Mpa	3400
Tensile Modulus Z Direction	ISO 527-1/-2	Mpa	2200
Tensile strength X Direction	ISO 527-1/-2	N/mm2	72
Tensile strength Y Direction	ISO 527-1/-2	N/mm2	56
Tensile strength Z Direction	ISO 527-1/-2	N/mm2	25
Melting point	ISO 11357-1/-3	°C	176

SLM/DLMS – Selective Laser Melting

- SLM Solutions AG (Německo)
- EOS (Německo)
- Renishaw (Velká británie)
- Concept Laser - GE (Německo)
- Trumpf (Německo)

Renishaw RenAM 500

EOS M290

DMLS

DMLS - Direct Metal Laser Sintering

Selective sintering of metal powder

Only for metal powders

There is only „sintering process"

Laser from 200W - 1000W - fiber laser

DMLS - Direct Metal Laser Sintering

Layers thickness from 20μm to 100μm

Build area up to 400 x 400 x 600mm

Patented by company EOS GmbH

DMLS – Direct Metal Laser Sintering

EOS M290

250 mm x 250 mm x 325mm

Fiber laser– 400W

Layer thickness up to 100µm

DMLS – Direct Metal Laser Sintering

Materials

Tensile strength

Titanium 6AI-4V - 1290MPa

Stainless Steel 316L - 640MPa

AISi10Mg - 460MPa

Stainless Steel 17-PH4 - 1250MPa

Materials

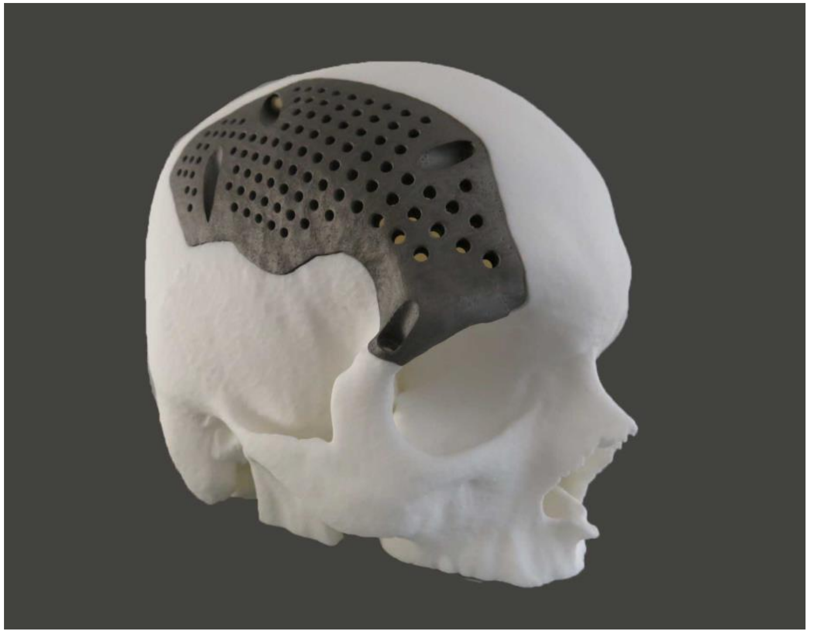
Titanium 6AI-4V

Titan

Alum

Vana

Titanium 6Al-4V

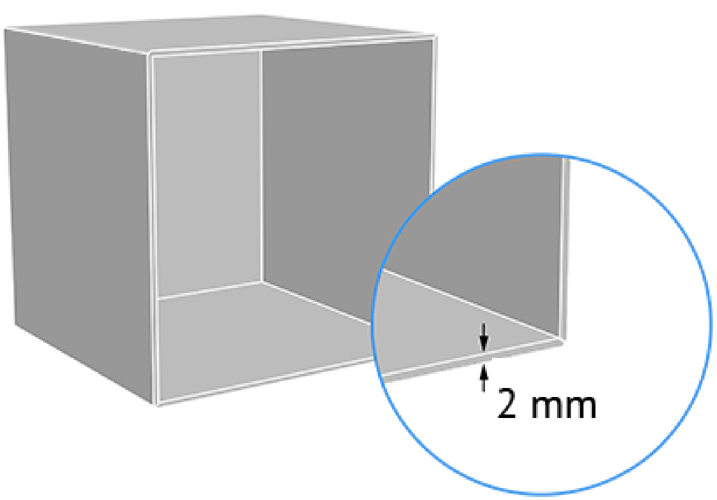


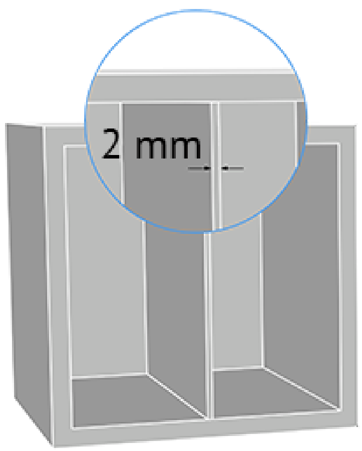
Standard layer thickness	30 µm

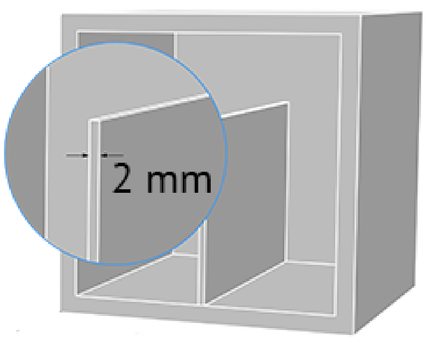
Titanium 6Al-4V

Minimum Thickness and Geometry

Minimum wall thickness	2mm
Minimum thickness particular design aspects	1 mm







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Titanium 6Al-4V

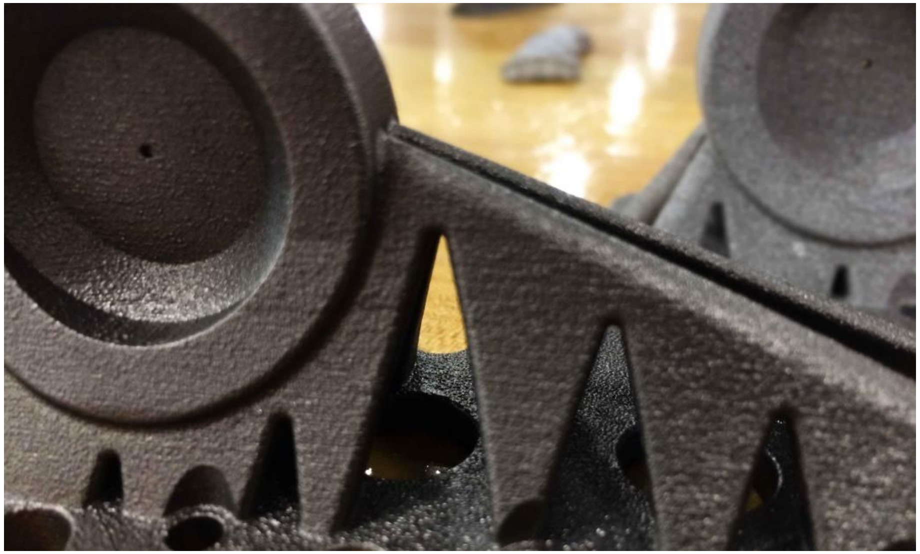
Mechanical Properties	Conditions	Unit	As Built
Density of laser-sintered part	EOS-Method	g/cm^3	4.41
Tensile strength		MPa	1290 ± 80
Elongation at break		%	8 ± 4
Melting point		°C	1660
Reference Temparature	N/A	°F	-

Stainless Steel 316L

316L

Iron : 66 - 70%
Chrome : 16 -18%
Nickel : 11 - 14%
Molybdenum : 2 - 3%

Stainless Steel 316L

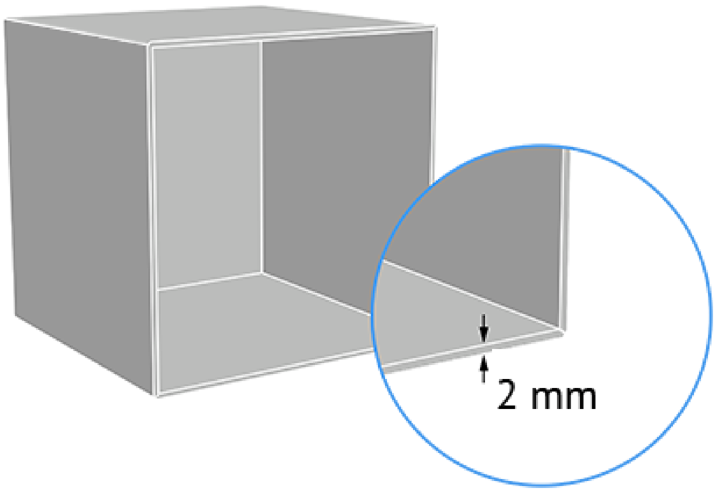


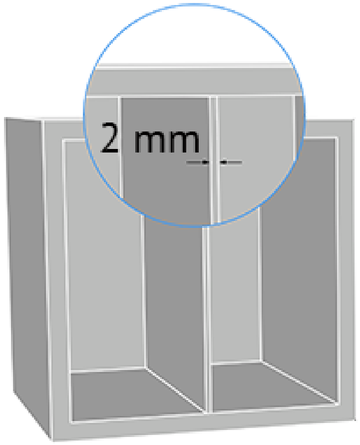
Standard layer thickness	40 μm

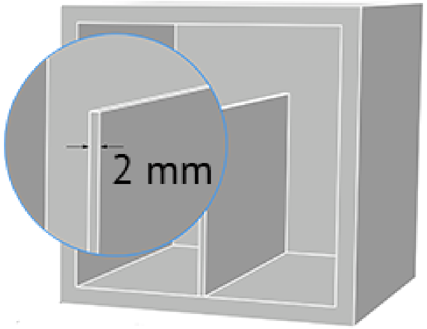
Stainless Steel 316L

Minimum Thickness and Geometry

Minimum wall thickness	2mm
Minimum thickness particular design aspects	1 mm







Stainless Steel 316L

Mechanical Properties	Conditions	Unit	Value
Density of laser-sintered part	EOS-Method	g/cm3	7,9
Tensile strength(XY)	ISO 6892 / ASTM E8M	MPa	640 ± 50
Tensile strength(Z)	ISO 6892 / ASTM E8M	MPa	540 ± 55
Yield strength(XY)	ISO 6892 / ASTM E8M	MPa	530 ± 60
Yield strength(Z)	ISO 6892 / ASTM E8M	MPa	470 ± 90
Young's modulus(XY)	ISO 6892 / ASTM E8M	GPa	185
Young's modulus(Z)	ISO 6892 / ASTM E8M	GPa	180
Elongation at break (XY)	ISO 6892 / ASTM E8M	%	40 ± 15
Elongation at break (Z)	ISO 6892 / ASTM E8M	%	50 ± 20
Melting point	N/A	°C	1400
Reference Temparature	N/A	°F	-

EBM

EBM - Electron-Beam Melting

Selective sintering of meta powder

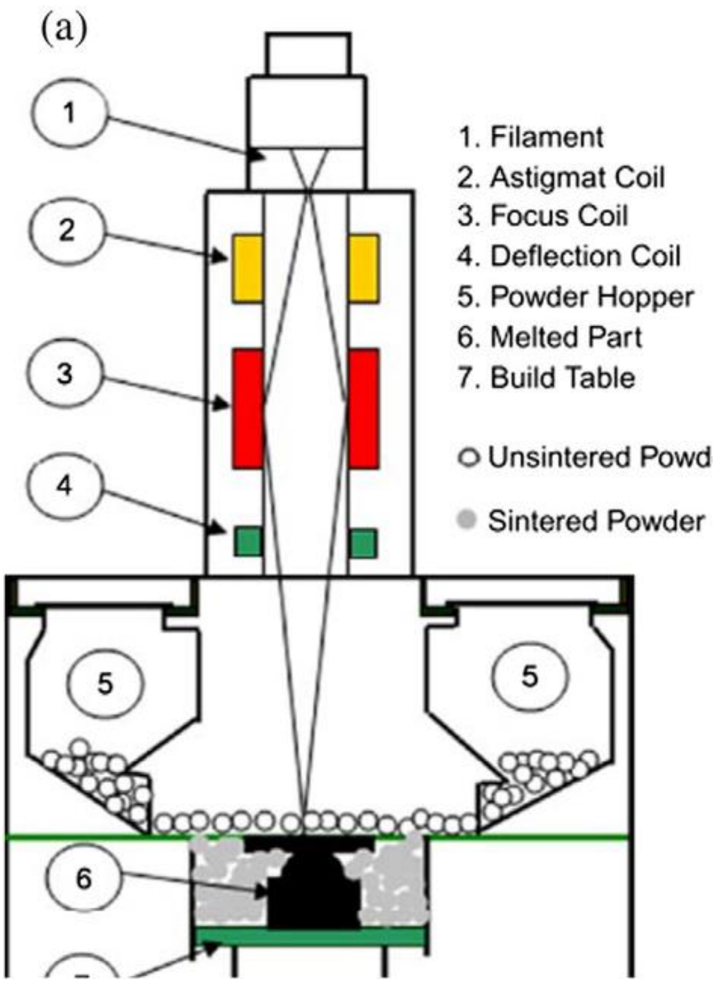
It works in a vacuum

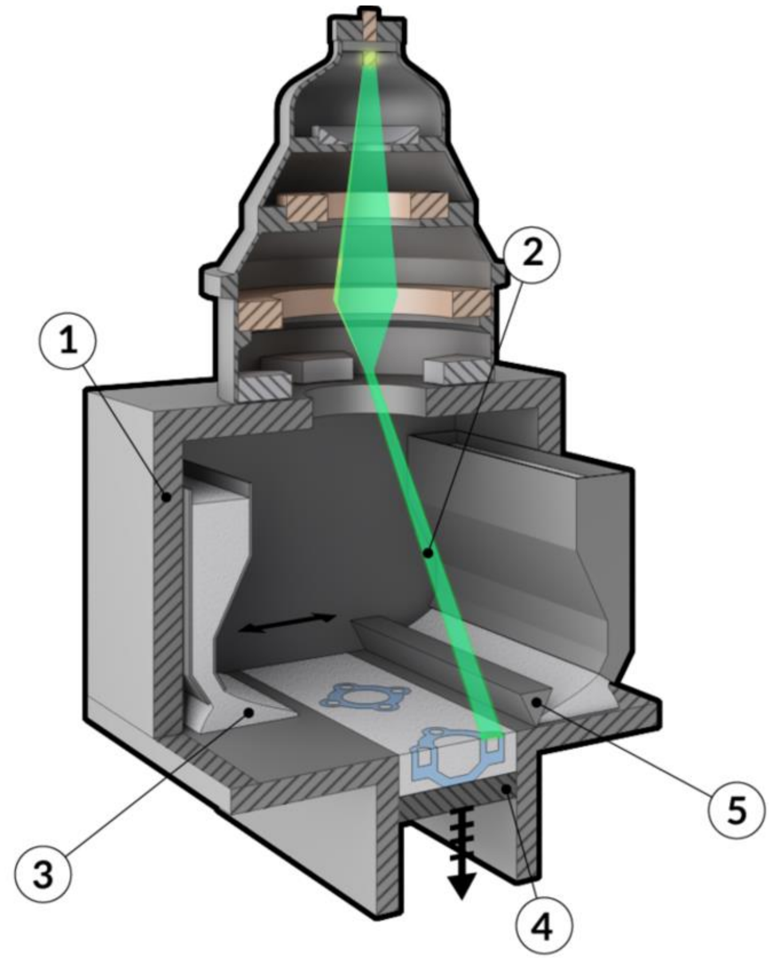
The material is completely melted

Electron beam up to 3000W

Temperature in the chamber above 1000ºC

EBM - Electron-Beam Melting





EBM - Electron-Beam Melting

Layer thickness from 50µm to 150µm

Build area up to 350 x 380mm

Patented by ARCAM company (GE)

Only for Titan material and Inconel

EBM - Electron-Beam Melting

EBM - Electron-Beam Melting

ARCAM Q10plus

200 mm x 200 mm x 180mm

Electron beam - 3000W

Layer thickness up to 100µm

Materials

Tensile strength

Titanium Ti6Al4V - 950MPa

Arcam ASTM F75 CoCr – 1050MPa

Medicína a letecký průmysl

SLM

SLM – Selective Laser Melting

Selective laser melting of metal powder

Only for metal powder

Full melted

Laser power from 400W   to 1000W

SLM – Selective Laser Melting

Layer thickness from 20μm to 75μm

Build area up to 280 x 500 x 800mm

Patented by SLM Solutions GmbH company

SLM – Selective Laser Melting

SLM 280HL

280 mm x 280 mm x 360mm

Fiber laser – 400W

Layer thickness up to 75μm

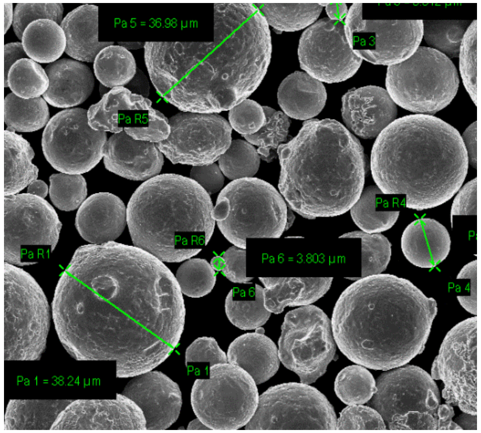
SLM – Selective Laser Melting

SLM – Selective Laser Melting

Materials

Build envelope:	280 x 280 x 365 mm	
Layer thicknesses:	Variable between 20 µm and 75 µm	
Available materials:	Titanium alloys	Ti6Al4V, Ti6Al7Nb
	Stainless steels	1.4404 (316L), 1.4540 (15-5PH), 17-4PH
	Tool steels	1.2344 (H13), 1.2709
	Aluminium alloys	AlSi12, AlSi10Mg, AlSi7Mg, AlSi9Cu32
	Cobalt-Chrome	
	Nickel-based	Inconel 718, Inconel 625, Inconel 939, Hastelloy X

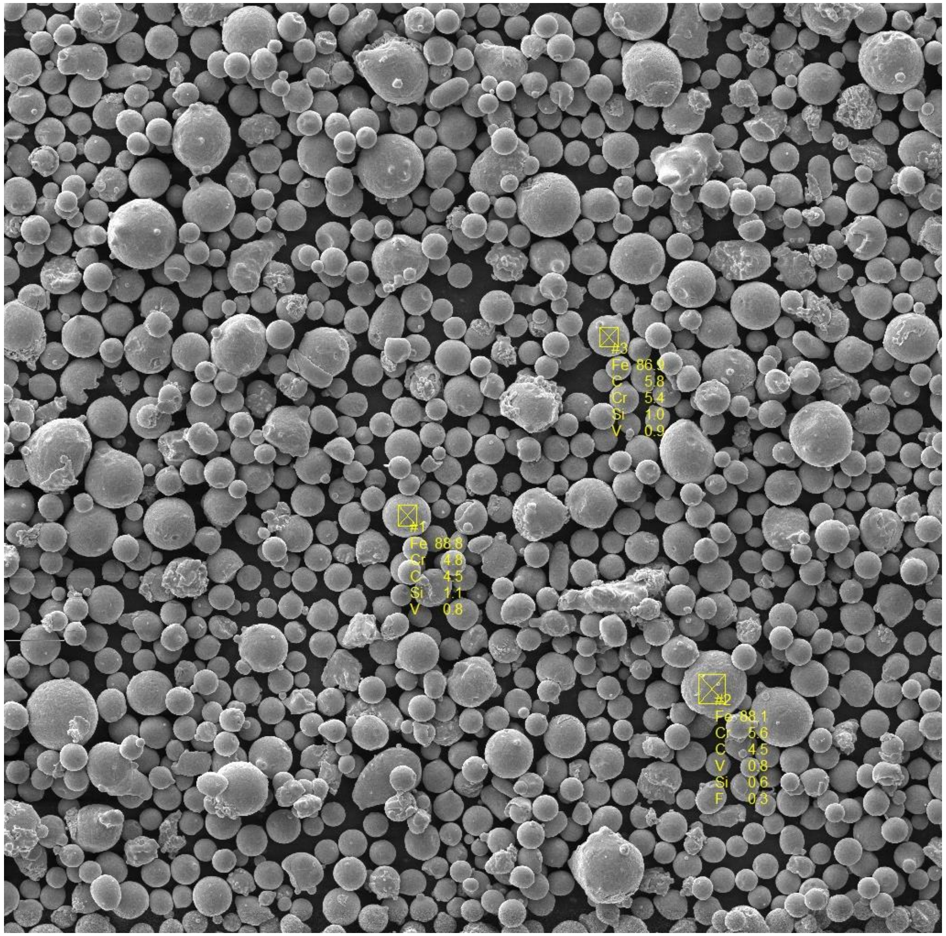
SLM | Specific demands on input materials



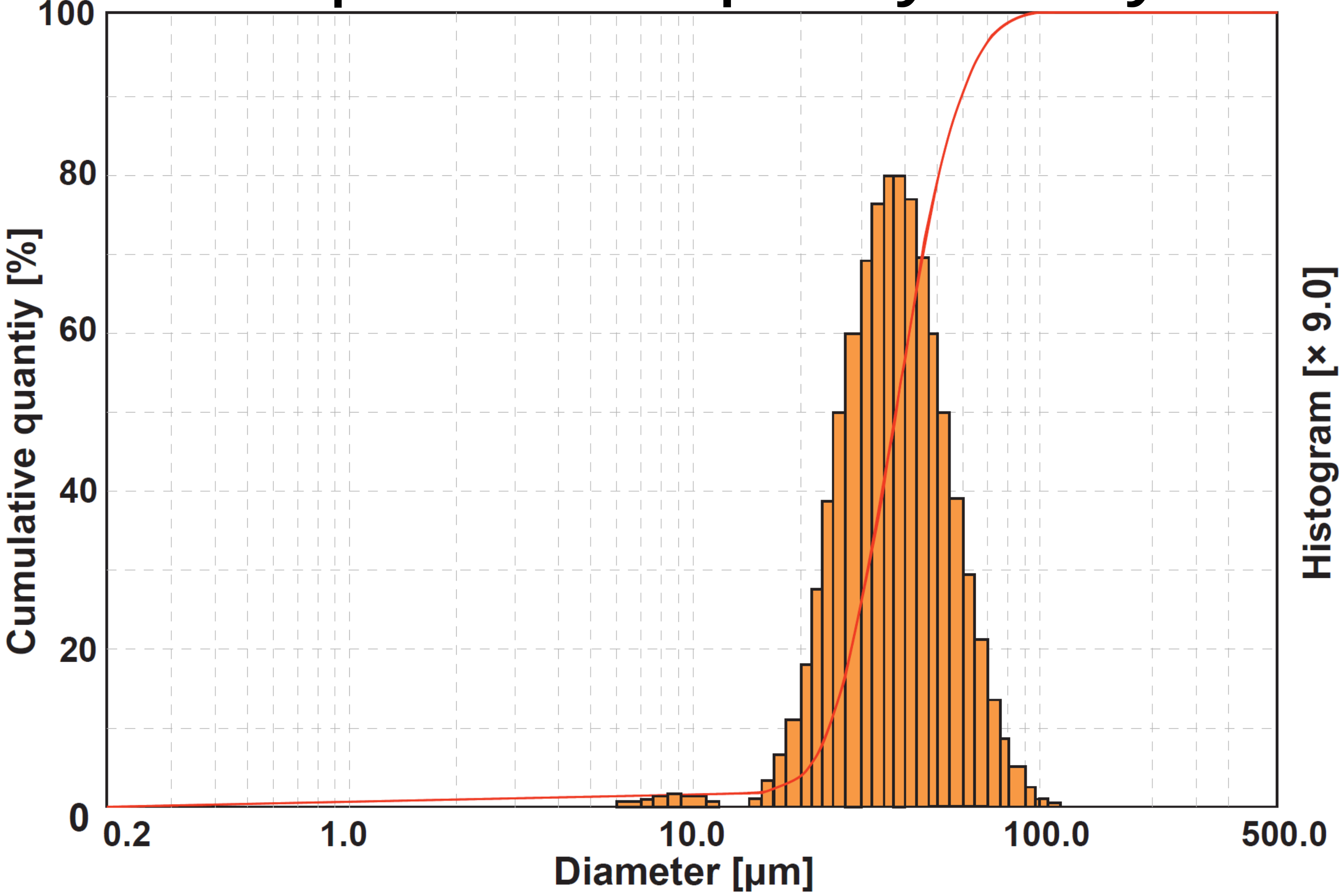
SLM | Specific demands on input materials

Basic characteristics of metal powders for SLM technology:

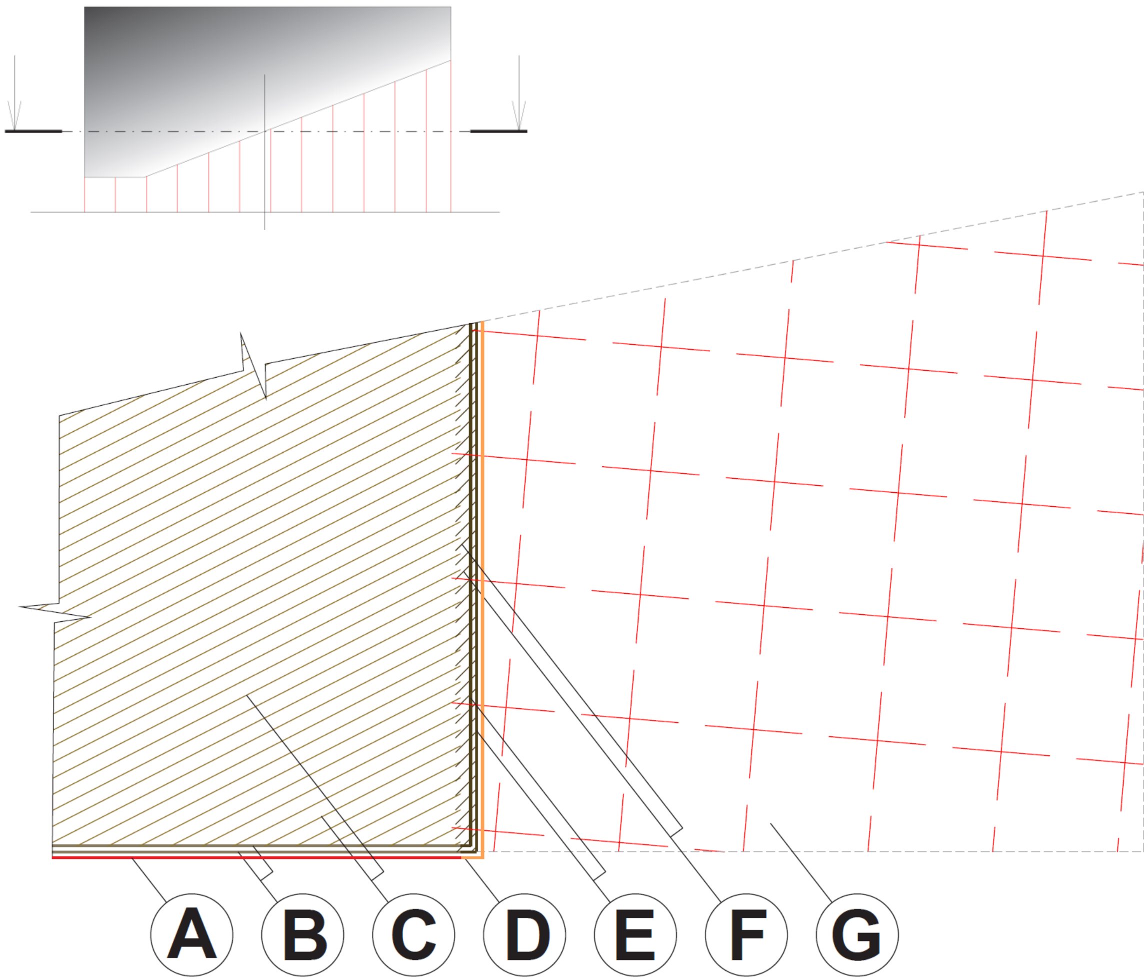
- Size distribution
- Topology of particles
- Humidity
- Chemical composition of the material



H13 | Powder quality analysis

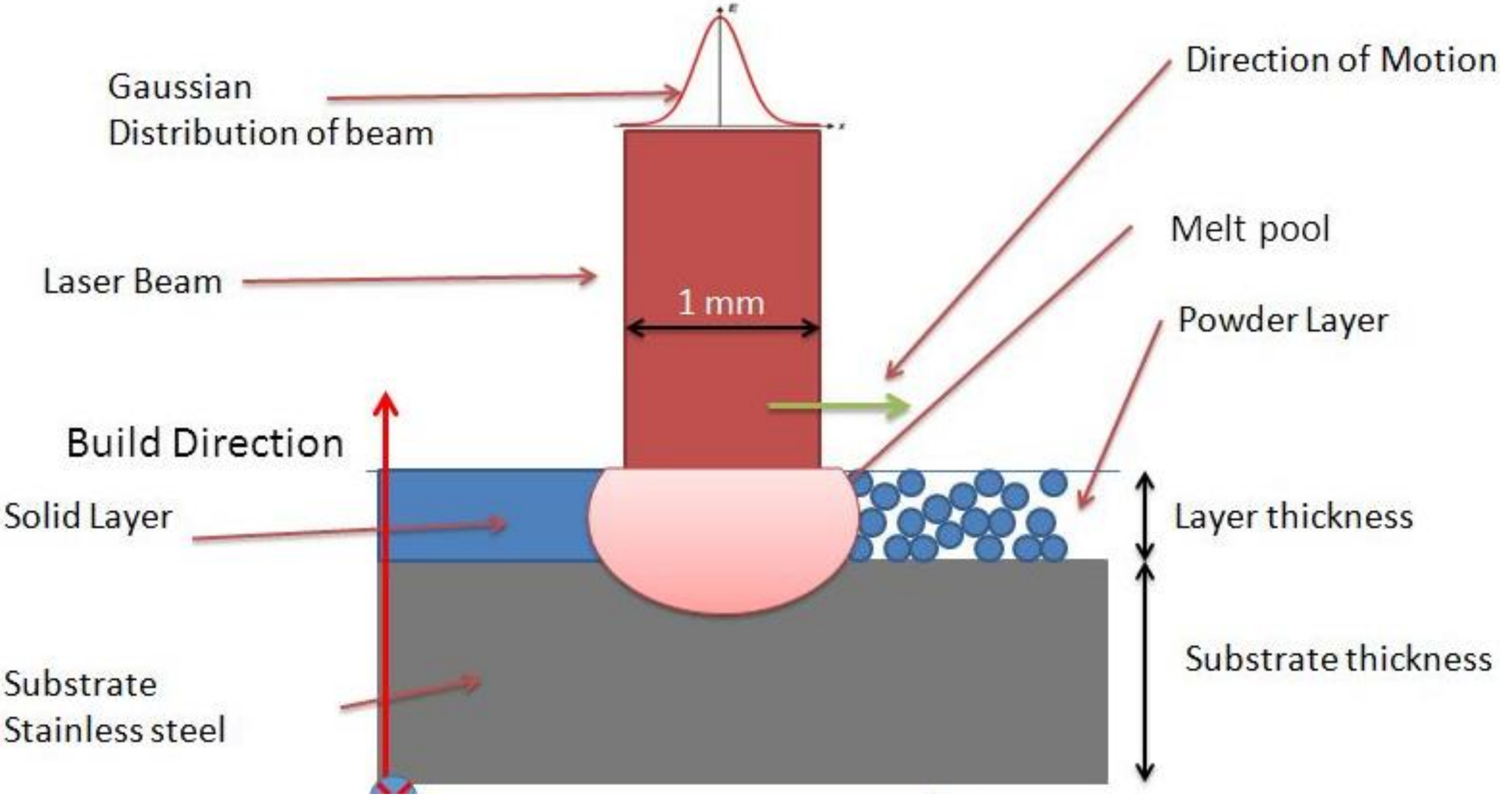


Building Strategy



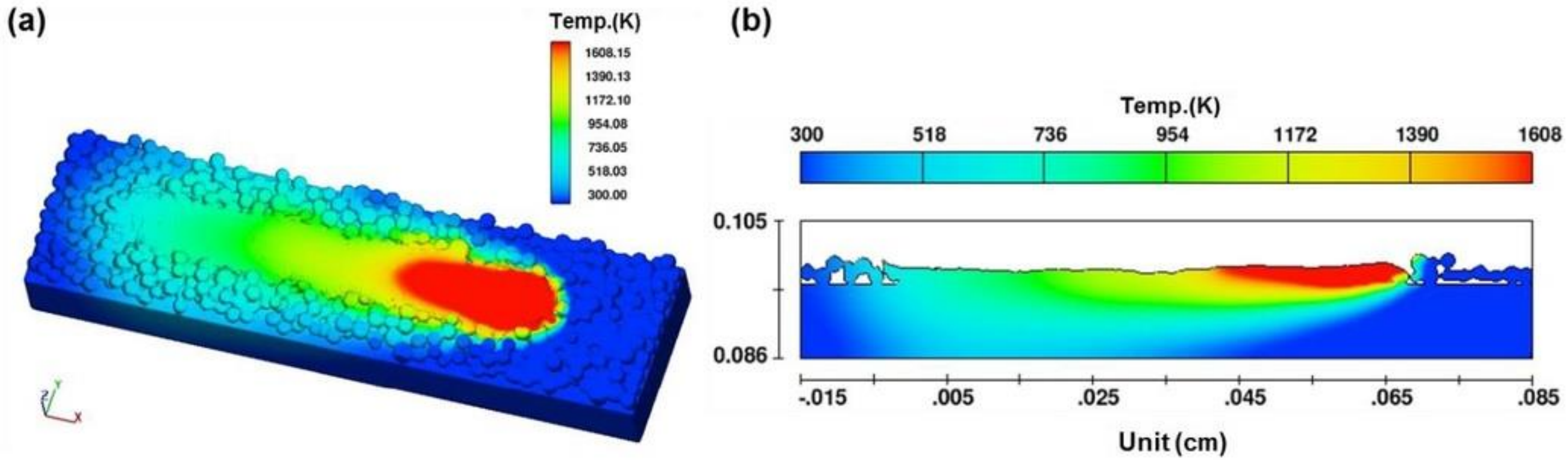
	Build processor
A	Border
B	Fill Contours
C	Hatches (Outer Hull)
D	Downskin border
E	Downskin hatches
F	Downskin Fill Contour
G	Vector Supports

Melt pool



G. A. Tilita: Effect of Individual input parameters on development of imperfections during SLM

Melt pool



Y.S. Lee and W. Zhang, Mesoscopic simulation of heat transfer and fluid flow in laser powder bed additive manufacturing, 2015.

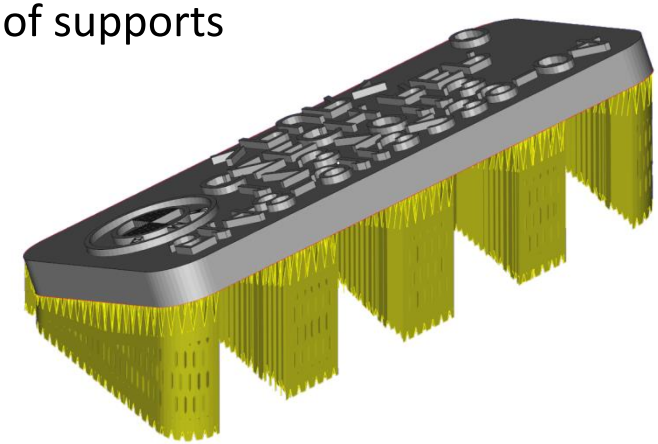
Energy density

$$E = \frac{P}{v \cdot s \cdot t} \qquad [\mathrm{J/mm^3}]$$

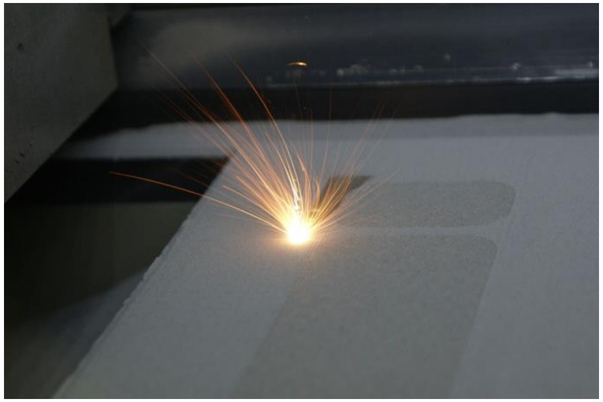
P [W] laser power
v [mm/s] scanning speed
s [mm] hatching space between the two adjacent paths of the laser
t [mm] layer thickness

Production process

1) Positioning of the part and generation of supports



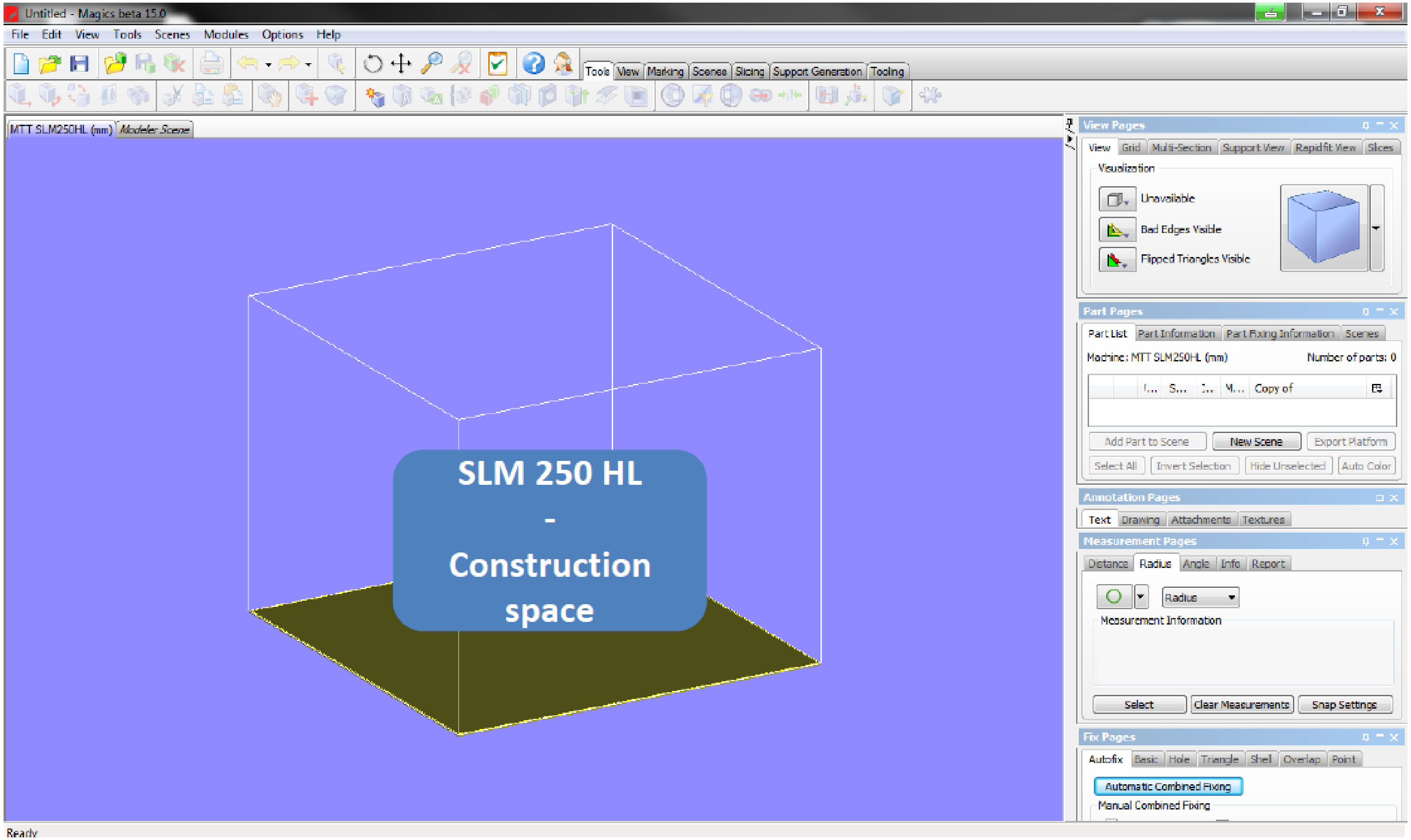
2) SLM process



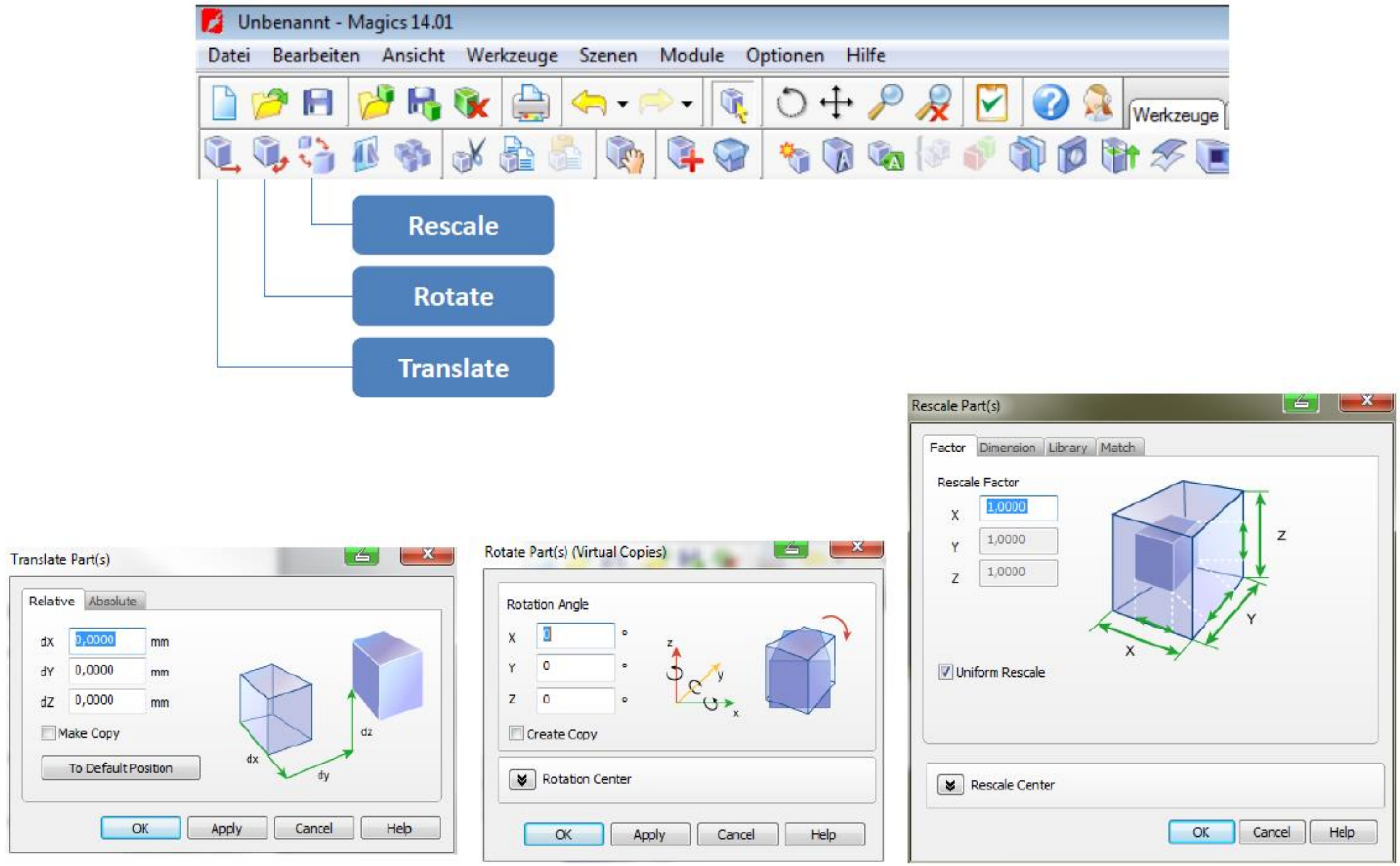
3) Unpacking of the part

4) Final part

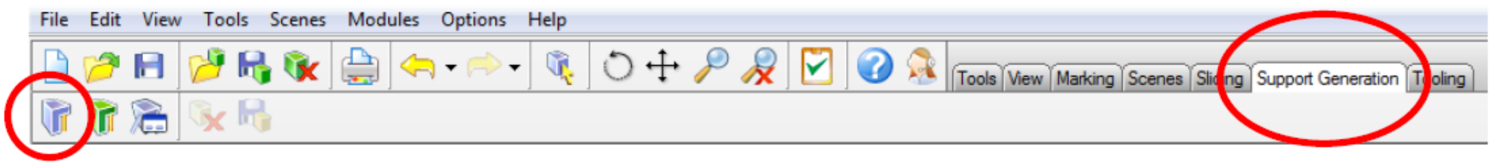
Data preparation - Magics

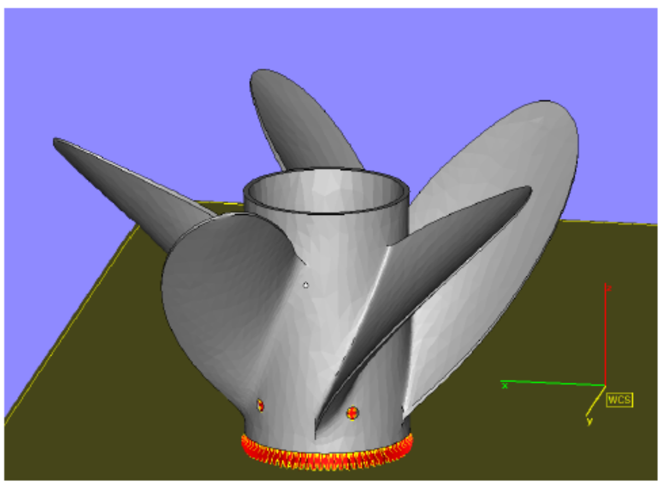


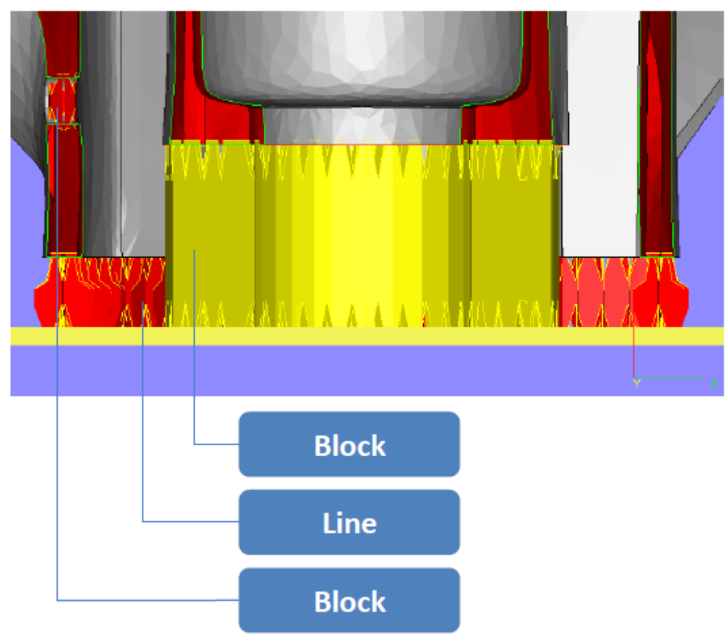
Data preparation - Magics



Data preparation - Magics

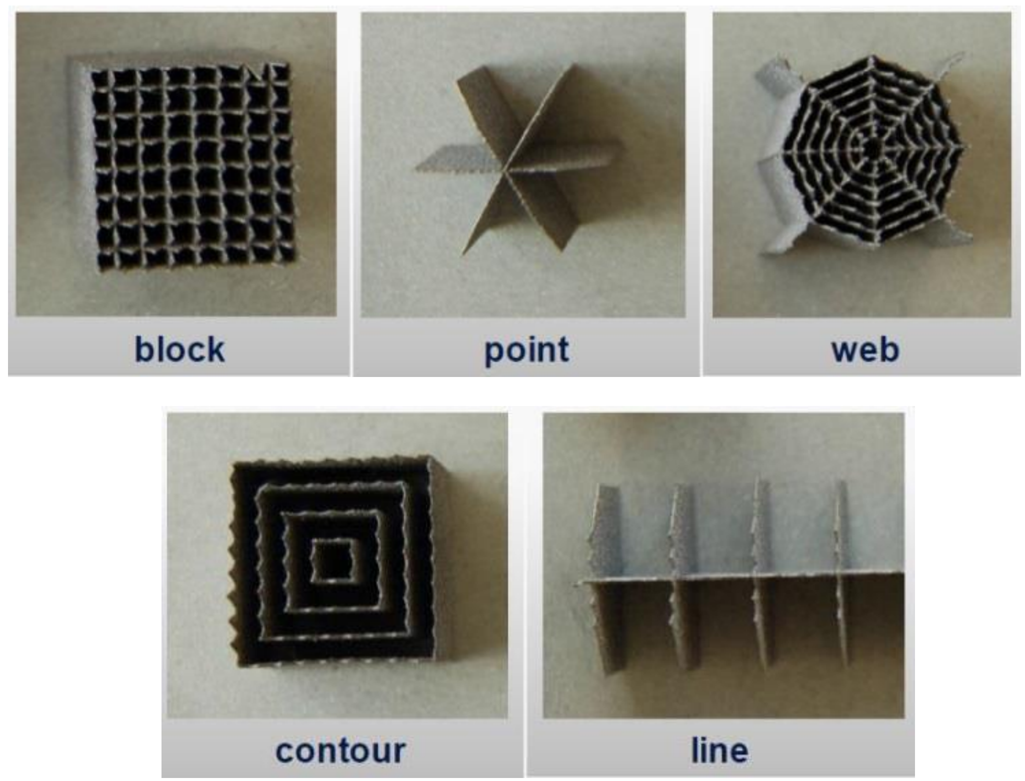






Data preparation - Magics

- Point
- Line
- Line*
- Block
- Web
- Combi
- Contur
- Gusset
- (Volume)



Data preparation - Magics